PRELIMINARY ARCHEOINTENSITY RESULTS FROM SOUTH BRAZIL

G.A. Hartmann[1,2*], W. Poletti[2], R.I.F. Trindade[2], L.M. Ferreira[3]

[1] Observatório Nacional, Rio de Janeiro, Brazil.
[2] Universidade de São Paulo, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, São Paulo, Brazil.
[3] Universidade Federal de Pelotas, Instituto de Filosofia e Ciências Humanas, Pelotas, Brazil.
[*] e-mail: gelvam@gmail.com

ABSTRACT

The knowledge of the historical geomagnetic field, is important to describe the axial dipole moment decay, as well as the non-dipole field variations. South America remains as a world sector that has a low number of archeomagnetic data to contribute to the debate about these two important field aspects. Here, we report preliminary archeointensity data from the city of Pelotas, State of Rio Grande do Sul, South Brazil. Samples were collected from baked-clay architectural brick fragments dated over the past two centuries. All archeointensity data were determined using the classical Thellier and Thellier (1959) double heating paleointensity method with modifications proposed by Coe (1967). Anisotropy and cooling rate effect were taken into account on all analyzed fragments. Our results describe a fast decreasing trend of ~6 μT per century in the considered time interval. This rate is stronger than that from previously reported values for South American, but they will be improved with more data from other periods (*e.g.* from XVI to XVIII centuries) in order to confirm the geomagnetic field variations observed in South Brazil.

Keywords: Archeomagnetism, South America.

RESUMO

A compreensão do campo geomagnético histórico é importante para a descrição do decréscimo no momento de dipolo axial, bem como para as variações do campo não-dipolar. A América do Sul ainda é um setor do planeta que apresenta um baixo número de dados arqueomagnéticos que contribuem para o debate desses dois importantes aspectos do campo. Neste trabalho serão apresentados dados de arqueointensidade preliminares de Pelota, Rio Grande do Sul, Brasil. As amostras foram coletadas de fragmentos de tijolos datados para os últimos dois séculos. Todos os dados de arqueointensidade foram determinados usando o método clássico de duplo aquecimento de Thellier e Thellier (1959) com modificações propostas por Coe (1967). Os efeitos de anisotropia e taxa de resfriamento foram efetuados em todos os fragmentos analisados. Os resultados descrevem um rápido decréscimo de ~6 μT por século no intervalo de tempo considerado. Esta taxa é maior do que aquelas previamente determinadas para a América do Sul, mas elas deverão ser aprimoradas com a aquisição de mais dados para outros períodos (*e.g.* entre os séculos XVI e XVIII) a fim de confirmar as variações do campo observadas no Sul do Brasil.

Palavras Chave: Arqueomagnetismo, América do Sul.

Introduction

The understanding of geomagnetic field variations at historical period is a great challenge due to two important field aspects. First, the historical field is characterized by a continuous decreasing of the axial dipole moment (ADM) at least over the past 170 years (*e.g.* Jackson *et al.*, 2000; Gubbins *et al.*, 2006; Finlay, 2008), although it can present an oscillatory behavior during this period (Genevey *et al.*, 2009;

Hartmann *et al.*, 2010; 2011). Second, strong non-dipole field features could be responsible to drive the ADM drop at the centennial to millennial timescales (*e.g.* Terra-Nova *et al.*, 2015). These characteristics are assessed via geomagnetic and archeomagnetic historical field data. Nowadays, however, it is possible to find out different conclusions for the evolution of the ADM, depending on whether all (scattered) data or a selection of them (with very stringent selection criteria) is considered. Regarding archeomagnetic data, it is known that the scarcity of archeomagnetic data in Southern Hemisphere is crucial to develop well-constrained geomagnetic field models (*e.g.* Genevey *et al.*, 2008; Donadini *et al.*, 2009).

