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

Sier, M.J.

Citation

Sier, M. J. (2014, January 21). *Neandertals in the forests : a palaeomagnetic study of the Eemian interglacial stage deposits from north-western and central Europe*. Retrieved from https://hdl.handle.net/1887/22207

Author: Sier, Mark J.
Title: Neandertals in the forests : a palaeomagnetic study of the Eemian interglacial stage deposits from north-western and central Europe
Issue Date: 2013-11-13

CHAPTER 5

The Blake Event recorded at the Eemian archaeological site of Caours, France

CHAPTER 5

THE BLAKE EVENT RECORDED AT THE EEMIAN ARCHAEOLOGICAL SITE OF CAOURS, FRANCE

Abstract

A palaeomagnetic study of the Last Interglacial calcareous tufa sequence at the archaeological site of Caours (northern France) identified a geomagnetic excursion that we interpret as the Blake Event. Palaeontological studies (molluscs, mammals) and geochemical proxy studies at the site of Caours allowed to reconstruct full interglacial conditions that were present during the deposition of the tufa sequence. The tufa sequence and associated Palaeolithic levels have been dated to the Eemian interglacial by a set of TIMS U/Th measurements on calcitic concretions (average : 123± 3 ka). By previous correlations of the Blake Event with the Eemian *sensu stricto* (as defined by Zagwijn (1961) in the Netherlands) pollenzones at Neumark Nord 2 (Germany) and Rutten (the Netherlands) it has been shown that the continental Eemian starts after the Marine Isotope Stage (MIS) 5e peak. The identification of the Blake Event at Caours implies a post MIS 5e peak age (Sier et al., in prep; Sier et al., 2011) for all four levels of the Palaeolithic occupations. Given the time lag between the MIS 5e peak and the beginning of the Eemian indentified in previous studies (Sier et al., in prep; Sier et al., 2011), this strongly suggests that during the main occupations of Caours a significant barrier was in place between north-western France and Great Britain, in the form of the English Channel. It is possible that the chronological position of the Last Interglacial environments in north-western Europe in relation to sea-level change is a key factor behind the apparent absence of Last Interglacial Palaeolithic sites in Great Britain.

1. Introduction

The character of occupation of interglacial Europe by hominins has been a topic of a long debate. Extensive research has been devoted to finding the limits of European hominin occupation, both in time (e.g. Carbonell et al., 2008; Roebroeks and Van Kolfschoten, 1995) and in geographic space (e.g. Parfitt et al., 2010; Roebroeks et al., 1992). The geographic and environmental limits to the spatial distribution of specific hominins are of major interest since they provide important information about hominin social and/or technological abilities to adapt to a specific ecosystem, or to find new ways of exploiting or competing for resources (e.g. Dennell, 2003; Potts, 2012; Roebroeks, 2001). Thus, improving the chronological and environmental framework of the pattern of hominin presence in a given region can provide us with data to infer changes in their behaviour as well as to assess the emergence of corridors or barriers that may have influenced their dispersals (e.g. Dennell and Roebroeks, 2005; Joordens et al., 2011; Roebroeks and Kolfschoten, 1994; Speleers, 2000). In this context, and due to its climate during the Palaeolithic, north-western Europe has been considered a marginal area for hominin occupation, stretching to the limits the biological and cultural adaptations of its inhabitants (Roebroeks et al., 2011). This is also important during the last interglacial, in which *Homo neanderthalensis* dominated Europe. This warm and temperate period was first described as the Eemian by Harting (1874). During his investigations of the subsurface near Amsterdam and Amersfoort (the Netherlands), he identified sands and clays containing abundant diatom and mollusk fossils. Among the fossil mollusks, there were Mediterranean and Lusitanian species which he could not correlate to any known stratigraphic unit. For this reason, Harting defined a new unit, the Eemian. Currently, the Eemian is defined by its terrestrial pollen zonation (Zagwijn, 1961). Due to the long research history in Europe and a relatively good preservation compared to previous interglacials, the Eemian has become a key period for study of the technological and social adaptations of *Homo neanderthalensis*.

In the early days of Palaeolithic research, interglacial Europe was seen as an ideal environment for hominins (Mortillet, 1883; Obermaier, 1912). Temperate interglacial climates were interpreted as periods in which survival and subsistence was relatively easy. Hominins could do without the protection of cliff overhangs and caves and thus move into regions that lacked these natural shelters (Mortillet, 1883), such as northern Europe. During the mid 1980´s, this view shifted to the opposite side of the spectrum. Inspired by the work of Kelly (1983), who stated that most of the primary biomass in forested environments consists of plant leaves and stems which are difficult to access for hominins, Gamble postulated (1986; 1987) that interglacial northern Europe was actually a hostile environment for hominins. In his view, *Homo neanderthalensis*, who was occupying more southern parts of Europe during the last interglacial, lacked the set of specialized skills and/ or social structure which would have been necessary for successful exploitation of the resources in the forested northern regions (Gamble, 1986). The apparent lack of archaeological sites during this period in northern Europe gave support to Gamble´s view. However, Roebroeks and colleagues (1992) refuted Gamble´s hypothesis by presenting evidence that *Homo neanderthalensis* was present in Europe in interglacial periods. Their extensive review of a number of northern European sites not only indicated the presence of *Homo neanderthalensis* in pre-Eemian interglacial periods but also indicated occupation in mixed-oak forest (fully interglacial) environments of the Last Interglacial.

Still, many questions remain to be answered regarding the character of Neandertal occupation of northern Europe and the adaptations and abilities required for long-term occupation of this region. Although there is plenty of evidence suggesting that Neandertals were able to colonize middle latitudes up to 55° N, it has been suggested that their presence in northern environments was discontinuous and strongly influenced by climatic fluctuations (Hublin and Roebroeks, 2009). Environmental degradation may have obliged *Homo neanderthalensis* to search for southern refuges for survival, although local extinctions due to the hard climatic conditions cannot be excluded either (e.g. Hublin and Roebroeks, 2009; Roebroeks et al., 2011).

One region of Europe, which seems to have remained unoccupied during the last interglacial is Great Britain, where unambiguous traces of Last Interglacial Middle Palaeolithic sites are absent. However, the archaeological record is a strongly biased one, and various workers have stressed the role of preservation processes in this apparent absence (Roebroeks et al., 1992; Roebroeks and Speleers, 2002). Explaining the absence of Neandertals in Great Britain could give valuable insights about migration speeds, migration barriers or preferred habitats of *Homo neanderthalensis*. Ashton (2002) proposed two hypotheses to explain the lack of human occupation in Great Britain during the last interglacial. The first one, termed “insularity of Britain”, explains the absence of Neandertals as the result of fast sea level rise during the last interglacial; the newly formed English Channel between Great Britain and France would have acted as a barrier for the Neandertal expansion. In the second model, focussing on “climatic extremes and the occupation of northwest Europe", the absence is explained as the result of the preference of Neandertals for mammoth-steppe-like environments in the eastern regions of Europe. This preference would explain the presence of Last Interglacial archaeological sites for instance in Germany, as well as their absence in the more Atlantic parts of northern Europe, which lacked a mammoth-steppe type of environment during the Eemian.

Related with both models, studies about the hominin occupation of north-west France have become key for understanding the character of Neandertal occupation in northern Europe in general, and in Great Britain in particular. Despite a long research history, no unambiguous traces of occupation during the Eemian were discovered in north-west France (Roebroeks and Speleers, 2002) until recently (Antoine et al., 2006; Locht et al., 2009). Research in the 1940´s and 1950´s at exposures at Caours (01°52'59'' /50°07'53'', Figure 1), situated on a tributary of the Somme river near the town of Abbeville (northern France), however had yielded some tantalizing evidence in the form of Levallois flakes and an interglacial fauna (Bourdier, 1974; Breuil, 1952; Breuil and Barral, 1955), as pointed out by Roebroeks and Speleers in their 2002 review paper.

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

Recent multidisciplinary studies have now enabled the unambiguous identification of Caours as Eemian in age and containing large numbers of in situ Palaeolithic flint artefacts and faunal remains (Antoine et al., 2006). The site is situated on a terrace 6 meters above the current valley floor and on basis of its position in the terrace system, the Caours fluvial sequence has been correlated to Marine Isotope stage (MIS) 6/5 (Antoine et al., 2006; Dabkowski et al., 2011). The sediments are dominated by calcareous tufa and contain abundant fossil remains (large mammals, micro-mammals, molluscs, leaf imprints). The fossils represent a temperate fauna indicating an Eemian age for the site (Antoine et al., 2006; Breuil and Barral, 1955). This age assessment is supported by ten U/Th (TIMS) ages of the tufa of ~120 ka (123 ± 3 ka) (Antoine et al., 2006), thermoluminescence ages of heated flints of 127.2 ± 10.4 ka and 119.6 ± 9.3 ka (Locht et al., 2009), and finally, electron spin resonance (ESR) age determinations of a deer molar of 124 ± 15 ka (Bahain et al., 2010). The ongoing work at Caours unambiguously confirms the Last Interglacial presence of *Homo neanderthalensis* in this region of Europe; hence, the site plays a major role in our understanding of human occupation and migration to this region of Europe during the last interglacial.

