ARCHAEOMAGNETIC INVESTIGATION FROM SOME HISTORICAL BUILDINGS IN BUENOS AIRES, ARGENTINA

Juan Morales[1*], Avto Gogichaishvili[1], Daniel Schavelzon[2] Carlos A. Vasquez[3], Claudia Gogorza[4] and Augusto Rapalini[5]

[1] Instituto de Geofísica, Universidad Nacional Autónoma de México, Unidad Michoacán, Campus Morelia, Laboratorio Interinstitucional de Magnetismo Natural, Morelia, México

[2] Centro de Arqueología Urbana, Universidad de Buenos Aires, Buenos Aires, Argentina.

[3] Universidad de Buenos Aires- CBC-IGEBA, Buenos Aires, Argentina.

[4] Centro de Investigaciones en Física e Ingeniería del Centro de la Provincia de Buenos Aires (CIFICEN-CONICET), Tandil, Argentina.

[5] IGEBA, CONICET, Universidad de Buenos Aires, Buenos Aires, Argentina.

ABSTRACT

Archaeointensity determinations using the Thellier method have been carried out on some selected bricks, tiles and pottery fragments in historical buildings of Buenos Aires. Four out of the five studied samples (25 out of 33 specimens) provided successful archaeointensity determinations. The fragment-mean archaeointensity values obtained in this study range from 26.5 ± 6.3 to 43.2 ± 4.1 μT, with a mean VADM (virtual axial dipole movement) of (7.3 ± 1.6) x 10^{22} Am^2. The synthetic archaeointensity variation record retrieved from Argentina consists of 38 mean archaeointensities distributed between 350 AD and 1890 AD. In order to ensure the reliability of ages provided by historical notes, we estimated the Probability Density Function (PDF) for each sample by using the global model CALS3k (calculated for the geographical position of the sampling site). More precise age estimations will require the use of the full geomagnetic vector.

Keywords: Archaeointensity, Historical buildings, Buenos Aires.

Introduction

Archaeomagnetism is an example of the interdisciplinary nature of most archaeometric research: it requires expertise from both Earth sciences and archaeology, with results benefiting both disciplines (Aitken, 1964; Eighmy and Sternberg, 1990). The geophysicist can gain information about the magnetization of materials and the behavior of the geomagnetic field, while the archaeologist can learn about the relative and absolute dating of baked artifacts. The suitability of archaeological artifacts to faithfully record the directional and intensity variations of the ancient geomagnetic field was revealed in late 1950's (Thellier and Thellier, 1959). Until now, numerous archaeomagnetic investigations have been carried out worldwide. In spite of the impressive cultural heritage and abundant archaeological sites found in South America, absolute geomagnetic intensity data are still scarce and of variable quality.

In the present study we report new archaeointensity data from some well studied historical houses in the city of Buenos Aires (*Convento de Santa Catalina de Sena, Casa de la Calle San Juan 338 and Casa Ezcurra).* Samples analyzed in this study come from different parts of these houses and consist of bricks, tiles, fireplaces and pottery.

Magnetic experiments and first results

The five fragments under study were further broken into at least 7 pieces and pressed into salt pellets to facilitate their treatment as standard paleomagnetic samples. The Thellier-Coe type experiments (Thellier and Thellier, 1959; Coe, 1967) were carried out using an ASC Scientific TD48-SC furnace; all heating/cooling runs were performed in air. Ten temperature steps were distributed from 200° C to 575º C with reproducibility between two heating runs to the same nominal temperature better than 2º C. The laboratory field strength was set to (30.00 ± 0.005) μT. Partial thermoremanent magnetization reinvestigations (pTRM checks) at each third temperature step as well as pTRM tail checks (Riisager and Riisager, 2001) determinations at 2 intermediate temperatures (350º C and 450º C) were also added to the laboratory procedure. TRM anisotropy corrections can be implemented in different ways (*e.g.* McCabe *et al.*, 1985; Selkin *et al.*, 2000; Chauvin *et al.*, 2000). It essentially requires the creation of a TRM along six perpendicular directions (+*X*, +*Y*, +*Z*, −*X*, −*Y*, −*Z*) by cooling samples from 575° C to room temperature in a known magnetic field. This involves six additional heatings, which may significantly alter the magnetic mineralogy of the samples. To circumvent this time-consuming procedure, individual specimens (belonging to the same fragment) were embedded into the salt pellet in the six positions. In this way, possible bias due to TRM anisotropy effects would be canceled, as attested by the results of our various previous experiments (Morales *et al.*, 2007).