Determining historical field evolution involves the acquisition of new well-dated archeointensity data around world. Concerning this, South America constitutes a very important region because this area is strongly affected by the lowest total field intensities known during the last two centuries. These low field intensity values are due to the presence of the so-called South Atlantic Magnetic Anomaly (SAMA), which is driven by strong non-dipole field components (*e.g.* Bloxham and Gubbins, 1985; Bloxham *et al.*, 1989; Olson and Amit, 2006; Gubbins *et al.*, 2006; Hartmann and Pacca, 2009). In order to improve our knowledge of the geomagnetic field in South America, we present preliminary archeointensity data from the city of Pelotas, State of Rio Grande do Sul, South Brazil. Samples were collected from baked-clay architectural brick fragments dated over the past two centuries.

Sampling and methods

The slave system, in the State of Rio Grande do Sul, began around 1737 AD, just after the foundation of the city of Rio Grande. During the XVIII century, the city of Pelotas (near to Rio Grande) concentrated the highest number of slaves in the State of Rio Grande do Sul. Since 1780 AD, Pelotas became the biggest production center of jerked beef (Guttierrez, 2001). This was possible due to the slave work, abundance of cattle and the privileged location near to the Rio Grande harbor. This important jerked beef center developed 40 farms at the banks of the Arroio Pelotas River. All farms operated from middle of XVIII until the beginning of XX century. Our sampling consisted of bricks collected from the basement of the buildings (Fig. 1). Studied buildings comprised farmhouses (locations of manufacturing of jerked beef) and historical

Figure 1. Pictures from Charqueada Santa Bárbara (CSB). Bricks from the building floor of the CSB site (a). Building wall of the CSB site (b).

buildings (from the center of Pelotas). A total of 86 brick fragments were sampled from the studied buildings (Table 1).

Archeointensity experiments were performed using the classical Thellier and Thellier (1959) double heating paleointensity method, with modifications proposed by Coe (1967). The Coe (1967) approach of Thellier

Table 1. Studied sites in Pelotas (31.8ºS, 52.3ºW).

Site	Number of collected fragments	Age (AD), age error
Charqueada Santa Bárbara (CSB)	28 brick fragments	1814 ±24
Chácara da Brigada Militar (CBM)	5 brick fragments	1841 ±11
Campus Porto da UFPEL (CPU)	13 brick fragments	1942 ±1
Fundação Simon Bolivar (Antigo Casarão da Faculdade de Turismo da UFPEL) (FSB)	12 brick fragments (cores sampled using a portable drill)	1886 ±3
Casa Número 08 (C08)	12 brick fragments	1874 ±5
Casarão da Família Emílio Maciel (Sede dos Conselhos Universitários da UFPEL) (FEM)	15 brick fragments (cores sampled using a portable drill)	1882 ±1

and Thellier (1959) method consists of double heating-cooling steps the first in Zero field and the second in field (TT-ZI protocol). Experiments were carried out between 100º C and 600º C, with temperature intervals of 50º C from 100º C and 25º C afterward. The magnetization measurements were performed at room temperature and the laboratory field of 35 µT was applied parallel to X-axis of the specimen. The standard partial Thermo Remanent Magnetization (pTRM) checks were performed every two temperature steps and the pTRM-tail checks were performed at six different temperatures (200º C, 300º C, 350º C, 400º C, 500º C and 600º C). The TRM anisotropy and the cooling rate effects were taken into account in order to correct the intensity value for each specimen, following the procedure described in Genevey and Gallet (2002), Hartmann *et al.* (2010; 2011) and Poletti *et al.* (2013). Analysis and selection criteria were the same adopted by Genevey and Gallet (2002) and Hartmann *et al.* (2010; 2011).

Results and discussion

The fragments from our collection were subjected to magnetic mineralogy experiments in order to characterize the magnetic minerals and to test the thermal stability for the latter archeointensity experiments. Low-field magnetic susceptibility versus temperature curves were carried out up to 550 °C using a Kappabridge KLY4-CS3 (AGICO) system. The 550 °C correspond to the maximum temperature considered for almost all intensity experiments. The reversibility behavior between the heating and cooling susceptibility curves was used for testing the stability of the magnetic mineralogy upon temperature. Only those samples showing a good stability of their magnetic mineralogy were further selected for intensity determinations (36 fragments). Figure 2 shows six examples of thermomagnetic curves.

