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Three archaeomagnetic applications of archaeological interest to the study of burnt anthropogenic cave sediments

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ABSTRACT

Recent archaeomagnetic studies carried out on Mid-to Late Holocene burnt anthropogenic cave sediments have shown that under certain conditions, these materials are suitable geomagnetic field recorders. Archaeomagnetic analyses carried out on these contexts constitute a rich source of information not only for geophysical purposes -in terms of reconstructing the variation of Earth's magnetic field in the past- but also from the archaeological point of view, for example by archaeomagnetic dating. Here, we report three different archaeomagnetic applications to the study of burnt cave sediments: (i) archaeomagnetic dating; (ii) determining palaeotemperatures and (iii) assessing post-depositional processes. The first case study is a dating attempt carried out on a Late Holocene (Bronze Age) burnt level from El Mirador Cave (Burgos, Spain). Using the directional European secular variation curve, several dating intervals were obtained for the last burning of this combustion feature. Considering the archaeological evidence and the independent radiometric (^{14}C) dating available the possible ages obtained are discussed. This is the first archaeomagnetic dating obtained in these contexts so far. The second case study is an application of the method to determine the last heating temperatures reached by the carbonaceous facies of these fires. Stepwise thermal demagnetization of oriented samples can be used to quantitatively estimate heating temperatures. An intermediate normal polarity component interpreted as a partial thermo-remanence (pTRM) with maximum unblocking temperatures of 400–450 °C was systematically identified, revealing the last heating temperatures experienced by this facies. These temperatures were confirmed with partial thermomagnetic curve experiments. Finally, archaeomagnetic analyses on a partially bioturbated burning event were performed in order to evaluate until what spatial extent the burnt sediments were affected by post-depositional mechanical alteration processes. For each case study, the archaeological implications are discussed highlighting the potential of archaeomagnetic methods to retrieve archaeological information.

1. Introduction

Since the pioneering work of Brochier (1983a,b), the study of Holocene burnt anthropogenic cave sediments has experienced considerable progress. A great number of archaeological excavations as well as the increasing amount of data provided by disciplines such as soil micromorphology (Boschian, 1997; Macphail et al., 1997; Angelucci et al., 2009), palaeobotany (Rasmussen, 1993; Delhon et al., 2008; Cabanes et al., 2009) or zooarchaeology (Rowley-Conwy, 1998; Martín et al., 2014) among others, is yielding valuable information about the formation and use of these deposits. Archaeomagnetism has emerged as one of these lines of research. Although it has a long tradition in Earth sciences its application in prehistoric archaeology is still sporadic and its potential to retrieve archaeological information remains underutilized.

Broadly speaking, archaeomagnetism deals with the study of the record of the Earth's magnetic field direction and/or intensity changes in the past in burnt archaeological materials. Most archaeological materials contain small amounts of ferromagnetic minerals (*s.l.*), such as magnetite or haematite. When heated to high temperatures (>500–600 °C) and subsequently cooled these

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minerals acquire a remanent (permanent) magnetization parallel to the ambient magnetic field. Under several conditions this information may be very stable over long periods of time and used in a wide variety of applications, among which dating is likely the most known. However, given their versatility, magnetic methods can provide valuable information ranging from determining palaeotemperatures (e.g., Brown et al., 2009), ash sourcing (Church et al., 2007) or assessing the degree of preservation in archaeological cave fires (e.g., Carrancho et al., 2012). This paper provides a review of some of these applications specifically applied to anthropogenic cave sequences.

These stratigraphic sequences usually contain multiple burning events generated by the periodic burning of organic material (e.g., vegetal remains and dung) produced by livestock penning (Angelucci et al., 2009). Their preservation state is usually good, are generally well-dated by independent methods (namely radiocarbon) and have a broad geographical distribution throughout the Mediterranean region (Angelucci et al., 2009). Therefore they constitute a great source of archaeomagnetic data and the information obtained has both geophysical and archaeological interest. The main goal of this article is to highlight the potential of magnetic methods to answer archaeological questions through three different applications. The first is a dating attempt of a firing event from El Mirador Cave (Spain) using the recently designed directional European Secular Variation (SV) curve for the Neolithic (Carrancho et al. 2013). The second is a methodological application to determine the last heating temperature undergone by these fires. The third consists on evaluating to what extent a burning event might be affected by post-depositional processes. The archaeological and archaeomagnetic implications of these cases studies will be discussed as well as the limits of each application.

2. Materials and methods

2.1. Sites

The studied materials correspond to samples from Neolithic, Chalcolithic and Bronze Age burning events exposed in the Holocene stratigraphies of El Mirador and Portalón de Cueva Mayor caves (Sierra de Atapuerca, Burgos) and El Mirón Cave (Cantabria, Spain; Fig. 1a). For detailed information on the archaeology, stratigraphy and chronology of these sites the reader is referred to Straus and González Morales (2012), Carretero et al. (2008) and Vergès et al. (2008, in this volume). These fires generally contain a grey/white ash facies of variable thickness (2–10 cm) over a thin (~2 cm) black carbonaceous subjacent facies.

