Neandertals in the forests : a palaeomagnetic study of the Eemian interglacial stage deposits from north-western and central Europe
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CHAPTER 1
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Modern humans are distributed all over the globe, occupying a wide variety of habitats. However, we can infer from the fossil record that earlier hominins had more limited geographic distributions. Starting from one or more core areas in Africa, hominins slowly expanded (as well as contracted) their geographical ranges over the last two to three million years to their present day distribution. Changes in geographic ranges are mostly attributed to climate change, environmental variation and technological innovations that provide new ways of exploiting or competing for resources (e.g. Dennell, 2003; Potts, 2012; Roebroeks, 2001). Thus, understanding the nature and variation of dispersals within a geographic range together with the corresponding climatic and environmental variations may provide us with data to study changes in the behaviour or biology of hominins that allowed them to colonize or adapt to a specific geographical region (e.g. Dennell and Roebroeks, 2005; Joordens et al., 2011; Roebroeks and Kolfschoten, 1994; Speleers, 2000).

Of all fossil hominin species, *Homo neanderthalensis* is not only the first to be discovered but it is also the most numerous in terms of fossil specimens and in studied archaeological sites. This, together with the long European research history, makes *Homo neanderthalensis* the best known hominin species after *Homo sapiens*. However, many details of the geographic range of the Neandertal lineage and especially modifications of this range through time are still poorly understood. Especially, a better knowledge of the migration of *Homo neanderthalensis* towards, and occupation of, middle and higher latitudes after glacial periods would be instrumental for our understanding of their limitations in terms of the biological and cultural capacities of this species (e.g. Potts, 2012; Roebroeks, 2001). In this respect, one of the key periods in Europe to assess the Neandertal ecological niche is the Eemian stage, also known as the Last Interglacial or

Marine Isotope Stage (MIS) 5e, the last and best documented interglacial stage in which Neandertals were present in Europe.

During the end of the 19th and the beginning of the 20th century, warm and temperate interglacial periods were considered ideal for the survival of hominins, because of their high faunal diversity and their climatically favourable conditions. It was even hypothesized that hominins did not need living structures or other forms of protection against the elements for survival (Obermaier, 1912). However, in the mid 1980's alternative interpretations arose. Steered by the ecological studies of hunter-gatherers of Kelly (1983), Gamble (1986) stated that interglacial Europe may have formed a hostile environment for hominins. That line of argument was based on the rationale that despite the biomass being higher during an interglacial period in comparison to a glacial period, most biomass is stored in primary biomass. Primary biomass consists of leave and stems of plants which are mostly inedible for hominins. Given the rarity of traces of full-interglacial occupation, Gamble (1986, 1987) concluded that, in contrast to the modern human hunter-gatherers of the Holocene, hominins in Last interglacial Europe lacked the social structures, specialized knowledge and skills that would have enabled them to survive in this type of ecosystem (Gamble, 1986; Gamble, 1987). The lack of well dated Eemian stage sites in north-western Europe with good indications of Neandertal presence was central in Gamble's theory. In terms of site distribution, this observation remains true for the British Isles. However, for the rest of north-western Europe it was refuted in 1992, when Roebroeks and colleagues (1992) proved, by analyzing in detail the chronological, archaeological and palaeoecological record available for this region and period, that not only there were archaeological sites in north-western Europe during glacial periods but also in fully interglacial deciduous forest conditions, long before the Upper Palaeolithic.

The debate about Neandertal ecological tolerances, particularly in north-western Europe, is however still ongoing, with the real limits of their distribution, in both time and space being an important issue. To investigate this distribution, it is essential to have reliable dates of the sites of interest, which place these occurrences in a precise chronological framework and thus facilitate consistent inter-site comparisons of the time and conditions of the occupation. The studies presented in this thesis aim to contribute to the debate by developing more precise correlations between the chronology and the environmental conditions of certain north-western European sites with documented *Homo neanderthalensis* presence. The studies use one of the main tools to build reliable geochronological frameworks for the study of early human evolution, but one which

has seen only very limited application in the Neandertal time range. This tool concerns the identification of certain palaeomagnetic reversals and excursions. The first are well documented full reversals, the latter are short-duration anomalies or events of the Earth´s magnetic field (e.g. Laj and Channell, 2007; Merrill and McFadden, 1994). The behaviour of the earth´s magnetic field is recorded in the sediments while they are being formed. Thus, from a sedimentary sequence a geomagnetic record can be retrieved and scrutinized for its veracity (post-depositional diagenetic processes may alter the record). As will be explained below in detail, the identification of a specific palaeomagnetic event, the so-called Blake Event, is an important new aid in the study of the Neandertal occupation of north-western Europe. The Blake Event, a palaeomagnetic excursion which occurs during our period of interest, has been correlated to MIS 5e (e.g. Channell et al., 2012; Thouveny et al., 2004) and can be used as a tool for environmental, marine and terrestrial sedimentary correlations.

