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New archaeomagnetic directions from Portugal and evolution of the geomagnetic field in Iberia from Late Bronze Age to Roman Times

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ABSTRACT

This study presents new archaeomagnetic results from 33 combustion structures (kilns and hearths) from the archaeological sites of Castelinho, Crestelos, Olival Poço da Barca and Fonte do Milho in NE Portugal. The age of the investigated structures ranges from 1210 BC to 200 AD according to calibrated radiocarbon dating, thermoluminescence dating and archaeological constraints. Stepwise thermal and alternating field demagnetization isolate a single, stable, characteristic remanence component with very well defined directions. Rock magnetic analyses suggest low-Ti titanomagnetite/maghemite as the main magnetic carrier of the remanence. Mean directions are well grouped in most structures. The effect of thermoremanent anisotropy on mean directions has been evaluated and was found to be important. Inclination increases of between 2° and 13° after applying the anisotropy correction at specimen level. This highlights the requirement of evaluating this effect on the directions of small and flattened thin kilns and hearths. The 31 new directional data improve both the temporal and spatial distribution of the Iberian archaeomagnetic dataset from Late Bronze Age to Roman Times. Finally, a new directional palaeosecular variation curve for Iberia for the last twelve centuries BC is proposed. The curve has been computed using the bootstrap method and includes data coming from sites within 900 km of Madrid. The new palaeodirectional secular variation curve for Iberia is consistent with the Western European palaeosecular variation curve and with the prediction of regional European models.

1. Introduction

Knowledge of the evolution of the ancient geomagnetic field is a crucial topic in geosciences: i) to constrain geodynamo models and therefore to understand the origin of the geomagnetic field, ii) to reconstruct past solar activity based on cosmogenic nuclide production rates (e.g., Muscheler et al., 2007; Usoskin et al., 2013) which are modulated by the solar and terrestrial magnetic field and iii) to provide chronological constraints of baked archaeological material, volcanic rocks, and Quaternary sediments (e.g., Gallet et al., 2009; Pavón-Carrasco et al., 2011; Roberts et al., 2013).

The variation of the geomagnetic field can be studied directly through observatory and satellite data and extended back to the 17th century AD using historical data. Further in the past, the study of palaeosecular variation of the geomagnetic field (PSV) is based on palaeomagnetic data. The most suitable materials are well-dated archaeological combustion structures (hearths and kilns) and volcanic rocks. Archaeomagnetic data provide the most precise, high-resolution palaeomagnetic data for the last millennia since their thermoremanent magnetization (TRM) is acquired in a short time interval (from hours to days) and they can be well dated using physical as well as archaeological techniques. Data obtained from lava flows, although very useful, can sometimes be problematic, presenting small inclination shallowing or dating problems (for more details, see Lanza et al., 2005; Pavón-Carrasco et al., 2016, and references therein). Palaeomagnetic data coming from sediments may smooth the apparent PSV of the geomagnetic field and could also show inclination shallowing effects (see Tauxe, 1993).

A compilation of archaeomagnetic data allows the construction of a Palaeosecular Variation Curve (PSVC), which then provides knowledge of geomagnetic field variations at regional scales for

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periods covering the last few millennia. If the PSV curve is well-defined it can be used as a master curve for dating purposes. At present, the secular variation of the geomagnetic field in the Iberian Peninsula is poorly constrained. The published directional Iberian PSVC, centred on Madrid, covering the last 3000 years (Gómez-Paccard et al., 2006b), contains 63 Spanish archaeomagnetic directions (Gómez-Paccard et al., 2006a), 63 data from South France and 9 from North Morocco. The resulting PSVC of Iberia is a mixture of French, Moroccan and Iberian data, but for pre-Roman Times is based exclusively on French data.

In recent years, new studies have been carried out in Iberia, covering the last three millennia (Catanzariti et al., 2008, 2012; Casas et al., 2014; Gómez-Paccard et al., 2008, 2013; Osete et al., 2016; Prevosti et al., 2013; Ruiz-Martínez et al., 2008). However, the extension of the directional curve to the first millennia BC still remains limited by the lack of reliable data. It is also unfortunate that the Iberian PSVC contains no data from Portugal and, despite numerous archaeomagnetic studies carried out during the last decade only one (Catanzariti et al., 2008) is from a Portuguese archaeological site.

This study addresses two of the great issues of the Iberian archaeomagnetic dataset; the scarcity of data for the first millennium BC and the near absence of palaeodirectional data from Portugal. We present new archaeomagnetic directional data from 33 hearths and kilns from four archaeological sites in northern Portugal, with ages ranging from 1210 BC up to 200 AD. A new Iberian directional PSVC for the period spanning 1200 BC – 200 AD is also proposed.

2. Sampling and laboratory protocols

The investigated archaeological sites are located in northern Portugal (Fig. 1a), Castelinho and Olival Poço da Barca (Lat. 41.2° N, Long. 7.0 ° W), Crestelos (Lat. 41.3 ° N, Long. 6.9 ° W) and Fonte do Milho (Lat. 41.1 ° N, Long. 7.4 ° W).