While the ages are reasonably well-constrained, having a tighter age control on the four layers with Neandertal artefacts in Caours would help with its interpretation and facilitate comparison to other sites in north-western Europe of similar age. Also the site is located just south of the English Channel and could potentially yield information regarding the accessibility of Great-Britain in the Last Interglacial, giving support to one of the hypotheses for the absence of human occupation in Great Britain mentioned above (Asthon and Lewis, 2002).

This paper reports the result of a study which attempted to constrain the period of Neandertal presence at Caours by the identification of the palaeomagnetic Blake Event which is tightly correlated to the Eemian, as we will explain below. The Blake Event was discovered in 1969 in a core from the Bermuda rise in the Atlantic Ocean (Smith and Foster, 1969). It is a period with transitional to reversed directions of the earth´s magnetic field (e.g. Laj and Channell, 2007; Langereis et al., 1997; Merrill and McFadden, 1994). Estimates of its duration are notably variable, ranging from less than 1000 to over 10,000 years (e.g. Channell et al., 2012; Nowaczyk et al., 1994). The Blake Event has also been correlated to the Eemian pollen zonation of north-western and central Europe (Sier et al., in prep; Sier et al., 2011). At the onset of this Caours study, the Blake Event was correlated with the early part of the Eemian (e.g. Sier et al., 2011). However, a recent study of an oriented undisturbed core, taken at the Rutten site, in the region of the Eemian type locality in the Netherlands, provides evidence that the Blake Event may have lasted throughout the entire Eemian *sensu stricto* (Sier et al., in prep). Even with this new evidence, the identification of the Blake Event at Caours would firmly place the archaeology yielding sediments in the Eemian *sensu stricto*. In the Neumark Nord and Rutten studies, the Blake Event was used to correlate the terrestrial Eemian record to the Marine Isotope Stage (MIS) record. Based on our correlation, we estimated that the Eemian lasted from ~120.5 ka to 109.5 ka (Sier et al., in prep; Sier et al., 2011). More importantly, in the context of the present paper, the correlation of the Eemian with the MIS record situates the Eemian in north-western and central Europe well after the MIS 5e peak. This would mean that already during the first phases of the Eemian *sensu stricto*, high sea levels in the English Channel would have been in place constituting a strong physical barrier for hominin movements from France into Great Britain.

A second focus of the study presented here is the behaviour of the magnetic field during the period of the Blake event. The Blake Event is recognized in sediments at Neumark Nord 2 (NN2) (Germany) (Sier et al., 2011) and at Rutten (the Netherlands) (Sier et al., in prep) mainly by excursional declinations, while in most cases the inclination remained normal. This is in contrast to the Blake Event as recognized in other northern hemisphere regions (e.g. Bourne et al., 2012; Smith and Foster, 1969; Tucholka et al., 1987) were mainly negative inclinations were identified. Confirmation of Rutten and NN2 type of palaeomagnetic directions for the Blake Event at Caours could help to give important insights on the behaviour of the palaeomagnetic field during the Blake Event.

To summarize, the main goal of this study is to identify the palaeomagnetic Blake Event in the Caours sediments. This identification could confirm the Eemian *sensu stricto* age of the site and would allow a more precise positioning of the hominin occupation at Caours on the global (MIS) sea-level curve. This research would potentially provide new data on the character of the occupation of north-western Europe by Neandertals and would allow the discussion of more specific scenarios such as the absence of humans during the last interglacial in Great Britain.

2. Methods and sampling

Palaeomagnetic samples were taken during the 2009 and 2010 excavations of the Caours site at sector 1 and 2. The geological units (See supplementary information (SI) for description of the units) consist of a basal periglacial fluvial gravel (flint and chalk: ~ 3m), overlain by calcareous silts (~ 0.6m) and then by carbonate tufas (~3.5m). The tufas have a range from fine grained laminated to massive porous tufa. The type of tufa had its direct reflection on its sample potential, with the fine grained units yielding a significant higher amount of samples. In total 78 samples were taken, 46 samples for Alternating Field (AF) demagnetization, and 32 samples for Thermal (TH) demagnetization of the natural remanent magnetization (NRM). In addition, five hand samples of various dimensions were taken in order to identify the main magnetic carriers within the sediment. All studied geological units were sampled with dedicated sample containers for both AF and TH demagnetization. AF samples taken were collected with perspex containers, while for TH samples custom-made quartz glass containers were used. Both sample container types have standard palaeomagnetic dimensions (25 mm diameter and 22 mm height) and were gently pushed into freshly prepared sections. One oriented hand sample was of sufficiently large size to be sub-sampled, in the laboratory, with a 36 cm long u-channel. A u-channel is a plastic container with a square 2 by 2 cm cross-section and clip-on lid (Weeks et al., 1993). The u-channel was measured intact with a measurement interval of 2 cm. Measurements of the samples were done within a couple weeks after retrieval of the samples to minimize possible alteration. During this period the samples remained in a cold storage (<5°C).

AF demagnetization was done with a robotized 2G DC-SQUID magnetometer with in-line AF demagnetization at the palaeomagnetic laboratory “Fort Hoofddijk” (Utrecht, The Netherlands). The instrument’s sensitivity is 3×10^{-12} Am^2; typical sample magnetic moments were at least two orders of magnitude higher. The instrument set-up is housed inside a magnetically shielded room (residual field < 200 nT); the robotized interface for field regulation and sample manipulation was built in-house. Up to 96 samples contained inside dedicated cubic holders (edge 30 mm) are loaded onto a sample plateau and the robot loads them in batches of eight onto a tray that slides through the magnetometer and AF demagnetization coils. Samples are processed fully automatically with the so-called ‘three position protocol’ that compensates for the magnetic moment of the transport tray. This ensures optimal processing of weakly magnetic samples. Maximum demagnetization field was 100 mT.

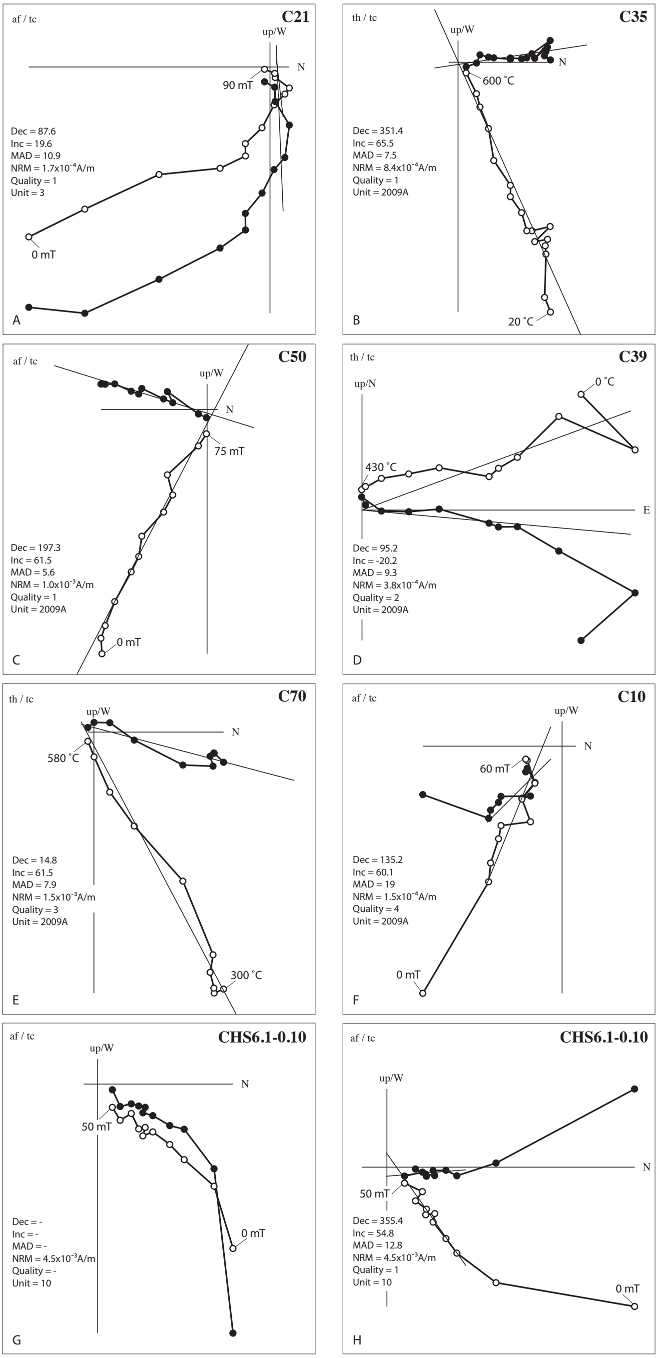
Thermal demagnetization of the NRM was performed with an ASC thermal demagnetizer (residual field < 20 nT) at CENIEH, Burgos (Spain). Maximum demagnetization temperature was 630°C. The remaining NRM was measured after each step with a SRM 755 4K DC-SQUID magnetometer (with built-in AF demagnetizer, instrument sensitivity $3x10^{-12}$ Am^2, typical sample NRM magnetic moments were at least a couple of orders of magnitude higher) with a low-field (< 5 nT) environment at the sample loading position. The u-channel was demagnetized and measured with the same equipment up to a maximum AF peak field of 100 mT.

