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First archaeomagnetic field intensity data from Ethiopia, Africa (1615 ± 12 AD)

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ABSTRACT

First archaeointensity determinations have been obtained from Ethiopia. Seven bricks (34 specimens) from the Däbsan archaeological remains were subjected to archaeointensity determination by means of classical Thellier–Thellier experiment including tests for magnetic anisotropy and magnetic cooling rate dependency. The age of the Däbsan Palace is well controlled by historical information: between 1603, when land grants were conceded to the Jesuits and the Catholicism was established as the official religion in Ethiopia, and the age of the Palace foundation in 1626–27. Successful archaeointensity determinations were obtained in 27 specimens from five individual bricks revealing an average field value of 33.5 ± 1.1 μT, which is 11–26% lower than expected values from global geomagnetic models based on historical and archaeomagnetic data.

Global models for 1615 AD predict a low in central-southern Africa related to past location of the present Southern Atlantic Anomaly (SAA). Our results suggest that the field intensity in central Africa may have been slightly lower than global model predictions. This would indicate that the low could be probably more extended towards central-eastern Africa (or more intense) than previously considered. Further data from this region are especially welcome to delineate the evolution of the SAA.

1. Introduction

Archaeomagnetic data provide important constraints on the local and global geomagnetic field variation during the historical past, a key issue for Earth Sciences. In the last decade, a considerable number of archaeomagnetic data have been produced and local and global databases have been compiled (e.g. Korte et al., 2005; Genevey et al., 2008; Kovacheva et al., 2009a; Donadini et al., 2006, 2009; Korhonen et al., 2008) to produce geomagnetic field models at global (Korte and Constable, 2005, 2011; Korte et al., 2009; Licht et al., 2013; Pavón-Carrasco et al., 2014a), regional (Europe, Pavón-Carrasco et al., 2009, 2010) or local scales: Paleosecular Variation Curves (PSVC, e.g., Gallet et al., 2002; Schnepp and Lanos, 2005; Gómez-Paccard et al., 2006a; Tema and Kondopoulou, 2011). These models allow for analyses of field morphology and global secular variation. Furthermore the detailed knowledge of local/regional secular variation is a powerful tool for archaeomagnetic dating (eg. Lanos, 2004; Schnepp and Lanos, 2006; Pavón-Carrasco et al., 2011).

Despite this effort, the global archaeomagnetic database is not homogeneously distributed in space and time (see Fig. 1), most data being located in the European continent (52% of the total data for the last 7 ka). The scarcity of data is especially pronounced for the African continent, and more significantly for central Africa. Only very recently a first archaeomagnetic study has been published on pottery from Senegal and Mali (Mitra et al., 2013) for the time period: 1000 BC to 1000 AD. From the eastern part of central Africa no archaeomagnetic data have yet been published.

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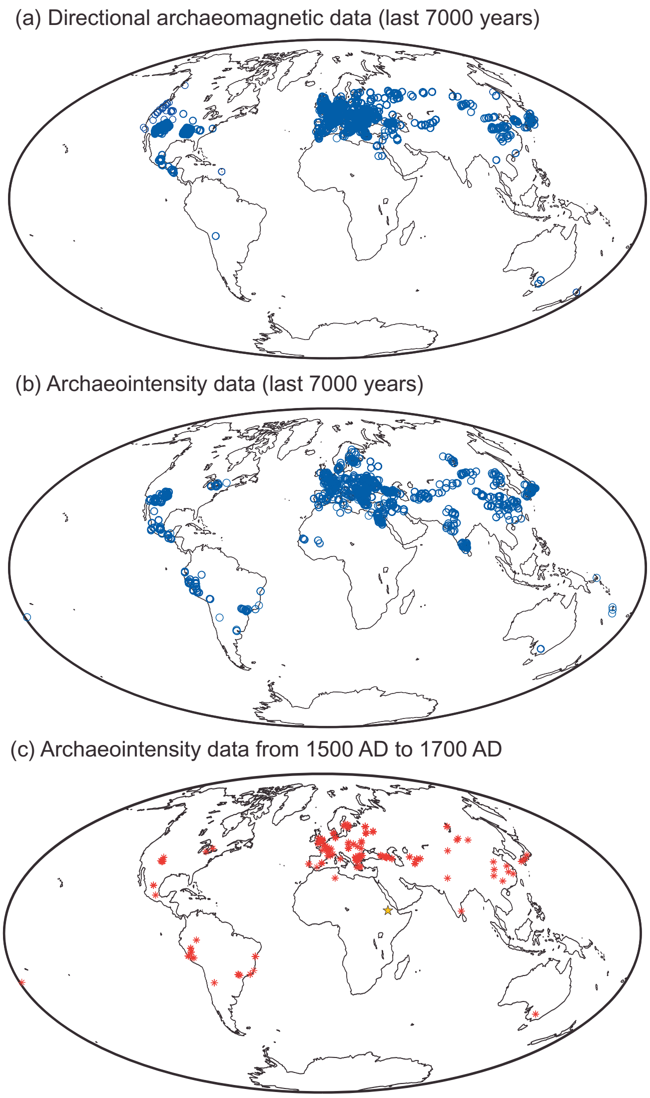