The Crestelos site (close to the locality of Meirinhos, Fig. 1b and c) is sub-divided into two excavation areas, an upper area named Povoado de Crestelos (labelled PCR in this study) and a lower area named Quinta de Crestelos (labelled QCR). 12 combustion structures were sampled from PCR and 16 from QCR, including hearths and small kilns (the basal level dimensions of the structures were around 0.5 m × 0.5m). The preserved part of the combustion structures is the 1–2 cm thick basal level made of a thin layer of flattened smooth clayish sediments (Fig. 1). Most of them were in a good state of preservation, with the exception of PCR20 A and PCR26, which were highly fractured and poorly preserved. On the basis of archaeological information the main occupation of the archaeological site occurred mostly during the Late Iron Age (2nd century BC to 1st century AD).

Olival Poço da Barca and Castelinho are located close to the locality of Felgar. At Olival Poço da Barca (labelled OPB) a large Roman pottery-making kiln was excavated, comprising a rectangular structure with three well-preserved supporting walls (Fig. 1e). At the Iron Age archaeological site of Castelinho (labelled CAST, Fig. 1f), three small hearths were sampled. Finally, close to the locality of Canelas, one structure was sampled at the Fonte do Milho archaeological site (labelled FM, Fig. 1d). The structures sampled at CAST and FM sites are similar to the hearths at PCR and QCR.

Further archaeological and dating details of the sites are given in the AHBS Monography (2014), C2TN Relatorio (2014) and in the Cambridge Publication (in press).

The surface of most hearths and small kilns was flat and subhorizontal. North was marked directly on the sample by means of a magnetic compass (see Fig. 1). Small tilts were considered original rather than post-cooling in most of the structures, but the strike and dip were carefully measured in all cases. In contrast, evidence of post-cooling tilting was observed in the FM and CAST structures, which was probably caused by younger superimposed walls. For these structures the strike and dip was measured.

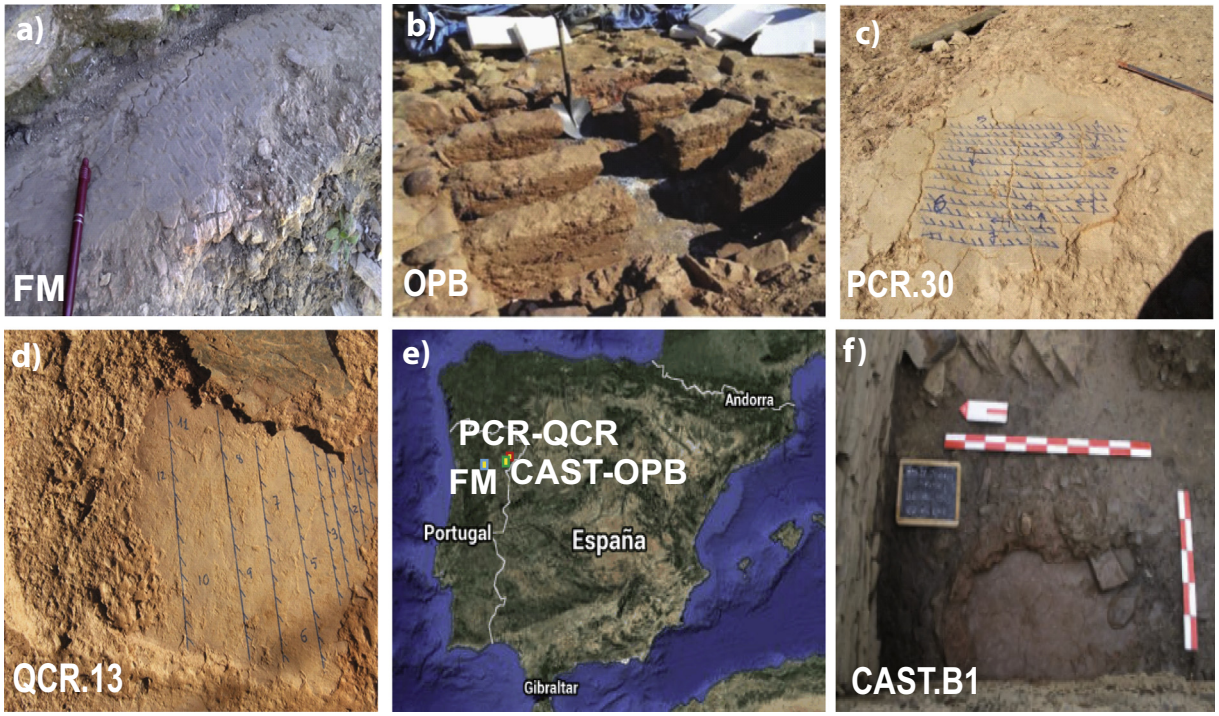

Fig. 1. a) Map with the location of the studied archaeological sites, b) Povoado de Crestelos (PCR), c) Quinta de Crestelos (QCR), d) Fonte do Milho (FM), e) Olival Poço da Barca (OPB) and f) Castelinho (CAST).