THE IMPORTANCE OF DETERMINING AND CORRECTING THE ANISOTROPY OF THERMORREMANENCE IN ARCHAEOMAGNETIC STUDIES: STRONG INCLINATION FLATTENING EFFECT ON BACKED CLAYS OF THIN COMBUSTION STRUCTURES FROM IBERIAN PENINSULA.

A. Palencia-Ortas[1,2]*, M.L. Osete[1,2], M. Gómez-Paccard[1], A. Molina-Cardín[1,2], A. Chauvin[3], P. Roperch[3]

[1] Instituto de Geociencias IGEO (CSIC-UCM), Spanish National Research Council, c/ del Doctor Severo Ochoa 7, Edificio Entrepabellones 7 y 8, 28040, Madrid, Spain.
[2] Depto. de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid (UCM), Avd. Complutense s/n, 28040-Madrid, Spain.
[3] Univ Rennes, CNRS, Géosciences-Rennes - UMR 6118, F-35000, Rennes, France.

*e-mail: ali@ucm.es

ABSTRACT

In directional archaeomagnetic studies it is not common to study whether the combustion structures present anisotropy of the thermoremanence (ATRM). However, it has been observed that in some specific cases (backed clays that are part of the base of fine hearths and kilns of the Iberian Peninsula) a high degree of anisotropy can affect archaeomagnetic directions. This anisotropy of the thermoremanence mainly affects the inclinations and systematically decreases their values (in some cases up to 13 degrees). The inclinations can be adequately corrected if the ATRM tensors are determined. It is highly recommended that the scientific community take into account that this effect can distort the directional values in archaeomagnetism studies, blur the paleosecular variations curves and get erroneous archaeomagnetic dating.

Keywords: Archaeomagnetism, Directional studies, TRM anisotropy, Inclination flattening, Iberian Peninsula

RESUMEN

En los estudios de arqueomagnetismo cuyo objetivo es la determinación de las direcciones arqueomagnéticas registradas en estructuras arqueológicas no es común estudiar la anisotropía de la termorremanencia (ATRM). Sin embargo, se ha observado en material proveniente de la Península Ibérica que las capas de arcillas cocidas que forman parte de la base de finos hogares y hornos pueden presentar un alto grado de anisotropía. Esta anisotropía de la termorremanencia afecta principalmente a la inclinación y hace que su valor pueda disminuir considerablemente (en algunos casos hasta unos 13 grados). Los valores de la inclinación se pueden corregir adecuadamente mediante la obtención de los tensores de la ATRM. Por ello, es muy recomendable que la comunidad científica tenga en cuenta que este efecto puede distorsionar los valores direccionales en los estudios de arqueomagnetismo y que puede enturbiar las curvas de variación paleosecular y las dataciones arqueomagnéticas.

Palabras Clave: Arqueomagnetismo, Estudios direccionales, Anisotropía TRM, Aplanamiento de la inclinación, Península Ibérica

1. Introduction.

The only source of knowledge of the paleosecular variation of the Earth`s magnetic field prior to the existence of instrumental data is derived from palaeomagnetic studies. The materials used for these studies are well dated archaeological structures that have been heated up to high temperatures (hearths, domestic ovens, kilns, thermal baths, ceramics, bricks, etc.). Ferromagnetic minerals present in these materials and structures

acquire a stable thermorremanence (TRM) which is parallel and proportional to the Earth´s magnetic field during their last heating and cooling. The archaeological structures found "in situ" allow obtaining the direction (declination, inclination) and intensity of the ancient geomagnetic field whilst displaced baked clays only inform about its intensity. From these studies, directional and palaeointensity data allow constructing the paleosecular variation curves (PSVC) for different regions around the world.

Different error sources could affect to archaeomagnetic studies: random errors during sampling, sample preparation and/or measurement, mineral alteration during thermal demagnetization processes, etc. Some of these errors could be properly canceled upon appropriate methods although for systematic errors it is necessary a carefully evaluation of their dimension and try to keep them as small as possible. For instance, one of the most important error sources in palaeointensity studies is the one caused by the anisotropy of thermorremanence (ATRM). However, whereas this effect is commonly corrected in archaeointensity investigations, for directional studies it is very rare to determine the ATRM tensor at the specimen level. Thus, the effect of the anisotropy in archaeodirectional studies is not being properly corrected. Hervé *et al*., (2013) only found a slight but non-systematic effect on their directions due to ATRM of combustion structures from France. On the contrary, Tema (2009) and Palencia-Ortas *et al*. (2017) found systematic inclination shallowing on the direction of well dated ancient bricks from Italy and on thin backed clay floors from hearths and kilns from the Iberian Peninsula respectively.

