# Neandertals in the forests : a palaeomagnetic study of the Eemian interglacial stage deposits from north-western and central Europe

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# CHAPTER 6
## CONCLUSIONS

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The main goal of this thesis-research was to provide a better geochronological control of the Last Interglacial, or more specifically the Eemian, in north-western Europe and to add to the palaeoenvironmental dataset of this period (see Introduction). During the Late Pleistocene, north-western Europe, the region where the Eemian was defined, was under the strong influence of glaciations which, in turn, had a profound effect on the presence and absence of hominins in this area. This thesis-research aimed to contribute to the long running debate on Neandertal (and other pre-modern hominins) environmental tolerances, focused on the issue of their occupation of Last Interglacial environments in Europe (e.g. Gamble, 1986; Gamble, 1987; Roebroeks et al., 1992; Roebroeks and Speleers, 2002). For this, detailed palaeomagnetic and environmental studies were carried out at the “interglacial” sites of Neumark Nord 2 (Germany), Rutten, (the Netherlands) and Caours (France). Neumark-Nord 2 and Caours (figure 1) were selected because of the presence of Neandertal archaeology in association with sediments thought to have been deposited during the Last Interglacial, a key period in the study of Neandertal adaptations, as explained in the introduction to this thesis (e.g. Gamble, 1986; Gamble, 1987; Roebroeks et al., 1992).

During the Last Interglacial, we can find a global stratigraphic marker, the Blake Event, the focus of this study (see Chapter 1). This palaeomagnetic event is recorded in both marine and terrestrial sediments (e.g. Baltrunas et al., 2013; Bourne et al., 2012; Osete et al., 2012; Smith and Foster, 1969; Thouveny et al., 2004) and has been found in settings which allows direct correlation with the MIS curve (Bourne et al., 2012; Channell et al., 2012; Tucholka et al., 1987). Our palaeomagnetic studies at Neumark Nord 2, Rutten and Caours have provided a strong indication for the presence of a palaeomagnetic event. This data, in combination with new or published direct and indirect dating methods for

***Figure 1.***
*Location map with the sites of Caours (France), Rutten (The Netherlands) and Neumark (Germany).*


the sites at stake has led us to conclude that the palaeomagnetic event identified at the three sites was indeed the Blake Event (See chapters 2, 4 and 5). Through the combination of a wide range of methods, including palaeomagnetism and palynology it was possible to establish better age control and palaeoenvironmental constraints for these sites.

In addition, this study has provided new data of relevance for our understanding of the relationships between developments recorded in the terrestrial and the marine records. Finally, our results have contributed to a better knowledge of possible time lags in the development of the Eemian vegetation in southern versus northern parts of Europe (see below).

For all the studied sites the inferred Eemian *sensu stricto* age was confirmed (see chapters 2 and 4). At Rutten and at Neumark Nord 2 the Eemian age was confirmed via the identification of the typical pollen sequence for this period (Bakels, 2012; Sier et al., in prep; Sier et al., 2011; Strahl et al., 2010), while at Caours the Eemian was identified indirectly (see below and chapter 5). At Neumark Nord 2, pollen studies identified the virtually complete Eemian vegetation succession, (Bakels, 2012; Sier et al., 2011; Strahl et al., 2010).

In relation to our research questions, the main conclusions of this thesis are (see also figure 2):

1. At all three sites a zone with excursional palaeomagnetic directions has been identified. In combination with the dating evidence obtained at the sites, these zones have been identified as the Blake Event (see chapters 2, 4 and 5).
2. The Blake Event was directly correlated to the pollenzones of the Eemian *sensu stricto* in north-western Europe at Rutten and in central Europe at Neumark Nord 2 (Chapter 2 and 4).

This correlation was possible because we identified both the Eemian pollenzones and the palaeomagnetic excursion within the Rutten core and within the Neumark Nord 2 section. This enabled a direction correlation between the palynological and palaeomagnetic data.

3. In north-western and central Europe, the lower boundary of the Blake Event is positioned below the first Eemian pollenzone.

In both Rutten and Neumark Nord 2 excursional directions of the Blake Event are found below the lower boundary of the Eemian (see chapter 2 and 4). This leads to the simple observation, crucial for our correlation, that the lower boundary of the Blake Event is older (estimated at a few hundreds of years at NN2) than the lower boundary of the Eemian in central and north-western Europe.

4. The upper boundary of the Blake Event is situated within pollenzone EVI (*sensu* Menke and Tynni, 1984), and might extend into the early Weichselian. Future study of an undisturbed EVI pollenzone and early Weichselian might clarify the true location of the Blake Event upper boundary.