Demagnetization results were analyzed by visual inspection of orthogonal demagnetization diagrams (Zijderveld, 1967) using the "Fort Hoofddijk" "paldir" software. Directions of the Characteristic Remanent Magnetisation (ChRM) were calculated using least-squares principle component analysis (Kirschvink, 1980) on at least 4 steps. Four different quality labels were assigned to the ChRM directions, with only quality 1 and quality 2 ChRM directions being used for interpretation. ChRM directions frim samples of quality 1 are those with vector end points close to the origin (quality 1, see figure 2A, 2B and 2 C). Diagrams with the endpoint slightly offset from the origin or the last step does not reach the origin or have ChRM directions that are forced to the origin are given quality 2 (figure 2D). Noisy diagrams with MAD below 15° or diagrams which show indications of a not completely resolved NRM component during high demagnetization levels (which cannot be calculated with 4 steps but do from a great-circle) are given quality 3 (figure 2E). Directions of samples with the minimum of 4 steps that however disintegrated in an early stage during measuring, were completely demagnetized in an early stage (below 20/30 mT or 360°C or have an maximum angular deviation (MAD) > 15° have been given quality label 4. All other diagrams were rejected (37 out of 96, see table I of the supplementary information).

For rock-magnetic purposes hand samples were measured to better understand their magnetic properties in support of the interpretation of the ChRM directions. A selection of samples were pulsed in three perpendicular axes according to Lowrie (1990). Maximum field was 1 T, intermediate field 0.4 T and the low field 0.12 T. Thermal demagnetization was performed up to a max temperature of 600 degrees °C in 16 steps.

Figure 2.
Representative Zijderveld diagrams of alternating field demagnetization (AF) and thermal demagnetization (TH) from discrete samples (C21, C35, C50, C39, C70, C10= and from a u-channel (CHS6.1 level 0.10). Quality 1 samples are in panels A, B and C, quality 2 in panel D, quality 3 in panel E, quality 4 in panel F. Finally examples of quality 1 u-channel are shown in panels G and H. Panel G is un-rotated and panel H rotated according to sampled direction.

Figure 2.

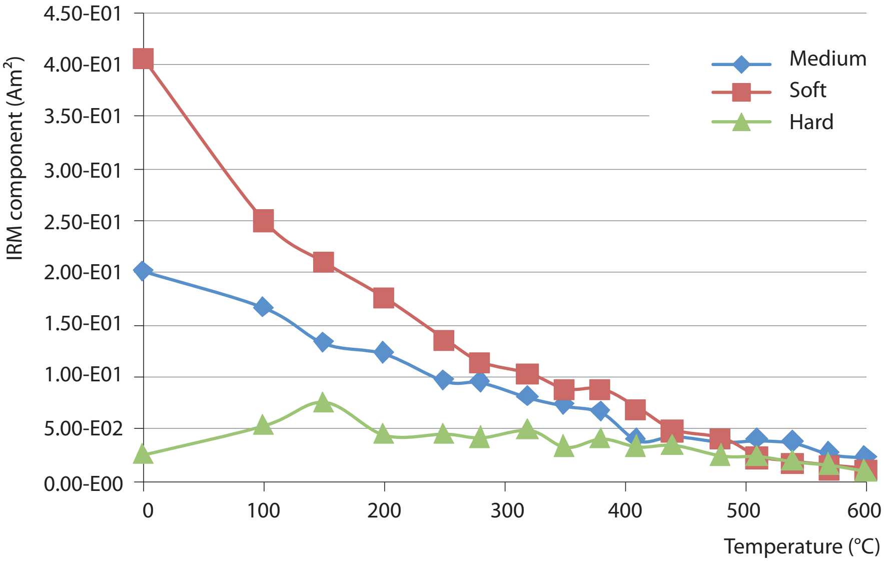

af / tc
C21
up/W
N
90 mT
Dec = 87.6
Inc = 19.6
MAD = 10.9
NRM = 1.7x10^{-4}A/m
Quality = 1
Unit = 3
0 mT
A
th / tc
C35
up/W
N
600 °C
Dec = 351.4
Inc = 65.5
MAD = 7.5
NRM = 8.4x10^{-4}A/m
Quality = 1
Unit = 2009A
20 °C
B
af / tc
C50
up/W
N
75 mT
Dec = 197.3
Inc = 61.5
MAD = 5.6
NRM = 1.0x10^{-3}A/m
Quality = 1
Unit = 2009A
0 mT
C
th / tc
C39
up/N
0 °C
430 °C
E
Dec = 95.2
Inc = -20.2
MAD = 9.3
NRM = 3.8x10^{-4}A/m
Quality = 2
Unit = 2009A
D
th / tc
C70
up/W
N
580 °C
Dec = 14.8
Inc = 61.5
MAD = 7.9
NRM = 1.5x10^{-3}A/m
Quality = 3
Unit = 2009A
300 °C
E
af / tc
C10
up/W
N
60 mT
Dec = 135.2
Inc = 60.1
MAD = 19
NRM = 1.5x10^{-4}A/m
Quality = 4
Unit = 2009A
0 mT
F
af / tc
CHS6.1-0.10
up/W
N
50 mT
Dec = -
Inc = -
MAD = -
NRM = 4.5x10^{-3}A/m
Quality = -
Unit = 10
0 mT
G
af / tc
CHS6.1-0.10
up/W
N
50 mT
Dec = 355.4
Inc = 54.8
MAD = 12.8
NRM = 4.5x10^{-3}A/m
Quality = 1
Unit = 10
0 mT
H

3. Results

Intensities of the NRM range from 1.7 10^{-5} A/m to 1.0 10^{-2} A/m (see SI table I). Thermal demagnetization of 3 axial Isothermal Remanent Magnetisation (IRM) acquisition curves (figure 3 and SI figure 1 a-d) show that the magnetic mineralogy in the Caours sediments is dominated by a "medium" and "soft" coercivity, indicative of fine-grained magnetite as the maximum unblocking temperature is slightly higher than 500 °C. No goethite is traced and very little high coercivity minerals like hematite is detected. It is important to note that our rock-magnetic studies have not found any indication of magnetic sulphides.

The ChRM directions for the samples treated with AF demagnetization were typically determined between 15 and 60 mT peak AF with occasionally a maximum of 80 mT. No indications of gyroremanent magnetisation (GRM) were observed during AF demagnetization. ChRM directions from the thermal demagnetization are not based on a typical set of temperatures; minimum temperatures vary from 230°C to 300°C. Upper temperatures show a broad range: from as low as 360°C to as high as 600°C. Notably

Figure 3.
Thermal demagnetization of 3 axial Isothermal Remanent Magnetisation (IRM) acquisition curves. Sample was taken from geological unit 5.



varying upper temperatures can even occur within a single geological unit; it indicates that different magnetic minerals carry the ChRM directions. There is a strong relation between the NRM intensity and the quality of the Zijderveld diagrams: intensities above 10^{-4} A/m give significantly better results than samples with lower NRM intensities (SI table 1). However, the polarity of the ChRM directions is not related to the NRM intensity.

No fully reversed ChRM directions are identified, but of the 59 samples (including the 18 u-channel measurements, SI table 1) that were given a quality label (between 1 and 4), 23 have virtual geomagnetic poles (VGP´s) that deviate more than 40° of the expected VGP position (SI table 1) and can be labelled “excursional” (Merrill and McFadden, 1994). Excursional directions are present throughout the sampled units (figure 2 and SI table 1). A few Zijderveld diagrams show a clear overprint between components. An example of a clear excursional direction due to an overprint, from 0 to 35 mT, on an excursional ChRM is given in figure 2A. In other samples it is not that clear-cut. An example is sample C70 (figure 2E) where the ChRM direction in the Zijderveld diagram passes the origin and could develop into an excursional orientation. This, however, cannot be determined with certainty because consecutive steps do not show a linear trend. The last steps are situated on a great circle indicative of a hidden component.

