The French connection: Hominin biogeography in north-west Europe during the Eemian - the contribution of palaeobotanical data

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(figure: M. J. Thompson, Cape Espenberg, https://www.britannica.com/science/land-bridge)

The French connection: Hominin biogeography in north-west Europe during the Eemian - the contribution of palaeobotanical data

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1. Introduction

The Eemian interglacial (also known as the Ipswichian in Great Britain (130 kya - 115 kya)) is a period that occurs between the Saalian glacial period (374 kya - 115 kya) and the Weichselian glacial period (115 kya - 11.7 kya). This interglacial was a warm period that allowed the glaciers that covered much of the northern hemisphere during the Saalian to melt. These conditions made it possible for hominins living in the vicinity to spread to the lands that were uncovered this way, just as they had in the period before the Saalian. One of the areas that was previously known to have been inhabited by hominins before was the British Isles. Additionally, since the climate is thought to have been so warm to have allowed hippopotamus to live in the Thames, it would follow that these conditions were also quite favourable for hominins to live in the same region. Travel to the Isles should have been possible due to the landbridge that existed between Britain and northern France at the end of the Saalien, although this would melt during the warmer Eemian due to sea level rise because of the melting glaciers. Yet despite all these favourable factors, there has been no evidence found indicating a hominin presence on the British Isles during this period (Ashton, 2002) in spite of campaigns intended to locate them and the fact that their presence is confirmed both before and after.

The Eemian was first described by Pieter Harting in 1874 . He did this by describing stratigraphic layers which he found near Amsterdam and Amersfoort in the Netherlands. Within these he found diatom and mollusc fossils that he could not link to any other epoch that he knew of. Some of these molluscs were typical of the mediterranean area and had not been known to appear in the Netherlands at any point during the Holocene interglacial that we live in at this moment. He therefore surmised that these sediments must have belonged to an interglacial which he called the Eemian after the Dutch river Eem (Sier, 2013, p. 18). Since then the Eemian has been defined by pollen zones that have been found throughout Europe rather than mollusc fossils (Zagwijn, 1961).

Hominin dispersal in north-west Europe, or the lack thereof, after the end of the Saalian is a frequently debated subject. Some have suggested that, after temperatures started rising and the amount of biomass that was available increased, this biomass occurred mostly in the form of forest vegetation. It was theorised that this environment was not suitable for hominins to properly exploit and that they lacked the social structures that were necessary to overcome this bottleneck (Gamble, 1986).Therefore there was little incentive for them to pioneer into west Europe early in the Eemian. Because of this they would have reached the French coast much later in the Eemian, when the land bridge between France and the British Isles had already disappeared (Ashton, 2002). Others have suggested that, while the disappearance of the land bridge was indeed the deciding factor, this was not due to a slow spread of hominins, but rather because the early Eemian saw such a rapid temperature increase that the land bridge was

already gone soon after the end of the Saalian. This was argued because there was hominin presence on the mainland of north-west Europe both during the glacial Saalian period and the more arboreal early Eemian, which meant that early hominins were perfectly capable of living in such conditions. However they do concede that this needs not to be the case for the British Isles (Roebroeks et al, 1992, pp. 559-560). Another theory by Ashton was that, while hominins were perfectly capable of surviving in more wooded conditions, they preferred to make use of the mammoth steppe conditions that could be found in Germany, but less so at the Atlantic coast. This would mean that the sites located in Northern France represent the furthest extent that hominins were willing to go in order to stay relatively close to their favoured habitat. This would have dissuaded populations to cross over to Britain as conditions there were even further removed from the preferred mammoth steppe (Ashton, 2002). It is also possible that the existence of the land bridge was not the deciding factor at all and that there is an entirely different reason for the absence of hominin activity in Britain.

An issue that arises when researching the Eemian is that as a term it is often used interchangeably with ‘previous interglacial’ and ‘MIS5e’ (Sier, 2013, p. 17). While these three terms roughly describe the same period there are semantic differences that must be kept in mind as there might be a small difference in their absolute date. ‘Previous interglacial’ describes the warmer period that follows upon the colder glacial period that precedes it, however there does not seem to be a clear delimitation as to when the border between these two periods is exactly. The term Eemian then refers to the sedimentary layers that were deposited during this period, or rather the difference is sediments when compared to the preceding layers belonging to the Saalian. Although these to terms logically roughly coincide it is possible that there is a minute difference as the warmer period must first commence in order for different sediments to deposit, ‘MIS5e’ (which is the abbreviation of Marine Isotope Stage 5e) then describes the isotope dated cores that were taken from marine sediments belonging to this interglacial which investigate the levels of δ16 oxygen isotopes within the sediments. Again this term means roughly the same as the previous two but there is also a significant variation in the exact period that it encompasses. For example, geomagnetic data from the German site of Neumark-Nord 2, has revealed that there is an approximate 5000 year difference between what is considered the ‘peak’ of MIS5e and the beginning of the Eemian sedimentary period (Sier, 2013, p. 83). This discrepancy is surprisingly large considering the fact that these concepts are often used interchangeably. Therefore it is important to keep this discrepancy in mind when using the terms to describe sites from the period that this thesis attempts to investigate, as there is a significant difference if hominins reached what is now the French coast already in the early Eemian, or whether they Encountered the Channel 5000 years later. This is especially the case considering that this 5000 year gap concerns the ‘peak’ in the marine record and not the start of it as this isotope sequence is said to have had a duration of around 3500 years. This means that the discrepancy between the beginning MIS5e and the beginning of the Eemian sedimentary sequence is even longer than that considering that the ‘Blake Event’ that is used to correlate these two concepts together as a whole lasted for approximately between 1000 and 11.000

years with some suggesting that it lasted as long as the entire Eemian while also incorporating the final part of the Saalian (Sier et al., 2011, pp. 216-217; Sier, 2013, pp. 102-104). Another relevant term is that of the ‘Blake Event’. This was a paleomagnetic event that has since been correlated with MIS5e and can therefore be used when attempting to correlate sedimentary, fossil or botanical material from sites in North-west Europe (Channell et al., 2012, pp. 21-24). It consists of a series of polarity intervals that have been observed in sediments all around the planet belonging to MIS5e, however there have not been any continental sediments that have been able to be correlated to the Eemian interglacial period using pollen data as no sediment samples have been found that contained both Blake Event material and Eemian pollen up until recently (Sier, 2013, pp. 17, 21, 84). In this thesis all three terms will be used not entirely interchangeably, but it will refer to all of them when appropriate or when earlier research specifies their use.

Another problem that is encountered while researching this subject is that sites with hominin activity dating back to the Eemian are exceedingly rare. One of the few known sites that is located in France is the site of Caours (which is located in northern France near the coast) and as mentioned there is a complete absence of sites in Britain. It is because of this that the recent discovery of the archaeological site of Waziers in northern France is so important, as this site has also been dated to the Eemian interglacial. It is for this reason that this thesis will focus on this site and compare it to other sites with hominin activity when applicable as it is located close to Caours near the French coast and is therefore a likely location from which hominins would then have expanded into Britain if they could. Its proximity to Caours will help in answering the question that this thesis will pose regarding hominin activity in north-west Europe:

Why was there no hominin activity on the British Isles during the Eemian interglacial period?

The answer to this question might shed light on hominin dispersal strategies in regard to climate and ecology, as well the dispersal rate within a spatial-temporal context, as they would have needed to have travelled from areas that were habitable during the Saalian to areas that were hitherto uninhabitable. This would have needed factors ranging from the availability of resources necessary for survival, to climatological conditions that were livable for early hominins.

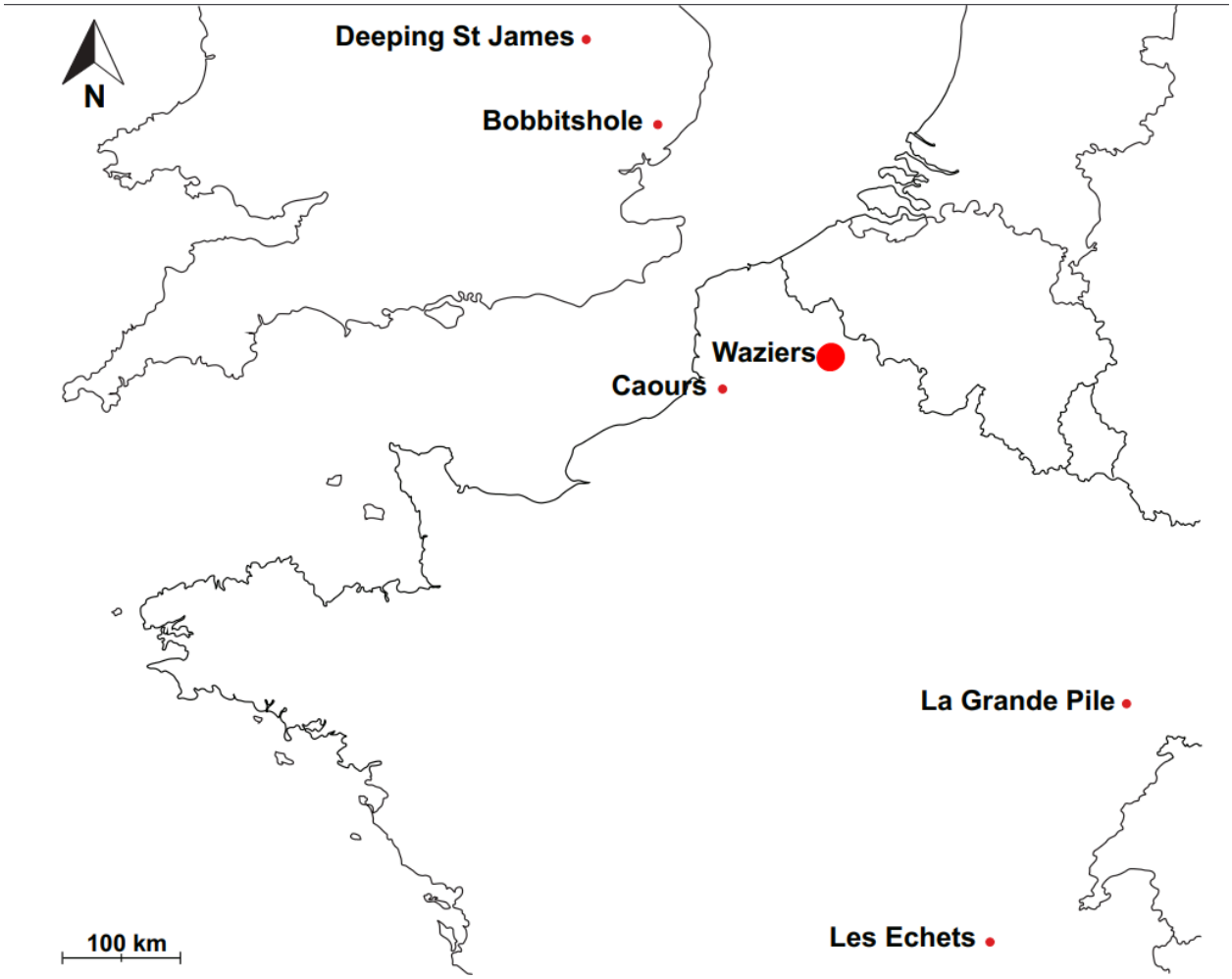

Figure 1 The site of Waziers relative to other Eemian typesites, (Field et al., 2023, p. 13, Figure 1)

In order to answer these questions, this thesis will investigate a fluvial site near Waziers in northern France (see figure 1). The site is located near the border of Belgium and although it is farther away from the coast than Caours, it is located closer to the Channel, which is the spot that early hominins will most likely have used when trying to cross over towards the British Isles. The nature of the site concerns an oxbow lake that dried up during the Eemian interglacial. The location of this site was close to the area where the land bridge between Europe and the British Isles would have been during the early stages of the interglacial. From this site several samples were taken for botanical study. The remains extracted from this sample have been examined on both a carpological and palynological level in order to make an environmental reconstruction so as to be able to make a contribution to our understanding of the ecological and climatological conditions of north-west Europe during the Eemian. Sub questions have been formulated in order to better explore the temporal and spatial context that is being investigated by means of these samples, because the aspect of time needs to be taken into consideration when attempting to reconstruct physical conditions based on several depositional layers:

1a) What was the vegetation during the period that the stratigraphical layers at Waziers belong to.

The answer to this will shed light on such factors such as the resources available to hominins while they were travelling through this area. Aspects such as the availability of food are of great importance for an area to be traversable or habitable. Unfavourable conditions might have deterred hominins from travelling through the Waziers area, especially considering that they were likely unaware of the conditions that they would find themselves in once they had crossed it, let alone the existence of the Isles themselves. In addition to this the vegetation will also define the type of climate that was present during the period of the sediment deposits. Plants have certain ecological tolerances such as temperature and precipitation which had to have been in place in order for them to be able to grow and propagate in the region. Zoological factors would also be relevant when exploring this subject, and while they will be considered in a minor fashion, an in depth analysis of this is beyond the scope of this thesis which will mainly focus on the botanical factors present within the region of north-west Europe. These factors extend to the second sub question:

1b) How can the botanical taxa that are present at Waziers contribute to our understanding of the local and regional environment during the chronology that the stratigraphical layers at Waziers belong to.

This question is closely related to the previous, as it is partly defined by the nature of the botanical conditions that were present at Waziers. For example, the physical conditions might have made it difficult for hominins to travel through the area. This could be due to factors such as densely forested areas or swamp like conditions which could have influence on the speed that the area was traversable, the resources that were available for consumption and the amount of danger that an organism would be in while crossing. These conditions would have been compounded by climatological factors such as temperature, precipitation and aeolian circumstances. Much like the climate, the ecological tolerances of flora is also influenced by the environment that they grow in. Chemical aspects such as the acidity, the calcareousness, or the salinity of the soil are of great importance for plants to be able to thrive. This is in addition to physical aspects such as the water levels in an area in the form of both climatological factors such as precipitation and geographical factors such as rivers or lakes. By analysing the botanical remains, all these factors can be attempted to be reconstructed in order to see what conditions hominins would have encountered when they arrived at Waziers and that may have influenced the choice whether or not to travel further beyond. These conditions may also influence the fact whether or not a land bridge between France and Britain still existed by the time that hominins would have been able to use it to cross it. It could be that the environment was too hard to travel through and that too much time had passed by when the bridge would already have disappeared. But it could also be the case that the climate was so warm that the glaciers would have melted very quickly, which would lead to the land bridge disappearing soon

after the start of the Eemian. This leads to the subsequent sub question that will need to be answered:

2) What is the chronological position of the site of Waziers within the Eemian stage?

This is important when considering the presence of the land bridge. By answering this question we can put the chronology of the stratigraphical layers at Waziers into context. This chronology will consider two different aspects. Firstly it is important to identify which period of the Eemian these sediments represent. This is important when considering the environment that can be expected to have existed during this time. For example it considers whether it represents the early Eemian which follows a cooler glacial period and which would therefore be expected to be relatively cold compared to the rest of the Eemian, or it could represent the Middle or Late Eemian which would have been relatively warm even when compared to modern temperatures in the region. This is important when considering the aforementioned issue of the existence of the land bridge, which disappeared during the Eemian. The second temporal aspect that is explored with this question is a period which the sedimentological sequence covers. Using this it is possible to look at the rate of change in environment and climate. Considering the site is an oxbow lake that is drying up, it is possible that there is a rapid change of environment, which is in turn an important consideration when looking at climatological change, as it could be that hydrological changes are local in nature, rather than the result of climate change. This is why it is important to use both macrobotanical data such as carpological remains (which give a local signal) and microbotanical data such as palynological remains (which give a regional signal), in order to attempt these different changes from each other. A rapid change in either environment or climate would regardless have a severe impact on any hominin activity in the area in regards to both resources and traversability. This might make local conditions unlivable which might deter hominins, although this change might also cause an impulse for settled hominins to travel further. However a rapid change in climate may also have had an impact on the amount of time that hominins would have had to cross the channel. Therefore both temporal aspects are of importance when considering the main research question.

Another important factor to consider is the anthropogenic aspect. Human dispersal rates during the Eemian are key when attempting to explain the absence of hominin activity in Britain, which is something the following two sub questions will consider.

3a) What are the archaeological conditions at the start of the interglacial cycle?

Much like the other questions, this too has both a local and a regional aspect. Locally it is important to consider whether or not there was already an established hominin presence if at all possible. A pre-existing hominin presence would mean that they would not have to travel as far in order to reach the French coast. In addition to that it would be likely that they would have been familiar with the local environment and geography, meaning that they might more easily

traverse the terrain and perhaps already know of the existence of the British Isles. Environmental and climatological change would have had an impact on these conditions, but assumedly not to such a degree to completely invalidate this knowledge. It could be possible that local populations would have had little reason to move away from the local region, however information on migration and dispersal might give more insight into the degree of movement local populations exhibited. Second is the consideration of population activity in Europe as a whole and perhaps even beyond. It could be possible that the end of the Saalian heralded large scale migration events from other parts of the world to areas that had been covered with glaciers during the glacial stage. Although such populations would lack the knowledge that local populations might have had that would have eased travel through possibly hazardous environments, they would in turn have a precedent of migration over long distances during which they might have already had to deal with adverse travel conditions. These could be climatological in nature such as the more extreme seasons associated with the land climate of inner Europe when compared to the milder sea climate of the Atlantic coastal regions. But these conditions might also be physical such as the Alps or the dense forests of Germany. Being accustomed to such hazards may have allowed such populations to be willing to traverse marshlands or densely wooded areas that might have contained local populations. Knowing anthropogenic habits during the start of the interglacial cycle and before might give insight into migration strategies. This is important because any crossing of the land bridge would have needed to occur during the early stages of the Eemian period. The next sub question condenses this information from larger patterns into the more immediate situation:

3b) What were the archaeological conditions at Waziers during the period represented by the sampled depositional layers.

This question will use the information gained by answering the previous question, in order to apply any possible patterns in a local context contained entirely within the information provided by the sample. In order to do this the information must be combined with the temporal information that was considered in earlier questions in order to properly reconstruct which part of the Eemian the site of Waziers represents and what local and regional migrational patterns were present during this period. This will in turn make it possible to attempt to extrapolate this information in order to argue why populations would have chosen to not cross the land bridge to Britain should both these populations and the bridge be present. This will then make use of the environmental and climatological considerations made before.

Once these conditions have been reconstructed there is then a final question to be considered that might have influenced a significant hominin presence on the British Isles:

4) What was the biogeography of Britain during the represented period of the Waziers deposits?

When considering population movements it is not just important where the population is coming from, but also where it is travelling to. Although it is likely that any hominins travelling from the mainland did not know the biogeographical conditions on the British Isles, in the case that these conditions were sufficiently bad it could have been enough reason to leave Britain soon after arriving. This would mean that hominins did travel to Britain, but did not have a presence that was significant enough to be easily found during a campaign. In the case of a large population it is to be expected that at least some sites will be found based on expectation models mapping out the areas with high anthropogenic potential. However if such sites are sufficiently abundant and the population sufficiently small, it is possible that there was a hominin presence that has simply not been found or not preserved. In order to explore this further it is first required to investigate the biogeographical conditions in Britain during the Early Eemian in order to see if there could have been conditions that would have stymied the propagation of hominins in Britain. Alternatively it could be possible that the biogeography led to a situation where taphonomic processes would leave little or no traces of hominin activity, however this is unlikely considering that there have been anthropogenic sites dated to before the Eemian period. This information should then be compared to the information from the Waziers site. Even if environmental or climatological conditions on the British Isles were poor for hominin propagation, if they were similar to those encountered at Waziers then they should not be the defining factor for hominin success. In order to fully explore this there needs also to be consideration for aforementioned factors such as the availability of a land bridge in order to cross and for conditions on this bridge to also be good enough to traverse. Taking these final considerations into account it should then be possible to suggest an answer to the main research question as to the seeming absence of hominins in Britain during the Eemian.

In order to answer this question several types of research were conducted. First a literature review was used in order to ascertain pre-existing knowledge of the local and wider region. These will consider palynological type sites in both France and Britain. These sites can be cross referenced in order to date the site of Waziers to a specific stage during the Eemien, which is needed for the temporal aspects of the research. The pollen records are also indicators for regional climate trends which are also important when considering long range migration. In addition to this, other climatological proxies need to be consulted in order to acquire a more accurate estimate of climate trends during the early Eemian. This could be in the form of botanical indicator species for local climates. Potential other techniques include ice core isotopes or zoological indicator species. The latter could possibly also be used for isotope analysis in order to map migration of animals besides hominins. However such considerations fall outside of the scope of this thesis. Ecological tolerances were also investigated in order to accurately reconstruct local environmental conditions. This is also aided by the study of botanical indicator species. Geological conditions were taken into consideration as well, since the existence of a corridor to Britain would have been important for early hominins in order to cross the channel, although marine traversal can not be ruled out conclusively. Therefore it is important to consider the time window during which the local geography would have allowed

travel. Finally literature study was performed in order to map hominin migration patterns during the Late Saalian and Early Eemian. This archaeological context was used in order to extrapolate possible strategies that would have allowed for travel to Britain or make it impossible. In addition to the literature study, several datasets were produced and used in order to make an environmental reconstruction of the Waziers area and wider region. In order to do this both carpological and palynological data was gathered to make a complimentary dataset. Carpological data can be used in order to reconstruct local conditions because these remains tend to travel only a limited distance. Therefore it is possible to accurately describe these conditions with a relatively high certainty when taking into account several pre-depositional and taphonomic processes that might have influenced the dataset. In turn the palynological data can be used in order to describe botanical trends over a large area, because pollen grains have the ability to be transported over large distances, as well as the fact that they preserve well in many environmental conditions, whereas carpological remains might be more fragile. As described these pollen grains can also be used as both temporal and climatological proxies by the use of type sites. Combining these datasets allows a large area reconstruction of biogeographical conditions while also having a high resolution on a local level. Answering these questions might lead to further insights into hominin strategies during the Early Eemian and perhaps to new considerations when producing expectation models for hominin sites from this period. In addition to this it might also lead to new climatological insights during the Early Eemian in north-west Europe during the transition from a late glacial cycle to an early interglacial cycle, as well as suggest further use of indicator species in the context of climatological reconstruction. Finally this thesis may prove the use of a wider multidisciplinary approach when combining environmental archaeology with a hominin migration context. This might lead to other disciplines besides palaeobotany to be able to be used when considering these research questions and therefore to a more conclusive answer in the future.