The main target of the present communication is to prevent the archaeomagnetic community on the necessity of taking into account the ATRM in the determination of the archaeomagnetic directions. We highlight the necessity of analysis and correction of the ATRM effect and present the main characteristic of some highly anisotropic combustion structures studied in Portugal and Spain.

2. The effect of ATRM corrections on archaeodirections.

Palencia-Ortas *et al.* (2017) observed a systematic inclination shallowing effect in the study of thin backed clays from the base of small hearths (Figure 1). After the ATRM correction, the inclination values increased between 2 and 13 degrees.

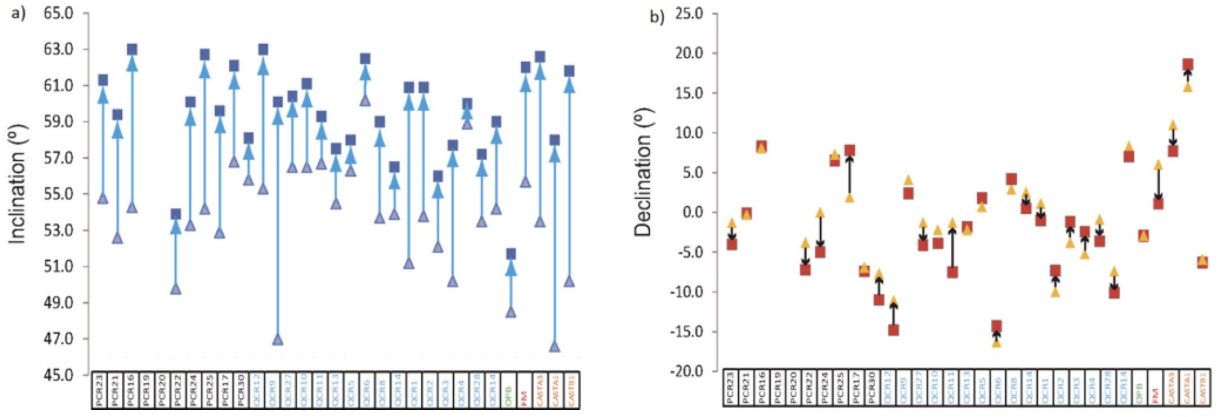

Figure 1. **a) - b)**: Inclination and declination values before (triangles) and after (squares) applying the anisotropy of thermorremanence correction in combustion structures from Palencia-Ortas *et al* (2017).

To go further in the analysis on the ATRM effect in archaeomagnetic directional studies, we revisited data from 55 combustion structures from the Iberian Peninsula (Gómez-Paccard, 2006; Osete *et al*., 2016; and Palencia-Ortas *et al*., 2017). In those studies, ATRM tensors were determined at the specimen level during thermal demagnetization. Archaeomagnetic directions were calculated before and after the ATRM correction at specimen level.

Archaeomagnetic directions have been compared with two reference paleosecular curves (PSVC) at Madrid coordinates: 1.- the PSVC from the regional SCHA.DIF.3k model for Europe (Pavón-Carrasco *et al*., 2009) and 2.- the PSVC of Hervé *et al*., (2013).

The Figure 2 shows that inclination dataset before anisotropy corrections are carried out (yellow dots) present lower values than the expected ones (in some cases more than 10 degrees). This flattening is properly corrected after ATRM correction (green dots). For declinations, there are not apparently distortions due to anisotropy of thermorremanence.