At Neumark Nord 2 the upper boundary of the Blake Event was positioned within pollenzone EIV (*sensu* Menke and Tynni, 1984) on the basis of the quality of the ChRM directions. However, at Rutten the excursional directions are found up to the hiatus that caps of the Eemian sediments (see chapter 4). This implies that the minimum duration of the Blake Event is similar in length as the Eemian up to pollenzone EVI, or even the duration of the complete Eemian and possibly into the Weichselian.

5. The Blake Event has a minimum duration similar to the duration of the Eemian up to pollen zone EVI in north-western and central Europe. For this region a minimum duration for the Eemian of ~6000 years (Hahne et al., 1994; Müller, 1974) has been confirmed, with its total duration estimated at ~11000 years (Müller, 1974).

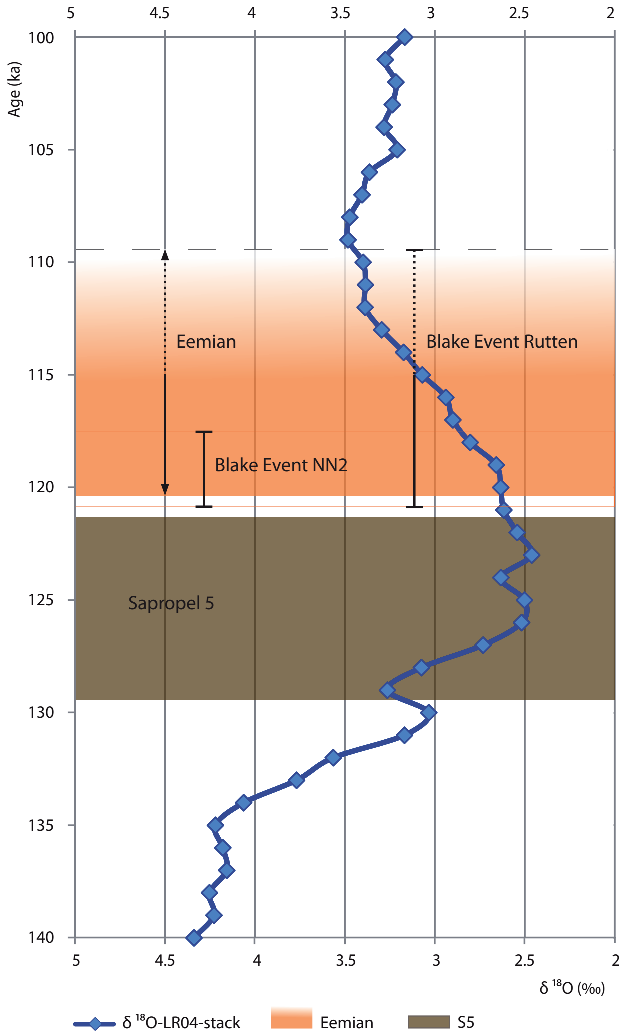
The generally accepted duration estimate of the Eemian in north-western and central Europe is the one of Müller (1974). This estimate was partly based on varve counting and on extrapolation by using an estimated sedimentation rate. Since the study of Müller (1974), more varve counting has been done on different pollenzones by Hahne and colleagues (1994). We used the counted varves of around 6000 as the minimum duration of the Eemian and the estimation of Müller (1974) as an arbitrary upper limit for the duration.

6. The ChRM directions of the Blake Event at all three sites are dominated by south and down ChRM directions. This means that the orientation of a compass during the Blake Event would have been pointing towards the south but that the dip of that same compass was dipping down. This direction of dipping is normally associated with a northward pointing compass in the northern hemisphere.

The ChRM directions of the Blake Event at all three sites are dominated by south and down ChRM directions which are indicative of a non fully dipole field. This finding contrasts with the results obtained in other regions where fully reversed directions have been identified (e.g. Bourne et al., 2012; Smith and Foster, 1969), and becomes an important observation for future studies of the directions of the earth's magnetic field during the Eemian. This might also explain why the Blake Event was not observed in some non orientated cores (e.g. van Leeuwen et al., 2000), as its identification is more dependent on inclination of the ChRM direction.

7. The Eemian in north-western and central Europe is now directly correlated to the MIS record via the Blake Event (see figure 2), and is entirely situated after the MIS 5e peak of the marine record (Sier et al. 2011).