Reading guide

Chapter 2 of this thesis will cover the background of the site of Waziers. It will investigate pre existing research that is done regarding botanical, zoölogical, stratigraphic, and lithological remains that have been discovered during earlier campaigns at the site in order to lay a foundation for further interpretation. Chapter 3 will discuss the climatological background of north-west Europe during the Eemian based on a number of proxies. These include botanical indicator taxa, typological pollen zones, and oxygen isotopes, which can be used to reconstruct palaeoclimates on both small and large scales. Chapter 4 will finish the background research by investigating the dispersal of hominins in north-west Europe during the early Eemian. It will do so by researching the sites of Neumark-Nord and Caours, which are some of the rare instances of Hominin activity during the early Eemian in this part of Europe. Chapter 5 will discuss the methodologies that were employed in order to prepare and analyse the botanical samples that were taken from Waziers, and which served as the main research subject of this thesis. In

chapter 6 the results from this research will be analysed in order to use these to answer the research questions that have been posed in the introduction. Chapter 7 will combine the results with the previously performed background research in order to put these into a wider historical context and investigate which possible conclusions might be able to be drawn from them. Finally in chapter 8 the previous chapters will be combined into possible answers for the sub questions that were established in the introduction. These will then be used in order to answer the main research question.

2. The Archaeological background of the site of Waziers

As mentioned before, Waziers has a significant importance from an archaeological perspective. Hominin sites from the Eemian are rare and were thought to have not existed at all until relatively recently. Because of this, the few sites that are known are all exceedingly informative regarding the dispersal of early hominins throughout north-west Europe during the Eemian interglacial and every potential new site can contribute to the little information that is presently available. The site of Waziers is situated in Northern France close to the Belgian border, near its namesake of the town of Waziers and just north-east of the town of Douai in the Bas-Terroir area (50°23'33.5”N, 3°06'48.2”E) (see figure 2). It was discovered during operations between 2011 and 2013, and it was first excavated during 2014 and 2015. During this investigation the research area was confined to an area of 500 m by 200 m. Located close by is the Scarpe river which is fed from the Gohelle plateau and the pévèle (Bahain et al., 2022, p. 3; Hérisson et al., 2022, pp. 227-228) and although it is canalised in current days, in the past when it was still the Scarbus it would have winded its way through the region. The site of Waziers was an oxbow lake that was cut off from the Scarpe when the meanders became too great. Over time this cut off lake would have dried up and eventually overgrown. What is interesting about this site is that, close to the oxbow lake, anthropogenic material was discovered. These early hominins are thought to have lived on the banks of the palaeochannels located at the site and in between the streams. This is interesting as the site was dated to the Eemian interglacial period and, apart from the site of Caours just to the south of Waziers, no other sites of early hominin activity dating back to this period have been found in France and for a long time it was thought that hominins could not have survived in north-west Europe at all. What sets Waziers apart from Caours is that the organic materials at Waziers were preserved exceptionally well, which is most likely due to the difference between the sediments found at the two sites. This is especially the case for plant material, which includes both palynological (microfossil) as carpological (macrofossil) remains, which this thesis uses in order to reconstruct the contemporary Eemian landscape. In addition to this the resolution of the sedimentology at Waziers is also very high which assists in identifying the approximate date that finds were likely deposited (Hérisson et al., 2022, p. 226).

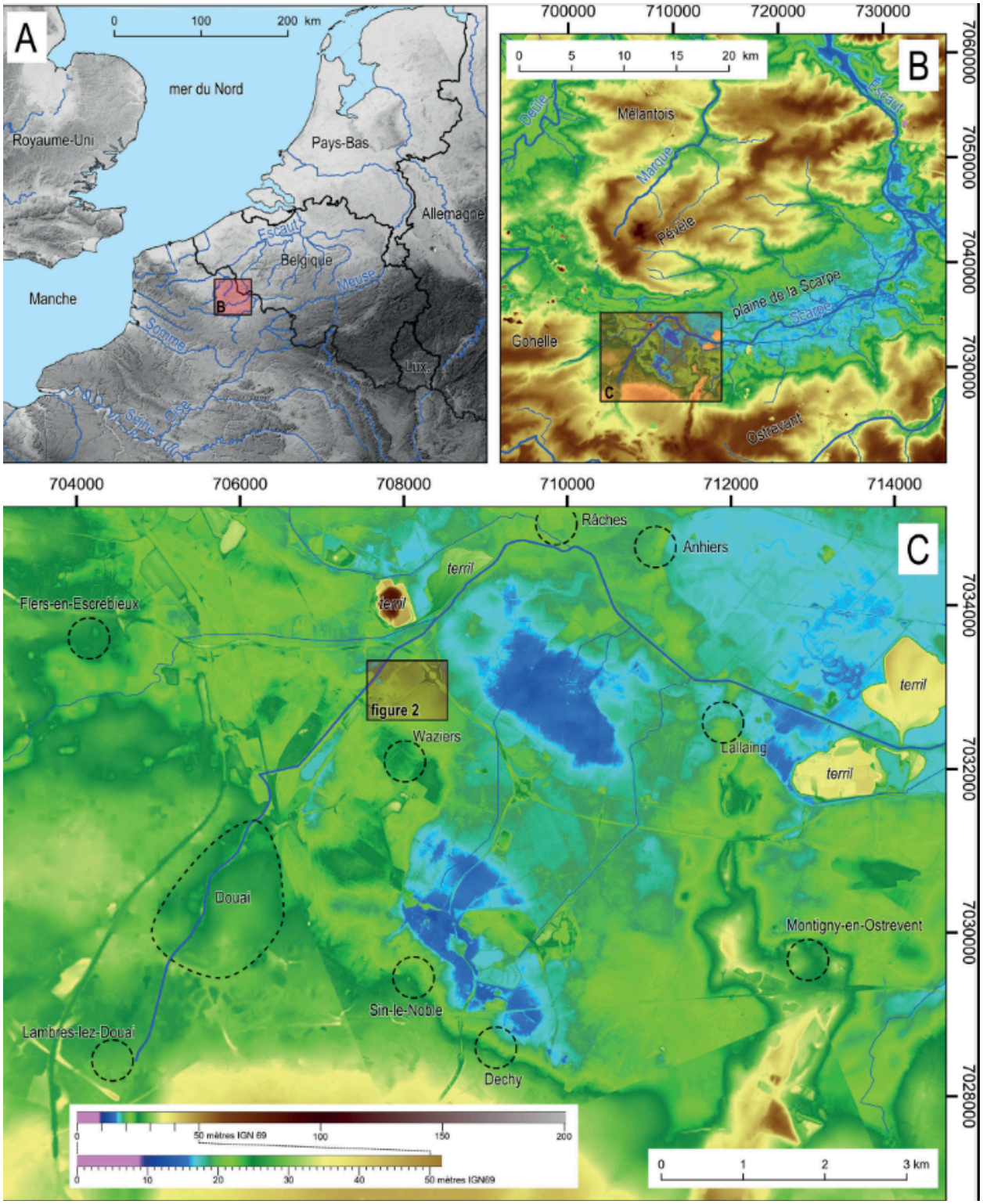

Figure 2 Localisation of the site of Waziers, France (Hérrison et al., 2022, p. 227, Figure 1)

Stratigraphy

The larger area is situated upon a layer of marine deposits which mostly consist of sands dating back to the paleocene which was between 66 and 56 million years ago. It is confined by chalky sediments to the south and clay deposits to the north. The plain itself is filled with sands that almost completely lack larger rocks and only a very small amount of gravel, and that bear signs of glacial geological structures. The Eemian sediments were covered up in the Weichselian by aeolian loess deposits (Hérisson et al., 2022, p. 230). During a survey in 2011 it was discovered at Waziers that within the sandy sediments that filled the plain, there were layers of peat at a depth of around 2,5 metres which over multiple investigations turned out to be part of a series of peat layers that went on as deep as 4,5 metres and were banded by silty sands which contained chalk nodes. Within the lowest of these layers contained a fragment of a radius belonging to *Bos primigenius* that showed signs that it was intentionally fractured in combination with a Levallois like pointed flint shard. These finds had been exceptionally well preserved within the peat. Initially it was thought that these belonged to late glacial deposits, but after the finds in the lower peat layers the site was investigated further and it became clear that the record of these peat layers went on into the Eemian (Field et al., 2023, pp. 1-2; Hérisson et al., 2022, pp. 229-236). As a result of this further research was performed in that layer and although there were more remains found belonging to mammals and avians, which will be discussed later in this chapter, there were no more flint artefacts found during this excavation that took place in 2013 (Deschodt et al., 2022, p. 251). The piece of flint was located in one of the lowest stratigraphic layers composed of silty sands which contained a large amount of botanical material. Sitting on top of this layer was a large deposition of silt containing tuff and exceedingly large amounts of characeae remains that would be used later to approximately date the site, whereas underneath this layer was a bed of chalky gravel in which faunal remains were found as well. Covering this are various layers of peat which contain the remains of wood, mammals and molluscs. The end of the peat sequence is then marked by a cover of silty sands that contain a large amount of organic remains. Covering this stratigraphic sequence are then layers of bedded sands, and decarbonated silts and sands. It is suggested that this later sequence represents an active channel that deposited first the heavy sands and later the sandy silts, before finally being covered by the loess layer that was mentioned earlier in this chapter (Deschodt et al., 2022, p. 251). Altogether it was concluded that there were four archaeological stages included within the multiple peat deposits (Bahain et al., 2022, p. 3). During the excavations that took place between 2013 and 2015, in a layer consisting of silty channel deposits that was located just above the sediment layer that contained the first piece of flint, four more flint artefacts were found in proximity to more faunal remains. Additionally in the sediments just above that more faunal remains were found that included beaver and another archaeological zone that had been missed during the excavations that came before (Deschodt et al., 2022, p. 261). At a depth of 3 metres located just under the Weichselian loess cover, the sediments range from organic fluvial deposits, to various peats which for the majority consist of

wood peat, to mollusc silts. Because there were several pieces of wood and other remains belonging to *Quercus* found as well as bone fragments belonging to deer, an initial environmental interpretation was made which identified Waziers as a wooded area. This pointed towards the more temperate conditions associated with interglacials rather than the initial thought that these peats might be from the Weichselian (Hérisson et al., 2022, pp. 229- 236). It is important to note that deposition of sediments is not a constant factor, but one that changes depending on environmental conditions (Deschodt et al., 2022, p. 247). In a fluvio-lacustrine ecology, and especially during conditions wherein peat is generated, rates of sedimentation will be much higher than in many dry ecologies, especially climax ecosystems such as the forests that closed in during the later stages of the site at Waziers and beyond that. During climax ecosystems such as advanced forests the rates of sedimentation would have been minimal. These factors are also different in the same layers even within the same site. Because of this a correlation was made between the different stratigraphic samples that were taken at Waziers and several thin sections were made in order to better understand the sedimentary processes that were active during the period of deposition (Deschodt et al., 2022, p. 256). By analysing the stratigraphic layers at Waziers these were eventually categorised in three main members. The nature of these was that there were 2 members with a clastic origin that encased the second member which was organic peaty in origin. The first clastic and the organic members are associated with the formation of the site of Waziers whereas the third member signifies the period that came after. However, part of the reason for this is that the availability of environmental data stops at the end of the second member, likely due to a lack of material (Deschodt et al., 2022, p. 262). As a result it is unknown how exactly the sequence progressed and the possible consequences this would have had if early hominins would have come through this area at a later date during the Eemian. Despite this it must also be conceded that all the known archaeological stages that are associated with the Eemian are found within the peat sediments or just below and that there is no sign of further hominin presence at Waziers past this point.

ESR/U-series dating

Dating the site of Waziers was done through electron spin resonance and the uranium series. Oöspores from characeae found at the base of what is considered to be the interglacial sequence were dated using the u-series and found these fossils to have a minimum age of 103.000 years (± 3,5 thousand years) which was combined by researching the mollusc remains found in the silt. When combined with palynological data it is possible to distinguish the transition at the site from a colder climate from the Saalian where there was an ecology consisting mostly of open plains, into the warmer period of the Eemian where there was found to be a progression from *Ulmus,* ranging though *Quercus* and *Corylus,* until it reached a climax at *Carpinus* forests. This mirrors the data that was found earlier at the site of Caours and is confirmed further by faunal remains which are consistent with forested environments. In contrast

the lower sediments in the sequence which were silty fluvial deposits and those included taxa such as equids which are more associated with open environments (Bahain et al., 2022, pp. 2-3). From these mammal remains enamel from four teeth were extracted from the earlier depositions at Waziers which would have coincided with the last part of the Saalian period. These teeth were then dated using ESR in order to measure their uranium series concentrations. From this came the results that these teeth had an approximate age of 129.000 years (± 11 thousand years within two standard deviations). This would put these teeth at the start of the Eemian interglacial although there is a wide margin of error in this data. Remarkable about the uranium levels of these teeth is that they were quite low, however this was deemed the result of the peat environment that these teeth were found in which would have meant that the uranium would have been caught within the humic acids of the peat rather than in the faunal remains. Because of these results it was concluded that the site of Waziers represented the transition of the Saalian into the Eemian, however it must be kept in mind that aside from the significant amount of variance that is associated with the U-series dating from Waziers, Bahain also conflates the term ‘Eemian’ with ‘MIS5e’ although it has been shown that there is a significant lag between the peak of the latter and the start of the Eemian (Bahain et al., 2022, pp. 1-2).

Zoological data

A large amount of animal remains were uncovered during the excavation campaigns at Waziers. During the excavation of 2014 and 2015 a number of 151 bones were extracted, most of which could be connected to a known stratigraphic unit. These bones included multiple taxa of mammals such as *Bos primigenius*, *Cervus elaphus*, cf. *Dama dama*, *Megaloceros giganteus*, *Capreolus capreolus*, *Stephanorhinus hemitoechus*, *Equus achenheimensis*, *Ursus arctos*, cf. *Aonyx antiqua*, *Castor fiber*, as well as several remains that could only be identified to belong to large herbivores and small mammals. Additionally several remains were found that belonged to various birds, tortoises and rodents. There is some discussion regarding the identification of the Dama dama as the bone seems to be too large to belong to a roe deer, however it is also not large enough to belong to a deer. However a relatively large amount of the bone material could be identified with certainty due to the fact that the remains were preserved very well within the peaty context that they were deposited (Auguste et al., 2022, pp. 313-318). While *Equus achenheimensis* is a species that is mostly associated with more open environments, *Cervus elaphus* and *Dama dama* are more often found in forested ecologies which is consistent with other conclusions regarding the environmental succession (Bahain et al., 2022, p. 3). Compounding this is the presence of *Castor fibre* whose habitat is generally defined as being both in proximity to running water as well as needing trees and other vegetation in order to make their burrows and dams. The bones show signs of anthropogenic activity such as butchering, such as cutting marks that were found on the tibia belonging to a beaver. In addition to this remains have been found of a beaver dam which contained the nearly intact skeleton of a

young beaver as well as skeletal remains belonging to a turtle. It has been theorised that a beaver dam might have attracted early hominins because it represented a food resource as well as being able to be harvested for wood. The remains of the rhinoceros seem to indicate that it belonged to a robust individual which would mean that it dates to the late pleistocene which started when the Eemian began, earlier rhinoceros belonging to the Chibanian during which the Saalian took place would have been more slender (Auguste et al., 2022, p. 316). However rhinoceros are also associated with open grasslands which is another sign that the environment at Waziers was more open during the start of its sequence, after which it became more forested which allowed the introduction of deer and beavers, which in turn could signify that Waziers does represent the transition from Saalian to Eemian. This data is consistent with other research based on stratigraphy, malacology, microfauna, palynology and climatological reconstruction (Auguste et al., 2022, p. 319).

Botanical data

Pollen zones can be used in various ways in palaeoclimatic research. It can be used in order to correlate the dating of a site to comparable sites in the region, but it can also be used to reconstruct the climate directly based on the taxa that can be encountered in the stratigraphic record. During earlier research at Waziers, three sequences were sampled from the sediment in order to investigate the archaeologically relevant period. These sequences were taken from two locations which were about 300 metres apart from each other. The lowest taken sequence samples came from the grey silt that was located below the peat and was part of stratigraphic member 1 and expanded into the base of the organic peat layer that comprises stratigraphic member 2. The second sequence samples included the entirety of the peat sediments deposited in stratigraphic member 2. The third and final set of sequence samples was taken at a later date and consists of a sequence in stratigraphic member 2 that correlates with a part of the peat sequence that was sampled in the second sample. The reason for this was so that this third sample would be able to be placed within the pollen zone record that was established during the earlier samples. In total a number of 53 samples were selected in order to reconstruct the entire pollen zone sequence, of which 49 were taken during the first two sequence samplings and 4 were taken during the third sequence sampling which was taken for auxiliary purposes. The preparation of the pollen samples were made using the research standard, making use of chemicals such as HF, HCl, KOH and acetolysis, and sieving the samples over a 200 µm mesh. Finally the pollen samples were mounted on slides suspended in glycerol (Gauthier, 2022, pp. 279-280). Pollen, spores and other microfossils were counted and identified. This methodology largely mirror the methodology that was used in this thesis, as will be described in a later chapter, with the exception of the HF, in place of which H_2SO_4 was used. In addition to this a slightly different strategy for counting was used during this thesis, with the count being based strictly on terrestrial pollen and although aquatic taxa, microfossils and some spores were identified, they were not included in the final tally, although the research of Gauthier

also does not include spores in the final count. The pollen zones that were identified based on this count were divided based on the standard that was set by Gordon & Birks (1972) and Birks & Birks (1980) (Gauthier, 2022, p. 280).

The lowest pollen zone (dubbed waz-1) was characterised by a high amount of *Pinus* (~20%) in combination with an abundance of Cyperaceae (21-29%) and Poaceae (8-19%), with lower but still significant amounts of *Artemisia* (3-8%) and Apiaceae (1-7%). In addition to this there was an arboreal and shrub signal of *Juniperus* (4-7%), *Salix* (0,3-2%), *Betula* (0,3-3%) and *Populus* (1%) (Gauthier, 2022, pp. 284-285). This is a signal that is consistent with colder climates that are associated with the late Saalian period.

Waz-2 saw a large increase in Cyperaceae (32-53%) and *Artemisia* (7-13%), whereas the values of *Pinus* (6-11%) halved and *Juniperus* (2-6%) also decreased slightly. The amounts of *Betula* (1-6%) and *Salix* (0,3-9%) increased as well where the concentration of Poaceae (15%) remained stable (Gauthier, 2022, p. 285). This reflects the decline of *Pinus* that happened during the rising temperatures in the transition from the Saalian into the Eemian interglacial which allowed pioneer taxa such as *Betula* and *Salix* to gain a better foothold in the region.

Waz-3 marks the transition into the organic silt sediments, which is clearly reflected in the pollen record. Most notably there is a drastic decrease in the amount of *Cyperaceae* (9-16%) pollen and the appearance of the aquatic *Myriophyllum verticillatum* (11-27%). In addition to this the waterside *Sparganium-Typha* type (1-26%) appears as well, in addition to other aquatic genera such as *Lemna*, *Menyanthes*, *Nymphaea* and *Potamogeton*. Terrestrial taxa such as Poaceae (14-25%), Urticaceae (0,4-1%) and Apiaceae (2-3%) see an increase as well while *Artemisia* (8-15%) remains stable. The trees and shrubs continue to decrease with the exception of *Betula* (8-17%) (Gauthier, 2022, p. 285). This marks the start of the fluvial sediments which will eventually turn into an oxbow lake after the river arm is cut off. It is important to note the aquatic taxa is counted in the total, this means that on land the increase of *Betula* was even more drastic than is reflected within these numbers, the same goes for the other terrestrial taxa within this dataset and will continue until the oxbow lake has dried up.

In waz-4 there is a spike in the amount of *Sparganium-Typha* type in the sediment whereas the Cyperaceae (3-4%) and *Myriophyllum verticillatum* (0.7-4%) almost completely disappear. The Poaceae (16-28%) continue to remain stable while there is a slight increase in Apiaceae (2-8%). *Artemisia* (2-4%) diminishes as well and other taxa that are associated with steppe environments are not represented at all. Finally most arboreal and shrub taxa continue to decrease slightly with the exception of *Betula* (4-10%) which sees a sharp decrease compared to waz-3 (Gauthier, 2022, p. 285). This shows that shallow waterside plants dominate the ecology at Waziers during this period whereas trees start to reduce in number.

Waz-5 sees a very sharp increase of Poaceae (66-72%) while aquatic herbs like the *Sparganium-Typha* type drop drastically. In addition to this there is a slight increase in the amount of *Pinus* (4-15%), however more importantly *Ulmus*, *Quercus* and *Corylus* are introduced in the stratigraphical layer (Gauthier, 2022, p.285). This indicates that the oxbow lake is starting to dry and large grasslands have developed. The new arboreal taxa also indicates that the temperatures have increased to temperate levels belonging to the developing early Eemian.

During waz-6 Poaceae (23-53%) drop again to reduced levels as at the same time *Betula* (7-30%) and *Ulmus* (20-22%) take their place. Additionally there is a sharp spike in *Sphagnum* spores (49-83% compared to the concentration of pollen) (Gauthier, 2022, p. 285), which are mosses that are associated with peats. This indicates that the oxbow lake has now progressed to boggy conditions.

Waz-7 marks the peak of *Ulmus* (47-49%) while at the same time the amount of *Betula* (12-17%) decreases. At the same time *Quercus* and *Corylus* have retained steady values since their introduction in waz-5. Furthermore Poaceae (4-11%) continue to decrease as well as any wetland taxa and *Sphagnum* (~1%) with the exception of Cyperaceae such as *Cladium mariscus* which are well represented in the carpological record (Field et al., 2023, p. 5; Gauthier, 2022, p. 285). At this point in time the bog has almost completely dried up as the area becomes densely forested leaving few opportunities for grasses and herbs to grow.

During waz-8 much of the *Ulmus* (9-26%) is replaced by *Quercus* (36-58%), the next step in the vegetational progression. *Corylus* (0-9%) also increases slightly and new taxa are introduced such as *Hedera* (1-4%), *Fraxinus excelsior* (0-2%), *Taxus* and *Alnus*. Meanwhile *Betula* (0-3%) disappears almost completely, while *Pinus* (5-21%) continues to be stable during the last few zones. More open landscapes with Poaceae (1-11%) and Cypereceae (3-12%) do seem to be resurging (Gauthier, 2022, pp. 285-286).