However, in order to make meaningful inter-site comparisons of thin time slices it is necessary to clarify the relationship among the different "interglacial terminologies". The Eemian stage, Last Interglacial and MIS 5e are concepts which are often used as virtual synonyms in the archaeological literature, but with each having its own definition; the Eemian stage was defined on the basis of sediments in a terrestrial record while MIS 5e was defined on basis of the study of fossils from marine sediments. The term "Last Interglacial" has no clear definition and is being used indiscriminately, to both indicate Eemian stage as well as MIS 5e sediments. Also the correlation of the marine and terrestrial records is less straightforward than previously thought (Sánchez-Goñi et al., 1999; Shackleton et al., 2003), with significant consequences for our views of past climate changes, as will be explained in this thesis.

Summarizing, the main goal of this thesis is to provide a better geochronological control of the Last Interglacial or Eemian stage in north-western Europe and to add to the palaeoenvironmental dataset of this period. North-western Europe is of particular interest, as it is the region were the Eemian stage was defined, and as it is under the strong influence of glaciations which, in turn, had a profound effect on the range of hominin occupations.

Background on terminology

It is important to stress the differences between the several terms used to describe our period of study. Often, the terms Eemian stage, Last Interglacial and MIS 5e are used indiscriminately in the literature. It is true that there is a large chronological overlap between the time periods these three terms refer to but all three have different definitions. The boundaries need not be synchronous and may even be diachronous from one region to another.

Harting was the first to use the term Eemian as a stratigraphic unit, back in 1874 (Harting, 1874). During his investigations of the sediments near Amsterdam and Amersfoort, he noticed a consistent occurrence of sands and clays containing abundant diatom and mollusc fossils. Among the fossil molluscs, there were Mediterranean and Lusitanian species which do not occur in the present-day Netherlands. Unable to correlate the stratigraphic unit with the known ones, Harting introduced a new stratigraphic unit, the Eemian (after the Dutch river Eem). With the development of Eemian pollen research from the late 1920's onwards, it became possible to identify the non-mollusc pollen-bearing levels of the Eemian. This also improved correlations of sequences over large parts over Europe and enabled studies of the Eemian vegetation development (for a recent overview see Bosch et al., 2000). The first pollen research of the Eemian stage in Denmark and northwest Germany indicated a temperate flora with woodland dominated phases (Jessen and Milthers, 1928). In the middle of the last century, Zagwijn (1961) restudied the Amersfoort section of Harting and expanded on the work of Van der Vlerk and Florschütz (1950; 1953). They had defined the Eemian stage, similar to Jessen and Milthers before them (1928), on the basis of the vegetation succession as reconstructed from the pollen record. The lower boundary of the Eemian stage was placed where tree taxa exceed 50% of the total terrestrial pollen sum and the upper boundary where the pollen signal falls below the 50%, stratigraphically in between the open vegetation of the Saalian and Weichselian glaciations (Zagwijn, 1961). For a long time, the Amersfoort section served as the stratotype locality of the Eemian stage. As a result of discussions about the delimitation and identification of the Eemian stage, the Geological Survey of the Netherlands was asked during the 1995 INQUA (International Union for Quaternary Research) Congress to re-investigate the type area (van Kolfschoten and Gibbard, 2000). Some results of the TNO (Dutch Geological Survey) Eemian stage project were published in a special volume of the Netherlands Journal of Geosciences (volume 79, 2/3, 2000). The

stratotype locality was re-evaluated (Cleveringa et al., 2000) and a parastratotype was selected in borehole 'Amsterdam-Terminal' (Cleveringa et al., 2000; de Gans et al., 2000; van Kolfschoten and Gibbard, 2000; van Leeuwen et al., 2000). Moreover, the Amsterdam-Terminal borehole publication provided the basis for a proposal to assign the official base of the Late Pleistocene; this still awaits formal approval of the international commission on stratigraphy (Gibbard, 2003; Gibbard et al., 2008). A problem for this boundary, as this thesis will show, is its diachroneity, as moving south of the Netherlands the proposed boundary increases in age.