***Figure 2.***
*Stacked δ¹⁸O-LR04 record (Lisiecki and Raymo, 2005) from 140 to 100 ka, using the Ziegler et. al. (2010) time scale, with the positions of sapropel 5, the duration of the Blake Event at Neumark Nord 2 and Rutten and the (central and north-western European) Eemian interglacial. The Eemian duration in orange is fading from the minimum duration of counted varves to the estimate of Müller (1974).*



The Blake Event was identified in all the studied sites by palaeomagnetic analysis of their sediments in combination with a wide variety of dating methods. All these methods, ranging from pollen analysis, bio-stratigraphy and different types of luminescence, all indicated a Last Interglacial age range. Due to the global registration of the Blake Event in both marine and terrestrial sediments, it was possible to make a correlation between the terrestrial and marine interglacial record. Via the Blake Event we were able to position the north-western and central European Eemian within the MIS record. Prior to the study presented here, only the Eemian record of Iberia had been correlated to the marine record in off shore deposits in southern Europe (Sánchez-Goñi et al., 1999).

8. The onset of the Eemian in north-western and central Europe is delayed by 4 to 5 ka compared to the onset of the Eemian in southern Europe.

Our first correlation between the MIS record and the Eemian was done on the basis of new data from Neumark Nord 2 and work published by many others (for details see chapter 2). We identified a large time-lag between our correlation and the Iberian correlation made by Sánchez-Goñi and colleagues (1999). In their study, Sánchez-Goñi et al. (1999) situated the beginning of the Eemian at 5000 to 6000 years after the onset of MIS 5e (Sánchez-Goñi et al., 1999; Shackleton et al., 2002; Shackleton et al., 2003). Our study of the Neumark Nord 2 dataset, in combination with a review of published data, suggests that the onset of the Eemian in north-western and central Europe, dates to around 5000 years after the onset of the Eemian in southern Europe (Sier et al., 2011). This hypothesis has been tested at the site of Rutten, situated in the region of the type locality of the Eemian. Both the Neumark data and the Rutten evidence, as presented in this thesis, indicate a significant time lag, of about 10.000 years, between the beginning of MIS 5e and the beginning of the Eemian. We came to this conclusion by matching the Eemian pollen signal of the Neumark Nord 2 site with the MIS curve via the Blake Event. Many identified Blake Event records have been matched to the global MIS curves (e.g. Channell et al., 2012; Tric et al., 1991) with nearly all situating the Blake Event on the declining side of the MIS 5e to MIS 5d curve. However, in the Mediterranean record published by Tric and colleagues (1991), the Blake Event, well-positioned on the MIS curve, was identified just above the sapropel S5 (Tric et al., 1991). This sapropel has been well dated from 121.4 to 129.5 ka (Ziegler et al., 2010). Using the sapropel ages we were able to estimate the lower boundary of the Blake Event at around 121 ± 0.5 ka (Sier et al., in prep; Sier et al., 2011). The main results of the Rutten and Neumark Nord 2 studies presented in this thesis are visualized in figure 2.

It is important to note that the position of the onset of Eemian after the MIS 5e peak is age-model independent. The beginning of the Blake Event has been recorded above the sapropel S5 and the onset of the Eemian is situated in Neumark Nord 2 above the onset of the Blake Event.

9. Provided that stratigraphy can constrain the position of deposits between late Saalian and Weichselian, the Blake Event can serve as coarse scale chronostratigraphic (~10.000 years) and palaeoenvironmental marker for the Eemian *sensu stricto*.
10. Using the Neumark Nord 2 and Rutten data, we have obtained an indirect confirmation of the inferred Eemian *sensu stricto* age of the Caours site (France) through the recording of the Blake Event (Chapter 5).

At the archaeological site of Caours we were not able to contribute to the dataset of marine terrestrial correlation of the Eemian, as no well-preserved pollen assemblages have been identified there. However, our study did contribute to a better age control of the archaeological levels. The site of Caours was already identified as Last Interglacial of age (e.g. Antoine et al., 2006; Bahain et al., 2010). Through our identification of the Blake Event, we were able to restrict the age of Caours to the Eemian *sensu stricto*, due to the establishment of the close relationship of the Eemian as defined by Zagwijn (1961) and the Blake Event at Rutten and Neumark Nord 2 (Sier et al., in prep; Sier et al., 2011).

11. Our data suggests that at the studied sites delayed acquisition of the palaeomagnetic signal did not occur.

For our correlation to be valid, it is not only important to have high quality data regarding the position of the Blake Event with respect to the deep sea record, but we firstly needed to exclude the possibility of delayed acquisition of the palaeomagnetic signal. Delayed acquisition in the Mediterranean record used in our studies would signify an even larger time gap, as this would increase the gap between the MIS 5e peak and the Blake Event (SI Sier et. al., 2011). Furthermore, the position of the Blake Event in the MIS record is well established, as discussed in chapter 4 of this thesis. Delayed acquisition at both Rutten and the Neumark Nord 2 site could have serious consequences for our main conclusions, as visualized in figure 2. The delayed acquisition could, in theory, be responsible for the observed north-south lag-time of the Eemian. Our study indicated that for both the Rutten as for the Neumark Nord 2 delayed acquisition of the Blake Event can be excluded (for details see chapters 2, 3 and 4). As seen in chapter 3, the rock-magnetic study of the Neumark Nord 2 sediments is very comparable to the local pollen signal, which constitutes a good indication for an in situ palaeomagnetic signal.