The record of waz-9 shows that *Quercus* (10-27%) is being replaced with *Corylus* (33-59%) and that *Alnus* (0,5-17%) and *Taxus* (0-2%) are also increasing where *Ulmus* (4-12%) continues to decrease as well as *Pinus* (1-4%). During this time the amount of Poaceae and Cyperaceae remains stable when compared to waz-8 (Gauthier, 2022, p. 286). So while the arboreal vegetational stages keep progressing the forests themselves are not encroaching further on the grasslands during this period.

Waz-10 is the final pollen zone that is identified in the sequence and in this period *Carpinus betulus* (2-13%) is introduced to the area. At the same time there is also an increase of *Alnus* (29-39%) in contrast to a decrease of *Corylus* (21-32%), *Quercus* (5-11%), *Ulmus* (3-8%) and *Pinus* (1%). *Abies* and *Picea* are also newly introduced taxa during this period whereas Poaceae (1%) almost disappear completely (Gauthier, 2022, p. 286).

The vegetational progression of Waziers as recorded within this pollen sequence clearly describes how the site evolved. While it started off as a steppe landscape with a presence of *Pinus* forests, it then became part of an aquatic ecosystem due to activity of the Scarbus river. After the meander that ran through the site was cut off, it started to dry up into a bog with Cyperaceae that bordered an open grassy landscape. After this the forest started to close in and different arboreal taxa usurped their dominant positions during the progression in the Eemian climate that would continue to warm up during this process.

Malacological research

Within the lower layers of the sequence at Waziers, within which the copious remains of characeae were also discovered, several types of terrestrial molluscs were discovered. These molluscs show that during the period in time that these layers represent, there is a progression in the diversity of these molluscs among which are useful in making an ecological interpretation of these stratigraphic layers. The species of these molluscs include *Pupilla muscorum*, *Trochulus hispidus* and *Oxyloma elegans*, which can tolerate colder climates with a high amount of humidity (Deschodt et al., 2022, p. 250). In addition to this there were also multiple aquatic taxa included in this early malacological data, that are often associated with interglacials and other warm episodes such as *Valvata piscinalis*, *Valvata cristata,* and *Radix labiata*, although it must be noted that these molluscs are also common during the quaternary as a whole (Deschodt et al., 2022, p. 250). In the layers above this which include the pear, in addition to the aforementioned taxa, several other pioneer taxa can be found as they appear throughout this early sequence of Waziers, which is already interpreted as a representation of the beginning of the Eemian through several other disciplines. These pioneer species are taxa which thrive within warmer temperate climates and include *Gyraulus laevis* and *Armiger crista*. There are also several aquatic taxa within these sediments that prefer warmer temperatures compared to those that are usual in the Saalian such as *Hippeutis complanatus*, *Bithynia tentaculata*, *Physa fontinalis*, *Belgrandia marginata* and *Anisus septemgyratus*. The latter two of these taxa are especially important from the context of dating as these place the sediments that they were found in, in the interglacial with certainty. The samples are collected from sites in France that date back to the Late and Middle pleistocene (Deschodt et al., 2022, p. 250) and since the sediments at Waziers do not include pleistocene interglacials prior to the Saalian, that means that they must be part of the Eemian period and not to the Weichselian as had been suggested before the excavation campaigns in 2013, nor can they belong to an older pleistocene interglacial. The two levels that were sampled and were located above the peat had little in the way of malacological data and could therefore not be used for an environmental reconstruction (Deschodt et al., 2022, p. 250).

Flint material

During several corings that were performed at Waziers, more than 30 pieces of flint were discovered. After analysis it was determined that these flint artefacts could be dated back to the Middle Palaeolithic based on their technical properties. It was also determined that due to fluvial taphonomic processes these inclusions were not native to the sedimentary layers that they were found in, although this displacement was concluded to have been short distanced. During further investigation even more flint artefacts were discovered bringing the total up to an amount of 236 pieces of flint. The typology of the artefacts identified them as being mainly Levallois type flints that were quite large and finely retouched. In addition to this several bone fragments were found within the same context, however these could not be identified (Hérisson et al., 2022 p. 233).

Implications for this thesis

There is much data, such as the date given by the ESR/U-series of teeth found at the site and the presence of a late pleistocene rhinoceros, that indicates that Waziers was a site that represents the end stages of the Saalian continuing forth into the early Eemian during which early hominins were active at the site during multiple stages. There have also been some interpretations into the different types of environments that are represented in the sequence through faunal remains, macrobotanical material and pollen research aimed at identifying pollen zones. This is oftentimes compared to the data of Caours, one of the only other archaeological sites dating to the Eemian found in North-west France. This thesis will add to that not only by making an environmental reconstruction based on both carpological and palynological data, but also by correlating this data to several other Eemian sites in France, Britain and Germany. This will not only result in a local reconstruction of the climate but also fit this into a larger regional framework of climate processes and hominin expansion. Doing this will assist in answering when during the Eemian the anthropogenic activity at Waziers was, but also the climate that early hominins existed in and how that might have impacted them should they have wanted to travel to the British Isles.

3. Climatological conditions in north-west Europe during the Eemian

Because the transition between the Saalian period to the Eemian period was one from a glacial stage to an interglacial stage, the prevailing climate during these periods is the primary factor used to identify this transition. There are several proxies through which the climate and the change therein can be reconstructed. An important example of this is the use of palynological typesites that signify the different stages within the glacials and interglacials. These in turn make use of the large scale ecological tolerances that are inherent to plants. Another example of the use of ecological tolerances is the presence of plants and animals on a local level such as the recorded presence of hippopotamus in the Thames or taxa that exhibit certain behaviours within specific climatological windows. Such organisms are called indicator taxa when observed within such a context. This will also be expanded on later in this thesis in the context of environmental factors that do not necessarily pertain to climatology. Other proxies are geological formations that may indicate the presence of terrestrial ice sheets that may have covered an area, as well as any soils that might distinguish a maritime or terrestrial environment. Although such formation might be indicative of climatological trends, it is difficult to put these into a temporal context in isolation. These proxies will also be discussed later in this thesis in the context of environmental reconstruction rather than climatology. A final proxy that can be used for climatological reconstruction are ice cores from places such as Greenland. The δ16 oxygen isotopes present within these ice cores can indicate the amount of ice present on a global scale, which in turn might give an indication of the amount of terrestrial ice that occurred during a certain period. This too needs to be temporally cross referenced in conjunction with other proxies. The climate trends during the Saalian and the Eemian would have influenced the rate at which the physical would change, which in the case of Waziers would have been especially relevant regarding the rise of sea levels. In addition to this the change of climate might have allowed hominins to expand into territories that were hitherto inaccessible or even provided the main impulse to do so with regards to available resources. Therefore it is important to understand the changes in climate that happened during this period.

Botanical Indicator taxa

Botanical material can be used in multiple ways when attempting to make a climatological reconstruction of a period. One of these is the aforementioned use of indicator species. When you have multiple taxa that are confined to specific conditions, it is possible to stack these different tolerances on top of eachother in order to see where these conditions overlap. In this way it is possible to make conclusions regarding the outer bounds that certain ecologies would have needed to adhere to. Another option is to observe the progression in the pollen record and to correlate this to other type sites. Not only does this make use of the tolerances of the taxa that can be observed, but if at the other sites the climate has been deduced by using taxa that have been observed at only a few or a single one of these site, then this temporal correlation

will sometimes allow you to correlate climatological factors as well. This is barring conditions that are extremely site specific such as being located in a lake basin, however such conditions can oftentimes be identified through analysis of the sediments that the pollen are found in.

A parallel research into the climate at Waziers contemporary to the site was performed due the discovery of several indicator species within its records (Field et al., 2023). The main point of interest here was the presence of several instances of *Lemna* cf *minor* seeds and pollen within layers that this research has identified as pollen zones W1 and W3, which are the earliest and latest zones. This research explains that up until now it has been suggested that the mean temperature at Waziers was approximately °C 8,6 (± °C 0,5) which was based on oxygen isotope research performed on *Capreolus capreolus* remains found at the site (Maréchal et al., 2022, p. 329). Because of this it has been assumed that the prevailing conditions at Waziers were that of a continental climate, with hot summers and cold winters, after which later in the early Eemian the climate would have changed to more maritime conditions, with less extreme temperatures during both summers and winters (Cheddadi et al., 1998, p. 81; Klotz et al., 2003, p. 284). In total it has been concluded that the Eemian interglacial in north-west Europe as a whole was significantly warmer and wetter than the conditions that are prevailing today in the area (Field et al., 2023, p. 8). However it has also been suggested that, although the Eemian saw a rapid increase in temperature and north-west Europe was likely experiencing continental conditions, temperatures at Waziers would most likely have been comparable to those that we experience today (Brewer et al., 2008, p. 2314). Despite this the presence of *Lemna* might indicate that in reality the temperature was significantly higher than has been suggested up until now, making the early Eemian even warmer than has been suggested until now. It has been observed that *Lemna* species in north-west Europe usually reproduce asexually and it is therefore unusual for them to develop flowers. Although it has also been acknowledged that there is still much unknown about the sexual strategies of *Lemna* and its requirements (Field et al., 2023 pp. 4-5; Preston & Croft, 1997 pp. 246-256; Stace, 2019, pp. 833-834). Research by Kapitonova & Nikolaenko (2021) has shown that sexual reproduction of *Lemna* in Siberia (which predominantly experiences continental climate conditions), happens in pools with a shallow depth and an acidity that does not go higher than pH of 5.96. Additionally the surface temperature of the water needs to be between °C 22 and 30 for an extended amount of time, while at the same time other research has shown that *Lemna* will not tolerate winters that are warmer than °C 15 and summers must not get colder than °C 10 (Field et al., 2023, p. 5; Landolt, 1975, pp. 356-361). It can be concluded that sexually reproducing *Lemna* is an excellent indicator for summer temperatures as they need a relatively specific water temperature in order to produce flowers and the temperatures as a whole can not be too cold. However for winter conditions *Lemna* does not work well as a proxy as it does tolerate a wide range of conditions as long as it does not get too warm to survive. This would mean that continental conditions are indeed ideal for *Lemna* to flower. However the presence of *Lemna* seeds at Waziers would indicate that, barring a taphonomic anomaly, conditions at Waziers during the hominin presence there were right for *Lemna* to produce flowers. This could mean that although

the interpretation of a continental climate for Waziers during the Eemian could be accurate, the suggestion that temperatures would have been comparable to today's conditions seems to be unlikely as extended periods that the surface temperature of pools are higher than °C 22 in north-west European maritime climates happen extremely rarely if at all. However another species was found that also has some climatological requirements in order to flourish. In the upper pollen zone of W3 pollen belonging to *Hedera helix* were found in addition to the Lemnaceae pollen and seeds that were also found at those depths (Field et al., 2023, p. 6). Hedera *helix* is a species which has specific tolerances for winter conditions, which helps in narrowing down the climate range during colder periods as *Lemna* seems to be tolerant to many winter conditions as long as they do not become too warm. This is important because many plants and animals have strategies in order to survive colder winters, which are conditions that frequently occur in continental climate zones. This makes it difficult to establish the lower temperature boundaries that occur during winter seasons. However it seems that the limiting factor for sexual reproduction for *Hedera helix* are winter temperatures . Whereas *Lemna* needs the warmer extremes that continental climates provide during summer, *Hedera* is usually unable to reproduce sexually under the extremes that this climate provides during the winter period. Research has shown that *Hedera* only thrives when air temperatures stay above °C -1,5 during the coldest periods as well as requiring a high humidity in the air (Field et al., 2023, p. 6). With this it can be concluded that in addition to relatively warm summers, the winter temperatures at Waziers would have had to be mild compared to what could be expected in a continental environment. This is in line with the interpretation of the Eemian as a whole being warmer and more humid, however it seems to go against the suggestion that Waziers, when it experienced early hominin activity during the Eemian, experienced a continental climate with conditions that were largely congruent with the maritime climate that is present today. When looking for an analogous climate with modern times, these humid conditions with warm summers and mild summers are more resembling climates found in Southern Europe and the Mediterranean. This could also explain why Harting found fossils belonging to Mediterranean molluscs and diatoms when he first identified the Eemian sediments. However since the Eemian warmed up more as it progressed it could be possible that the site of Waziers is actually contemporaneous with the middle or later Eemian, which could explain these elevated temperatures. Another option that could be suggested is that the climate has no modern analogue in Europe and had different conditions altogether (Field et al., 2023, pp. 7-8).

Pollen type sites

Another site that seems to indicate this increase of temperature is the British site of Deeping St James. This is an Ipswichian type site which is considered to be slightly younger than the site of Waziers, although it is still considered to date back to the early part of the Eemian before *Corylus* and *Tilia* reached their peak in the record. Using the remains of Coleoptera it was calculated that the mean temperatures of the warmest month at the time was °C 21, which is

about °C 4 warmer than it is in England during modern times (Keen et al., 1999, pp. 433-434). These results from Coleoptera seem consistent with those that can be gained from molluscs that were found at the site, as well as the presence of *Salvinia natans* and *Najas minor*. These two species are nowadays exotics to Britain as they prefer warmer climates. For example *Salvinia natans* prefers to grow in subtropical and tropical climates and can not abide freezing temperatures (Rothmaler et al., 1986). This species is also represented at Waziers as it shows up early in the sedimentary sequence between 28 and 40 cm in unit US 6a (Field et al., 2023, p. 5). Ascertaining the preferred ecology for *Najas minor* is difficult as this species seems to be able to shift climatic niches at least in modern times (Wang et al., 2017, p. 1637). This seems to indicate that temperatures during the earlier stages of the Eemian were already significantly warmer than they are today, which seems to be at odds with the interpretation that the temperatures at Waziers would have been comparable to those experienced in current day France. This site is not only important because it gives more insight into the climate of the Eemian, but also since it is able to confirm that not only was it warmer in France where there is currently considered to have been a continental climate. Compared to Waziers, which would have indeed been further inland relative to today due to a possible existence of a land bridge between France and Britain and the fact that sea levels were lower as a whole due to a significant amount of water being trapped in terrestrial glaciers, and glacial isostatic adjustment; British sites such as Deeping St James would have been significantly closer to the Atlantic Ocean and would have been much more likely to have had a maritime climate rather than a continental climate. If Waziers would indeed have been comparable in temperatures despite being a continental climate, then locales that were situated closer to the ocean and would have trended towards maritime climates would have been much cooler in summer and milder in winter rather than being °C 4 warmer than the current mean temperature. However it must also be kept in mind that although Deeping St James is dated to the early Eemian, it is also considered to be younger than Waziers which, coupled with the fact that the Eemian is characterised by a rapid rise of temperatures, could mean that the temperatures had simply risen by that much in the time between them.

Deeping St James shows how pollen sequenced type sites can be used in climatological reconstruction beyond being able to correlate the temporal position of a site. Oftentimes the projects that these sites are part of are multidisciplinary and many proxies are used in tandem in order to analyse a site, especially in the case of archaeological sites. Another example of such an archaeological site is Neumark-Nord 2. The presence of Emys orbicularis that was found at the site indicates a warmer climate while also indicating hominin activity in north-west Europe during the Eemian, which is consistent with the climate signals of Deeping St James. The site was correlated with this period by correlating the pollen records with other sites which were dated to the Eemian using various techniques. Neumark-Nord 2 will be further analysed in the chapter discussing hominin activity and expansion in north-west Europe. Although archaeological sites in north-west Europe from the Eemian are exceedingly rare, there are several other pollen type sites located in France and Britain besides Deeping St James (Keen et

al, 1999), such as La Grande Pile (de Beaulieu & Reille, 1992; Woillard, 1978), Les Echets (De Beaulieu & Reille, 1983), East Anglia (West, 1980) and Bobbitshole (West, 1980). Waziers has had an initial pollen analysis as well (Gauthier, 2022).

The type of pollen that are used for such sequences are those belonging to arboreal taxa and large shrubs (although the distinction of the border between shrub and tree is not always clear and can be debated). These taxa have different ecological tolerances which means that, although they overlap in where they can survive, these taxa are dominant during different ecological stages. It starts with an abundance of *Pinus* combined with a low amount of *Betula* during the final stages of the Saalian. *Pinus* (the pine tree) is a coniferous tree that is adapted to survive in colder conditions and can nowadays still be found in higher latitudes than most deciduous taxa can tolerate. *Betula* (the birch) is considered to be a genus of pioneer species and is oftentimes the first real tree that springs up in the progression of vegetation. *Betula* pendula and *Betula pubescens* are taxa that can be found at the edges of heathlands. In addition to this *Betula nana* is a smaller variety of birch that can be found in northern latitudes growing in tundra and steppe conditions. This means that *Betula* is a species that tolerated the cooler conditions and steppe landscapes of the late Saalian, while at the same time being among the first taxa to spread north from the warmer southern climes when the Saalian started to transition into the Eemian and temperatures started rising. In addition to this there would have been a relatively large amount of Poaceae (grasses) growing on the open steppes of north-west Europe. It is important to keep in mind that this ecological transition is a reaction to changing climates. Because of this it is likely that there is a small lag between the point where the climate started to warm up,as this would also have been a fluctuating process, and the moment where taxa would have started to expand. This would mean that the actual start of the Eemian would have been slightly earlier than the pollen signal would imply. During the initial warming up of the Eemian, *Pinus* and especially *Betula* would have peaked as they pioneered north-west Europe, after which their numbers slowly diminished. In addition to this there would also be a modest presence of *Alnus* (alder) which would remain largely stable throughout the early Eemian. After this these taxa made way for mixed oak forest consisting mainly of *Quercus* (oak) and *Ulmus* (elm). These would have pushed away the pine forests and almost completely replaced *Betula*, removing that genus from the pollen record almost entirely. In addition to this there would also be the start of a rising *Corylus* (hazel) signal which will steadily increase during this period. As the early Eemian progressed and that climate continued to get increasingly warm, *Corylus* would peak even further until stabilising for a longer amount of time. During this period mixed oak forest would start to dwindle and therefore so would the representation of *Quercus* and *Ulmus* in the record and during this time *Pinus* would steadily decline as well. By that point *Betula* would already have disappeared to such an extent that further decline would be scarcely noticeable. After this a period followed where these relative numbers stabilised although it can be observed that sometimes the amount of *Corylus* in the record sharply dropped which then coincides with a resurgence of taxa like *Pinus* and *Betula*, implying that the increasing temperatures during the Eemian were sometimes interrupted by significantly colder fluctuations.

After this stabilisation would sharply drop and instead be replaced by Pinus and the newly appeared *Carpinus betulus* (the European hornbeam). Along with these would come other, less numerous taxa such as *Tilia* (linden or lime), *Picea* (spruce), and *Abies* (fir). At this point in the record it is considered that the Eemian has moved past its early stage. This development is thought to represent a point in the Eemian where temperatures fell drastically (which could explain the drastic resurgence of *Pinus*) and even reached levels that were more comparable with the Saalian glacial period rather than the Eemian interglacial (Field et al., 1994, pp. 782-783; Litt et al., 1996, pp. 254-255).

When correlating these pollen type sites it is important to keep in mind the fact that these sites are located on different longitudes and latitudes. As this technique makes use of the progression of vegetation over time it must be remembered that this would not homogeneously happen at every site at the same moment in time. Latitudes that were further north most likely would have reached the warm temperatures later than more southerly located sites would have reached equivalent temperatures needed for this vegetation progression. Similarly, sites that are located further west would have been closer to the Atlantic Ocean. This would have tempered the hot and cold extremes that are associated with sites that were situated further inland which would have conditions more akin to a continental climate. An upside to using this technique over for example using indicator taxa based on carpological or faunal remains, is that pollen sequences give a regional climate signal rather than a local. This means that they are less subject to small scale climate fluctuations that impact a specific locale. Instead any fluctuations within the pollen record in such a way are usually caused by more large-scale processes and therefore more representative of climatological conditions in the region.

Oxygen Isotopes

Another method of reconstructing the climate is making use of the physical properties of isotopes. It makes use of the difference in weight of two oxygen isotopes: δ16 and δ18. Of these δ16 is lighter in weight than δ18. When water from the ocean evaporates, it is for the majority the lighter δ16 isotopes that evaporate, whereas the heavier δ18 oxygenated water precipitates first when this vapour cools down. This means that δ18 will be mostly concentrated around the equator. When the overall climate cools further during glacial stages, this means that much of the lighter δ16 oxygen that travels further laterally towards the poles will be trapped in the land based ice sheets that appear during ice ages. This ratio of oxygen isotopes that is trapped in ice sheets can be measured and correlated. The oxygen can be measured from ice cores from ice sheets or remains from corals and foraminifera which absorb the oxygen isotopes within the calcium carbonate that they produce. In addition to this it can also be used on certain animal remains such as the enamel from teeth. This means that during glaciations, deep sea cores will show a large amount of δ18 within its material whereas ice cores taken at the poles that date to these periods will have the opposite signal and contain a relatively high concentration of δ16.

Using this method conditions are measured on a global scale which is even larger than the pollen sequences do. This means that the oxygen levels are even less susceptible to small scale fluctuations that would have affected specific regions during relatively short periods of time (although this could still cover centuries). When using ice cores it is important to keep in mind that during interglacials it is possible that the final part of the ice record belonging to the preceding glaciation has melted away and that the odds of this having happened increases the further equatorial the ice sample is taken.

An example of this being used within the context of palaeoclimatic reconstruction is the GRIP ice core which was collected in Greenland. This core showed a significant increase in temperature at the end of the Saalian glacial stage and subsequently showed a similar sharp decrease in temperatures at the end of the Eemian interglacial when this period was succeeded by the Weichselian period and showed little fluctuation during the course of the Eemian itself. However when comparing this to pollen data that was dated to a period within the Eemian itself, it seems that there actually were temperature fluctuations within the Eemian that reached lower temperatures that were closer to the glacial stages, as mentioned earlier in this chapter (Field et al., 1994, pp. 782-783). It might be possible that because the fluctuation was relatively short, the layer of ice that was created during this period was so thin that it had completely melted away during the period after when the temperatures of the Eemian bounced back to conditions warmer than the current day climate. The part of the GRIP core that was correlated with the Eemian had other issues however, for example the values that it represented were not consistent with the GISP core that was gathered at the same location in Greenland. In addition to this it deviated from the normal curves of oxygen isotopes (Litt et al., 1996, pp. 247-248). However, an upside of using isotope data is that it can be procured from places where organic material is not necessarily preserved well, which would destroy the material needed in order to produce a pollen sequence or identify indicator taxa. In addition to this, because these cores cover data on such a large scale it means that the research material does not need to come from the investigated site itself, but can instead be correlated to cores that come from far away such as Greenland as long as the site can be dated. Prior to the botanical approach of reconstructing the climate at Waziers, a reconstruction was performed making use of oxygen isotopes as mentioned earlier in this chapter, although reservations have been expressed regarding the accuracy of the results (Maréchal et al., 2022).