4. Discussion and Conclusions

As mentioned above, the quality of the Zijderveld diagrams and the intensity of the NRM show a positive correlation. There is no clear relation between the direction of the ChRM and the quality of the Zijderveld diagrams. The geological units (see figure 4 and figure 5) sampled, except unit 7, yielded Zijderveld diagrams of quality 2 or higher. All geological units above unit 7 have high quality samples with VGPs of over 40° deviation of the expected VGP position (SI table 1) which are considered as excursional (e.g. Merrill and McFadden, 1994). Unit 6a, 6b (coarse fluvial gavels, see SI) have not been sampled and unit 8 was sampled unsuccessfully, whereas units 9 and 10 give both directions of normal polarity in samples of high quality and excursional in some of the lower quality samples. Insert Figure 4 and 5 around here As only high quality ChRM directions are included in the interpretation these units are interpreted to have normal palaeomagnetic polarity. Based on the position of the Caours terrace in the Somme valley terrace sequence, given the presence of warm-temperate animals, and in view of the numerical age estimates

Figure 4.

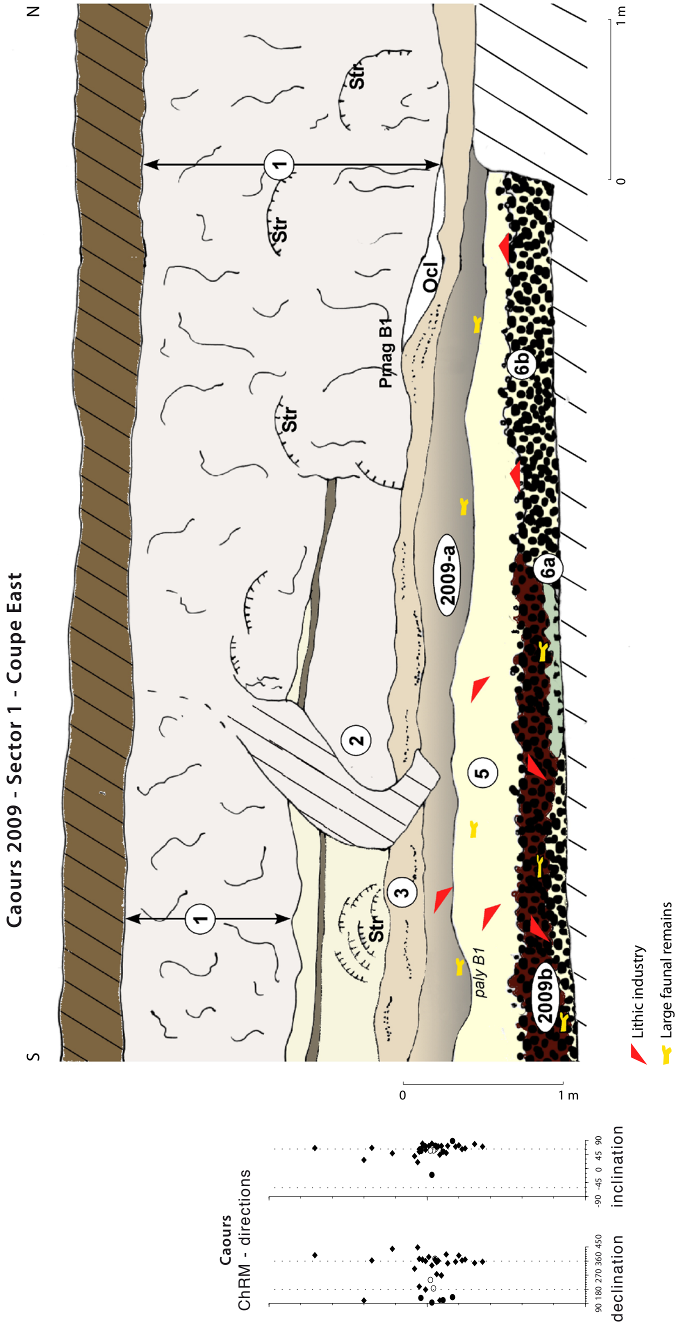
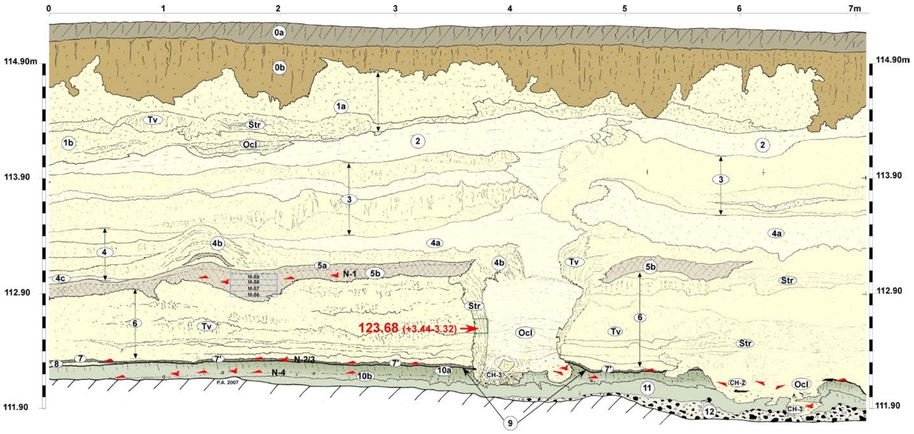

Caours 2009 - Sector 1 - Coupe East
N
S
1
1
Str
Str
Str
Str
Ocl
Pmag B1
2
3
2009-a
5
6b
6a
2009b
paly B1
0
1 m
0
1 m
Lithic industry
Large faunal remains
Caours
ChRM - directions
-90 -45 0 45 90
inclination
90 180 270 360 450
declination

Figure 4.
ChRM directions of sector 1 plotted next to the samples from the East profile of sector 1. Numbers represent different stratigraphic units, for details see SI. Ocl is oncolith, Str is stromatolith.

(Antoine et al., 2006; Bahain et al., 2010) which suggest a last interglacial age for the sediments, we interpret these excursional directions as the Blake Event. The Blake Event is known to consist of two reversed parts interrupted by a brief period of normal polarity and also known for its elusiveness (Parés et al., 2004). The zones of normal polarity have been described for several locations from various parts of the globe (e.g. Fang et al., 1997; Thouveny et al., 2004). In one publication of the Jiuzhoutai section (Lanzhou, western Loess Plateau, China) even three zones with excursional or reversed directions were identified (Zhu et al., 1994). In addition, recent studies have given support for a long duration of the Blake Event. These studies suggest a duration of at least 6000 years and even up to possibly 11.000 years (Bourne et al., 2012; Sier et al., in prep) and in strong correlation with the Eemian *sensu stricto* (Sier and Dekkers, 2013; Sier et al., in prep; Sier et al., 2011).

The lower boundary of the Blake Event at Caours is possible situated between unit 7 and 9 (note: at Caours units are labelled from top to bottom), as the higher quality ChRM directions all have a normal direction. However, ChRM directions of lower quality (SI table I) show excursional directions, but these are due to the low quality excluded

Figure 5.
South profile of sector 2. Taken in 2007 but similar to the 2010 profile. Ocl is oncolith, Str is stromatolith, Tv is travertine.



from interpretation (see methods and sampling). The lower boundary of the Blake would identify these Caours sediments as late Saalian in age if we correlate with the NN2 and Rutten sites. At NN2 the lower boundary of the Blake Event was identified in late Saalian age sediment (Sier et al., 2011). At the site of Rutten this boundary could not be identified with certainty, though a late Saalian age is very probable based on the stratigraphical position of the sediments (Sier et al., in prep).

The numerical ages of the concerned units at Caours (Antoine et al., 2006) fall well with the estimated age and duration of the Blake Event (Sier et al., in prep; Sier et al., 2011). Fossils found at the lower units of the Caours sequence, between units 10 and 11 (archaeological level 4), also suggest fully temperate conditions (Antoine et al., 2006; Locht et al., 2009). More importantly, the study of the malacological succession at Caours shows that unit 10 , and the contemporaneous Palaeolithic level N4, is fully interglacial (Limondin-Lozouet, 2011). Considering this evidence we interpret that the lower part of the Caours section is most likely of Blake Event age, at least up to the unconformity that separates unit 10 and the lower unit 11. This unit 11 contains evidence of a cold climate malacological assemblage (Limondin-Lozouet, 2011).

At NN2 and Rutten, the Blake Event has been identified in conjunction with an Eemian pollen record, together in the same sections and core, respectively. From this we can infer that the Caours sediments not only record the Blake Event age but can be considered of Eemian *sensu stricto* age as defined at its type locality (Zagwijn, 1961). This is well in-line with numerical and biostratigraphic ages derived in the previous studies (Antoine et al., 2006; Antoine et al., 2007; Bahain et al., 2010; Breuil and Barral, 1955; Limondin-Lozouet, 2011).