Fig. 1. Global distribution of archaeomagnetic data. Location of directional (a) and archaeointensity data (b) for the last 7000 years. (c) Archaeointensity data for the 1500–1700 AD timespan. Location of the studied site is marked with a yellow star. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Directional archaeomagnetic data are mostly concentrated in the Eurasian and north American region and almost lacking from the southern hemisphere. In contrast palaeointensity data are slightly better distributed. However, archaeointensity investigations are more complex than archaeodirectional studies, since the theory to obtain palaeointensities (Thellier and Thellier, 1959) is restricted to single domain (SD) grains carrying a thermoremanent magnetization (TRM) or a partial TRM (pTRM); and other factors as the cooling rate dependence or the chemical alterations produced at the laboratory can strongly alter the results. In addition, the anisotropy of the TRM can affect both directional and palaeointensity results, being the last very important, especially in highly anisotropic materials (ceramics, tiles, etc.). Therefore palaeointensity studies should be appropriately analyzed and corrected. In some of the first studies such corrections were not applied, consequently the reliability of archaeointensity database is uncertain and has been widely debated (e.g. Chauvin et al., 2000; Genevey et al., 2008; Kovacheva et al., 2009b). New archaeointensity data of high quality especially for sparsely investigated regions are strongly needed to understand the field evolution of the Earth's magnetic field in the past.

Historical declination (mostly) and inclination data are available for the last four centuries from shipboard and navigational records (Jonkers et al., 2003). In contrast, no direct intensity measurements are available until 1837, when C.F. Gauss devised the first method to measure it (intensity measurements became widespread by 1840). Based on historical data Jackson et al. (2000) build up a global geomagnetic model (GUFM) for the period 1590 AD to 1990 AD. To correct for intensity, Jackson et al. (2000), assumed a constant dipole decay rate with time (the observed ratio at 1840). The GUFM model was modified by Gubbins et al. (2006) and Finlay (2008) for the expected intensity in the time interval: 1590 and 1840 AD, based on archaeomagnetic and lava flow data compilation of Korte et al. (2005). New global geomagnetic models for the last 3 ka have also been proposed (Korte et al., 2009; Korte and Constable, 2011): the ARCH3k.1 (based on archaeomagnetic and volcanic data) and the CALS3k.4 (including also sedimentary records). Very recently other global models have been published (Pavón-Carrasco et al., 2014a; Licht et al., 2013). These models give different intensity predictions for the period 1590–1840 AD.

The magnetic anomaly over the South Atlantic (or South-Atlantic Anomaly, SAA), where the total field intensity is unusually low, is one of the most outstanding features of the geomagnetic field, presently occupying the area between South America and South Africa (see Hartmann et al., 2011 for more details). Gubbins et al. (2006), based on a readjustment of the GUFM model (Jackson et al., 2000) proposed that the magnetic field dipole intensity was nearly constant for the 1590–1840 AD time period, in contrast to the more recent period when the Earth's magnetic field has decayed by about 5% per century. Extrapolating the model to the core surface Gubbins et al. (2006) showed that the fall in strength was originated in patches of reverse magnetic flux in the Southern Hemisphere (responsible of the SAA anomaly) which started around 1840 AD. However constrains of the evolution of SAA prior to 1840 is based only in directional data. Geomagnetic models also show a westward drift of the SAA, at least since 1970. Based on historical model predictions the anomaly would be located in the African continent around 1600 AD. The evolution of this important feature of the geomagnetic field should be constrained by additional palaeointensity data.

Here we present the first archaeointensity results obtained from bricks from Ethiopia (Däbsan archaeological complex, dated as 1603–1627). The aim of this study is to contribute to the global archaeomagnetic database and discriminate between the different global models predictions (Jackson et al., 2000; Gubbins et al., 2006; Finlay, 2008; Korte et al., 2009; Licht et al., 2013; Pavón-Carrasco et al., 2014a).

2. Archaeological context and sampling

Between 1603 and 1633, the religious order of the Jesuits managed to establish Catholicism as the official religion in Ethiopia, period in which land grants were conceeded to the missionaries, associated to a considerable "foreign" building activity (Anfray, 1988; Pennec, 2003; Ramos and Boavida, 2004; Angelini, 2006). Within this historical context the Däbsan complex was constructed. Jesuits were expelled in 1633–1634 AD, and since that period, the sites with Jesuit remains were progressively abandoned, being nowadays in a strongly deteriorated state.

In 2006, following an application of the Complutense University of Madrid (Spain), the Ethiopian government officially launched archaeological investigations on the Jesuit Mission in the region of Lake Tana, where the Däbsan archaeological site is located (Fig. 2a). This action was basically centered on surveying, identification, and consolidation of the sites of interest, photographic and topographic documentation and excavations (Fernández, 2007, 2008, 2013; Fernández et al., 2012).