Choosing techniques

When choosing which technique to use when making a climatological reconstruction it is important to first realise what the scope is of the questions that are being answered. As the three techniques discussed in this chapter all yield a different scale of results. Making use of indicator taxa gives a high resolution of the climate at the exact moment that the organism lived. However the sediments that show hominin activity sometimes cover several centuries and small

scale local climate shifts on a short term might give a wrong impression if a species was used to reconstruct an ecology that is 50 years off. This is especially the case for fluvio-lacustrine sites which can see significant changes within relatively short amounts of time (although this also means that there might be a detailed record of this change). When artefacts and bones are deposited in such a context, taphonomic processes may cause them to end up in a layer that exhibits a different ecology than that was actually present at the time of deposition. Using pollen data increases this scope but loses the finer details that are provided by macrofossil analysis. For this thesis it is relevant because a site in France was used to correlate to temporally comparable sites in Britain, meaning that this increased regional scale is necessary. However the analysis of indicator taxa is still valid as these too might be correlated with these sites after contemporality is established. Oxygen isotope data increases this scope even further at the cost of all but the largest climatological signal. It is a useful technique to have when the soil does not allow the preservation of organic remains such as the soils that are present at Caours, a site that will be discussed in the next chapter. For Waziers however, this technique might lack the resolution that is needed in order to make finer conclusions about the environment that the hominins there thrived in during the early Eemian.

4. Hominin activity in north-west Europe during the early Eemian

In order to properly discuss why hominins might have elected not to cross the English Channel from France, it is important to understand how early hominins dispersed after the transition of the glacial period into the interglacial stage. Due to the fact that sites dating back to the Eemian are few and far between in north-west Europe there have been several propositions as to the nature of hominin expansion, especially so during the earlier part of the previous century when the rare sites that we know now had not yet been discovered. One of the prevailing theories by Gamble is that the biomass in north-west Europe during the early Eemian was mainly concentrated in forests in the forms of leaves, stems and wood. He then argued that early hominins such as *Homo neanderthalensis* did not have the necessary social structures and intellectual fortitude so as to be able to survive in such conditions (Gamble, 1986; Gamble, 1987), which would explain the lack of archaeological sites. This would later be debunked as an absolute hurdle by the discovery of some archaeological sites dating back to the Eemian and even some that date back to the Saalian which suggest that early hominins were very much able to exist in such conditions, such as the sites of Neumark-Nord 2 for the Eemian and Schöningen for the Saalian (both located in Germany) (van Kolfschoten et al., 2015; Roebroeks et al., 1992). Instead some have suggested that, although climatological and environmental conditions were not directly detrimental to hominin expansions, they instead caused the geography of north-west europe to change so that they became physically harder to reach. An example of this could be the disappearance of the land bridge that connected France to Britain during the Saalian (Roebroeks et al., 1992, p. 567). This chapter will focus on the Eemian sites of Neumark-Nord 2 in Germany and Caours in France in order to better understand the exact conditions that early hominins chose to exist in, rather than the general overview of conditions as explored in the other chapters.

Neumark-Nord 2

Neumark-Nord 2 is an open air multiphase archaeological site located in Germany in the region Saxony-Anhalt in the Geisel valley about 10 km to the south of Halle in an open cast mine (see figure 3). It was scientifically investigated between 2003 and 2008 postdating earlier theories that assumed that an early hominin presence in Northern Europe was impossible. Its horizons have been dated to the early Eemian (Neumark-Nord 2/1, 2/2 and 2/3) and the Weichselian (Neumark-Nord 2/0). Both horizons concern lacustrine sediments in accompaniment of hominin activity such as lithic technology and faunal remains like crushed bones. It is part of a series of lakeshore sites numbered 1 to 3, of which the earliest dates to the Saalian glacial stage (Laurat & Brühl, 2021, pp. 1-3). Although Neumark-Nord 1 is also dated to the early Eemian, this chapter will focus on the Eemian horizon of Neumark-Nord 2/2 specifically. The reason for this is that this site contains sediments which feature signs of the Blake Event, as well as pollen material that can be correlated to the Eemian pollen sequence which is one of the reasons why

it is possible to observe the slight discrepancy between the dating of the Eemian and that of MIS5e (Sier, 2013, p. 84). In addition to this, this layer has the richest archaeological record of the Neumark-Nord 2 layers (Laurat & Brühl, 2021, p. 9).

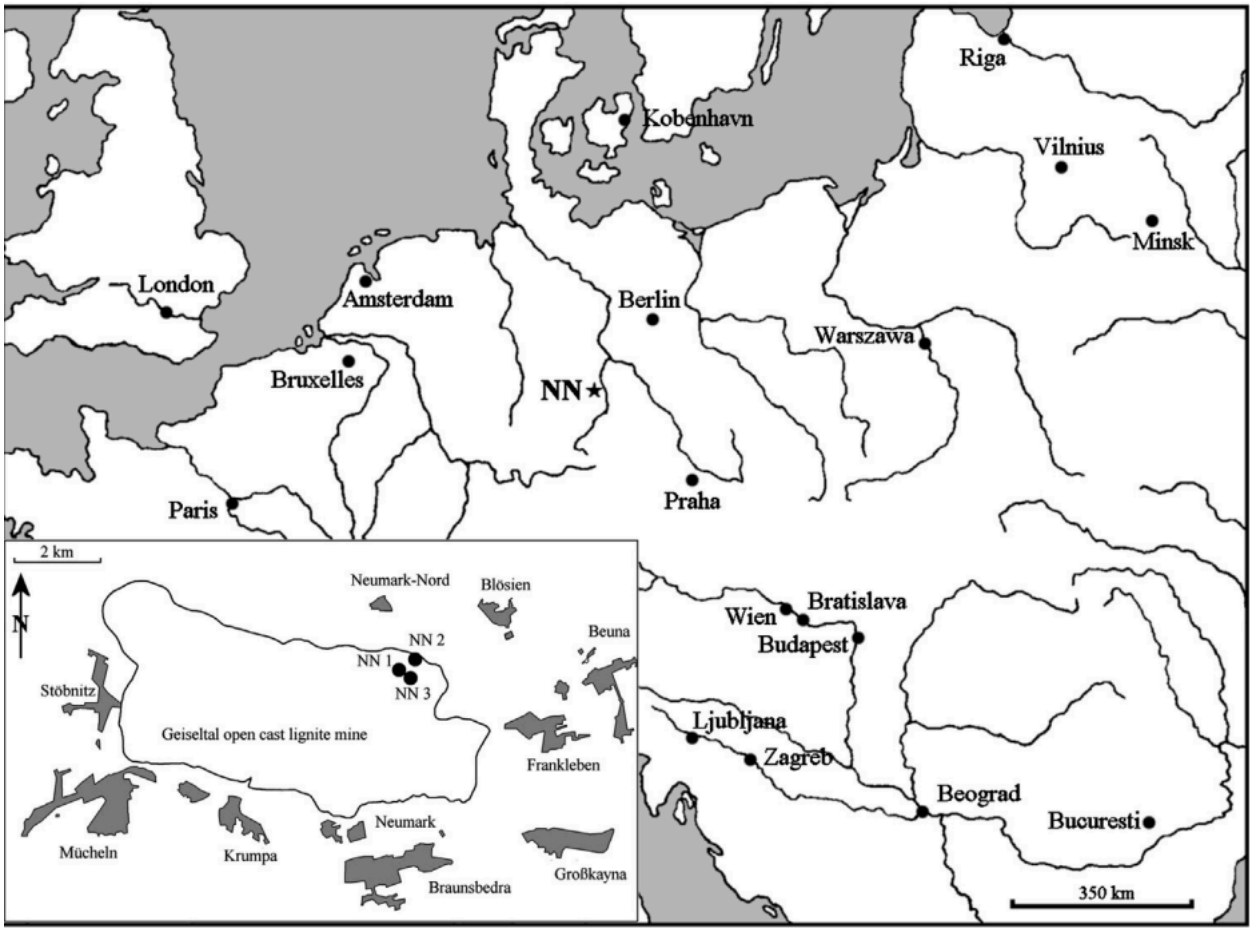

Figure 3 Localisation of the site of Neumark-Nord, Germany (Laurat & Brühl, 2021, p. 3, Figure 1)

The geology of the lake basin of Neumark-Nord 2/2 consists of a complex mesh of sedimentary layers. There are alternating layers of banded clay, meltwater sands, limnic sands and loess deposits. The edges of the basin are dominated by sandy deposits while clay and silt deposits are included more towards the centre of the basin. This is precluded by the strongly laminated layers described above while lower layers towards the Saalian depositions are mostly sandy in nature. The archaeology of Neumark-Nord 2/2 was found within the laminated lacustrine sediments and the silty deposits directly above it . This could be consistent with meltwater currents first depositing sandy sediments after which the lake filled up allowing more fine grained material to be deposited. The predominant deposition of sediments contemporary with Neumark-Nord 2/2 consists mainly of silty sediments. The silty layer on top of the lamination might be caused by the drying up of the lake, which means the cycle of high load suspension melt water and low load suspension stagnant water would have stopped. The palynological identity of the sedimentary layer that Neumark-Nord 2/2 is a part of is dominated by the

presence of *Corylus*. The laminated lacustrine layers also contained relatively smaller amounts of *Quercus* and *Ulmus*. Interestingly the pollen signal containing large amounts of *Pinus* and *Betula* occurred significantly earlier, which would imply that the pollen signal of Neumark-Nord 2/2 is more congruent with the later stages of the early Eemian when the climate was already warmer, rather than being part of the initial transition from the Saalien to the Eemian. Although some have argued that Neumark 2/2 coincides with the first *Corylus* peak with a continued dominance of *Quercus* (Laurat & Brühl, 2021, pp. 5-8), the data shows that while still relatively numerous the *Quercus* was already declining (see figure 4). In addition to this, while the sediments were indeed part of the first *Corylus* peak, this peak continues over several strata including the precluding lacustrine stage and stopping soon after Neumark-Nord 2/2. In the sediments directly on top of this layer, a sharp drop of *Corylus* can be observed that has its levels drop as low as they were before the rise of *Quercus* and *Ulmus*. In addition to this there is a resurgence of both *Pinus* and *Betula*. This could indicate that Neumark-Nord 2/2 was followed by a cold episode that reset the vegetation progression for a short time. There could however also be other explanations for this reset such as a forest fire destroying the prevailing *Corylus* population, however this should then be visible in the sediment record as a layer of carbon. Although it must be kept in mind that rates of sedimentation would have been comparatively rapid during the lacustrine stage, Neumark-Nord 2/2 still would have been positioned at the tail end of the early Eemian. The strata containing the pollen signal with *Pinus* and *Betula* were the ones that could be correlated with the Blake Event (Laurat & Brühl, 2021, p. 7). This means that the pollen data is congruent with the Blake Event as signalling the start of the Eemian. It must however be kept in mind that while the Blake Event was a global geomagnetic occurrence, the reintroduction of

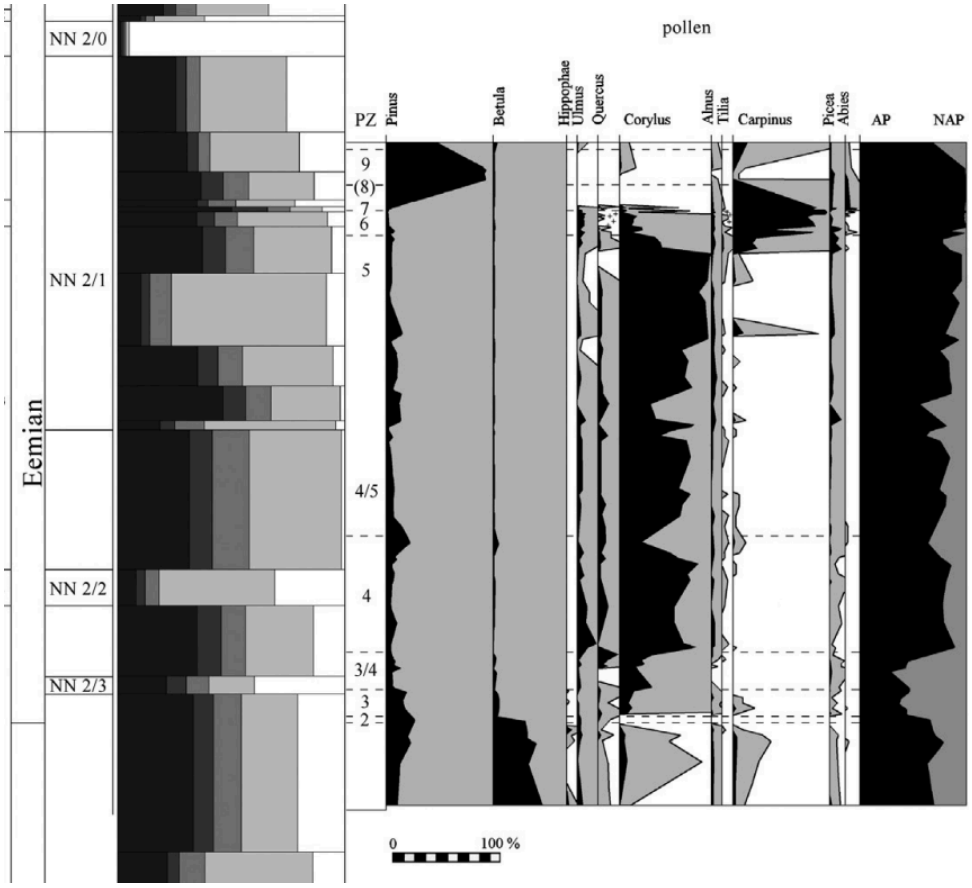

Figure 4 Palynological diagram of Neumark-Nord (Laurat & Brühl, 2021, p. 8, Figure 4)

plants and trees was a process that would have happened over time and not been homogenous over the entirety of Europe. This would mean that the Blake Event would coincide differently with pollen signals spending on latitude, or at least be skewed on where exactly it overlapped with the *Betula/Pinus* signal.

As mentioned earlier this chapter Neumark-Nord 2/2 is the richest in terms of archaeological finds. In total approximately 140.000 objects were encountered which include 118.400 bones and teeth, 19.700 flint artefacts and 400 non-flint lithic objects. Many of the bones were found in six pit-like structures, where they were encountered in proximity to several lithic artefacts. They also show signs of being cut or otherwise being altered through hominin activity. Although it could be possible that these pits were waste pits for butchering animals, which could explain the small amount of discarded lithic artefacts among the faunal remains, this can not be concluded with certainty. The bones consisted mostly of cervids and bovids and included large mammals such as *Palaeoloxodon antiquus*, *Bos priscus*, *Bos primigenius*, *Cervus elaphus*, *Dama dama*, *Capreolus capreolus*, *Equus sp.,* and *Equus hydruntinus*. In addition to this *Sus scrofa*, *Stephanorhinus sp*., *Ursus spelaeus*, *Panthera spelaea*, *Canis lupus*, *Vulpes vulpes,* and *Crocuta sp.* were also encountered. There were several other animals such as avians, reptiles, and fish as well. Most important of these was the occurrence of *Emys orbicularis*, whose presence indicates warm conditions which is in congruence with other climatological data from the Eemian. The grand majority of the bones that were found in the pits were fragmented, however there were several partial skeletons located within the lake basin itself. Aside from cut marks the bones also show signs of burning and scraping, this is reflected in the lithic technology that was found in the vicinity. Most of the flint objects were fragmented, although it is unclear whether this was through intensive use or because of other taphonomic processes. However many of the cores show that they were intensively exploited with most having multiple striking platforms. Most of the lithic artefacts were found in or around the pits or the shoreline, with other concentrations being located near areas where much organic debris was found, this lends credence to the conclusion that these objects were deposited near areas of productivity after they were used up, it is however possible that these were deposited due to taphonomic processes especially in the case of the geological depression in the form of the pits or in the case of lithics found near the shoreline which might have been move due to aqueous activity. Based on the sedimentation it was calculated that the duration of deposition of archaeological objects lasted for around 460 years, while the horizon as a whole would have taken approximately 1200 years to form (Laurat & Brühl, 2021, pp. 9-17).

Both paleomagnetic and palynological data can also be used for environmental and climatological reconstruction as discussed in the previous chapter and as such this site is of special interest when considering early hominin ecological tolerances. When combining paleomagnetic data from magnetite and limonite found in the sediments with the pollen record that was found at the site, it could be concluded that the lakeside ecology rapidly became one of a closed forest with little to no waterside herbs. The environment that is needed for such herbs

to thrive is created by trampling of animals when they use the lake as a drinking spot. If it is the case that the lakebed frequently dries up, then faunal activity would diminish which combined with the increasing encroachment of trees during the early Eemian would lead to a closing of the forest surrounding the lake. However in the sedimentary sequence there are also plateaus of lower amounts of magnetite which indicates the possible presence of pondweed, which would imply that this location experienced wet periods (Sier, 2013, pp. 104-105). The site repeatedly switched between wet and dry which can be inferred from both the paleomagnetic and pollen data showing the presence of aquatic taxa in the area, as well as the fact that despite this the surroundings were still repeatedly overgrown with closed forest during dry periods in the cycle, which in turn implies a lack of sufficient faunal activity to provide the environment for a more open lakeside herb ecology to occur. This process is reflected in the laminated nature of the sediments that were deposited just below the thicker layer silt that was topped off by soil. This top layer might be the point where the lake dried up completely and was subsequently overgrown by dense forest. Despite this the site still features hominin activity which implies that not only were they capable of existing within a densely forested area, they were also capable of compensating for this apparent diminished faunal activity which also implies that they had the behavioural complexity that earlier scientists claimed early hominins lacked. This is also noteworthy when taking in consideration the suggestions that early hominins preferred to make use of the mammoth steppes provided by the German landscape. This site suggests that hominins elected to stay at least for a time after the forest started to encroach on the dried up lake basin, rather than rapidly opting to move on to more open steppe areas with access to megafauna like mammoths.

Caours

Caours is a site located in north-west France, 4 kilometres north-east of the town of Abbeville. It is found on a river terrace belonging to one of the tributaries of the Somme river and has provided indication of hominin activity in the form of levallois flakes in combination with faunal remains (see figure 5). It is another Eemian site that was able to be linked to the Blake Event by means of investigating the calcareous tufa layers found in situ. The sediments at the site are largely composed of calcareous tufa and fine grained fluvial silts wherein a large amount of fossils belonging to both large and smaller mammals, molluscs and leaf imprints can be found. Located on top of the silty layers is a peat soil, which might suggest that the river moved away from the site or was subject to a cut off which allowed the bed to dry up and develop into a marsh. Higher still on top of the peat and marsh soil, are again layers of more tuff and grey soil (Locht, 2021, p. 2). When reconstructing the contemporary climate it was found that the faunal remains belonged to a more temperate ecology which is in line with the site dating to the interglacial period. This combined with the flint artefacts located at the site confirms the presence of early hominins (which some argue to be *Homo Neanderthalensis* despite the lack of conclusive skeletal remains found at the site) in north-west France (Sier, 2013, pp. 177-179).

Included within the five occupation levels at Caours were several types of animals such as *Bos primigenius*, *Cervus elaphus*, *Dama dama, Capreolus capreolus, Sus scrofa, Stephanorhinus sp.*, and others. These taxa imply a temperate climate with ample wooded areas. From the skeletal remains found at the site it can be concluded that while smaller mammals such as cervids were transported to Caours in a complete state, larger taxa such as aurochs and rhinoceros were butchered in the field and only the most rich parts were transported back to the site. Compared to the faunal remains at the site, lithic artefacts themselves are few in number and mostly consist of flakes that were the byproduct of the production of butcher knives. Interestingly, although there is both debris of knife production and the cores that were used to make them, there seems to be almost a complete absence of actual tools, retouched or otherwise. The cores were either Levallois or discoid, although there is difficulty in distinguishing the two types either through the shape of the core or the nature of the debris. The origin of the lithic tools are nodes harvested from the layers of gravel that are located beneath the tuff at the site itself and are quite small with the majority being smaller than 15 centimetres. Because of these reasons the site has been interpreted as a butchery site, meaning that it was not the site of residence for the hominins making use of it, but likely not too far away from it (Locht, 2021, pp. 4-7). In total there were 4600 pieces of lithic artefacts found at Caours, with the most of them being deposited within the two oldest layers and the techniques used to produce these lithics are considered to be low in technical investment while at the same time having a rapid output of tools. Because of this it is considered that the early hominins that were present at Caours were highly adaptable with regard to the climate that they lived in, be that steppe or interglacial (Locht, 2021, pp 7-28). Much like the site of Neumark-Nord this seems to be at odds with both the ideas that early hominins lacked the behavioural structures that were needed in order to thrive within the changing Eemian climate and the idea that they would not stray too far from mammoth steppe type environments. Although it might be possible that they would prefer such an ecology, the fact that they seemed to be at ease with interglacial climates and densely wooded environments with the toolset to facilitate such lifestyles suggests that this was not a hard requirement for them to expand into new territories.