Another aspect worth mentioning is the lack of fully reversed directions at Caours, similar to the Rutten site (Sier et al., in prep) and the NN2 locality (Sier et al., 2011). All together the data of Caours, NN2 and Rutten seem to suggest that these excursional directions, rather than truly reversed ones, characterize the Blake Event in north-western and central Europe. This issue, although is beyond the scope of the present work, gives important insights for modellers of the behaviour of the Earth´s geomagnetic field during excursions or events, but it also complicates the identification of the Blake Event in unorientated cores (e.g. IODP cores, where declination can only be analysed on a relative basis within individual core segments).

Finally, as mentioned above, the Blake Event has been directly linked to the Eemian pollen sequence which in turn has been correlated to the MIS record via the same event, positioning the Eemian *sensu stricto* and the Blake Event after the MIS 5e peak (Sier et al., in prep; Sier et al., 2011). Placing the archaeological occupation layers of Caours within the Eemian *sensu stricto* is an important fact since it tells us when Caours was occupied but also that the occupation was well after the "window of opportunity" (as Ashton 2002 calls it) for range expansion into Great-Britain, i.e., before the last interglacial sea level maximum. This means that the "dry path towards Great Britain" was already submerged by high sea level for some time when Neandertals discarded their first stone artefacts at Caours (unit 10). The presence of a physical barrier in the form of the sea water in the English Channel may have been the main obstacle to a Last Interglacial occupation of England by Neandertals.

References

Antoine, P., Limondin-Lozouet, N., Auguste, P., Locht, J. L., Galheb, B., Reyss, J., Escudé, E., Carbonel, P., Mercier, N., Bahain, J. J., Falguères, C., and Voinchet, P. (2006). Le tuf de Caours (Somme, France) : mise en évidence d'une séquence eemienne et d'un site paléolithique associé. Quaternaire 17, 281-320.

Antoine, P., Limondin Lozouet, N., Chaussé, C., Lautridou, J. P., Pastre, J. F., Auguste, P., Bahain, J. J., Falguères, C., and Galehb, B. (2007). Pleistocene fluvial terraces from northern France (Seine, Yonne, Somme): synthesis, and new results from interglacial deposits. Quaternary Science Reviews 26, 2701-2723.

Ashton, N. (2002). Absence of human in britain during the last interglacial (oxygen isotope stage 5e). In "Publications du CERP." (A. Tuffreau, and W. Roebroeks, Eds.), Lille.

Asthon, N., and Lewis, S. G. (2002). Deserted Britain: declining populations in the British Late Middle Pleistocene. Antiquity 76, 388-396.

Bahain, J. J., Falguères, C., Dolo, J. M., Antoine, P., Auguste, P., Limondin-Lozouet, N., Locht, J. L., Tuffreau, A., Tissoux, H., and Farkh, S. (2010). ESR/U-series dating of teeth recovered from well-stratigraphically age-controlled sequences from Northern France. Quaternary Geochronology 5, 371-375.

Bourdier, F. (1974). La « marne blanche » d' Abbeville, gisement type de l'Abbevillien. Quaternaire 11, 161-163.

Bourne, M., Mac Niocaill, C., Thomas, A. L., Knudsen, M. F., and Henderson, G. M. (2012). Rapid directional changes associated with a 6.5 kyr-long Blake geomagnetic excursion at the Blake-Bahama Outer Ridge. Earth and Planetary Science Letters 333-334, 21-34.

Breuil, H. (1952). Glanes conchyliologiques en France (Nord et Sud-Ouest) determinées par A.S. Kennard. In "Congrès Préhistorique de France. Compte rendu de la XIIIe Session, 1950." pp. 191 -240., Paris.

Breuil, H., and Barral, L. (1955). Bois de Cervidés et autres os travaillés sommairement au Paléolitique ancien vieux monde et au Moustérien des grottes de grimaldi et de l´observatoire de monaco. Bulletin du Musee d´anthropologie prehistorique de Monaco 2, 1-32.

Carbonell, E., Bermudez de Castro, J. M., Pares, J. M., Perez-Gonzalez, A., Cuenca-Bescos, G., Olle, A., Mosquera, M., Huguet, R., van der Made, J., Rosas, A., Sala, R., Vallverdu, J., Garcia, N., Granger, D. E., Martinon-Torres, M., Rodriguez, X. P., Stock, G. M., Verges,

J. M., Allue, E., Burjachs, F., Caceres, I., Canals, A., Benito, A., Diez, C., Lozano, M., Mateos, A., Navazo, M., Rodriguez, J., Rosell, J., and Arsuaga, J. L. (2008). The first hominin of Europe. Nature 452, 465-469.

Channell, J. E. T., Hodell, D. A., and Curtis, J. H. (2012). ODP Site 1063 (Bermuda Rise) revisited: oxygen isotopes, excursions and paleointensity in the Brunhes Chron. Geochemistry Geophysics Geosystems 13, Q02001.

Dabkowski, J., Limondin-Lozouet, N., Antoine, P., Marca-Bell, A., and Andrews, J. (2011). Recording interglacial climatic changes from stable isotopes of pleistocene tufa calcite in northern france: Examples from caours (Mis 5e; Somme) and la celle-sur-seine (Mis 11; Seine-et-Marne). Quaternaire 22, 275-283.

Dennell, R. (2003). Dispersal and colonisation, long and short chronologies: how continuous is the Early Pleistocene record for hominids outside East Africa? Journal of Human Evolution 45, 421-440.

Dennell, R., and Roebroeks, W. (2005). An Asian perspective on early human dispersal from Africa. Nature 438, 1099-1104.

Fang, X., Li, J., Van der Voo, R., Mac Niocaill, C., Dai, X., Kemp, R. A., Derbyshire, E., Cao, J., Wang, J., and Wang, G. (1997). A record of the Blake Event during the last interglacial paleosol in the western Loess Plateau of China. Earth and Planetary Science Letters 146, 73-82.

Gamble, C. (1986). “The Palaeolithic settlement of Europe.” Cambridge University Press, Cambridge.

Gamble, C. S. (1987). Man the shoveler: Alternative models for Middle Pleistocene colonization and occupation in Northern latitudes. In “The Pleistocene old world. Regional perspectives.” (O. Soffer, Ed.), pp. 81-98. Plenum Press, New York.

Harting, P. (1874). De bodem van het Eemdal. Verslagen en Verhandelingen Koninklijke Academie van Wetenschappen, 282-290.

Hublin, J. J., and Roebroeks, W. (2009). Ebb and flow or regional extinctions? On the character of Neandertal occupation of northern environments. Comptes Rendus Palevol 8, 503-509.

Joordens, J. C. A., Vonhof, H. B., Feibel, C. S., Lourens, L. J., van der Lubbe, H. J. L., Dupont-Nivet, G., Sier, M. J., Davies, G. R., and Kroon, D. (2011). An astronomically-tuned climate framework for hominins in the Turkana Basin. Earth and Planetary Science Letters 307, 1-8.

Kelly, R. L. (1983). Hunter-Gatherer Mobility Strategies. Journal of Anthropological Research 39, 277-306.

Kirschvink, J. L. (1980). The least-square line and plane and the analysis of paleomagnetic data. Geophysical Journal of the Royal Astronomical Society 62, 699-718.

Laj, C., and Channell, J. E. T. (2007). Geomagnetic Excursions. In “Geomagnetism.” (M. Kono, Ed.), pp. 373-416. Treatise on Geophysics Elsevier, Amsterdam.

Langereis, C. G., Dekkers, M. J., Lange, G. J., Paterne, M., and Santvoort, P. J. M. (1997). Magnetostratigraphy and astronomical calibration of the last 1.1 Myr from an eastern Mediterranean piston core and dating of short events in the Brunhes. Geophysical Journal International 129, 75-94.

Limondin-Lozouet, N. (2011). Successions malacologiques à la charnière Glaciaire/Interglaciaire: du modèle Tardiglaciaire/Holocène aux transitions du Pléistocène. Quaternaire 22, 211-220.

Locht, J. L., Antoine, P., Auguste, P., and Limondin Lozouet, N. (2009). Rapport de fouille programmée. Caours 2009 (Somme). Amiens. In “SRA Picardie.” pp. 40.

Lowrie, W. (1990). Identification of ferromagnetic minerals in a rock by coercivity and unblocking temperature properties. Geophysical Research Letters 17, 159-162.

Merrill, R. T., and McFadden, P. L. (1994). Geomagnetic field stability: Reversal events and excursions. Earth and Planetary Science Letters 121, 57-69.

Mortillet, G. d. (1883). “Le Préhistorique, antiquité de l´homme.” C. Reinwald, Paris.