Archeointensity determinations using the TT-ZI protocol were applied on 36 fragments (72 specimens) from 6 buildings of Pelotas. Intensity values from the TT-ZI protocol were determined from the least square fitting of linear segments in the Arai diagrams, comprising at least 5 temperature steps and 40% of the total NRM. For the retained samples, the standard deviation of the linear slopes was in all cases of less than 5%. Moreover, they had to present less than 5% of variations on pTRM checks and less than 10% on pTRM tail checks. At the fragment level, a mean intensity value was computed using a minimum of 2 individual values (specimens) determined using the TT-ZI. That value was retained when the difference between the individual values, after TRM anisotropy and cooling rate corrections, was less than 5% of the mean. At the site level, a mean intensity value was computed using the intensities from a minimum of 3 different fragments (*i.e.* 6 specimens). The value was considered as satisfactory when its standard deviation was of less than 10% of the mean (Genevey and Gallet, 2002; Hartmann *et al.*, 2010; 2011; Poletti *et al.*, 2013).

The Figure 3 shows four representative examples of Arai and corresponding orthogonal diagrams obtained for specimens that passed our selection criteria. In all cases, the thermal demagnetization revealed a single

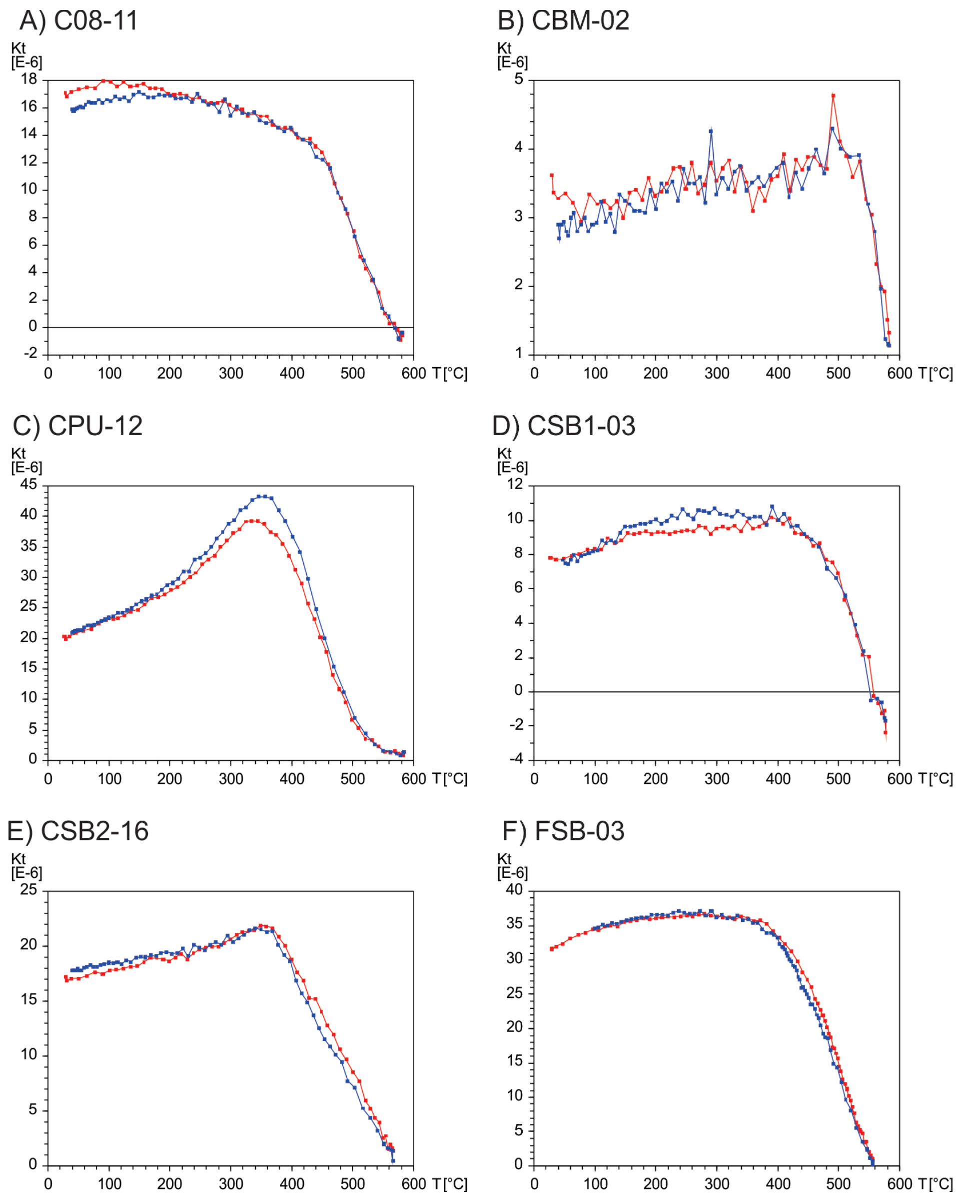

Figure 2. Low-field magnetic susceptibility curves measured during heating-cooling cycles for six representative fragments, which were retained for archeointensity determinations. Red curves indicate heating and blue curves indicate cooling cycles, respectively. Susceptibilities are dimensionless.

magnetization component generally isolated between ~100 – 250° C and 575° C (Figures 3b, 3d, 3f, 3h). In the Arai diagrams, however, the intensity values were often computed from a narrower temperature interval in order to take into account only the temperature steps for which no magnetic alteration was detected (Figures 3a, 3c, 3e, 3g).

Figure 4 shows the 6 high-quality archeointensity averages (27 fragments, 54 specimens) of the South Brazil. It is worth to mention that these results were computed only after anisotropy and cooling rate corrections. Intensity averages describe consistent variations with values varying between ~28.2 μT and ~36.5 μT . These intensity values are compared with an available geomagnetic field model (Korte and Constable, 2011). They describe a fast decreasing trend of ~6 μT per century in the considered time interval. This rate is stronger than that previously reported values for South American sector (*e.g.* Hartmann *et al.*, 2010; 2011; Goguitchaichvili *et al.*, 2011).