In order to be considered as reliable estimations of the ancient field, archaeointensity determinations obtained in this study have to fulfill the following criteria:

1) Directions of natural remanent magnetization (NRM) end-points at each step obtained from archaeointensity experiments have to fall along a reasonably straight line, trending toward to the origin in the interval chosen for archaeointensity determination.
2) No significant deviation of NRM directions towards the applied field direction should be observed, as revealed in Zijderveld plots (Zijderveld, 1967), a plot of vector magnetization during the course of AF or thermal cleaning, projected on two orthogonal planes.
3) A number of aligned points N ≥ 5 on the Arai plot; specimens suspected to carry viscous remanent magnetization acquired *in situ* are rejected.
4) NRM fraction factor (f, Coe *et al*., 1978) ≥ 0.3. This means that 30 per cent of the initial NRM was used for archaeointensity determination.
5) A quality factor *q* (Coe *et al*., 1978) ≥ 4 (generally above 5). Being $q = \frac{f \cdot g}{\beta}$; *g*, the gap factor (Coe *et al*., 1978) and b the relative standard deviation of the slope.
6) Archaeointensity results obtained from NRM - pTRM diagrams must not show an evident concave up shape, since in such cases remanence is probably associated with the presence of multi-domain (MD) grains (Levi, 1977; Kosterov *et al*. 1998).
7) Positive pTRM checks, *i.e*., the deviation of 'pTRM' checks less than 15%.

Evaluation of pTRM-tail checks performed at two different temperatures were in all cases lower than 15%, except for one fragment for which the remaining tail reaches up to 40% at 400º C. It should be noted that MD grains may show pTRM-tails as large as 50% (Dunlop and Özdemir, 2000). At 500º C, however, the pTRM tail is significantly reduced to < 20% - a value commonly adopted as a cut off value in different studies (*e.g.*, Riisager and Riisager, 2001).

Twenty five specimens (out of 33 analyzed) fulfill the above described basic criteria and definitively correspond to high technical standards. The site-mean archaeointensity values obtained in this study range from 26.5 ± 6.3 to 43.2 ± 4.1 μT. These first archaeointensity values obtained for a historical period in Argentina were combined to recently obtained results from Paraná and Catamarca (Goguitchaichvili *et al*., 2011 and 2012). Most of the currently available, reliable archaeointensity data from South America agree within some uncertainties with ARCH3K model prediction between 350 AD and 1890 AD. In order to check the reliability of the ages provided by historical notes, we estimated the Probability Density Function (PDF) for each sample (fig. 1) by using the global model CALS3k (calculated for the geographical position of the sampling site) of Korte *et al*. (2009). This was made by using the Matlab tool of Pavón-Carrasco *et al*. (2011). The ages supplied by this model are in excellent agreement with those reported by urban archaeologists.

Acknowledgments

The authors wish to thank Secretaría de Políticas Universitarias del Ministerio de Educación de la República Argentina. Proyecto "Formación de una Red de Trabajo para la Ampliación de la Base de Datos Paleomagnéticos de Latinoamérica" Código: 17-16-458, Proyecto de Fortalecimiento de Redes Interuniversitarias VI.