Nowaczyk, N. R., Frederichs, T. W., Eisenhauer, A., and Gard, G. (1994). Magnetostratigraphic Data From Late Quaternary Sediments From the Yermak Plateau, Arctic Ocean: Evidence For Four Geomagnetic Polarity Events Within the Last 170 Ka of the Brunhes Chron. Geophysical Journal International 117, 453-471.

Obermaier, H. (1912). “Der Mensch der Vorzeit.” AVG, Berlin.

Parés, J. M., Van der Voo, R., and Yan, M. (2004). After the Dust Settles: Why Is the Blake Event Imperfectly Recored in Chinese Loess? In “Timescales of the Paleomagnetic Field “ (J. E. T. Channell, D. V. Kent, W. Lowrie, and J. G. Meert, Eds.).

Parfitt, S. A., Ashton, N. M., Lewis, S. G., Abel, R. L., Coope, G. R., Field, M. H., Gale, R., Hoare, P. G., Larkin, N. R., Lewis, M. D., Karloukovski, V., Maher, B. A., Peglar, S. M., Preece, R. C., Whittaker, J. E., and Stringer, C. B. (2010). Early Pleistocene human occupation at the edge of the boreal zone in northwest Europe. Nature 466, 229-233.

Potts, R. (2012). Environmental and Behavioral Evidence Pertaining to the Evolution of Early Homo. Current Anthropology 53, S299-S317.

Roebroeks, W. (2001). Hominid behaviour and the earliest occupation of Europe: an Exploration. Journal of Human Evolution 41, 437-461.

Roebroeks, W., Conard, N. J., and van Kolfschoten, T. (1992). Dense Forests, Cold Steppes, and the Palaeolithic Settlement of Northern Europe. Current Anthropology 33, 551-586.

Roebroeks, W., Hublin, J. J., and MacDonald, K. (2011). Continuities and Discontinuities in Neandertal Presence: A Closer look at Northwestern Europe. In "Developments in Quaternary Science." (N. M. Ashton, S. G. Lewis, and C. B. Stringer, Eds.). Elsevier, Amsterdam.

Roebroeks, W., and Kolfschoten, v. T. (1994). The earliest occupation of Europe: a short chronology. Antiquity 68, 489-503.

Roebroeks, W., and Speleers, B. (2002). Last interglacial (Eemian) occupation of the North European plain and adjacent areas. In "Publications du CERP." (A. Tuffreau, and W. Roebroeks, Eds.), pp. 9. Université des sciences et technologies de Lille, Villeneuve-d'Ascq, France.

Roebroeks, W., and Van Kolfschoten, T. (1995). The Earliest Occupation of Europe. University of Leiden, Leiden.

Sier, M. J., and Dekkers, M. J. (2013). Magnetic property analysis as palaeoenvironmental proxy: a case study of the Last Interglacial Middle Palaeolithic site at Neumark-Nord 2 (Germany). In "Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany)" (S. Gaudzinski-Windheuser, and W. Roebroeks, Eds.), Saxony-Anhalt, Germany.

Sier, M. J., Peeters, J., Dekkers, M. J., Chang, L., Busschers, F. S., Wallinga, J., Parés, J. M., and Roebroeks, W. (in prep). The Blake Event recorded near the Eemian Type locality, revised timing of the onset of the Eemian in north western Europe.

Sier, M. J., Roebroeks, W., Bakels, C. C., Dekkers, M. J., Brühl, E., De Loecker, D., Gaudzinski-Windheuser, S., Hesse, N., Jagich, A., Kindler, L., Kuijper, W. J., Laurat, T., Mücher, H. J., Penkman, K. E. H., Richter, D., and van Hinsbergen, D. J. J. (2011). Direct terrestrial–marine correlation demonstrates surprisingly late onset of the last interglacial in central Europe. Quaternary Research 75, 213-218.

Smith, J. D., and Foster, J. H. (1969). Geomagnetic Reversal in Brunhes Normal Polarity Epoch. Science 163, 565-567.

Speleers, B. (2000). The relevance of the Eemian for the study of the Palaeolithic occupation of Europe. Geologie en Mijnbouw 79, 283-291.

Thouveny, N., Carcaillet, J., Moreno, E., Leduc, G., and Nérini, D. (2004). Geomagnetic moment variation and paleomagnetic excursions since 400 kyr BP: a stacked record from sedimentary sequences of the Portuguese margin. Earth and Planetary Science Letters 219, 377-396.

Tucholka, P., Fontugne, M., Guichard, F., and Paterne, M. (1987). The Blake magnetic polarity episode in cores from the Mediterranean Sea. Earth and Planetary Science Letters 86, 320-326.

Weeks, R., Laj, C., Endignoux, L., Fuller, M., Roberts, A., Manganne, R., Blanchard, E., and Goree, W. (1993). Improvements in long-core measurement techniques: applications in palaeomagnetism and palaeoceanography. Geophysical Journal International 114, 651-662.

Zagwijn, W. H. (1961). Vegetation, climate and radiocarbon datings in the late Pleistocene of the Netherlands: I. Eemian and Early Weichselian, Nieuwe Serie. Mededelingen van de Geologische Stichting 14, 15-45.

Zhu, R. X., Zhou, L. P., Laj, C., Mazaud, A., and Ding, Z. L. (1994). The Blake Geomagnetic Polarity Episode Recorded in Chinese Loess. Geophysical Research Letters 21, 697-700.

Zijderveld, J. D. A. (1967). Demagnetisation of rocks: analysis of results. In “Methods in Palaeomagnetism.” (D. W. Collinson, K. M. Creer, and S. K. Runcorn, Eds.), pp. 254-286. Elsevier, Amsterdam.

Supplementary Information

Geological Descriptions

Sector 1 2009 / 2010

Description of the units

1 - Massive porous tufa, highly indurated, with very big concretions, local occurrence of stromatolith layers and subvertical tubular stromatoliths (columns ø: 2-5cm), secondary carbonate coatings in the porosity (mycelium).

2- White to light beige granular to sandy tufa facies, weakly stratified, including little oncoliths and incrusted twig fragments. This unit shows numerous in situ incrusted unrolled twigs and mosses. Locally it shows some porous laminated and undulated stromatolith layers (“floor”). A thin grey tufa layer with some scattered large mammal remains has been observed at the top.

3 - Horizontal lens of fine grained laminated tufa (silty to medium sandy light grey to beige grey) with thin dark grey layers including numerous mollusc shells and humified vegetal debris. The upper part of this unit shows a coarser facies with thicker laminations (3a), alternating with layers of granular tufa.

4 - Porous granular tufa with low cohesion, made from rolled and incrusted twig fragments and oncoliths (average ø: 5mm, locally 2-3 cm to the base of profile West), marked fluvial structure (tilted stratification and discordances). The basal boundary of this unit is very sharp indicating relatively strong erosion processes as supported by the occurrence of downcutting features down to the upper part of the gravels (unit 6)

2009-a - Finely laminated grey to beige silty tufa (± 10cm). In the lower part: more homogeneous and darker facies including lenses of granular tufa a few centimetres large. A reworked archaeological layer (a) is included in the base of this unit.

5 - Fine grained beige tufa with sandy to silty texture, weak coherency and poor stratification. Close to the boundary with unit 6, this unit is richer in scattered little flint gravels reworked from the top of the gravel (reworked archaeological layer b).

2009-b - Heterogeneous rounded flint gravels (~ 1 to ~ 10 cm) with brown to brown red clayey-silty organic matrix (organic carbon: 1.4%). This layer includes numerous reworked lithic artefacts and large mammal remains.

6a - Heterogeneous coarse fluvial gravels (flint and chalk) with calcareous sandy matrix. The upper part of these gravels (~ upper 5 cm) shows a finer matrix composed by calcareous light grey to greenish silts showing the same facies as described in sector 2 (Unit 10).

6b - Heterogeneous coarse fluvial gravels composed by rounded flint and chalk blocks (coarse alluvial gravels of the terrace)

The in situ archaeological layer, excavated in 2009-2010, is localised at the top of the coarse gravels of unit 6a, on which the larger artefacts and large mammal bones have been found. Some reworked flint artefacts and fragments of large mammal remains have nevertheless been observed at the base of unit 5 (a few cm) and in the fine grained tufa matrix that penetrates between the blocks at the top of the gravels.

Sector 2 2010

Description of the units

Caours Sector 2 : units 5 to 11 / archaeological layers 1 to 4

5 - Massive porous tufa, highly indurated, with very big concretions, local occurrence of stromatolith layers and subvertical tubular stromatoliths (columns ø: 2-5cm), secondary carbonate coatings in the porosity (mycelium).

7 - White to light beige granular to sandy tufa facies, weakly stratified, including little oncoliths and incrusted twig fragments. This unit shows numerous in situ incrusted unrolled twigs and mosses. Locally it shows some porous laminated and undulated stromatolith layers ("floor"). A thin grey tufa layer with some scattered large mammal remains has been observed at the top.