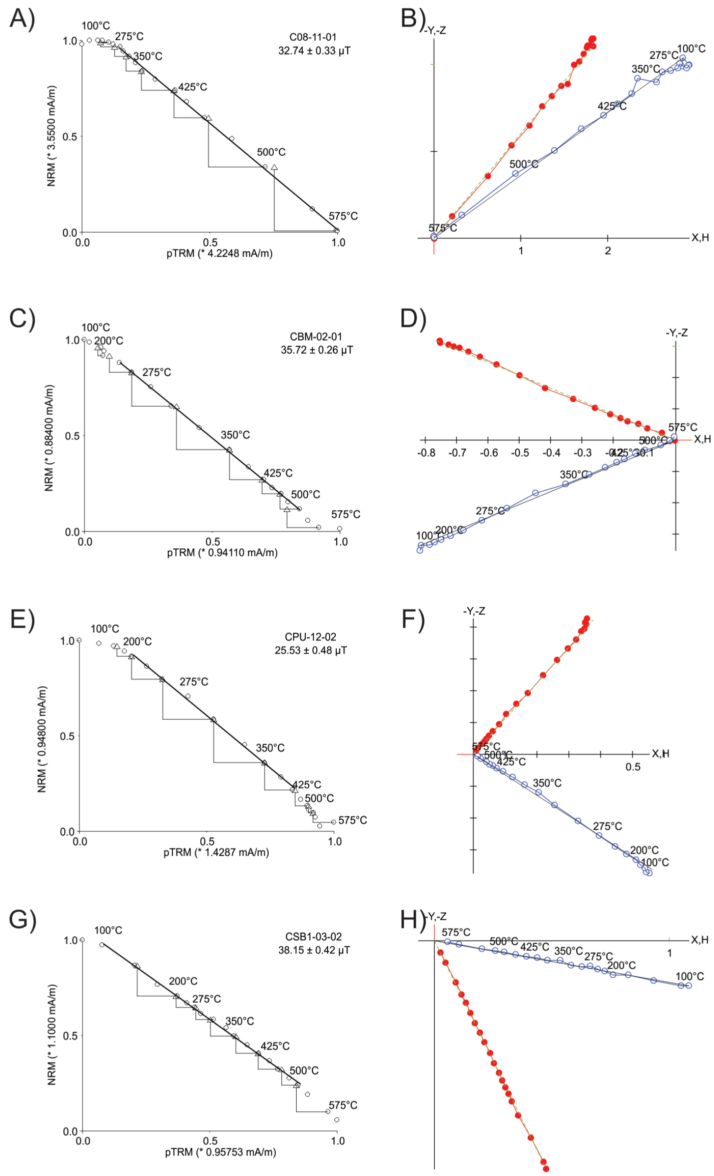

Figure 3. Intensity determinations using the TT-ZI protocol. Representative examples of Arai diagrams (a, c, e, g), and corresponding thermal demagnetization diagrams (b, d, f, h). In Arai diagrams, the circles represent the remaining NRM versus gained TRM and the triangles show the pTRM-checks performed every two-temperature step. Intensity values were computed from the linear fit displayed on the diagrams. In the thermal demagnetization diagrams, the solid (resp. open) symbols indicate the vector end points projected onto the horizontal (resp. vertical) plane (arbitrary specimen coordinate system).