12. Fully interglacial human occupation in central Europe (Roebroeks et al., 1992) is confirmed by the position of the Neumark Nord 2 main find horizon within the Eemian pollen zonation.

The main find horizon of the Neumark Nord 2 site is situated in pollen zone IVa2 (sensu Menke and Tynni, 1984) indicating a fully interglacial environment. This position in the Eemian pollen zonation re-affirms the presence of Neandertals in fully interglacial central Europe as already indicated by Roebroeks and colleagues (1992). However, a study by Bakels (2012) indicated that the surrounding of the Neumark Nord 2 basin was relatively open (see also SI Sier et.al., 2011 and chapter 3). It is true that due to taphonomic reasons, site preservation is higher in lacustrine or fluviatile settings but it cannot be excluded that Neandertals avoided the “dense forest” parts of interglacial environments. This means that more than 20 years after the Gamble and Roebroeks (Gamble, 1986; Gamble, 1987; Roebroeks et al., 1992) Eemian occupation of northern Europe debate (see introduction of this thesis) the character of Neandertal presence in northern Europe in an interglacial context is still not completely understood.

13. At the time of Neandertal Last interglacial presence at Caours, and also at Neumark Nord 2, access to England was blocked by high sea-levels in the English Channel. This can be concluded by the position of the Caours occupation on the global MIS curve.

Another interesting conclusion resulting from this thesis is related to the timing of the occupation of the site of Caours in regard to former sea levels. As discussed in chapter 1 and chapter 4, a puzzling issue in the debate on Neandertal occupation of northern Europe during the Eemian is the absence of Neandertal sites of last interglacial age in Great Britain. In this study, we were able to correlate the Eemian to the global MIS curve and situated both Neumark Nord 2 and Caours well after the MIS 5e global high sea level stand. This implies that during these occupations, easy access to the British Isles was blocked by the fully developed English Channel. We cannot reject the hypothesis that Great Britain lacked the preferred habitat of Neandertals, as suggested by Ashton (2002) as one of the two possible hypotheses to explain the absence of Neandertal occupation in Great Britain during that period. However, the timing of occupation at Caours (as well as at Neumark Nord 2) as known so far, suggests that high sea levels played an important role, making the missed "window of opportunity" for the crossing into Great-Britain a more likely explanation for their absence (Ashton, 2002).

## Implications outside the scope of this thesis and directions for future research

The hypotheses developed in this thesis research regarding position and timing of the Eemian have consequences for various models of palaeoclimate reconstructions (e.g. Sánchez Goñi et al., 2012) and isostatic modelling of the earth crust after deglaciation of northern Europe (e.g. Lambeck et al., 2006; Sánchez Goñi et al., 2012). These models assume a much smaller lag-time between the Eemian interglacial in southern and northern Europe than the one suggested here. It could be interesting to make a systematic assessment of the consequences of the lag-time proposed in this thesis for these models.

Another aspect worth investigating is the development of the Eemian lag-time in a larger geographical context. For example, how does the lag develop over a north to south transect? Do we have a linear development of the lag, which would suggest a steady pace migration of the Eemian vegetation from south to north? Or can we observe a fast migration of the Eemian to one or more spatial thresholds that first need to be overcome before further migration of the vegetation can occur? If thresholds indeed exist, are these climatic, geographic or of other type? Needless to say, one or the other outcome would have different implications for our thinking about past vegetation and climate change and hence, on the climatic models now in use to predict future changes.

As mentioned in the introduction of this thesis, the Amsterdam borehole section has been proposed as the type section for the Middle to Late Pleistocene boundary (Gibbard, 2003; Gibbard et al., 2008). The conclusions of this research underlines that this boundary is a diachronous one; hence, it would be better to use the lower boundary of the Blake Event as the boundary of the Middle to Late Pleistocene: this boundary corresponds (more or less) with the lower boundary of the Eemian in the Netherlands and when properly identified, it is not diachronous and it is retraceable in both marine and terrestrial sequences.

Finally, once a proper framework of the development of the Eemian in the whole of Europe has been established, we can start to systematically evaluate the patterns of Neandertal presence and absence in this area, which will contribute to our understanding of hominin behavior on a large European scale.

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