2.2. Sampling

Archaeomagnetic sampling was carried out with the aid of a non-ferromagnetic cylindrical tube which incorporates a built-in orientation system specifically designed for soft (unlithified) lithologies (Carrancho et al., 2013). Its main advantage is that it allows a precise geographical orientation of the samples besides being minimally invasive. The tube is pressed against vertical profiles where the burnt facies outcrop. After the azimuthal reading, the sediment is carefully inserted in cylindrical plastic boxes (Ø 16.5 mm, 17 mm length; volume of about 3.6 cm^3) and stored in cold conditions (3–4 °C) until measurement to avoid chemical alterations. Samples for thermal (TH) demagnetization of the natural remanent magnetization (NRM) were oriented by the same means and introduced into home-made plaster cubes (Carrancho, 2010). These contain a cylindrical hole with the same dimensions and volume as the plastic capsules in order to keep the sample in fixed position. The NRM of the plaster cubes is at least two orders of magnitude less than the sample's magnetization. Details of the number and type of samples collected for each case study are given below.

2.2.1. Case study 1 (archaeomagnetic dating)

A burning event (Ci1) from El Mirador Cave (42° 20′ 58″ N, 03° 30′ 33″ W; Sierra de Atapuerca, Burgos, Spain) was intensively sampled for archaeomagnetic dating purposes (Fig. 1a–b). The archaeostratigraphic unit where Ci1 is located (MIR103 – Sector 100) has a ^{14}C (AMS) dating (sample code: Beta – 339094) obtained from a charcoal fragment with a 2σ dating interval of 1510 to 1410 cal. BC (3190 ± 30 BP). Archaeological evidence is limited to few pottery remains suggesting a possible Bronze Age for the MIR103 unit. The objective here was to obtain an archaeomagnetic date of the last heating of this event using the directional European SV curve (Carrancho et al., 2013). The Ci1 burning event is composed of an ash and a carbonaceous facies. The ashes are white on top and reddish brown on the bottom with a total thickness of about 15 cm. Just beneath, a dark carbonaceous (~2 cm) facies is preserved delimiting the surface where burning occurred (Fig. 1). At the top of the lower level, just at the base of the burning event, a burrow can be observed that may have partially affected the structure. A total of 29 oriented samples (22 ashes and 7

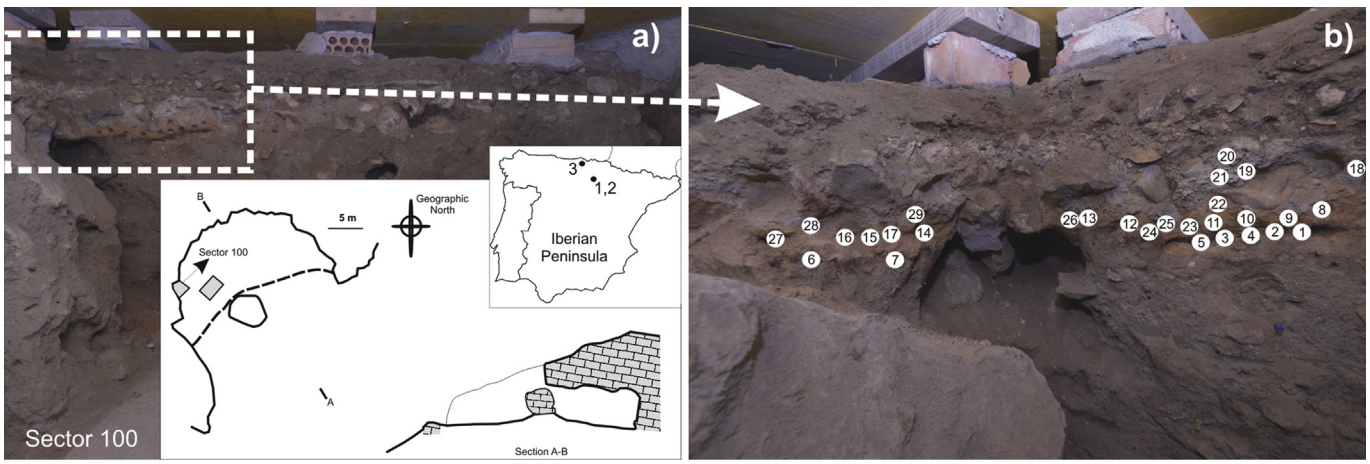

Fig. 1. (a–b) Photographs showing the studied burning event with the location of the samples. The plan and section view of Mirador Cave showing the survey pit where Ci1 is located (sector 100). The location of the three caves studied is shown in the map: 1, 2 (El Mirador and Portalón Caves, Sierra de Atapuerca, Burgos) and 3 (El Mirón Cave, Cantabria).

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