8 - Horizontal lens of fine grained laminated tufa (silty to medium sandy light grey to beige grey) with thin dark grey layers including numerous mollusc shells and humified vegetal debris. The upper part of this unit shows a coarser facies with thicker laminations (3a), alternating with layers of granular tufa.

9 - Porous granular tufa with low cohesion, made from rolled and incrusted twig fragments and oncoliths (average ø: 5mm, locally 2-3 cm to the base of profile West), marked fluvial structure (tilted stratification and discordances). The basal boundary of this unit is very sharp indicating relatively strong erosion processes as supported by the occurrence of downcutting features down to the upper part of the gravels (unit 6)

10 - Finely laminated grey to beige silty tufa (± 10cm). In the lower part: more homogeneous and darker facies including lenses of granular tufa a few centimetres large. A reworked archaeological layer (a) is included in the base of this unit.

10/11 - Fine grained beige tufa with sandy to silty texture, weak coherency and poor stratification. Close to the boundary with unit 6, this unit is richer in scattered little flint gravels reworked from the top of the gravel (reworked archaeological layer b).

11 - Heterogeneous rounded flint gravels (~ 1 to ~ 10 cm) with brown to brown red clayey-silty organic matrix (organic carbon: 1.4%). This layer includes numerous reworked lithic artefacts and large mammal remains.

Table I:

Thermal (TH) and alternating field (AF) palaeomagnetic results. ID#: sample identification; Sample Type (AF or TH); Level: stratigraphic level in meters; sublevel in case of u-channel measurements; sector: excavation sector (1 or 2); unit: geological unit; NRM natural remanent magnetization; Dec: Declination of characteristic remanent magnetization (ChRM) direction; Inc: Inclination of ChRM direction; MAD: Maximum Angular Deviation; Q: quality of ChRM direction, with 1 the highest quality and 4 the lowest; AF/Tinf: lowest AF level or temperature step of ChRM in mT/°C; Tsup: highest AF level or temperature step of ChRM in mT/°C; Dir: ChRM forced or free; VGP: latitude of the virtual geomagnetic poles. - = Non determined.

Table I:

ID#		Level	Sublevel	Sector	Unit	NRM	Dec.	Inc .	MAD	Q	AF/T_inf	AF/T_sup	Dir.	VGP
						E-6 A/m	(°)	(°)			(mT/°C)	(mT/°C)		
C01	AF	11,475		1	5	82	135,4383	50,9191	5,068226	4	0	20	free	0,76
C02	AF	11,6		1	5	42	-	-	-	-	-	-	-	
C03	AF	11,645		1	5	1309	355,7295	69,49532	3,787332	1	20	80	free	85,93
C04	AF	11,7		1	5	852	348,3316	77,84927	1,25818	1	20	70	free	72,39
C05	AF	11,755		1	5	4519	10,15761	64,27957	1,358973	1	20	60	free	82,11
C06	AF	11,775		1	2009A	5877	4,375075	61,64964	1,702286	1	20	60	free	82,11
C07	AF	11,795		1	2009A	2386	35,55967	73,94691	0,9697142	1	20	60	free	67,71
C08	AF	11,815		1	2009A	1053	356,3341	69,73158	2,355098	1	15	50	free	85,89
C09	AF	11,835		1	2009A	191	129,8695	87,85837	11,09703	2	15	60	free	47,27
C10	AF	11,86		1	2009A	148	135,1635	60,128	19,03379	4	15	50	free	9,26
C11	AF	11,88		1	2009A	101	42,27478	49,12875	9,265203	1	15	50	free	52,63
C12	AF	11,9		1	2009A	112	110,824	53,65593	10,72291	2	15	70	forced	14,05
C13	AF	11,915		1	2009A	89	109,0835	43,92373	10,06761	1	15	50	free	8,28
C14	AF	11,94		1	2009A	687	352,9843	68,24062	4,728421	1	15	50	free	85,38
C15	AF	11,95		1	2009A	1077	11,01876	73,12807	2,056628	1	15	80	free	79,27
C16	AF	11,975		1	2009A	264	240,124	57,60479	11,71148	3	15	50	free	12,95

C17	AF	11,99		1	2009A	709	26,81013	71,68762	2,886008	1	15	70	free	72,89
C18	AF	12,01		1	2009A	666	359,7549	71,10347	1,759465	1	15	80	free	84,51
C19	AF	12,025		1	3	305	9,947073	79,35636	1,560843	1	40	70	free	70,14
C19/2	AF	12,025		1	3	433	8,435709	69,31351	3,576263	1	15	80	free	84,05
C20	AF	12,04		1	3	101	125,114	55,95523	10,01412	2	15	50	free	9,21
C21	AF	12,06		1	3	171	87,59654	19,55246	10,93568	1	40	80	free	9,24
C22	AF	12,08		1	3	81	311,4322	38,92595	10,95501	1	15	40	free	42,90
C23	AF	12,11		1	3	83	-	-	-	-	-	-	-	
C24	AF	12,13		1	3	130	307,5316	61,19757	17,20543	4	25	70	free	53,64
C25	AF	12,215		1	3	91	78,74007	48,37146	13,06034	1	15	70	free	29,04
C26	AF	12,4		1	2	179	108,2321	26,71798	7,528283	1	15	50	free	-0,42
C27	AF	12,71		1	2	113	37,82857	65,16662	13,56956	1	15	40	free	65,12
C28	TH	11,74		1	5	2350	-	-	-	-	-	-	-	
C29	TH	11,78		1	2009A	3551	-	-	-	-	-	-	-	
C30	TH	11,815		1	2009A	70	-	-	-	-	-	-	-	
C31	TH	11,85		1	2009A	17	-	-	-	-	-	-	-	
C32	TH	11,89		1	2009A	30	-	-	-	-	-	-	-	
C33	TH	11,93		1	2009A	355	2,098184	70,11536	9,528232	1	230	490	free	85,80
C34	TH	11,965		1	2009A	429	332,9986	79,30524	12,95322	1	230	560	free	66,89
C35	TH	12		1	2009A	589	351,4187	65,54382	7,532476	1	230	600	free	83,87

C36	**TH**	**12,04**		**1**	**3**	**63**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C37	**TH**	**12,11**		**1**	**3**	**37**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C38	**TH**	**12,71**		**1**	**2**	**93**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C39	**TH**	**11,97**		**1**	**2009A**	**375**	**95,15664**	**20,16062**	**9,360264**	**2**	**230**	**360**	**free**	**11,26**
C40	**TH**	**11,95**		**1**	**2009A**	**no sig**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C41	**TH**	**11,92**		**1**	**2009A**	**no sig**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C42	**TH**	**12,09**		**1**	**3**	**52**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C43	**TH**	**12,05**		**1**	**2009A**	**4469**	**14,2**	**53,6**	**4,5**	**1**	**230**	**580**	**free**	**70,94**
C44	**TH**	**12.005**		**1**	**2009A**	**191**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C45	**TH**	**11.965**		**1**	**2009A**	**134**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C46	**TH**	**11,94**		**1**	**2009A**	**80**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C47	**TH**	**11,9**		**1**	**2009A**	**50**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C48	**TH**	**11,87**		**1**	**2009A**		**345,9**	**72,2**	**8,9**	**1**	**230**	**520**	**free**	**79,03**
C49	**AF**	**12,09**		**1**	**3**	**48**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	
C50	**AF**	**12,05**		**1**	**2009A**	**1017**	**197,3**	**61,5**	**5,7**	**1**	**20**	**75**	**free**	**3,98**
C51	**AF**	**12.005**		**1**	**2009A**	**183**	**178,3**	**59,3**	**11,7**	**1**	**20**	**75**	**free**	**0,23**
C52	AF	11.955		1	2009A	114	186,5	57,8	13,5	3	20	65	forced	-1,25
C53	AF	11.915		1	2009A	80	-	-	-	-	-	-	-	
C54	AF	11,9		1	2009A	54	-	-	-	-	-	-	-	
C55	AF	11,87		1	2009A	8319	115,0	70,5	2,8	1	20	60	free	28,01