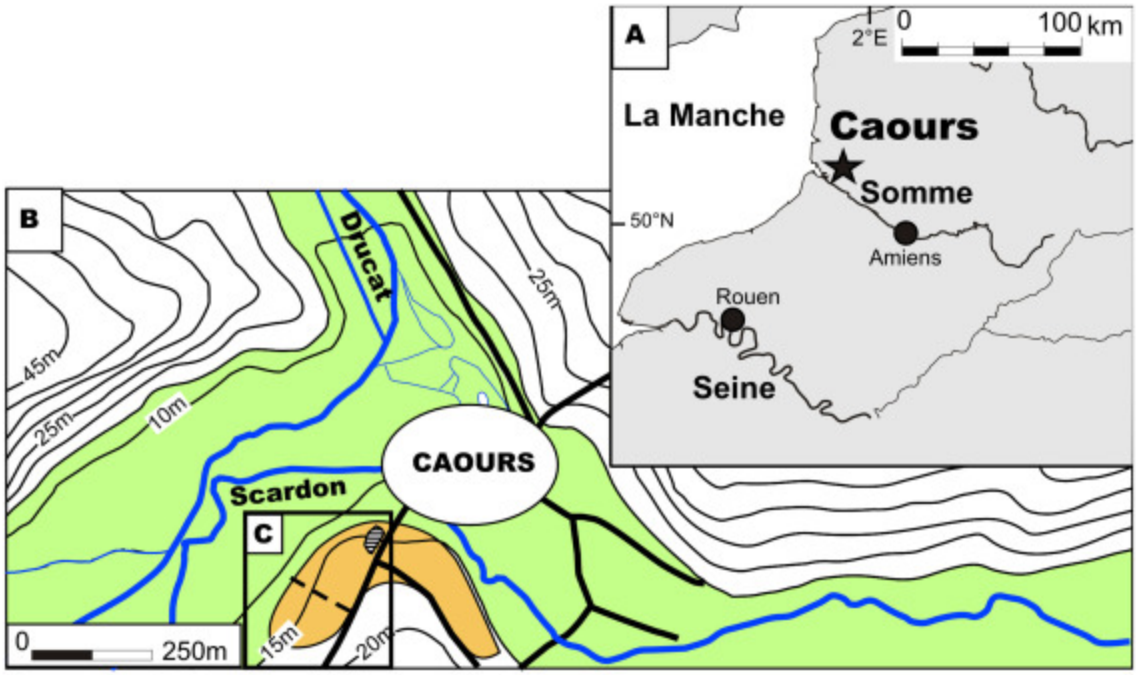

Figure 5 Localisation of the site of Caours, France (Locht, 2021, p. 2, Figure 1)

By correlating the sedimentary signals of the Blake Event with, among others, the pollen zones found at Neumark-Nord 2, it could be confirmed that the site could be dated to the Eemian and that this was a significant amount of time after the peak of MIS5e. This correlation was used in tandem with dating the plethora of flint artefacts and organic material that was found at the site. Dating the sediments showed an approximate age of 120 thousand years (Antoine et al., 2006), while dating the flint using thermoluminescence gave an age range between approximately 127 thousand (± 10.4 thousand years) and 119.5 thousand years (± 9,3 thousand years) (Locht et al., 2009) and electron spin resonance performed on a deer molar yielded a date of around 124 thousand years ago (± 15 thousand years) (Bahain et al., 2010, p. 373; Sier, 2013, pp. 173-179). In addition to this mollusc and mammal data has been used in order to make a climatic reconstruction of the area during the period that the Blake Event tufa layers were deposited. The site is of special import because, although it was already discovered in the 1940's, it was only recently identified as an Eemian site. Before this point there had been no French sites with hominin activity in the north-west that could conclusively be linked to that period (Roebroeks & Speleers, 2002; Sier, 2013, pp. 178-179). The Blake Event signals in the sediment, when correlated with the pollen data from Neumark-Nord 2 and data from other sites such as Rutten in the Netherlands (Sier, 2013, pp. 188), place the age of the site of Caours somewhere at the end of the Saalian, while the dates provided by dating the materials find in situ suggest an age closer to 125 kya which is already several millennia into the Eemian. However, keeping in mind the variance that is associated with these dates it is not unlikely that the actual age of Caours lies somewhere close to the start of the Eemian.

When combining the age of Caours with climatological signals that are provided by analysing the biological remains that are found there, it could be concluded that while there was already early hominin activity in the north-west of France close to the English channel, the climate was already temperate in nature. This means it could be possible that the window of opportunity that hominins had to cross the English channel, before this land bridge had been submerged due to rising sea levels because of the land based glaciers melting off, had already closed by the time that they could have reached it. This would pose a considerable challenge to early hominins which might have dissuaded them from making the journey to the British Isles (Ashton, 2002; Sier, 2013, p. 189).

Deciding factors regarding settlement strategies for early hominins

Three main ideas were expressed regarding the reason why there was no hominin activity in Britain during the Eemian, which is assumed due to the lack of archaeological sites from that period in Britain.

The first is that early hominins lacked the advanced behaviours and social structures in order to survive in an environment which saw a large amount of the available biomass being trapped in arboreal sources such as leaf stems, bark and wood which is unfit for consumption. This would mean that foraging for food would have required relatively advanced social skills. However the site of Neumark-Nord 2/2 shows that early hominins were perfectly capable of existing within a forest when located near a water source which animals would have been using as a drinking place. There are even signs that this hominin population remained for a time after the lake basin had already dried up, which would have seen a decrease of animal activity and a further closing of the surrounding forest. This theory was devised before there were any north-west European sites linked to hominin activity during the Eemian.

The second theory was posited after the confirmation of sites like Neumark-Nord 2 as being from the Eemian. It states that while early hominins demonstrably did have the capability of existing within the more heavily wooded conditions of the early Eemian, they would have preferred to stay in regions which had more ready access to mammoth rich steppe environments which are located more in continental Europe such as in Germany, rather than the Atlantic west coast of Europe such as France or even Britain, as these were more reminiscent of the ecology that they were accustomed to from the Saalian. However the dating of Caours confirms that hominins were already in north-west France early in the Eemian, which means that hominins did not shy away from more coastal regions. This is in combination with the fact that the hominins from Neumark-Nord elected to stay there for some time even after the forest started to close up, rather than leaving for a more open environs.

Finally there is the theory that early hominins were not limited by an ecological niche, but rather by a changing landscape making it physically impossible or at the very least extremely challenging to get to Britain, because the landbridge that had connected the British Isles to the French main land would have already been submerged by the time that hominins had reached that location. Climatological data from Neumark-Nord and Caours seems to corroborate this as the ecological signal of Caours seems to indicate a temperate climate and the presence of animals such as *Emys orbicularis* at Neumark-Nord even seems to suggest that the climate was trending towards warm conditions. However it must be kept in mind that the site of Neumark-Nord 2/2 was likely active later during the Eemian with the tail end of the early Eemian, when *Corylus* was already dominant for some time, at its earliest. In addition to this the material dating places Caours at a likely age of around 124 kya which was also a significant amount of time into the Eemian. And although Blake Event data suggests that the site is trending towards the older side of variance, it must be remembered that there is a significant amount of variance with this technique as well. This means that although it is not unlikely that the hominins at Caours might have encountered a submerged Channel, this does not necessarily mean that this submerging already happened during the very early stages of the when the climate would have already allowed hominins to spread to north-west Europe and the land bridge had not yet submerged.

5. Methodology

Material acquisition

The main samples were collected from the site at Waziers, France by dr. M Field in 2017 as part of a multidisciplinary archaeological investigation of a cut off from a paleofluvial channel resulting in fluviolacustrine deposits. A number of six (6) samples were taken at the first sequence in the cross section of the trench, whereas a number of five (5) were taken at the second cross section (respectively named ‘coupe 1, partie 1’ and ‘coupe 1, partie 2’ (see figure 6)), leading to a total of eleven (11) samples. These samples were taken based on sedimentary layers rather than set distances. This was done in order to later make a temporal environmental reconstruction based on the change in landscape, as the oxbow lake that the samples taken from was subject to desiccation over time. The samples were taken at a depth of several metres just above the water table in order to get a sediment sequence that covers as large of a period belonging to the deposits as possible. Bulk samples were taken from the bottom up in order to minimise cross contamination of the different sedimentary layers, by reducing the need to clean the wall surface as would be needed if the samples were taken from the top down. As a result of this, the sample locations were also recorded from the bottom up, in part because measuring from the surface down would be impractical, but also because that information was unnecessary for the reconstruction that was proposed to be created. This in turn, resulted in an inverse measuring system when compared to conventional stratigraphical measurements, which is something that is important to take into account when interpreting the data as failure to do so would lead to opposite conclusions. Important of note is also the fact that these sediments had yielded artefacts, indicating a hominin presence contemporary to the period that active sedimentation happened in the channel cut off. After these samples were collected, they were then transported back to Leiden University in the Netherlands and stored in cold storage in order to minimise sample degradation. At the university these samples were analysed by students for both macrobotanical carpological remains and microbotanical palynological remains. This was done in order to make the reconstruction as detailed as possible, because these two types of data yield different kinds of information. Carpological remains give a high resolution local signal for vegetation, geology and climate, while palynological remains give a lower resolution signal, but one that covers a larger region and that is less subject to climatological outliers which may occur locally. The mesh widths that were used while preparing the subsamples of the carpological remains and the palynological remains overlap. This was done in order to ensure that no data was lost in between analysing both samples. For this reason any palynological remains found during the carpological analysis were also recorded. An example for this are *Picea sp.* pollen grains that are sufficiently large in size to be caught by the carpological sieves. After this several Tilia diagrams were produced based on the type of reconstruction that was required, for example a reconstruction of terrestrial plants or a reconstruction of aquatic plants. The diagrams of both carpological data and palynological data

were also combined in order to explore taphonomic and environmental conditions that may have influenced the pollen record that was preserved.

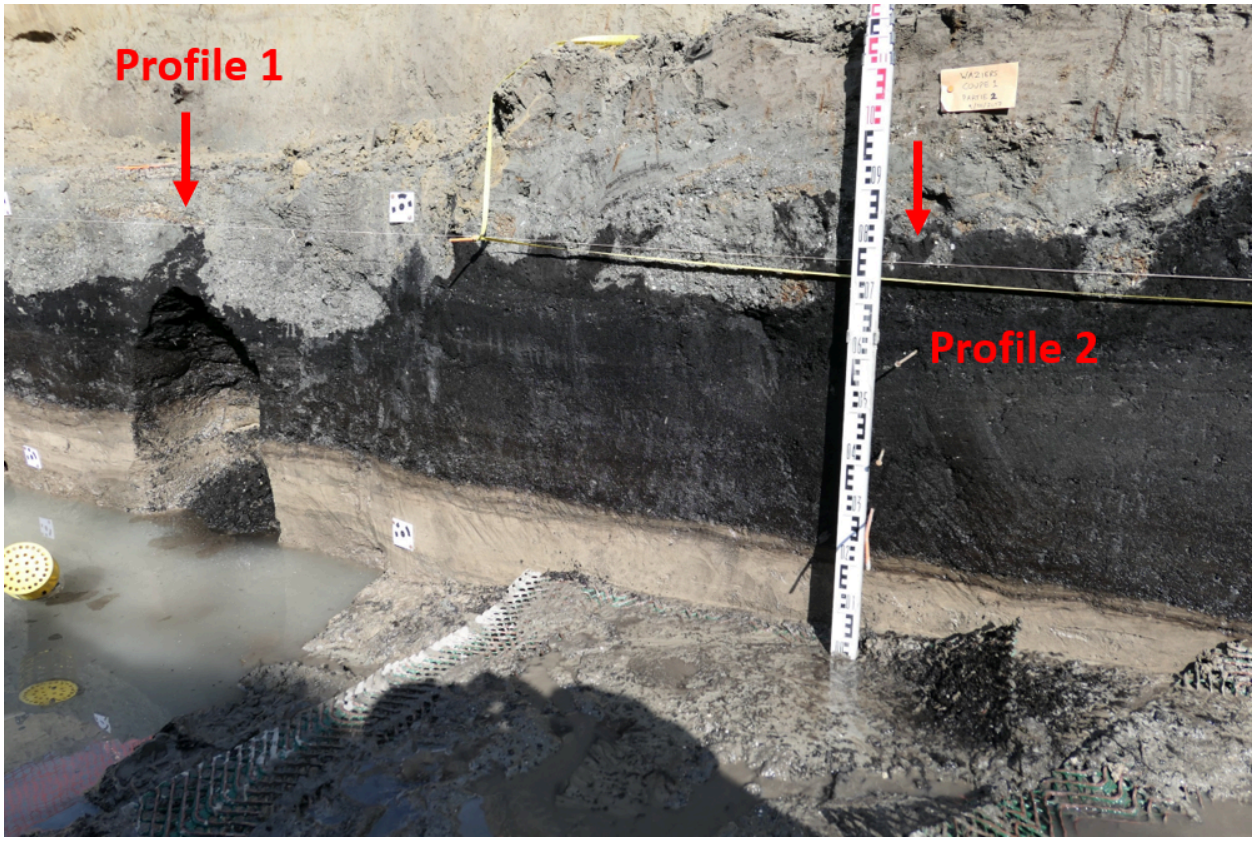

Figure 6 The two profiles which were sampled (photograph: M.H. Field)

Carpological remains

The carpological data was produced in cooperation with students at Leiden University over several years. The data was subsequently verified in order to confirm the accuracy of the results. In order to prepare for carpological analysis first a subsample was taken from each of the sedimentary layers. First a known volume of 150 cm^3 sediment was taken using the displaced water method taking parallax into account. This was then left to soak in water in order to disaggregate the sediment from the carpological remains. Because the age of the sediment made carbon dating not impossible, it was decided to add soap to this water in order to more efficiently break down any present clay sediments which would have otherwise invalidated the carbon date of any organic material. The sediment was then left to soak for between one to three weeks in order to completely disaggregate the sediment. Sediments that were still conglomerated were put into a fresh soak with more soap. After the sediments were sufficiently disaggregated they were then sieved using a sieving tower with four (4) levels of mesh widths. Because the sediments originated from a waterlogged context, it was decided to use wet sieving

to separate the materials. Dry sieving would require the subsamples to be dried out which would desiccate the organic material in the sediment. This could cause severe damage to any carpological remains which could render them unidentifiable. It was also decided not to use flotation, because this technique has the risk of losing the heavier carpological remains as these would not float to the surface to be skimmed. The sieves used fractions of 1 millimetre, 500 micrometres, 250 micrometres and 150 micrometres. This ensures that even the smallest identifiable carpological remains are present within the subsample while removing most of the silicate grains. Sediments that were left to soak multiple times in the case of severe conglomeration were sieved after both periods of soaking in order to remove excess sediment as efficiently as possible. After sieving the sieves were then decanted into separate containers for each different level. These containers were filled with water in order to best preserve any botanical remains contained within. After decanting the containers were then stored together based on the sedimentary layer that they originate from in order to reconstruct the environments based on their temporal position. This would make it possible to track the transition of Waziers as a lacustrian site into a terrestrial site over time.

After the subsamples were separated they were analysed using an optical microscope with a magnification up to 40x, although for larger fractions the magnification that was used was usually lower. The fractions were then scanned and handpicked for any identifiable remains. These remains often contained false positives and therefore they were periodically checked in order to separate the useful material. The identifiable remains were stored in a fridge hydrated by a glycerol mixture containing 30% glycerol ($C_3H_8O_3$), 30% ethanol (C_2H_6O) and 40% demineralised water (H_2O). This prevented the carpological remains from drying out without needing to keep them submerged in water. This allowed these remains to be stored in a sorted fashion which would make it more efficient to tally them at a later moment. The residue material was preserved and stored separately in case it was deemed necessary for revision at a later date. The carpological material used for identification were not only seeds and fruits, but also other remains such as leaves and fruits. The seeds and fruits were encountered in both an intact and a fragmented state. Therefore a minimum number of individuals for each taxa was established based on identifier traits based on the individual taxa. This technique could not be applied to the other carpological remains, for those it was instead decided to have a total count instead. This could be used as a tool to affirm proximal presence of taxa, as some of these remains would not have been able to travel as far by taphonomic processes as the seeds and fruits. Because a minimum number of individuals could not be ascertained for this material, instead the abundance of remains was recorded based on magnitudes of ten. This could possibly give insight into the approximate population density of taxa, although this data is not conclusive in isolation. Because of the size of the subsamples and the available carpological material it was decided to completely analyse each fraction. An exception to this methodology was made if the minimum number of individuals for a single taxa would exceed 500 specimens, in which case a number of 500+ was recorded. Because the data of different samples were later combined these recordings could exceed the 500+ in the total count of the final diagram. The

carpological material was then identified using literary, photographical and physical reference material (Cappers, 2006), which was then subjected to a second opinion from a specialist in order to verify the identification. For the naming convention of the carpological remains Cappers was used as the primary basis. In case of missing taxa the flora of Mennema (1994) was used as a secondary source. All the fractions of each individual sedimentary layer were analysed by a single pair of students in order to ensure a consistent analysis per subsample. In addition to this, a second analysis was performed for the purpose of finding taxa of interest. These taxa could be used as identifiers in order to produce the environmental reconstruction of the site. These datasets were then combined into a singular data set in order to be converted into a Tilia diagram. Different diagrams were produced for terrestrial and aquatic species in order to reconstruct different environmental factors pertaining to both the physical and chemical properties of the site of Waziers. Only diagrams for the total count of taxa were produced, because no spike was added to the sample in order to make a concentration diagram. This technique was instead used during the pollen analysis.

Pollen and spores

In order to produce a pollen sample, the sequence of partie 2 was chosen to be investigated based on the amount of the samples that still remained compared to the bulk samples belonging to partie 1. A larger amount allows for an easier selection of subsections in order to have the highest quality material possible. From each of the five layers a subsample was taken of one (1) cm^3. These subsamples were taken from the centre of the sample as much as possible. This was done in order to have the least risk of contamination and in order to avoid material that might have deteriorated over time due to exposure to oxygen, which could possibly affect the pollen grains. These subsamples were submerged in water in order to disaggregate the sediment in order to more easily extract the pollen later. In addition to this a *Lycopodium* spike was added to the subsamples. When analysing the data later, this would then allow for the construction of a concentration diagram. The construction of such a diagram gives more insight into the rate of pollen accumulation. This could then provide context for possible climatological or vegetational variables that might affect the total amount of pollen that was produced over a certain period. This in turn might give more information about the chronology of the site of Waziers. *Lycopodium* was chosen as it was not something that occurred at Waziers during that period, so any *Lycopodium* grains that were encountered were guaranteed to be from the pollen spike, and therefore a controlled contamination, and not a native inclusion from the site or even the product of aeolian dispersal. The amount of *Lycopodium* grains in the tablets were approximately 10.000 grains per tablet. The sediments were then given several days to disintegrate in order to make the extraction of pollen as efficient as possible.

To start the pollen extraction, first a solution of tetrasodium pyrophosphate ($Na_4P_2O_7$) with a 0.1 molar dilution was added to the subsamples. These were then heated to 100 °C for a duration of

20 minutes. This would allow for a final disaggregation of pollen from any clay particles that were present in the samples. The samples were then centrifuged for three (3) minutes at 3.000 rounds per minute in order to separate the sample from the tetrasodium pyrophosphate. This was done subsequently for three (3) times in a row. In order to remove the tetrasodium pyrophosphate the sample was also washed with demineralised water during this process. This was done once after every round of centrifuging. After this hydrochloric acid (HCl) with a dilution of 10% was introduced to the subsamples. This was done in order to remove any traces of calcium carbonate ($CaCO_3$) that were present in the samples. After this the samples were again centrifuged for three minutes at 3.000 rounds per minute and washed with demineralised water. After this a potassium hydroxide (KOH) solution with a dilution of 10% was added to the subsamples. These were then heated to 100 °C for a duration of 20 minutes. This process would remove any organic materials besides the pollen that were present in the samples such as intines and cell contents, while at the same time leaving the exines of the pollen grains intact (Reitsma 1969, p. 176). The subsamples were then sieved over a mesh width of 212 micrometres. This would remove any large organic and inorganic particles that were present in the subsamples while allowing the largest pollen grains to filter through. After this the subsamples were again centrifuged three times at 3.000 rounds per minute and washed with demineralised water. The subsamples were then washed with acetic acid (CH_3COOH) in order to remove any traces of water. This is important as any remaining water would react violently during the next step. After this acetolysis would be performed on the subsamples. In order to do this sulphuric acid (H_2SO_4) with a concentration of 95% was diluted in acetic anhydride ($C_4H_6O_3$) to a concentration of 10%. This would remove any remaining organic material still present within the subsamples. After this the subsamples were centrifuged two (2) times at 3.000 rounds per minute and washed with acetic acid in order to remove any traces of the acetolysis mixture. The subsamples were then centrifuged three (3) more times at 3.000 rounds per minute and washed with demineralised water in order to remove the last traces of any remaining acidic components. After this heavy liquid separation was performed using sodium polytungstate ($H_2Na_6O_{40}W_{12}$) which was diluted with water to a concentration of 56%. This solution then had a density of 1,85 - 1,9 g/cm³ in order to float the pollen grains. The subsamples were then centrifuged in this mixture for 20 minutes with a revolution of 2.000 rounds per minute. After this the subsamples were skimmed into a new container in order to separate the pollen from the heavier particles that were centrifuged out. After this the new subsamples containing the pollen grains were again centrifuged three times at 3.000 rounds per minute and washed with demineralised water. After this ethanol with a concentration of 96% was added to the subsample in order to dehydrate the pollen grains. The subsamples were then centrifuged one (1) time at 3.000 rounds per minute. After this isopropyl alcohol (C_3H_8O) was added and the subsamples were centrifuged one time at 3.000 rounds per minute for a final time. The subsamples were finally submerged in silicon oil in order to protect the pollen grains from oxidation and to make them ready for analysis. It was decided not to stain the pollen grains in order to better be able to discern the features of the grains as colouring might obscure the defining features making identification more difficult.

After the subsamples were prepared and stored in silicon oil, they were then analysed using an optical binocular microscope with a magnification of 400x. It was decided to count pollen until a minimal number of 500 pollen grains belonging to terrestrial plants were identified per sample for a minimum of 2500 terrestrial pollen grains in total. Therefore aquatic plants, lower plants, fungi and the added *Lycopodium* spike did not count towards this total. However aquatics and monolete spores were recorded for an analysis of the aquatic conditions. In addition to this the *Lycopodium* spores encountered were recorded for the purpose of making a concentration analysis. This was done in order to have a significant amount of pollen for a terrestrial analysis.Terrestrial plants were chosen as the main subject for this research, as they give the best climatological signal when compared to other types of plants such as aquatic plants. In addition to this, the consideration was made that hominins would have most likely taken a terrestrial route to cross the channel and therefore the terrestrial environment would have been the most important factor for them. The pollen grains were identified to the lowest taxonomic level possible, but it was decided that the highest acceptable level was Family. Although identifications made to this level are not indicative of any environmental conditions on their own, they could be useful when combined with better defined pollen grains that might be better indicators but lower in number. Literary, photographical and physical reference material was used in order to identify the pollen grains (Beug, 1961; Moore et. al., 1991). For the naming convention of the pollen grains, Beug (1961) was used as the primary source. In case of missing entries Moore, Webb and Collinson (1991) was used as a secondary source if needed. In addition to this all identifications were consulted with a specialist in order to have a second opinion and thus greater certainty in the identifications. The residue slides were numbered and stored separately for later use and revision. It was also decided to photograph several of the pollen that defined the subsamples as well as pollen grains from *Lemna sp.*, as the latter of these would later be used for a more in depth climatological reconstruction. For this research a second pollen analysis of the Waziers site was performed. This made use of the same subsamples that were prepared during this analysis, however it produced different slides from this subsample to be analysed. After this the analysed data was combined in pollen diagrams with the use of Tilia. Both a total pollen count and a concentration pollen count was used in order to investigate both the rate of pollen deposition in the sediment layers and the comparative amount of pollen relative to each other. These diagrams were also compared to typesites located both in France and in Britain in order to date the site of Waziers within the Eemian period using cross referenced data. Botanical indicator species were used for this purpose. The data gained from this research was then compared to the data from the second pollen analysis in order to verify its accuracy.