The duration of the Eemian stage in north-western Europe has been constrained to approximately 11,000 years by varve counting and extrapolation of sedimentation rates at the German site of Bispingen (Müller, 1974), confirmed by studies of other localities north of the Alps (Turner, 2002). Various estimates exist for the duration of the Eemian stage in southern Europe, from around 15,500 years (Tzedakis et al., 2003) to ~16,000 years (Shackleton et al., 2003) and to 16,400 years (Sánchez-Goñi et al., 1999). The difference in age duration estimates for the north and the south of Europe already suggests diachroneity of the upper or lower boundary (or both) of the Eemian stage. In order to distinguish between the Eemian stage in northern and southern Europe, we use the term Eemian stage *sensu stricto* for Eemian stage in northern Europe.

It needs to be emphasized that the definition of Last Interglacial is not a straightforward one. An interglacial is defined as a period of warmer climate, much like the present day climate or warmer, which separates two glacial periods. Or as Fairbanks (1972: 293) puts it, "A certain formation is said to be "interglacial" if it is characterized by an assemblage of sediments, soil, fauna or flora that are characteristic of climatic conditions generally as warm as or warmer than today". The problem is that these boundaries are inherently diachronous (Fairbridge, 1972) e.g. due to migration of flora and fauna. Recognizing an interglacial in the geological record is difficult, and setting boundaries is even more complicated (Kukla et al., 2002). In practice, pollen stratigraphy is used for defining an interglacial in terrestrial sediments and oxygen-isotope ratios are employed to establish MIS boundaries in marine sediments. These boundaries between land and sea may not correspond in time and correlating over large geographical areas can only be done with a global chronological marker that is not restricted to either the terrestrial record or the marine record. Palaeomagnetic reversals and excursions, if present and identifiable in the studied time period, are excellent global chronological markers.

The development of the MIS record represented a major advancement in Quaternary stratigraphy (e.g. Shackleton, 1967; Shackleton, 1987). In the MIS record, changes in the oxygen isotope ratios of benthic foraminifera indicate changes in global ice volume and by inference, warm and cold periods can be identified over time. The precise boundaries between periods with high and low sea levels are to some extent arbitrary, for the "last interglacial" (or MIS 5e) drawn halfway on the curve between the minimum and maximum oxygen isotope values of MIS 5d/5e (upper boundary) and MIS 5e/6 (lower). Just as the boundaries of the Eemian stage, these boundaries are arbitrary but more likely to be global as they reflect changes in global ice volume. MIS 5e has been correlated to the Eemian stage by means of amino acid racemization of shells from the distinctive sediments by Miller and Mangerud (1985), but the precise relation of the boundaries remained unclear until the work of Sánchez-Goñi and colleagues (Sánchez-Goñi et al., 1999). They analyzed a marine core taken from offshore Iberia and used pollen, washed in from terrestrial settings, to correlate the southern Europe Eemian stage with the MIS record from the same core. They concluded that the lower boundary of the Eemian stage is around 5000 to 6000 years younger with respect to the lower boundary of MIS 5e (Sánchez-Goñi et al., 1999; Shackleton et al., 2003). This method, however, cannot work for terrestrial records as no direct MIS record is registered in terrestrial sediments.

Fortunately, there is a global stratigraphic marker around the period of our interest, the palaeomagnetic Blake Event. The Blake Event was first discovered in 1969 in marine cores taken near the Blake Outer Ridge, western subtropical North Atlantic (Smith and Foster, 1969) and, in recent years, it has served as a marker event for MIS 5e (e.g. Laj and Channell, 2007; Langereis et al., 1997; Lourens, 2004). Short polarity intervals like the Blake Event are global and can be recorded both in marine and terrestrial records. Even though the chronostratigraphic relation between MIS 5e and the Blake Event is quite well established, no terrestrial records are known that contain both an Eemian stage pollen signal and the palaeomagnetic Blake Event.

Key Research Questions and outline of thesis

As mentioned in the introduction, the overall goal of this thesis is contribute to a better geochronological control of, and add to, the palaeoenvironmental dataset of the Eemian stage in north-western Europe. This study is performed in order to contribute to our understanding of the distribution limits of Neandertals in north-western Europe and thus, their ecological tolerance. The following key research questions were put forward.

