Physics of the Earth and Planetary Interiors 257 (2016) 205–219

Contents lists available at ScienceDirect

Physics of the Earth and Planetary Interiors

journal homepage: www.elsevier.com/locate/pepi

New archeointensity data from French Early Medieval pottery production (6th–10th century AD). Tracing 1500 years of geomagnetic field intensity variations in Western Europe

Agnès Genevey [a,*], Yves Gallet [b], Sébastien Jesset [c], Erwan Thébault [d], Jérôme Bouillon [e], Annie Lefèvre [f], Maxime Le Goff [b]

[a] Sorbonne Universités, UPMC Univ Paris 06, CNRS, UMR 8220, Laboratoire d'archéologie moléculaire et structurale (LAMS), 4 place Jussieu, 75005 Paris, France
[b] Institut de Physique du Globe de Paris- Sorbonne Paris Cité- Université Paris Diderot, UMR 7154 CNRS, Paris, France
[c] Mairie d'Orléans, Service Archéologique Municipal d'Orléans, Orléans, France
[d] Université de Nantes, LPG UMR-CNRS 6112- Laboratoire de Planétologie et Géodynamique de Nantes, Nantes, France
[e] Institut National de Recherches Archéologiques Préventives, Centre de recherches archéologiques de Tours, Tours, France
[f] Institut National de Recherches Archéologiques Préventives, Centre de recherches archéologiques de la Courneuve, La Courneuve, France

ARTICLE INFO

Article history:
Received 16 February 2016
Received in revised form 24 May 2016
Accepted 6 June 2016
Available online 8 June 2016

Keywords:
Archeointensity
Geomagnetic secular variation
Medieval period
Western Europe
Experimental archeological firing
Pottery

ABSTRACT

Nineteen new archeointensity results were obtained from the analysis of groups of French pottery fragments dated to the Early Middle Ages (6th to 10th centuries AD). They are from several medieval ceramic production sites, excavated mainly in Saran (Central France), and their precise dating was established based on typo-chronological characteristics. Intensity measurements were performed using the Triaxe protocol, which takes into account the effects on the intensity determinations of both thermoremanent magnetization anisotropy and cooling rate. Intensity analyses were also carried out on modern pottery produced at Saran during an experimental firing. The results show very good agreement with the geomagnetic field intensity directly measured inside and around the kiln, thus reasserting the reliability of the Triaxe protocol and the relevance of the quality criteria used. They further demonstrate the potential of the Saran pottery production for archeomagnetism. The new archeointensity results allow a precise and coherent description of the geomagnetic field intensity variations in Western Europe during the Early Medieval period, which was until now poorly documented. They show a significant increase in intensity during the 6th century AD, high intensity values from the 7th to the 9th century, with a minimum of small amplitude at the transition between the 7th and the 8th centuries and finally an important decrease until the beginning of the 11th century. Together with published intensity results available within a radius of 700 km around Paris, the new data were used to compute a master curve of the Western European geomagnetic intensity variations over the past 1500 years. This curve clearly exhibits five intensity maxima: at the transition between the 6th and 7th century AD, at the middle of the 9th century, during the 12th century, in the second part of the 14th century and at the very beginning of the 17th century AD. Some of these peaks are smoothed, or nearly absent when the selection of the data is extended to a 1250 km radius around Paris. The apparent regularity in the occurrence of intensity maxima, with a recurrence of ~250 years, is particularly intriguing and might reflect a new characteristic of the secular variation, at least in Western Europe. It clearly requires further investigation and in particular the acquisition of new data from older periods.

1. Introduction

The Early Middle Ages in Western Europe spanned from the end of the 5th century to the beginning of the 11th century AD (e.g. Devroey, 2003; Davis, 2005). The perception of this period, often called the "Dark Ages", has largely been re-evaluated in France over the past 20 years thanks to rescue archeology. Numerous archeological excavations conducted during the re-development within towns and in the countryside have enabled a better understanding of the medieval habitat and of everyday life. This new information has revealed a less abrupt transition period after the fall of the Roman Empire (e.g. Catteddu, 2009). Furthermore, these

* Corresponding author.

http://dx.doi.org/10.1016/j.pepi.2016.06.001
0031-9201/

excavations have offered unique opportunities for studying the geomagnetic secular variation during this time interval. In particular, a large set of domestic kilns was sampled for archeomagnetic directional analyses in the Ile-de-France region, near Paris (Warmé, 2009) and the new results aim to contribute to the refinement of the French directional variation curve during the Middle Ages. The discovery of pottery workshops, ranging from small units to large production centers, also provided material for archeomagnetic directional and/or intensity studies.

The need for new archeointensity results from the Early Middle Ages has long been recognized (e.g. Chauvin et al., 2000; Genevey and Gallet, 2002). Despite recent and significant improvements (Donadini et al., 2008, 2012; Gallet et al., 2009; Tema et al., 2009; Gómez-Paccard et al., 2012), this period remains poorly documented, which penalizes the construction of accurate regional and/or global archeomagnetic field models (e.g. Pavón-Carrasco et al., 2014a,b). The acquisition of new archeointensity data dated to the Early Middle Ages is thus still necessary in order to build a detailed and continuous geomagnetic field intensity variation curve for Western Europe over the past 2000 years (Genevey et al., 2009, 2013).