Because this dataset became relevant for a different research study, it was decided that the samples would also be counted by dr. Ilse Kamerling. Through this reevaluation of the samples it was concluded that there were small discrepancies even when accounting for variance between individual subsamples. Although the overall results and conclusions of these counts remained largely the same, it was considered best to have the most accurate results possible.

Therefore it was decided that for the purpose of this thesis, the double checked pollen values would be used when available, because of the increased proficiency of dr. Kamerling and the greater likelihood of that data being more accurate. This concerns the pollen counts of samples 1, 4 and 5. The difference is sample 5 was the greatest because of a misidentification of the Poaceae pollen and even though sample 1 and 4 lacked this discrepancy, it was deemed best to replace those results as well for the sake of consistency. When appropriate it will be clarified of which origin the pollen data in the figures is, in order to optimise the clarity of the research.

In addition to this, parallel research on this dataset was conducted by Dr Mike Field, Dr Ilse Kamerling and myself with the intent of further mapping out the climatological conditions at the site of Waziers during the period of sediment deposition. This was done by looking at the different ecological tolerances of several indicator taxa such as *Lemna sp.* and *Hedera helix*. By looking at the exclusivity of these tolerances and where they overlap, these indicator taxa could give insight into conditions such as the minimum and maximum average temperatures during summer and winter periods. These can subsequently be used to argue in favour of certain analogue climate types. Additionally, making use of the arboreal pollen signal that was present within the sediment, a cross reference was made using several other type sites within France and Britain. For France it concerns the site of Waziers in Northern France (as described by Gauthier, 2022), La Grande Pile in North-east France (as described by De Beaulieu & Reille, 1992), La Grande Pile (as described by Woillard, 1978) and Les Echets in Eastern France (as described by De Beaulieu & Reille, 1983). The British type sites include East Anglia in the Eastern United Kingdom (as described by West, 1980), Bobbitshole in the Eastern United Kingdom (as described in West, 1980) and Deeping St James in the Eastern United Kingdom (as described by Keen et al, 1999). These sites show a progression of arboreal taxa during the transition of the Saalian into the Eemian. A problem with this is that all the different sites use their own individual dating nomenclature, making it difficult when trying to compare periods. The goal of this cross reference is that these periods will be bundled into a single dating, which is then compared to the pollen data that was garnered from the sediments of Waziers. If the same progression can also be seen in the pollen data from this research and the temporal zones identified within them, this can then be given a relative date of its temporal position within the Eemian. For this research both French and British pollen sites were used in order to minimise variance in local signals due to climatological factors, as pollen sites further inland would be subject to slightly different conditions than coastal sites. This cross reference could subsequently be used in order to get a better idea of the chronology of the site of Waziers, such as a more accurate proxy date for the sediments and which parts of the Eemian were represented within them. Combining both the climate and a more concrete dating is important for this thesis as these factors might have implications for the geographical conditions pertaining to the land bridge that connected France to the British Isles, as well as the rate of hominin dispersal throughout Northern Europe during the Eemian.

6. Results

Carpological results

The analysis of the carpological remains is divided between the data that was gathered from profile partie 1 (see figure 7) and that from profile 1 partie 2 (see figure 8). In the case of both sequences the results are recorded in absolute numbers rather than concentrations and counts that exceed a number of 1000 are referred to as '1000+'. The categorization of the sequences distincts between the favoured ecologies of the found taxa as 'Woodland and shade tolerant', 'Grassland, disturbed and open ground', 'Waterside and damp ground', 'Aquatic' and 'Unclassified'. For the purpose of working with Tilia, the average depths at which the samples were taken from of the stratigraphic sequence are used in the results, starting from the top and working to the bottom. When describing the results however, the order of the sequence starts at the bottom in order to better observe the transition of the site through time. Partie 1 consists of a sequence of six (6) samples whereas partie 2 consists of a sequence of five (5) samples due to a stratigraphic layer missing. As a result of this the sequence of partie 2 is of a slightly lower resolution compared to partie 1.

Macrofossils from Partie 1

The lowest sample taken from Partie 1 belonged to the stratigraphic layer that was found at a depth of 82,5 cm. This layer featured a large amount of aquatic taxa within its record. There was an abundance of fruits belonging to *Zannichelia palustris* (1000+) as well as remains of Characeae oöspores (1000+). In addition to this there were smaller but significant amounts of *Hippuris vulgaris* fruits (32) and *Potamogeton* endocarps (13). Besides aquatic type plants there were also several waterside taxa such as achenes belonging to *Ranunculus scleratus* (2), a nutlet of *Mentha aquatica* (1), a *Valeriana officinalis* seed (1) and fruits from *Thalictrum Flavum* (5). There were also smaller amounts of remains that belonged to woodland and grassland in the form of various remains belonging to *Betula* (12) and a seed of *Thlaspi arvense* (1).

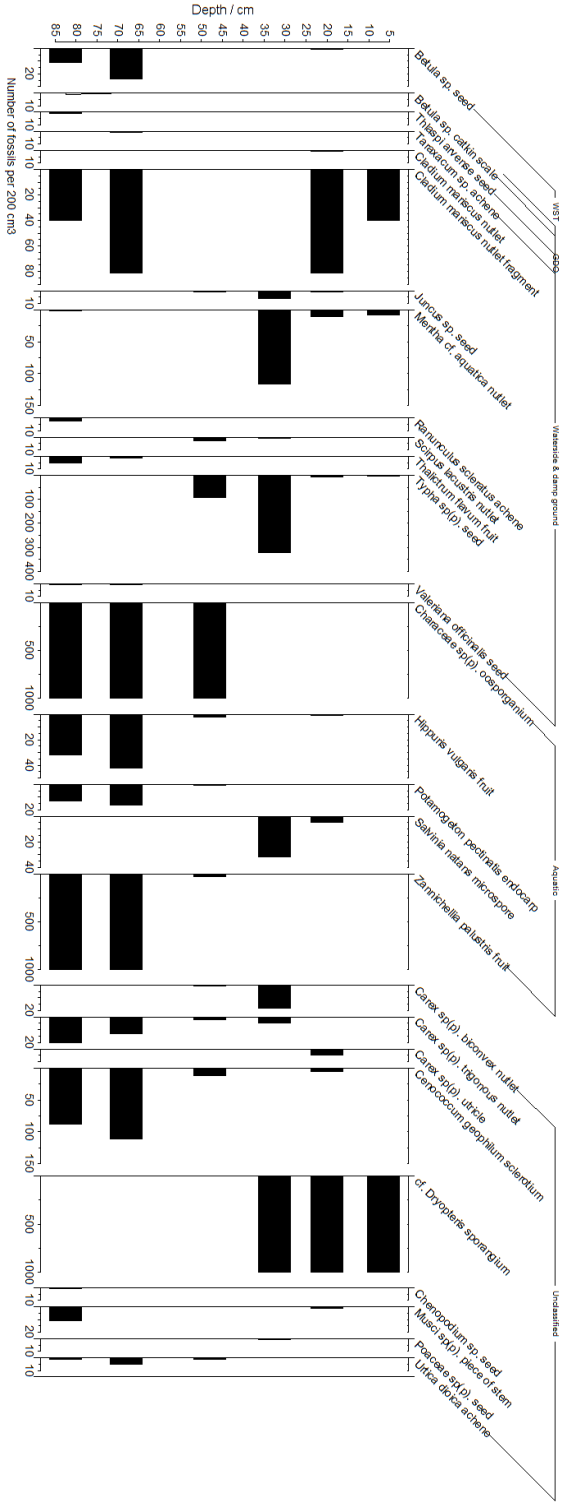

Figure 7 Carpological diagram of Partie 1 (Figure: M. Top, adapted from: Top, 2019, Figure 1)

Finally this layer also contained remains of *Carex* (20), *Chenopodium* (1) and *Urtica dioica* (1), as well as lesser plants and fungi such as *Cenococcum* (88) and *Musci* (11). These lesser plants will not be included further in the analysis unless their results are remarkable or typologically relevant for the identification of the ecology. This sediment represents the aquatic period of the site when it was still an active component of the Scarbus river as can be seen from the large amount of aquatic taxa represented in the record. The water is at this point alkaline or at least non-acidic as the calcium carbonate remains of the Characeae can not be formed in acidic conditions. It must however also be kept in mind that the context that these remains were found in are flavio-lacustrine in nature, which means that if they are present, there is likely to be an overrepresentation of aquatic and waterside taxa when compared to terrestrial plants. This might skew the record even more in favour of the aquatic environment than was the case in reality.

The second sample was taken at a depth of 68 cm. This layer continues the aquatic nature of Waziers during that time as can be seen in the continued abundance of Characeae (1000+) and *Zannichelia palustris* (1000+), as well as an increase in the number of remains from *Hippuris vulgaris* (42) and *Potamogeton* (16). At the same time there is a decrease in waterside plants such as *Thalictrum Flavum* (1), whereas *Ranunculus scleratus* and *Mentha aquatica* have disappeared completely. This might indicate that the channel has become more active which would have allowed aquatic taxa to thrive, but forced the waterside species to decrease in number. At the same time there is a slight increase in terrestrial taxa such as *Betula* (24) and *Urtica dioica (5)* and *Thlaspi arvense* is replaced by *Taraxacum* (1) as grassland species. The increase of Betula might indicate the encroachment of birch trees as pioneer species as the climate continued to warm up in the transition from the Saalian into the Eemian. Because of the amounts of remains that were found such as *Thlaspi* and *Taraxacum*, there is likely to be a degree of variance with these results. The disappearance and introduction of taxa might not necessarily mean that these taxa are actually gone or newly introduced, however it is relevant to look at the trends of these ecological indicator species as a whole when they are represented in such low numbers in order to see if there is a change in ecology.

The third sample of partie 1 came from a depth of 48 cm. In this sample there is a notable change in the record. Although there remains an abundance of Characeae (1000+), the *Zannichellia Palustris* (27) sees a very sharp decrease in number and disappears almost completely just like *Potamogeton* (1) and *Hippurus* (2). The terrestrial taxa growing on dry grounds have also completely vanished and will remain absent for the remainder of the samples taken in this stratigraphy, although terrestrial lesser plants such as ferns will be represented. Instead there is an increase in waterside and wet ground taxa such as nutlets from *Scirpus lacustris* (3) and the introduction of *Typha* (93) in the record. Additionally the presence of *Carex* (3) and *Cenococcum geophilum* (12) has almost completely disappeared. This development likely indicates that the channel has been cut off from the main river, meaning that the water is

no longer flowing and that the area is starting the process of drying up. Interesting however is the drop in terrestrial plants which no longer seem to be represented in the carpological record.

Sample four was taken at a depth of 32,5 cm. In this sample both the Characeae and the *Zannichellia Palustris* have dropped from the carpological record, to be replaced by a small number of microspores belonging to *Salvinia natans* (32), which is an aquatic fern. At the waterside *Typha* (322) reaches its peak in the record of Waziers as well as the presence of *Mentha aquatica* nutlets (116). Additionally there is also an increasing amount of *Juncus* seeds (6) present in the sediments. Also remarkable is a sudden spike of *Dryopteris*, a terrestrial fern, sporangia (1000+) as it is newly introduced at the site. The disappearance of the Characeae could have multiple reasons: it could be possible that the ecology of the site has become more acidic as the environment takes on marshy conditions, however it is also possible that the conditions are not aquatic enough for it to survive. Although in case of the latter, it would probably have diminished over time instead of disappearing so suddenly.

The (fifth) sample above this was taken at a depth of 20 cm. Aquatic taxa are almost completely absent with the exception of a small number of *Salvinia natans* (5) and *Hippuris vulgaris* (1) remains. Both *Typha* (6) and *Mentha aquatica* (10) are also greatly diminished in number and in the place of those wetland plants comes *Cladium Mariscus* (82) which dominates what are likely boglike conditions after the marsh has largely dried in. *Carex* (5) remains are still present in low numbers as well as an abundance of *Dryopteris* (1000+). Of note is the inclusion of a singular fruit belonging to *Betula* (1) in this sediment, meaning that there was likely some arboreal activity in proximity to this location. As mentioned this sample might represent a turning point in the marshy conditions that are ideal for taxa such as *Typha,* as it is gradually drained which gives an opportunity for Cyperaceae such as *Cladium* to take advantage. Despite this the conditions are still wet and carpological remains of dry ground terrestrial vegetation is almost completely absent.

The sixth and final sample of partie 1 was taken at a depth of 6,5 cm. Aquatic, woodland and grassland taxa are all completely absent from this sample as well as *Carex* which had been present in all the other sediments. In addition to this the wetland taxa also greatly diminished with only a small amount of *Cladium* (40), *Mentha* (8) and *Typha* (1) remaining, whereas *Juncus* has disappeared from the record. The only presence that remains in abundance is *Dryopteris* (1000+). This might be the result of the last of the bog drying up and creating conditions in which botanical remains are poorly preserved. This has also been observed during previous research at Waziers, where it was noted that preservation of most of the organic materials stops at the upper threshold of the peat sediments. As a result of this the vegetation in the region would have likely progressed in its stages, however none of this remains in the stratigraphic record due to taphonomic reasons.

Macrofossils from Partie 2

The first sample was taken at an approximate depth of 59 centimetres. It is dominated by a large amount of Characeae (1000+), although remarkably there are no other aquatic taxa besides a single endocarp belonging to *Stuckenia pectinata* (1). Unlike in partie 1, *Zannichellia Palustris* seems to be completely absent in this sediment. In addition to this there is already a strong *Typha* (302) signal in this lowest sample as well as a limited amount of *Ranunculus sceleratus* (2) within the wetland taxa. Other unclassified taxa include *Carex* (1), *Urtica dioica* (2) and *Carduus/Cirsium* (1). There is also no record of any dry ground terrestrial plants or woodland taxa. The absence of *Zannichellia palustris* in combination with the large presence of *Typha* and the fact that there seems to be hardly any terrestrial taxa represented in this sample, implies that this lowest sample of partie 2 correlates roughly with the third sample of partie 1. Furthermore this is consistent with the depth at which both samples are taken relative to the upper bounds of the peat layer. Taking this in consideration, the ecological signal of sample in this layer coincides roughly with that of sample three of partie 1 with the exception of some variance within the low yielding taxa in that sediment.

The second sample of partie 2 was taken at an average depth of 44 centimetres. The Characeae (1) in this sample have almost completely disappeared and are the only remaining aquatic taxum present in this sediment. The *Typha* (240) is slightly reduced in number, however there is a sharp peak in *Mentha aquatica* (58) which is newly introduced in this layer. Other wetland taxa that appear are

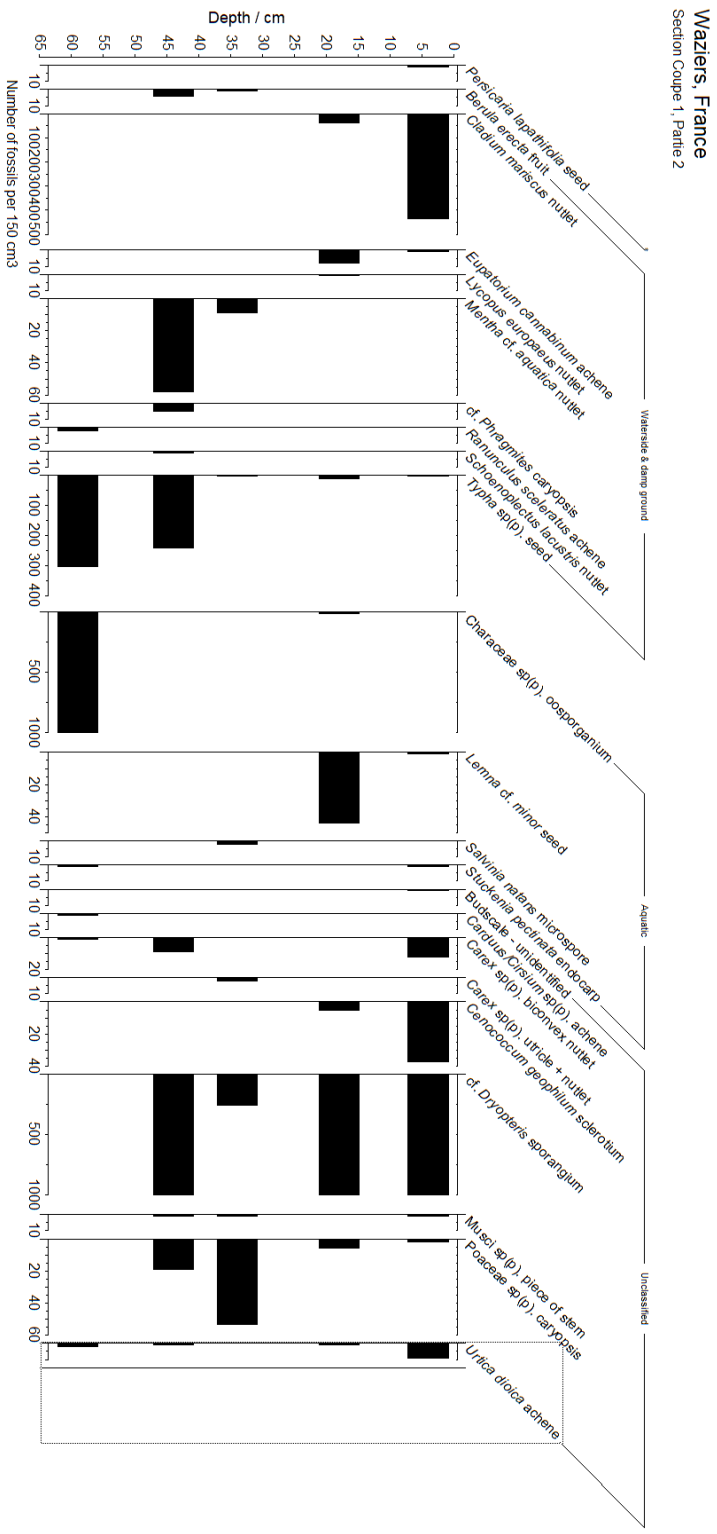

Figure 8 Carpological diagram of Partie 2 (Figure: M. H. Field, & M. Top)

Schoenoplectus lacustris (1), cf. *Phragmites caryopsis* (5) and *Berula erecta* (4). In addition to this there is a slight increase in *Carex* (9) and a sharp peak of *Dryopteris* (1000+), which mirrors the signal of partie 1, and the introduction of Poaceae (19). This again is consistent with the progression also seen in partie 1 as the oxbow lake slowly starts to shrink and dry up.

The third sample was taken at an approximate depth of 34 cm. The Characeae have completely disappeared, however a small number of *Salvinia natans* (2) microspores are introduced in the aquatic category. In addition to this *Typha* has disappeared from the record and *Mentha aquatica* (9) has decreased as well relative to the second sample. There is also a dip in the amount of *Dryopteris* (258), however there is also a relatively significant increase in the amount of Poaceae (53). This signal is consistent with the existing marsh drying up and turning into a bog, however it is remarkable that there is a large Poaceae signal considering that this was completely absent at the location of partie 1. It could indicate that in direct proximity to the remaining pools at the site there was a more open environment lacking trees.

The fourth sample was taken approximately 18 centimetres from the top of the peat sediments. There is a small reintroduction of Characeae (14), however the most important inclusion in this sediment is the presence of several *Lemna* cf. *minor* seeds (44), which is an important climatological indicator species for reconstructing summer temperatures. *Mentha aquatica* has disappeared from the wetland taxa, however there is a small resurgence of *Typha* as well. There are also other new wetland taxa such as *Eupatorium cannabinum* (8) and *Lycopus Europaeus* (1), as well as the appearance of *Cladium Mariscus* (37) in the record. Furthermore the Poaceae have again sharply diminished, whereas the *Dryopteris* (1000+) is back to high levels of abundance. This sediment represents the transition to a boggy landscape that is relatively dry compared to the marshy conditions that came before. However as mentioned it also contains *Lemna* seeds which indicate relatively high summer temperatures for the temporal placement of the site in the early Eemian.

The final sample of partie 2 was taken at a depth of 4 centimetres. In this layer almost all aquatic taxa have disappeared with only a very small amount of *Lemna* (1) and *Stuckenia pectinita* (1) remaining. On wet ground the amount of *Cladium Mariscus* (435) rises sharply whereas the amount of *Eupatorium cannabinum* (1) drops. For the first time in this sequence there was also a single dry ground species in *Persicaria lapathifolia* (1), as well as the reintroduction of *Carex* (12) and *Urtica dioica* (9). Despite this there are little conclusions to make from this minimal amount of terrestrial vegetation. Due to the sharp increase in *Cladium* it is possible that this sample correlates with the fourth sample of partie 1 which also saw a sharp rise of Cladium in the record.

Partie 2 represents a similar sequence to partie 1, but it shows the later stages of the aquatic zone as it transitions into a bog over time, as well as it seems to end just under the highest sample of partie 1. However this could also be due to variance influencing the exact

concentrations of remains in the sediment, seeing as the overall ecological signals are largely consistent. As such partie 2 has five (5) samples since it might be missing some of the outlying stages that are present in partie 1. There is also a slight difference between the taxa that have very low representation in the sequence, however it is likely that this is due to variance inherent in case of more rare carpological remains when compared to taxa that are in abundance such as *Zannichelia palustris*.

Palynological results

The pollen samples were taken from coup 1 partie 2 (see figure 9), which means that it uses the same depths as the carpological results of that sequence. The counts for this palynological research are absolute with the exception of the monolete spores which have been counted until a number of 100 after which they were referred to as “100+’. In addition to this, these numbers have then been converted to concentrations and these will be used in the analysis of this data. The taxa are split up in the categories ‘Trees’, ‘Shrubs’, ‘Climbers’, ‘Herbs’, 'Multi-class', ‘Aquatics’ and ‘Pteridophytes’. They are not subdivided in habitats as the most important of this data was the identification of pollen zones based on the arboreal signal, as well as the identification of the climate based on indicator taxa, rather than make a detailed local reconstruction which pollen data is less suited for. Furthermore for the concentration values only terrestrial plants were used and both aquatics and pteridophytes were excluded in order to prevent those taxa from skewing the terrestrial signal. These latter categories will however have concentration data that is relative to the total amount of terrestrial pollen. In total five (5) palynological samples were taken from partie 2 from the same approximate locations as the carpological samples. The depths that are recorded use the same principle as those from the carpological samples.