1. To identify, by means of detailed palaeomagnetic studies, the chronostratigraphic marker known as the Blake Event in Eemian stage sites such as Neumark-Nord 2 (Germany), Caours (France) and Rutten Gemaalweg (The Netherlands) of north-western Europe (see figure 1).
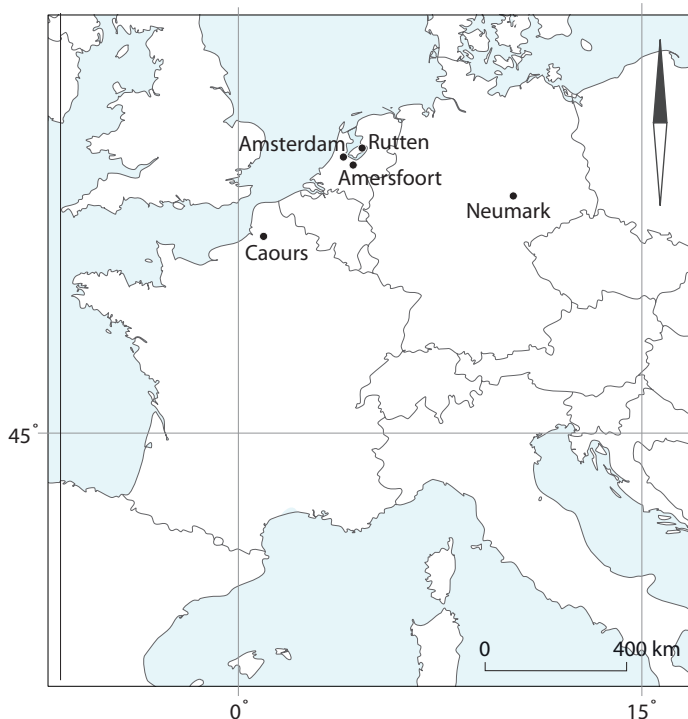

Figure 1.
Location map with the sites of Caours (France), Rutten (The Netherlands) and Neumark-Nord 2 (Germany) and the Eemian stage type-localities of Amsterdam and Amersfoort.

2.   To get a better age control of the Blake Event by collecting new palaeomagnetic, environmental magnetic and palaeoenvironmental data and by reviewing published datasets.

3.   To establish the relationship between the Blake Event and the environmental developments within the Eemian stage.

4.   To evaluate the consequences of the newly dated Eemian stage sites and their palaeoenvironment for our understanding of hominin behaviour in north-western Europe.

Research questions 1, 2 and 3 will be discussed in chapters 2 through 5, while research question 4 will be treated in chapter 6 of this thesis. Chapters 2 and 3 present the palaeomagnetic, environmental magnetic and palaeoenvironmental research of the Neumark-Nord 2 archaeological site near Halle (Germany). Chapter 4 furnishes a test of the interpretation of the dataset of Neumark-Nord 2 and expands on the data collected there. This chapter is based on an interdisciplinary study of an orientated core from the village of Rutten (the Netherlands). Rutten was chosen as a location due to its vicinity to the Eemian stage "type localities" (Amersfoort, Amsterdam) and the expected presence of a complete Eemian stage pollen sequence in the sediments sampled in the core. The study uses the palaeomagnetic signal to compare the timing of the Eemian stage with the signal found in Neumark Nord 2 in order to provide better estimates on the duration of the Blake Event. Both in Neumark Nord 2 and Rutten, the palaeomagnetic Blake Event has been identified in conjunction with high-resolution and high-quality pollen data which enabled the identification of the Eemian stage, sandwiched in between Saalian and Weichselian deposits at both locations. As the Blake Event is a global chronostratigraphic marker, independent of marine or terrestrial environments, we were able to correlate the Eemian stage *(sensu stricto)* of the Neumark Nord 2 and Rutten records to the MIS record.

The final site where fieldwork was done for this thesis is the Last Interglacial archaeological site of Caours, in the Somme valley, in northern France (Antoine et al., 2006; Antoine et al., 2007) discussed in chapter 5. At this site, palaeomagnetism was used for chronostratigraphic purposes. Caours is well-dated to the Last Interglacial by means of a variety of dating methods, including U-series and electron spin resonance (Antoine et

al., 2006; Bahain et al., 2010). The identification of the Blake Event within the sequence is important as it may narrow down the uncertainty in the age range.

The palaeomagnetic behavior of the Blake Event is also briefly discussed in chapter 5 as the characteristic remanent magnetism (ChRM) directions of the Blake Event identified at Neumark Nord 2, Rutten and Caours offer possible insights into the behaviour of the earth's magnetic field during that period in north-western Europe.

A synthesis of the main conclusions of this thesis is given in chapter 6 together with some possible consequences for our understanding of hominin behaviour. This final chapter finishes with recommendations for future research.

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