C56	TH	1,67		2	lower 6	91	-	-	-	-	-	-	-	
C57	TH	1,71		2	lower 6	44	-	-	-	-	-	-	-	
C58	TH	1,74		2	lower 6	57	-	-	-	-	-	-	-	
C59	TH	1,87		2	7	101	-	-	-	-	-	-	-	
C60	AF	1,63		2	lower 6	173	234,7	72,7	8,6	2	20	55	forced	27,09
C61	AF	1,71		2	lower 6	85	-	-	-	-	-	-	-	
C62	AF	1,77		2	lower 6	48	-	-	-	-	-	-	-	
C63	AF	1,87		2	7	56	-	-	-	-	-	-	-	
C64	AF	1,87		2	7	132	-	-	-	-	-	-	-	
C65	TH	12,15		1	3	61	-	-	-	-	-	-	-	
C66	TH	12,12		1	3	181	262,5	65,8	4,2	4	260	360	forced	30,98
C67	TH	12,08		1	3	92	-	-	-	-	-	-	-	
C68	TH	12,04		1	2009A	67	-	-	-	-	-	-	-	
C69	TH	12		1	2009A	72	-	-	-	-	-	-	-	
C70	TH	11.945		1	2009A	1526	14,8	61,5	8,0	3	300	540	free	77,38
C71	TH	11,91		1	2009A	984	18,3	62,7	10,0	1	300	580	free	76,21
C72	AF	12,15		1	3	82	-	-	-	-	-	-	-	
C73	AF	12,12		1	3	100	-	-	-	-	-	-	-	
C74	AF	12,08		1	3	112	-	-	-	-	-	-	-	
C75	AF	12,04		1	2009A	92	-	-	-	-	-	-	-	

C76	AF	11.995		1	2009A	70	-	-	-	-	-	-	-	
C77	AF	11,94		1	2009A	1133	277,0	71,5	7,7	1	20	55	free	42,94
C78	AF	11,91		1	2009A	708	268,8	71,5	7,4	1	20	55	free	39,07
CHS6.1_0.04	AF	1,78	-0,04	2	9	3531	331,5	48,2	10,6	2	15	45	free	60,04
CHS6.1_0.06	AF		-0,06	2	10	4529	338,3	56,9	10,2	1	15	45	free	70,01
CHS6.1_0.08	AF		-0,08	2	10	4605	346,8	62,9	16,5	4	15	50	free	79,36
CHS6.1_0.10	AF		-0,10	2	10	4507	355,4	54,8	12,8	1	15	50	free	74,84
CHS6.1_0.12	AF		-0,12	2	10	3582	355,3	54,3	12,8	1	15	50	free	74,33
CHS6.1_0.14	AF		-0,14	2	10	2768	349,6	58,8	17,0	4	15	50	free	77,13
CHS6.1_0.16	AF		-0,16	2	10	2396	345,0	55,4	18,3	4	15	50	free	72,14
CHS6.1_0.18	AF		-0,18	2	10	2181	350,6	51,2	20,4	4	15	50	free	70,47
CHS6.1_0.20	AF		-0,20	2	10	2070	338,6	66,6	7,2	4	15	30	forced	76,15
CHS6.1_0.22	AF		-0,22	2	10	2047	52,0	23,8	25,4	4	15	30	free	33,42
CHS6.1_0.24	AF		-0,24	2	10	2315	66,5	52,6	18,1	4	15	50	free	39,34
CHS6.1_0.26	AF		-0,26	2	10	2529	67,6	46,9	17,6	4	15	50	free	35,25
CHS6.1_0.28	AF		-0,28	2	10	2558	56,6	54,5	16,0	4	15	50	free	46,84
CHS6.1_0.30	AF		-0,30	2	10	2612	30,1	49,4	14,2	2	15	50	free	59,98
CHS6.1_0.32	AF		-0,32	2	10	2450	37,6	51,6	12,7	3	15	40	free	57,05
CHS6.1_0.34	AF		-0,34	2	10	2340	14,5	46,7	21,4	4	25	50	free	65,24
CHS6.1_0.36	AF		-0,36	2	10	2560	35,0	64,5	14,6	2	20	60	free	66,61

Demagnetization steps of AF and TH palaeomagnetic samples and u-channel

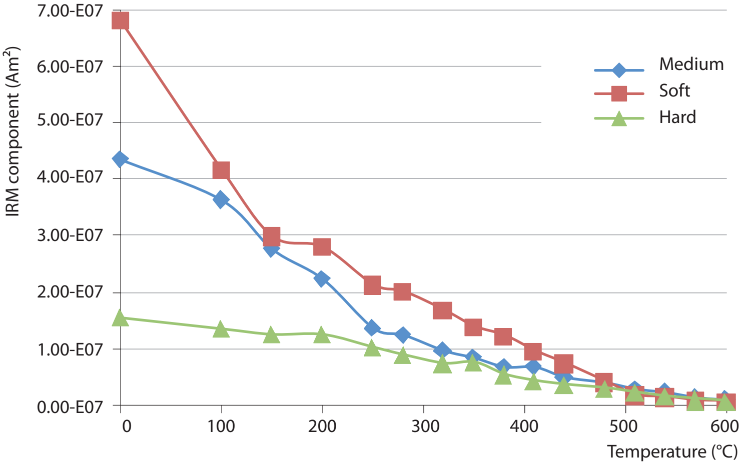
Steps 2009 AF: 0, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 mT

Steps 2010 AF: 0, 10, 15, 20, 30, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100 mT

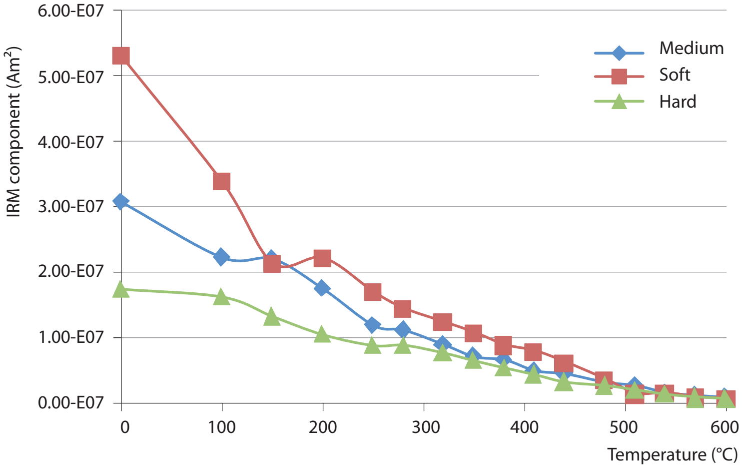
Steps 2009 and 2010 TH: 20, 90, 150, 200, 230, 260, 300, 330, 360, 400, 430, 460, 490, 520, 540, 560, 580, 600, 620, 630°C

Steps u-channel: 0, 5, 10, 15, 20, 20, 25, 30, 30, 40, 45, 50, 55, 60, 65, 70, 80, 90, 100 mT

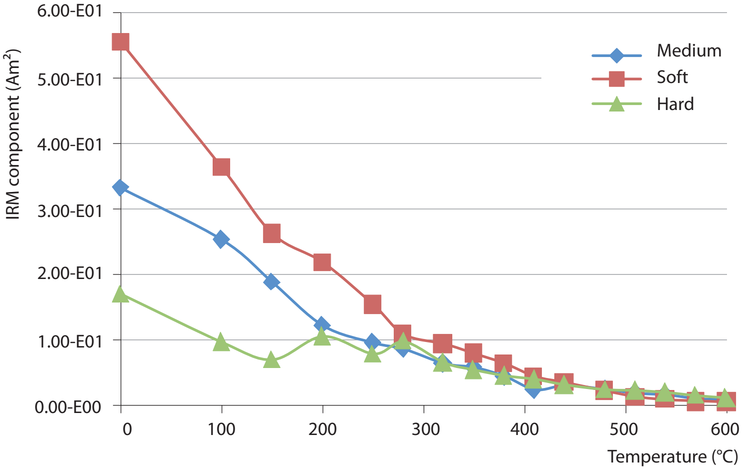
SI Figure 1 a



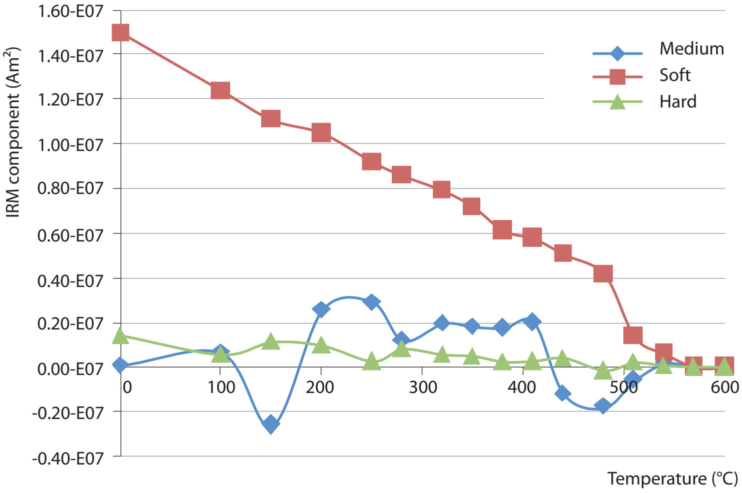
SI Figure 1 b



SI Figure 1 c



SI Figure 1 d



Thermal demagnetization of 3 axial Isothermal Remanent Magnetisation (IRM) acquisition curves. Samples were taken from geological unit 10 (a, b), unit 6 (c) and unit 3 (d)