Initial results during preparation

During the initial preparation of the pollen samples it was of note that some of the samples had distinct reactions with the chemicals that were introduced to them. Sample 1 was a clay sample with a wet consistency which reacted violently when it made contact with the hydrochloric acid wash. This indicates that there was a significant amount of calcium carbonate present within the sample. In addition to this the sample took on a greenish yellow hue after being washed with the acetic acid, it is unclear what the colour change of this sample and the others seems to indicate, or what causes the difference between the colourations. The other samples were dried out peat sediments. Sample 2 had no remarkable reactions after any of the chemicals. Sample 3 reacted with the acetic acid and turned pink after it was introduced. Sample 4 reacted with the hydrochloric acid as well although in a less extreme fashion compared to sample one, therefore this sample also contained calcium carbonate but in a lower concentration than sample 1. In addition to this sample 4 also turned dark after being treated with potassium hydroxide, which

indicates that there were elevated amounts of organic material present within the sample even when compared to the other peat sediments. This sample also reacted with the acetic acid, turning greenish yellow in the same way that sample 1 had. It could be possible that this colour has a relation to the presence of calcium carbonate, since it is the same as the colour of sample 1 which also contained calcium. Finally sample 5 became dark after potassium hydroxide was introduced in the same way that sample 4 had reacted. This sample had no remarkable reactions with any of the other chemicals. The reactions that the samples had are important to note as they might reflect the ecological conditions in which they were deposited. For example the presence of calcium carbonate in the sediment indicates that the ecology during that time was almost certainly alkaline, because in a more acidic environment the chemical composition of calcium carbonate would have already broken down or even not been created in the first place. An increased amount of remaining organic material in the peat sample might indicate a good preservation of the sample, or at least conditions in which organic material did not break down as much. It is remarkable that there seems to be a difference of this organic preservation between the different peat samples considering that these already have a relatively large amount of organic material remaining in them compared to sediments like the clay sediment of sample 1, despite clay also being an excellent preserver of organic material.

Microfossils from Partie 2

The lowest sample comes from a depth of approximately 59 centimetres. The arboreal signal of this layer mainly consists of *Betula* (20.8%) (with even a minute amount of *Betula nana* (<1%)) although there is a small amount of *Pinus* (3.9%) as well. In addition to this there are also trace amounts of *Ulmus* (4%), *Quercus* (3%), *Salix* (2%), and *Cornus mas*-type (<1%). Other numerous terrestrial taxa include *Juniperus* (8.2%), *Artemisia* (11.4%),

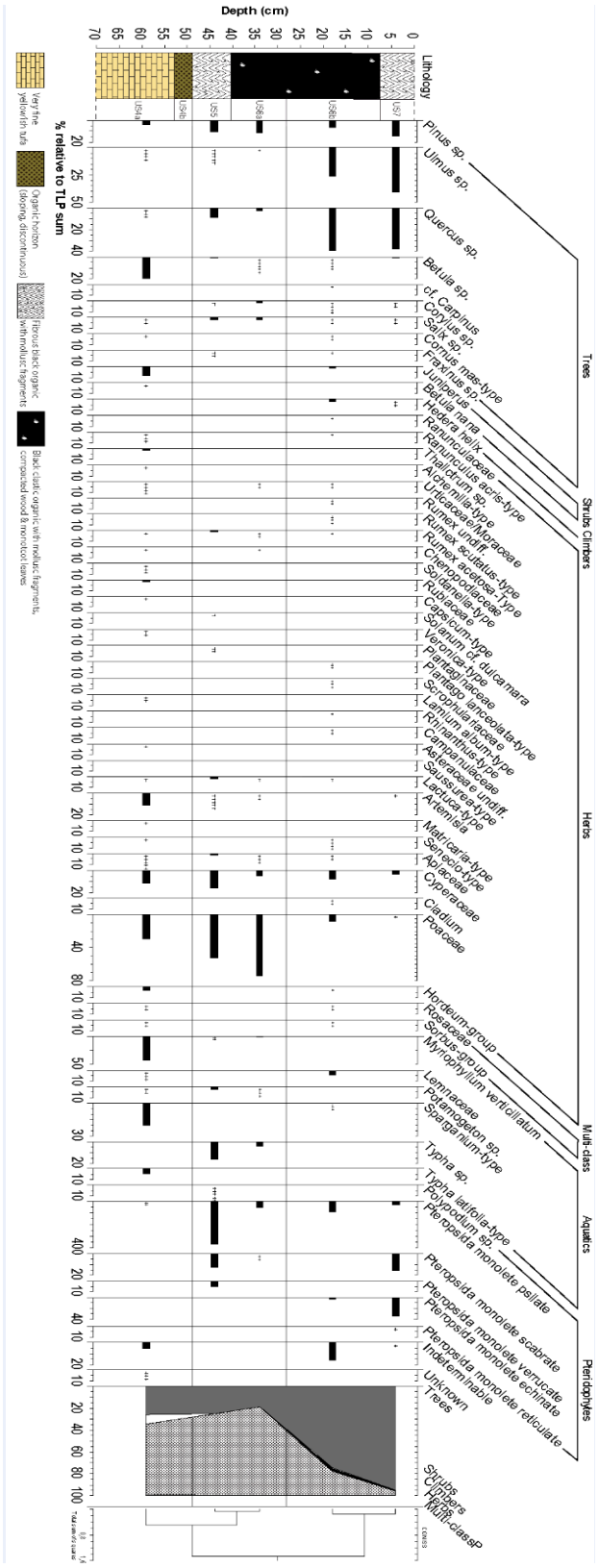

Figure 9 Palynological diagram of Partie 2 (Figure: I. M. Kamerling, & M. Top)

Cyperaceae (11.9%), and Poaceae (29.7%). In the aquatics there was a significant amount of *Myriophyllum verticillatum* (43.2%), *Sparganium*-type (20.7%), and a smaller amount of *Typha* (4.1%). Interestingly there were also trace amounts of Lemnaceae (3%). The presence of *Betula* is consistent with the small existing terrestrial signal from the carpological material and the pioneer species that thrived during the end of the Saalian. The trace of *Betula* nana also indicates that steppe species did continue to exist in the region during this period, however the amount of *Pinus* is lower than expected for the period as its presence should be at its peak. The large amount of *Myriophyllum* is indicative of the fact that at this moment the area was significantly wet. The inclusion of Lemnaceae is interesting as no carpological record of *Lemna* was discovered so early in the sequence, however it might also be possible that this signal consists of other genera of the family.

The second palynological sample was taken at an approximate depth of 44 centimetres. The amount of *Betula* (1.2%) pollen in the sediment decreases sharply, while there is an increase in the amount of *Pinus* (10.4%) present. A genus that sees a relatively larger increase in number is *Quercus* (9%) and the amount of *Salix* (2.8%) remains largely stable throughout the rest of the sequence. Furthermore *Rumex Acetosa*-type (1.4%) and the *Lactuca*-type (1.6%) see an increase in number as well, while *Artemisia* (5%) is reduced to much smaller amounts. Another increase can be seen in the Cyperaceae (15.5%) and a significant increase happens in the concentration of Poaceae (52.6%). *Myriophyllum* (2%) has been reduced to traces in the aquatics and the *Sparganium*-type pollen have disappeared entirely, while *Potamogeton* sees an increase in its number (2.8%). There is also a sharp rise in the amount of *Typha* (16.3%) and the Lemnaceae have disappeared from the record. This second sample marks the vegetational progression of arboreal taxa that is completely invisible in the carpological record due to its local scope. Remarkable is that *Pinus* seems to be increasing in number where conventional pollen zones see it drop alongside *Betula* in the sequence. Instead these taxa are replaced over time by mixed oak forests. The aquatics such as the sharp drop in *Myriophyllum* might indicate that there is change in ecology happening, perhaps due to the body of water being cut off from the main river.

The third sample was taken at a depth of roughly 34 centimetres. Both *Pinus* (11.2%) and *Corylus* (1.4%) experience a slight increase in number while there is a decrease in *Quercus* (2.6%). Although *Betula* (5%) is still present in the record, it is only decreasing in amounts from this point on in the sequence. Many of the terrestrial herbs are hardly represented and the Cyperaceae sharply decrease as well (4.6%), meanwhile the Poaceae (74.4%) reach their peak and dominate this layer by a large margin. The amount of aquatic pollen continues to drop with only *Typha* (4%) maintaining a significant presence, whereas *Potamogeton* (3%) remains in smaller amounts before disappearing in younger layers. The ecology of this layer seems to be dominated by the presence of either large amounts of grasses or a smaller patch of grassland nearby. This might have skewed the arboreal signal into numbers that have little influence on the total concentration although the amount of *Pinus* present still seems to be increasing. This

might also be the reason that most other herbs have fallen off the record as well, as a count of 500 terrestrial pollen was maintained and much of this was occupied by the large amount of Poaceae pollen.

The fourth sample was taken at an approximate depth of 18 centimetres. The amount of *Pinus* (6.9%) decreases and instead there is an extreme increase in concentration of both *Quercus* (38.5%) and *Ulmus* (26.5%). Other arboreal taxa are reduced to low concentrations. A newly introduced species in the pollen record is *Hedera helix* (2.1%) which is now represented in low amounts. There are only minor concentrations of herbs and Poaceae (8.6%) have greatly diminished in number, while there is a slight increase in Cyperaceae (7.7%) and also small amounts of *Cladium mariscus* (2%). The aquatics continue to disappear, however there is a sudden small spike of Lemnaceae in this sediment (3.8%). The sudden spike in arboreal activity might be due to a large expansion of mixed oak forests, however it could also be possible that a small number of trees are releasing large amounts of pollen close by, much like what could have been the case with the Poaceae in the third sample. The appearance of both *Hedera helix* and Lemnaceae are significant in a climatological context and the latter is consistent with the significant amount of *Lemna* cf. *minor* seeds that were found in the same layer during the carpological research. There would also be expected to be a large number of *Cladium* pollen when taking into account the carpological research, however it could be possible that the majority of the *Cladium* is included in the Cyperaceae count.

The fifth sample of the pollen sequence was taken at an approximate depth of 4 centimetres from the top of the organic layer. The combined concentration of *Quercus* (37.5%) and *Ulmus* (40.6%) remains continues to increase and in addition to this *Pinus* (14.5%) is increasing as well. Herbs have largely disappeared from the record as well, as *Hedera* (2%) and Poaceae (<1%) only occur in minimal amounts. The only significant herb presence belongs to the Cyperaceae (3.1%) and these are decreasing as well. In addition to this no aquatic taxa remain in the pollen record at this layer. The mixed oak forests seem to continue to dominate in the region as herbland disappears and remarkably *Pinus* still seems to thrive. There is also only a minute amount of Cyperaceae remaining in the concentration despite the abundance of *Cladium mariscus* in the carpological material. Based on the present pollen it could be concluded that at this point the aquatic taxa have all but disappeared as the entirety of the oxbow lake has turned into a damp ground bog.

7. Discussion

Carpological Reconstruction

Overall the sequences together show a site that started off as an aquatic river environment in cooler climatic conditions. In addition to this there was only a slight amount of dry ground taxa growing in the direct vicinity of the river, although the lowest samples did include some fragments belonging to *Betula*. As the sequence goes up the amount of Betula that is encountered initially increases. This might represent the transition into warmer climates which sees pioneer taxa such as *Betula* expand into north-west Europe, to be followed by other organisms that prefer warm water. After this the *Betula* suddenly disappears as well as the *Zannichelia palustris*. This is interesting as this can not only be the result from the oxbow lake being cut off, because *Zannichelia palustris* can tolerate both slow moving and stagnant waters (Weeda, 1985). However since any arboreal carpological remains remain absent for the rest of the sequence (although there is in interesting single inclusion of *Betula* high up in the sequence of partie 1), it seems unlikely that there was a significant amount of forest directly at the waterside, but rather this would be a small distance away, or at least close enough for beavers to make use of. It must also be taken into consideration that in other parts of the peat remains of *Quercus* were discovered as well as the fact the the peat was identified as being wood peat, which could mean that there is a certain amount of variance dependent on the exact location of the site that is investigated (Deschodt et al., 2022, p. 247; Hérisson et al., 2022, pp. 229-236). Going further up the sequence the Characeae disappear as well. Although it could be possible that this is related to the level of acidity in the area, this is probably unlikely however, as the highest level of partie 2 contain the remains of *Persicaria lapathifolia*, which prefers neutral or alkaline trending grounds. This would imply that the acidity can not have been too low for calcium carbonate to exist (Weeda, 1985). Instead it could be the result of a change in trophic levels due to the site being an oxbow lake that would have slowly accumulated plant material, thereby perhaps increasing the trophic levels over time to a point that the Characeae could not abide. Following this stage is the introduction of *Cladium Mariscus* which prefers damp ground, but thrives in boggy conditions which would be too dry for aquatic taxa and waterside taxa that prefer deeper standing water such as *Typha*. It is in this process of increasing desiccation of the area that the sediment breaks off and further deposition of botanical material is lost to taphonomic processes. Additionally partie 2 shows that Poaceae were growing in the proximity of the site, which implies the presence of more open grassland ecologies, rather than the bog existing surrounded by dense forest. While the sequence already implies a transition in climatological conditions in its modest terrestrial signal, the most important ecological data lies possibly within its aquatic taxa. As discussed earlier in this thesis, *Lemna* cf. *minor* is a species that is particular about the conditions in which it chooses to sexually reproduce (Kapitonova & Nikolaenko, 2021) and as such its presence in partie 2 implies considerably warm summer conditions in order to facilitate that. In addition to this is the presence of *Salvinia natans*, a

species that has been recorded as being present at Deeping St James while being absent from current day Britain due to it preferring subtropical or tropical conditions (Keen et al., 1999, p. 417; Rothmaler et al. 1986). Deeping St James is considered to be an early Eemian site, so it will be important to discover what the relative date is of Waziers compared to that of Deeping St James, should it be significantly earlier then this would have implications regarding climatological conditions during the different stages in the early Eemian and the consequences that this might have had for early hominins in the region at that time. In addition to this, although there is a strong indication in regards to temperatures during the warmer seasons at Waziers, there is not yet an indication as to the cooler conditions. Despite the fact that it is known that *Salviania natans* prefers temperatures to stay above freezing, the palynological record will be required in order to make a more conclusive statement regarding the colder seasons at Waziers. This is important in order to be able to distinguish whether the climate at Waziers was trending more towards continental conditions, or towards southern European or Mediterranean conditions (or towards a climate that is not analogous to any current day climate found in Europe).

Palynological reconstruction

The slight amount of aquatic pollen that can be found in this sequence is indicative of a progression as is described by an analysis of the palynological data, be it in a lower resolution. As such the value of this sequence does not lie in its local reconstruction, but rather in the regional trends it signifies, with a much greater number of terrestrial taxa within a much higher concentration than can be found in the macrofossils. When comparing the results to the research done by Gauthier (2022), it can be concluded that these largely overlap and that there certainly is a similar signal that is expressed regarding the vegetational progression that is happening in the area surrounding Wazier. This information will be used to place the site of Waziers within a chronological time frame with other pollen zone type sites such as Deeping St James and other early Eemian archaeological sites such as Neumark-Nord 2 and Caours. However it does seem that the sequence described by Gauthier postdates the results that were gathered during this thesis. This can be deduced from the presence of *Fraxinus*, *Alnus* and *Taxus* in those sediments, which are taxa that follow upon the peak of *Quercus* and *Ulmus* forests.

The inclusion of vegetation such as *Betula nana* and the abundance of *Artemisia* in the lower sediments signifies an ecology that still contains some of the steppe taxa which would have thrived during the Saalian when compared to the temperate taxa that followed, which at that time would have grown at latitudes much further south and in refugia. And as the sequence progresses the expansion of more temperate vegetation can be observed, such as the expansion of mixed oak forests, which especially later seem to dominate the landscape and replace sources of Poaceae such as open grasslands which were abundant in the lower half of

the sediment. Remarkable is the relatively low amount of Betula that is present throughout the entire sequence, considering that the carpological data shows that there were *Betula* growing in proximity to the site. Compared to the extreme peaks of *Quercus* and *Ulmus*, which are not represented in the macrofossils at all, the *Betula* does not manage to surpass a concentration of 20% total land pollen. This might be due to differences in pollen production between the different taxa, which is always a consideration when analysing palynological data. The increasing amount of *Pinus* is also surprising, since this genus usually peaks before and alongside Betula, after which it diminishes. However, rather than slowly disappearing into trace amounts like the *Betula* did in the sequence, *Pinus* only seems to increase in number. This might be caused by *Pinus* forests being less sensitive to ecological variance than pioneer species such as *Betula*. Considering that the amount of *Pinus* pollen was also not overwhelming suggests that these trees were either low in number or located far away, as this genus is known to produce exceedingly large quantities of pollen that are capable of travelling vast distances through aeolian means. A final remarkable result was the relatively low amount of pollen belonging to *Cladium Mariscus* that was found in the sediment. Carpological material signifies that a significant population was present during the later stages of Waziers, however it is almost completely absent from the palynological record. Although it is possible that some of the *Cladium* was included within the larger Cyperaceae category, these too were not represented in abundant concentrations in the upper layers of the sequence whereas they existed in relatively large numbers in earlier sediments. Besides the presence of *Betula nana* early in the sequence there are several other taxa which also bear ecological implications. In the fourth sample the pollen contained a significant amount of Lemnaceae, which is consistent with carpological material from this same sediment, which also contained a large amount of *Lemna* cf. *minor* seeds. As explained this indicator tells something about the optimum summer temperatures in the region (Field et al. 2023, p. 5). However there was also a minimal amount of Lemnaceae found in the lowest sediment, which signifies the early transition of the late Saalian into the early Eemian. This presence is also confirmed by Gauthier, which could imply that summer temperatures were warm already very early in the Eemian. Furthermore there was a number of *Hedera helix* pollen in the fourth sample as well, this complements the carpological data as this species gives an indication as to the coldest winter temperatures, an indicator that was largely missing from the carpological data, besides the preferences of *Salvinia natans,* and it implies that winters in the region of Waziers were relatively mild (Field et al., 2023, p. 6). Interesting is the observation that specimens of Lemnaceae were encountered in the earliest sediments when the sequence should have experienced the coldest conditions, which is also alluded to through the presence of *Artemisia* and *Betula nana*, after which it disappears from the record until reemerging in the fourth stratigraphic layer. This could be interpreted as a possible contamination of the sample, considering the exceedingly low amounts that were encountered, however Gauthier also makes note of the presence of *Lemna* in the zone that correlates with the earliest sample of this thesis. It is unlikely that this would be a coincidence and, although in both cases the amount of *Lemna* remains within these layers is extremely low, it is undeniable that at that point in time that was sexual reproduction of *Lemna* occuring at Waziers. It is

possible that what is represented is a short spike of warmer temperatures during the transition from the Saalian to the Eemian, which could explain why there is both a low amount represented in the record, as well as why this signal of sexual reproduction disappeared for a significant amount of time after this stage. This could indicate that *Lemna* was still present, but due to a drop in temperatures returned to reproducing asexually.

Pollen zones and Correlation

The correlation mostly focuses on Arboreal pollen and some taxa belonging to terrestrial non arboreal pollen. Aquatic vegetation and specific taxa such as *Hedera helix* and *Lemna*, while indispensable for ecological reconstruction, are less relevant for the correlation of pollen type sites as they are often not represented at other sites. In cases where this is the case this will be included in the interpretation, but they are not a focal point. Based on the pollen sequence at Waziers, the zones of partie 2 were divided into three main zones for the use of dating the site through correlation with other pollen zone type sites. Although further subzones could be identified within the sediments, for the purpose of correlation with multiple sites it was most effective to narrow these subzones down into three larger categories that were distinguished by the concentration of arboreal pollen versus non arboreal pollen and the concentration of pioneer taxa within a sediment (see figure 10).

The zone typologies come in two forms in this case. The first is a local zonation which is often site specific. In this correlation the zones as described in the French sites are often

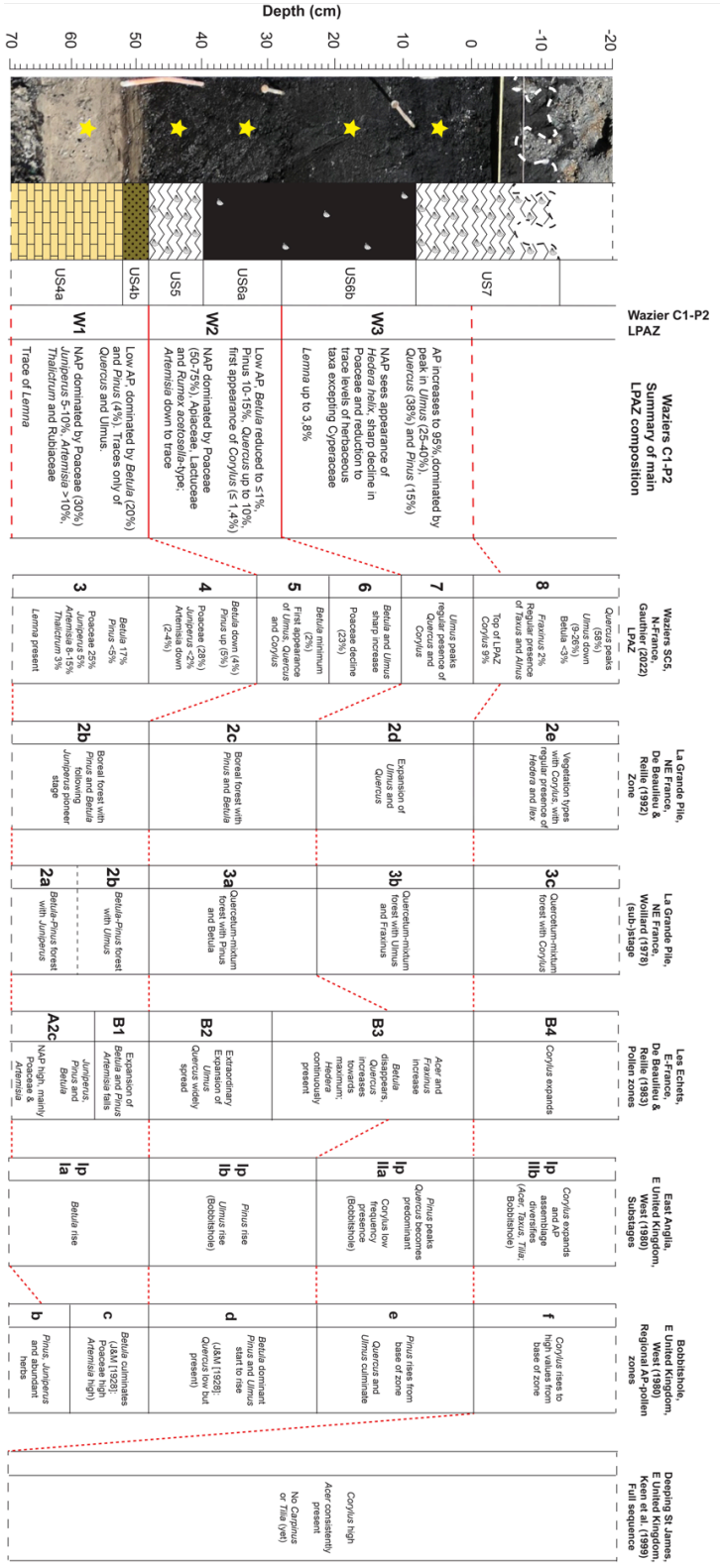

Figure 10 Correlation of palynological typesites (Field, 2023 et al., p. 15, Figure 3)

made for the site itself, which can result in (sub) zonation which can not be recognised as readily on a larger scale. The other type of pollen zones are based on regional standards as is used in the case of pollen research performed by West. These place the zones of a site within a larger framework, however this can come at a cost of resolution. When correlating pollen zones from different sites with each other it is important to keep these differences in mind when interpreting the data.