South America is an important region for research in archeomagnetism due to the presence of the SAMA (which is affected by strong non-dipole fields) and the scarcity of archeomagnetic data. The lack of reliable archeomagnetic data and heterogeneity of data distribution are puzzling and clearly demand further confirmation by continuing acquisition of new archeointensity data from this region. The results presented here will be improved with more data for other periods (e.g. from XVI to XVIII centuries) in order to confirm the geomagnetic field variations observed in South Brazil.

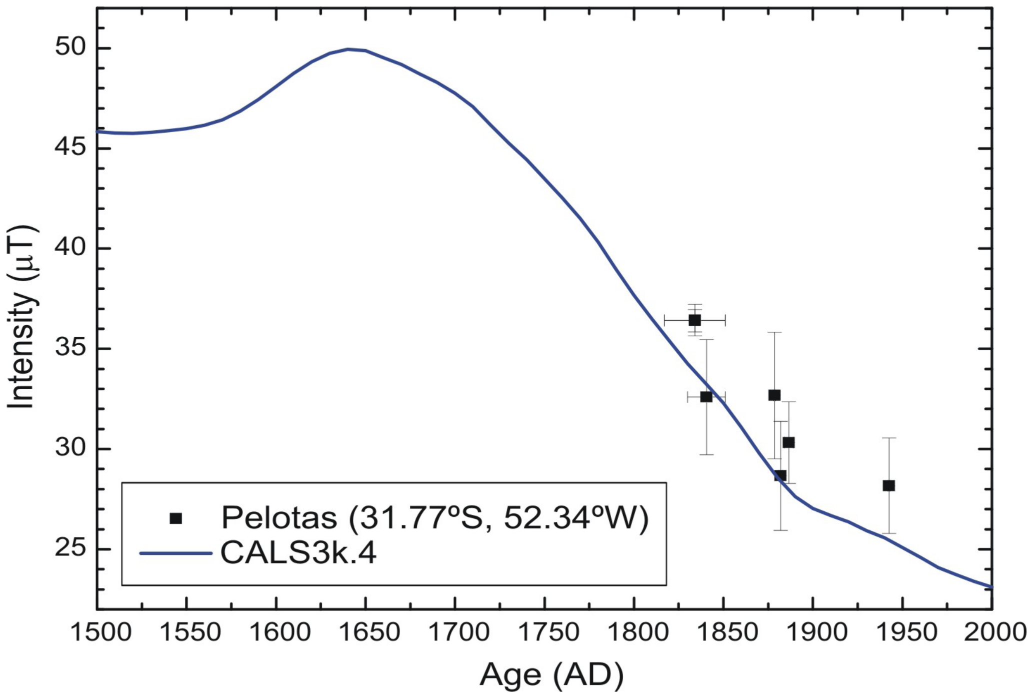

Figure 4. Intensity field variations for Pelotas city, State of Rio Grande do Sul, Brazil, over the past five centuries. All intensity data were anisotropy and cooling rate effects corrected.

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