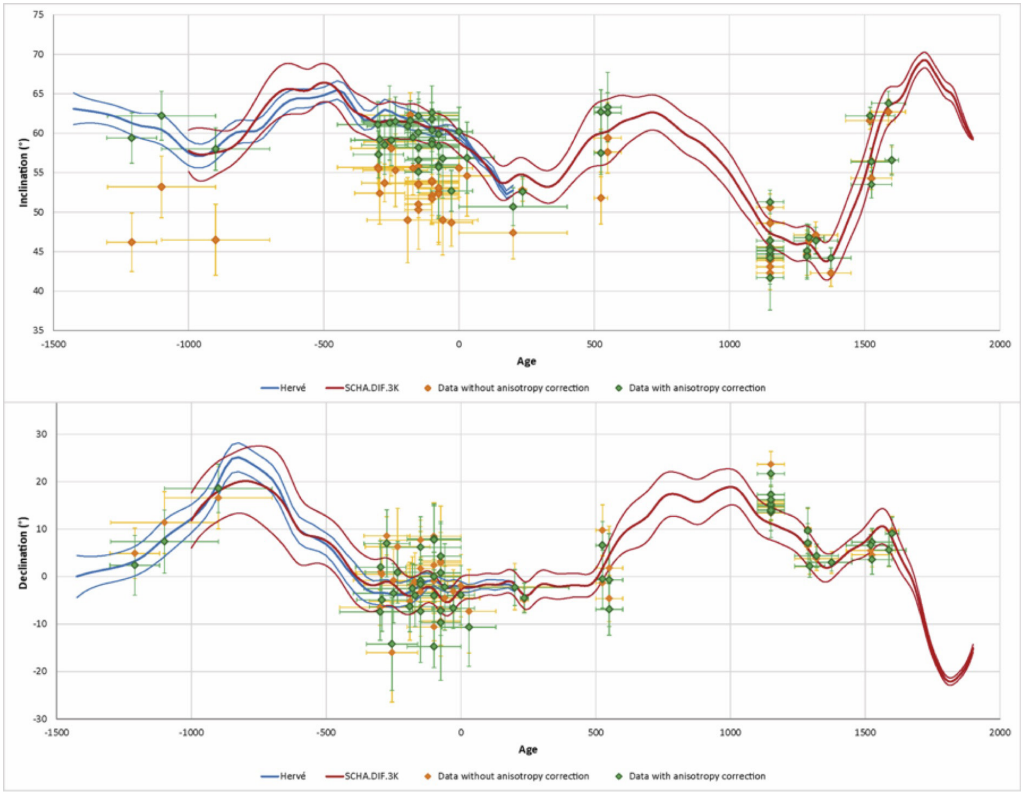

Figure 2. Inclination and Declination versus time at Madrid coordinates before ATRM corrections (yellow dots) and after (green dots) together with the paleosecular curves (PSVC) at Madrid coordinates: In red the PSVC from the regional SCHA.DIF.3k model for Europe (Pavón-Carrasco *et al*., 2009) and in blue colour the PSVC of Hervé *et al*., (2013).

Conclusion.

We would like to alert the scientific community on the possible presence of a high anisotropy of the thermorremanence effect that can strongly disturb the directions obtained in archaeomagnetic studies. The principal effect of the ATRM is a flattening in the inclinations values. However, this effect can be properly corrected if the ATRM tensor is obtained at the specimen level.

The structures that potentially could present this effect are thin backed clays from the base of small hearths and kilns. This effect has been also observed in bricks in some previous studies.

Therefore, it is highly recommended to analyse and correct this effect in directional combustion studies from structures with the previously described characteristics.

References

Gómez-Paccard M., Lanos P., Chauvin A., McInstosh G., Osete M. L., Catanzariti G., 2006. First archeomagnetic secular variation curve for the Iberian Peninsula: Comparison with other data from Western Europe and with global geomagnetic field models, *Geochemistry,Geophysics, Geosystems*, *7,* Q12001. https://doi.org/10.1029/2006GC001476

Hervé G., Chauvin A., Lanos P., 2013a. Geomagnetic field variations in Western Europe from 1500 BC to 200 AD. Part I: Directional secular variation curve. *Physics of the Earth and Planetary Interiors, 218*, 1–13.

Osete M. L., Chauvin A., Catanzariti C., Jimeno A., Campuzano S. A., Benito-Batanero J. P., 2016. New archeomagnetic data recovered from the study of celtiberic remains from central Spain (Numantia and Ciadueña, 3rd-1st centuries BC), Implications on the fidelity of the Iberian paleointensity database. *Physics of the Earth and Planetary Interiors, 260*, 74-86.

Palencia-Ortas A., Osete M. L., Campuzano S. A., McIntosh G., Larrazabal J., Sastre J., 2017. New archeomagnetic directions from Portugal and evolution of the geomagnetic field in Iberia from Late Bronze Age to Roman Times. *Physics of the Earth and Planetary Interiors*, *270*, 183–194.

Pavón-Carrasco F. J., Osete M.L., Torta M., Gaya-Piqué L., 2009. A regional archeomagnetic model for Europe for the last 3000 years, SCHA.DIF.3K: Applications to archeomagnetic dating. *Geochemistry, Geophysics, Geosystems*, *10*, 10.1029/2008GC002244.

Tema E., 2009. Estimate of the magnetic anisotropy effect on the archaeomagnetic inclination of ancient bricks. *Physics of the Earth and Planetary Interiors*, *176*, 213-223. 10.1016/j.pepi.2009.05.007.