The first zone (W1) contains a low arboreal pollen signal that nonetheless had an approximate concentration of 20% *Betula* pollen. In addition to this there was a lower amount of *Pinus* and only trace amounts of *Quercus* and *Ulmus*. For the non arboreal pollen there was an abundance of Poaceae, but also a large amount of remaining steppe taxa in *Juniperus* and *Artemisia*. As mentioned before, the data of this sequence mirrors the conclusions that were gathered by Gauthier (2022), although that sequence continued both before and after the data that was gathered by this investigation. In addition to this, the research published in 2022 identified at least seven subzones based on earlier research. W1 coincides with subzone 3 and 4 of that research based on the concentration of pioneer taxa present, as well as the inclusion of taxa that represent steppe environments. In regard to other French sites it correlates to zone 2b at La Grande Pile as identified by De Beaulieu & Reille (1992) and zone 2a and 2b as identified by Woillard (1978) at the same site. This was based on the presence of Betula and *Pinus* forests and *Juniperus* pioneer activity. At Les Echets this zone correlates with zone A2c and B1 as identified by De Beaulieu & Reille (1983), which also included a concentration of *Artemisia*. In Britain this zone correlates to Ip Ia at East Anglia as interpreted by West (1980) and with the upper part of zone b and c at Bobbitshole (West, 1980), which was based on arboreal pollen.

The second zone (W2) also had a low amount of arboreal pollen, but in this zone the concentration of *Betula* had decreased to under 1%. Instead *Pinus* has increased to 10-15% and *Quercus* is starting to take over and has a concentration of approximately 10%. Furthermore in this zone *Corylus* starts to be a significant presence in the wider region. In addition to this the Poaceae in the area arrive at their peak, reaching levels of 50-75%, in combination with a small rise of Apiaceae and *Rumex acetosella*-type. Meanwhile *Artemisia* has almost completely disappeared from the pollen record as it decreases to trace amounts. In Gauthier's sequence this zone encompasses zone 5 and 6. However zone 6 is reported to exhibit a sharp rise in *Betula*, which is completely missing in W2. In addition to this zone 6 alo has a decrease in the amount of Poaceae whereas W2 has an overwhelming abundance of this family. It could be that zone 6 marks the transition from W2 to W3 since the latter has a sharp drop in the amount of Poaceae. W3 also has a very slight increase of *Betula*, but not something close to a description of a 'sharp' increase. As such zone 6 seems difficult to analogue with either W2 or W3. At La Grande Pile this zone correlates with 2c (De Beaulieu & Reille 1992) and 3a (Woillard 1978) and is largely marked by the rise of mixed oak forests. Woillard also mentions the continued presence of *Pinus* and *Betula*. Les Echets describes this zone as B2 and the earlier stage of B3. It describes a signal of *Acer* and *Fraxinus* which is not mirrored at

Waziers, however it focuses on the sharp growth of mixed oak forests and the disappearance of *Betula*. In Britain this zone correlates with zone Ip Ib in East Anglia and zone d at Bobbitshole, both describing the rise of *Ulmus*.

The final zone (W3) sees a sharp increase in the concentration of arboreal pollen up to 95%. Most of this is represented in *Quercus* (~38%) and *Ulmus* (25-40%), although there is also a significant amount of *Pinus* (15%). In the category of non arboreal pollen both Poaceae and other herbaceous taxa almost completely disappear from the record. An exception for this is the remaining presence of Cyperaceae, which is potentially a representation of *Cladium mariscus* growing at the site itself rather than a regional signal. Gauthier describes this at zone 7 with W3 possibly also incorporating the beginning of zone 8. Zone 7 describes the peak of *Ulmus* and the presence of both *Corylus* and *Quercus*, while zone 8 mentions the beginning of the presence of *Fraxinus*. However it also mentions a significant increase of *Corylus* pollen, which means that zone 8 also incorporates the period after W3. At La Grande Pile W3 correlates with zone 2d (De Beaulieu & Reille, 1992) and zone 3b (Woillard, 1978). These describe the maximum of *Quercus* and *Ulmus* with a signal of *Fraxinus*. Zone 2e also mentions the presence of *Hedera helix*, however this is in combination with *Corylus* and therefore later than W3. Zone 3c also mentions *Corylus* and correlates to a later period. At Les Echets, Waziers correlates with the second half of zone B3 as largely a mixed oak signal. It also mentions a continuous presence of *Hedera* which is consistent with zone W3. Zone B4 describes the expansion of *Corylus* populations. In Britain this zone correlates to Ip IIa at East Anglia, as it describes a peak in *Pinus*, which could be compared to the rise which can be observed at Waziers. It also records a peak in *Quercus* forests with a low amount of *Corylus*. Ip IIb describes then the dominance of *Corylus* in the following period. At Bobbitshole it correlates with zone e as this also describes a rise of *Pinus* as well as the peak of *Quercus* and *Ulmus* forests. It follows this up in zone f with a rise of *Corylus*, as is consistent with the other pollen zones that postdate the sequence at Waziers that was created during this thesis.

It was concluded that the site of Deeping St James postdates the sediments that are represented at Waziers. This was based on the high amount of *Corylus* that was present at that site, which although it had already expanded into the region at Waziers, had not yet started to occur in significant concentrations in the record. At Deeping St James there was also the inclusion of *Acer*, however *Carpinus* and *Tilia* had not yet started to appear (Keen et al., 1999), which would have expanded into the area as the Eemian progressed. The archaeological site of Neumark-Nord 2/2 is also located later in the pollen zone sequence, as this site also features a high *Corylus* plateau and in addition to this, while it is stated that there was also a peak of *Quercus* and *Ulmus*, these genera where already in decline at the time of Neumark-Nord 2/2. This site is already considered to date to the early Eemian and the entire sequence of Waziers seems to be even younger. The early pollen zones at Waziers more closely resemble the site of Neumark-Nord 2/3. However, further archaeological analysis is difficult because of the relatively low amount of material compared to 2/2 (Laurat & Brühl, 2021). It is not possible to correlate

dating Waziers relative to Caours using palynological data beyond the interpretation that both sites date back to the early Eemian. This is due to the fact that vegetational remains were not preserved well, if at all, in the tuff sediments that make up the stratigraphy at Caours. It is for this reason that Neumark-Nord was chosen as an additional archaeological site that was identified as early Eemian despite being further removed from Waziers than Caours. This makes it possible to get a relative temporal position of Waziers compared to other archaeological sites that are also considered to be from the same period and not only compared to other pollen type sites which are more abundant.

Taphonomic considerations

As mentioned earlier in this thesis it is important to take taphonomy into consideration when interpreting botanical data in order to produce a reconstruction of the environment. It is particularly to acknowledge that, while the presented reconstruction might be a likely scenario, it might not be the only interpretation of the data. This is especially the case in dynamic environments such as an active river channel which facilitates the possibility for both micro- and macrofossils (especially those belonging to terrestrial taxa) to travel significantly further than they typically would otherwise. This factor would likely have a greater effect on pollen than on carpological remains, as the latter are much heavier and therefore are deposited closer to the origin and in stronger currents than palynological remains. As a result palynological data between different sample sites within the same larger site is also much more likely to be more homogenous than carpological remains. The record of macrofossils can be very different between sample sites that are mere tens of metres apart, as can be observed in the relative difference in taxa representation between partie 1 and 2. Conversely this should also mean that the pollen records observed by this thesis and the research done by Gauthier are likely to be relatively similar when compared to the differences in macrofossils, despite the fact that these samples were taken hectometres apart from each other. After the active floodplain was cut off from the main waterway, this elevated reach of dispersal should have become less of a factor, however there are several other conditions that have an impact on this. The amount, quality and diversity of taxa that will be encountered in both micro- and macrofossil records, is affected by several taphonomic factors that can be aeolian, hydrological, chemical, geographical, entomological and otherwise zoological in nature. These records are also affected by the sexual strategies of their botanical origins which pertains to factors such as amount of production, mode of dispersal and the durability of the remains within different conditions. These factors are different between different botanical taxa and each have consequences for the effect of subsequent taphonomic processes. Therefore, in order to make a reconstruction with absolute certainty all these conditions must be known. This is hardly feasible to do with current day sites due to the amount of possible variance, let alone for a site dating back a hundred thousand years where much of the exact data can only be inferred through proxies. Because of this there is always an amount of possible variance with the interpretations based on this data, which

stresses the importance of multidisciplinary studies, in order to mitigate this variance as much as is reasonably possible.

8. Conclusion

By combining the results of the botanical research presented by this thesis with the earlier campaigns that took place at Waziers, as well as incorporating information from other archaeologically and climatologically relevant sites, it is possible to answer the multiple sub questions that were posed in order to make an interpretation regarding the lack of hominin activity during the Eemian on the British Isles, in spite of their presence in the rest of north-west Europe.

Local and close range regional conditions at Waziers

Firstly it is important to understand the conditions at the site of Waziers itself, both botanical and otherwise physical, which can be done using the diagrams produced by the data of this thesis and earlier research campaigns at the site. For the vegetation at the site itself the macrofossils are the most important, as these will have likely travelled the least distance after deposition. Through this it can be concluded that Waziers initially featured a significant population of aquatic vegetation such as *Zannichelia palustris,* which is related to the palaeochannel that the site is located in. Comparatively during these early stages there was a relatively low amount of terrestrial taxa represented in the record which might indicate that the aquatic population was significant, depending on seed and fruit production. However it stands to reason that, as the aquatic taxa were spatially closer to the zone of deposition that these are likely overrepresented. There is however a notable arboreal presence in the vicinity in the form of *Betula*. Over time the site was cut off from the main channel and slowly desiccated into a bog, which is visible in the disappearance of aquatic taxa and the introduction of plants which thrive in such conditions such as *Cladium mariscus*. During this time the arboreal macrofossils in the record disappear which could imply that the site was not densely wooded in the direct vicinity and instead consisted of a more open herb- and grassland. In addition to this it is possible to deduce other physical conditions in the local area. The presence of skeletal remains of *Castor Fiber* as well as its dam implies that there used to be wooded zones close to the site, if not directly adjacent. It is likely that these remains represent the early stage of Waziers when it was still part of the active channel, as beavers have been recorded to dam running water rather than standing water. This is consistent with the present arboreal signal during these earlier sediments and since it has been suggested that the presence of these animals is what could have attracted hominins to settle in the region, as well as the observed presence of lithic tools, it can be concluded that they were already present during these early environmental stages. Climatologically it is suggested that at least the later sediments of Waziers were formed during a climate that featured summers that could reach temperatures that are considered subtropical or tropical, as can be observed by the presence of macrofossils and pollen belonging to *Lemna* cf. *minor* and *Salvinia Natans*. The *Salvinia natans* in conjunction with the presence of pollen from *Hedera helix* however implies that the winters that were experienced during this period were

relatively mild, with the air temperature not or barely dropping to levels below freezing. This conflicts with earlier suggestions that climatic conditions in north-west Europe during the early Eemian were continental in nature and instead suggests that they were likely trending towards conditions more reminiscent of a current day southern European climate or else one that is not analogous with anything that is currently present in Europe. The earlier sediments give a signal of a more steppelike environment through the presence of taxa such as *Betula nana* and a relative abundance of *Artemisia* as well as the occurrence of *Megaloceros giganteus, Stephanorhinus hemitoechus* and *Equus achenheimensis*. However the added presence of a small concentration of Lemnaceae pollen in the earliest period implies that there was likely at least a small period with highly elevated temperatures for the time.

Age of the Waziers sediments and their temporal position within the Eemian stage

In order to understand the temporal position of Waziers both in relation to the transition from Saalian to Eemian and within the Eemian itself, but also in relation to other archaeological and botanical sites that are associated with the Eemian, it is possible to refer to the palynological data that was preserved in the sediments that were investigated. These can be correlated with pollen data from other dated sites in order to conclude a relative temporal position in comparison to those. In addition to this, environmental conditions can be taken into account when considering at which point in the climatological transition between glacial and interglacial stages the pollen were deposited. Several other dating methods such as electron spin resonance have also been performed on material found at Waziers. However these methods were found to be not very accurate for a high resolution interpretation of the chronology at Waziers. The ecological signal from the lower sediments indicates that the regional ecology of Waziers started off as a steppe environment, after which it transitioned into encroaching forests that featured an ecological succession of taxa. This succession started with pioneer species such as *Pinus* and *Betula*, after which these were largely replaced by mixed *Quercus* forests with a significant amount of *Ulmus* present as well. These would in the sequence eventually start to be replaced by *Corylus* populations. Later during the Eemian the *Corylus* would be followed by *Carpinus*, however the sequence at Waziers does not go that far into the Eemian. This sequence can be correlated with several pollen zone type sites that can be found in both France and Britain, which map out the Eemian stage. These confirm that not only does Waziers date back to the Early Eemian, but it includes the transition from the previous glacial period as well. In addition to this the pollen record can be compared to the Archaeological site of Neumark-Nord 2/2 which is also considered to date back to the early Eemian. However this site seems to start during the optimal stage of *Corylus* when *Quercus* was already in decline. If there is a temporal overlap between the two sites then it would only be with the final stage of the chronology at Waziers. This means that if Neumark-Nord 2/2 is already considered to belong to the early Eemian, then this would even more so be the case for Waziers as this site would then predate Neumark-Nord. There is also the site of Neumark-Nord 2/3. Much less is known about

this site, however its pollen record has much in common with the older sediments that were sampled at Waziers partie 2 and would therefore be much more relevant when comparing early hominin presence in north-west Europe.

Hominin dispersal in north-west Europe

Next, in order to better understand hominin activity in north-west Europe during the early Eemian, it is important to look at how they behaved and expanded in other parts of the region. Up until recently there were no sites in north-west Europe linked to the Eemian interglacial. It was for this reason, that it was thought that hominins could not survive in this area due to the distribution of biomass which was thought to be skewed to be mainly arboreal and therefore not fit for consumption. It was claimed that in order to do so, early hominins would have needed to have organisational skills which they were thought to have lacked. However not only have several sites been linked to the (early) Eemian since then, making this claim demonstrably wrong, it has also become clear that early hominins were more intellectually sophisticated than was hitherto presumed. Some of these sites are difficult to place within the temporal framework of the Eemian, such as the site of Caours which is located relatively close to Waziers. This is because the soil that the sediments there are composed of are very permeable for oxygen, which is detrimental to any preservation of pollen material that might be used in order to correlate Caours with other pollen type sites. Furthermore material found at the site is difficult to date and the techniques that are available are relatively inaccurate with variance ranging in the thousands of years. This is a lot for a period that only lasted for roughly 15.000 years and as such makes it difficult to identify when during the early Eemian the site was active exactly. Neumark-Nord 2 is a different site that is located significantly further away in Germany. However, since this is also a lacustrine archaeological site, a detailed pollen record was preserved that could be correlated. As it has been concluded that Neumark-Nord 2/2 was younger than the sediments that were found at Waziers, this also means that hominins had already expanded further north-west in Europe during the start of the early Eemian. This would then mean that soon after the Saalian, hominins would have already had the opportunity to expand into Britain from a temporal point of view, especially since it is likely that there was already a hominin presence in the earliest stages of the sediments examined at Waziers.

Climatological conditions in the wider region of north-west Europe

While it is important to know the local conditions that hominins would have experienced at Waziers, it is also relevant to take into consideration the conditions that were present in other regions, as these would have had implications for the geographical possibilities to reach certain areas, as well as possibly the motivation of hominins to do so. As has been concluded earlier, it has been demonstrated that early hominins certainly had the social sophistication to implement structures which would have allowed them to exist, if not thrive, in conditions that may be

considered adverse. Therefore conditions would have needed to be exceedingly prohibitive in order to dissuade these hominins to expand further into new territories. It can also be concluded that, climatologically, several regions in north-west Europe besides coastal northern France did not have inhospitable conditions for early settlers. At Neumark-Nord 2/2 remains of *Emys orbicularis* have been found, which indicates that temperatures rose to significant heights during the warmer periods of the year. However it must also be considered that Neumark-Nord 2/2 is a younger site than Wqziers and that at this point during the Eemian, the climate was still becoming increasingly warmer before encountering an interstadial. Not only this, but because the site is located much further inland, it is not unlikely that there would have been climate conditions more akin to a continental climate, rather than the climate that was identified at Waziers. However these warmer climate conditions are mirrored in the data that was gathered at British typesites, several of which are contemporary with the sediments of Waziers. Much like in Waziers, taxa have been found such as *Salvinia natans*, which as earlier noted prefer at least subtropical or warmer conditions, as well as *Hedera* and *Lemna* which create the climatological parameters for the warm and cold annual periods. This means that during this period in Britain there was a climate that was comparable to the one that was present at Waziers, which means that these were conditions that hominins were very much capable of existing in.

The absence of Hominins in Britain

Although it can be concluded that the climate was suitable for hominin occupation already very early in the transition from the Saalian Glacial into the Eemian and in addition to this there is evidence that there was already hominin activity at what is nowadays near the French coast during this period, there have still not yet any archaeological sites in Britain been attributed to the Eemian. There could be several reasons to explain this apparent absence of hominins during this time. Firstly it could be possible that such sites have simply not yet been uncovered or not attributed correctly to the Eemian. Up until recently the same was the case for the entire region of nort-west Europe which has since then been proven to be incorrect. It is possible that, now that there is precedent which can be used to identify or find these sites, in the near future Eemian archaeology will be found in Britain as well. Another possibility is that the Eemian was significantly warmer during its early transition than what was theorised until now, and that because of this the amount of land based ice had already been reduced significantly. This should be visible in the oxygen isotopes that can be measured in ice cores. However it has been found that these ice cores are not necessarily without anomalies and climatological discrepancies when compared to other climatological data from the Eemian. It is therefore possible that this change can not be observed within the ice records, also because this would have happened within a relatively short timespan when compared to chronology that has already been identified. As a result of this it is possible that sea levels had already risen significantly during the very early stages of the Eemian, which could have meant that the Channel, which was a land bridge during the Saalian, had already been submerged under the

sea. This could have posed an insurmountable obstacle for early hominins or at least dissuaded them to try and cross and instead move on elsewhere to greener pastures.

Future research

There are multiple avenues in order to further explore this subject during future investigations. As observed there is great merit in performing multidisciplinary research when identifying the physical conditions that were present during past periods. The research at Waziers of the excavation from 2013 and at Neumark has benefited greatly from its multidisciplinarity, so the same would also be the case for the 2017 Waziers campaign, as well as future Eemian archaeological sites. In addition to this it might also be beneficial to perform more in depth carpological and palynological research at known pollen zone type sites such as La Grande Pile in France or Bobbitshole in Britain if possible. These are now mostly arboreal in nature, which works well for identifying botanical procession, however it might also be of value to identify the prevailing climates that were present at these sites during these periods. This would give further insight into the climate conditions across Europe during the Eemian and might vindicate the theory of the land bridge between France and Britain already having disappeared early in the transition of the Saalian to the Eemian. Finally it is important to finely investigate all known Eemian sites since there are so few known and this might be useful in finding and identifying these sites in the future in this part of Europe.

Abstract

It is currently believed that there was no hominin presence on the British Isles during the Eemian interglacial stage, which lasted from 130 kya to 115 kya. However it is unclear what the reason for this apparent absence is. This is especially the case considering that during the Eemian, temperatures in north-west Europe are known to have been several degrees warmer than even today, making it a potent habitat for early hominins. Several theories have existed is to possibilities from this, which include a complete absence in north-west Europe due to constraints in mental fortitude and an ecology that would have been unsuited for hominins to survive, as well as an early disappearance of the land bridge that connected France to Great Britain during the glacial periods. This was based on the fact that hominin sites that date back to the Eemian are exceedingly rare in north-west Europe, with the first examples only having been discovered relatively recently. This thesis aims to further explore these possibilities by making an ecological reconstruction of the site of Waziers, which is located in northern France and dates back to the Eemian. It does this based on carpological and palynological material that was found at the site. In addition to this a correlation of pollen records was made using several other Eemian type sites located in both France and Great Britain. This data is then combined with pre existing literature of other Eemian sites in north-west Europe with signs of hominin activity, in order to correlate these sites together so that Waziers can be placed in a wider chronological and climatological framework. In addition to this several other biological factors that were encountered at Waziers, are compared to the climatological conditions that were prevalent in the wider region as well. In doing so it was found the hominin activity that was detected at Waziers took place very early in the Eemian, when the stage had just transitioned from the Saalian glacial stage. In addition to this it could also be concluded that this early period was much warmer than originally anticipated. This could be seen in the presence of such indicator taxa as *Lemna* cf. *minor*, *Hedera helix*, and *Salvinia natans*, which could all be found within the vegetational record of the site. Because of these factors it is concluded that while there was already a hominin presence very early in the Eemian interglacial, which indicates that climatological conditions were at least adequate to sustain a hominin presence. It also shows that these hominins did not lack the mental fortitude to exist in these conditions, as was suggested by earlier theories. Despite this it is likely that, due to the high temperatures melting the land based ice locked in the glaciers during the Saalian, the land bridge that had existed between France and Britain during the glacial stage had already disappeared, inhibiting further hominin dispersal to the British Isles.

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