We present here 19 new archeointensity data dated to the Early Middle Ages, among which 16 were obtained from the analysis of pottery fragments produced at Saran (Fig. 1a). This site, located a few kilometers north of the city of Orléans, France, was an important center of pottery production during the Middle Ages as evidenced by the numerous pottery kilns and associated ceramics found during excavations (Jesset et al., 2001, 2010; Jesset, 2013, 2015a,b; Bouillon, 2015). The archeointensity analysis of two groups of potsherds produced in Saran had previously been carried out by Genevey and Gallet (2002). These results are here reassessed in the light of new information provided by an experimental firing conducted on a reconstructed ancient kiln, which allowed a re-estimation of the cooling rate experienced by the ceramics. We further present intensity results obtained from modern pottery produced in known field conditions during this experimental firing.

2. Archeological collection

In the late sixties, when the archeological site of Lac de la Médecinerie was discovered in Saran (47.9°N, 1.9°N; Fig. 1a) and partially excavated (Chapelot, 1973), Emile Thellier sampled the kilns that were unearthed at the time. While being amongst the first structures analyzed in France for their archeomagnetic directions (Thellier, 1981), the Lac de la Médecinerie was the first archeological site revealing a medieval pottery activity in this city. Since then, other production units have been discovered at Saran and archeological excavations are still being conducted some 40 years later, in particular at the Lac de la Médecinerie site (Jesset et al., 2010). This on-going work has allowed Saran to be recognized as a major center of ceramic production in Central France during the Merovingian (5th–mid 8th century AD) and Carolingian (mid 8th–10th century AD) royal dynasties.

A detailed chrono-typology for the Saran production was constructed by crossing different information (e.g. Jesset, 2013, 2015b). It relies on constraints derived from the excavations conducted at Saran and also on various elements obtained from other sites where ceramics produced at Saran were discovered in a consumer context. These elements include radiocarbon dating, coins and historical constraints among others. The chronology is based on the recognition of the changing characteristics of pottery over time, such as the shape of the ceramics including the evolution of the lips, spout and the base, their function, the color and the texture of the paste, the overall quality of the production and also the decor, here often made with a small wooden wheel. The derived chronology runs from the 6th to the beginning of the 11th century AD. We only summarize below the major evolutionary trends of the ceramics produced at Saran, whose resolution allows dating with a precision of ±25 years in favorable cases. This should not hide the fact that the typo-chronology relies on the identification and integration of more elements than those presented here (Jesset, 2013, 2015b).

The beginning of ceramic production in Saran, during the 5th century AD, remains relatively unknown. Only a few grey shards with polished surfaces, fired in redox conditions and of Gallo-Roman appearance give evidence of some preliminary small-scale production. The 6th century AD is better documented; this period is characterized by forms and decors also inherited from the Gallo-Roman corpus, with thick walls (>5 mm) and by ochre-yellow clay paste with a light grey color at the core. The 7th century sees the reinforcement of the production activity and the expansion of its area of distribution, reaching a monopoly position during the early 8th century through a region of 50–70 km around Saran. While most technological characteristics of the production do not change during the 7th century AD, such as the texture, the color and the thickness of ceramics, the production tends, however, to become more standardized due to the higher rate of production, with simpler decor and more rounded shapes. In contrast, the 8th century is characterized by significant evolution: the walls become thinner (3–4 mm) and the color of the pots darkened to red-ochre. The old forms are abandoned or evolve and new forms emerge. As an example, the trefoil tubular spout, which had appeared at the end of the 7th century, was at first separated from the neck of the pottery before gradually converging with it and finally fusing into it in the second half of the 8th century. A decline in quality of the ceramic production is also perceived during the second half of the 8th century, as evidenced by pots presenting defects discovered in consumer contexts. This decline continues during the 9th century, with a more reduced corpus of production, which foreshadows the end of the main workshops of Saran in the second part of the 9th century. For this period, the evolution of the shapes and of the lips of the globular pots serves as a chronological marker. The color of the ceramics dated to the 9th century is dark at first, before becoming brighter in the late 9th century, with a light ochre-yellow clay paste that characterizes the ceramics of the 10th century. The ceramics at this point are produced in small production units at Saran and the weaker activity likely favors an overall higher quality of the ceramics. Thicker walls are observed and a new profile of lips "en bandeau" appears during the second part of the 10th century, before the generalization of the latter during the 11th century, when, unfortunately, the ceramic production in Saran is no longer documented.

Considering only the groups of potsherds that successfully provided archeointensity results, our collection from Saran is composed of 17 groups encompassing the period from the 6th to the 10th century. They are mostly associated to two important production units excavated at the sites of Lac de la Médecinerie (6 groups) and La Guignace (7 groups), both situated along the old Roman road between Chartres and Orléans. Three other groups consist of pottery fragments from a smaller workshop excavated at the archeological site of Zac des Vergers, which had been in activity during Saran's period of peak production. The last group, dated to the end of the 9th century, was sampled from a large set of ceramic fragments discovered during domestic building works in the current center of Saran (Saran le Bourg).

All fragments collected at Saran were found in pits inside or nearby the kilns where they were originally produced. They correspond to pottery wasters that were used to fill in the kilns after their abandonment. The selected fragments (as illustrated in Fig. 1b) are from units with a low level of pottery fragmentation and the potsherds show sharp (rather than eroded) sides. These are