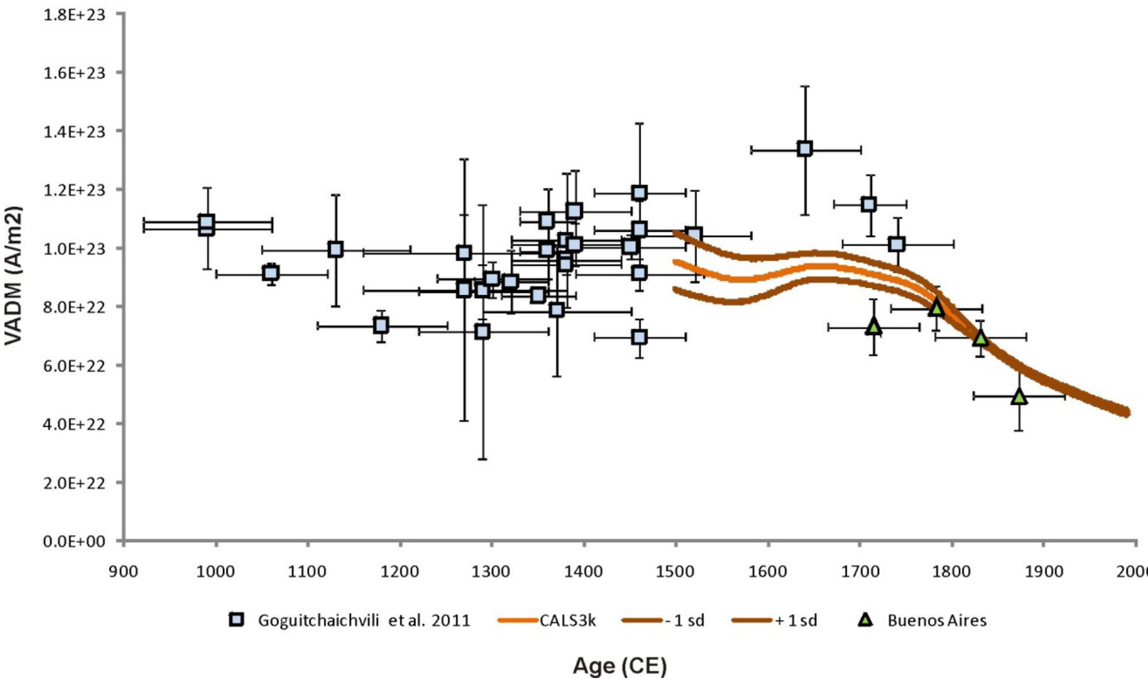

Figure 1. Mean VADM values obtained in this study together with the available data for Argentina (Goguitchaichvili *et at.* 2011). Also shown is the model curve CALS3k (Donadini *et al*. 2009) for the period of interest.

References

Aitken, M. J., 1964. Archaeomagnetic Results: Some Geophysical Implications. *Archaeometry, 7(1)*, 43-46.

Chauvin, A., Garcia, A., Lanos, Ph., Laubenheimer, F., 2000. Paleointensity of the Geomagnetic Field Recovered on Archaeomagnetic Sites from France. *Physics of the Earth and Planetary Interiors, 120,* 111-136.

Coe, R. S..1967. Paleo-Intensities of the Earth's Magnetic Field Determined from Tertiary and Quaternary Rocks. *Journal of Geophysical Research, 72, (12)*, 3247-3262, doi:10.1029/JZ072i012p03247.

Coe, R. S., Grommé, S., Mankinen, E. A., 1978. Geomagnetic paleointensities from Radiocarbon-dated Lava Flows on Hawaii and the Question of the Pacific Nondipole Low. *Journal of Geophysical Research, 83(B4),* 1740-1756, doi:10.1029/JB083iB04p01740.

Donadini, F., Korte, M., Constable, C.G., 2009. Geomagnetic field for 0–3 ka: 1. New data sets for global modeling. *Geochem. Geophys. Geosyst. 10,* Q06007. doi:10.1029/2008GC002295.

Dunlop, D.J., & Özdemir, Ö. 2000. Effect of Grain Size and Domain State on Thermal Demagnetization Tails. *Geophysical Research Letters, 27*, 1311-1314.

Eighmy, J. L. & Sternberg, R. S. (editors) 1990 Archaeomagnetic Dating. Tucson: University of Arizona Press.

Goguitchaichvili, A., Greco, C., Morales, J., 2011. Geomagnetic field intensity behavior in South America between 400 AD and 1800 AD: First archeointensity results from Argentina. *Phys. Earth Planet. Int., 186*, 191-197. doi:10.1016/j.pepi.2011.03.007.

Goguitchaichvili, A., Loponte, D., Morales, J. and Acosta, A., 2012. Archaeointensity of the Earth's Magnetic Field retrieved from Pampean Ceramics (South America). *Archaeometry, 54, 2,* 388-400. doi: 10.1111/j.1475-4754.2011.00620.x.

Korte, M., Donadini, F.,Constable, C.G. 2009. Geomagnetic field for 0-3 ka: 2. A new series of time-varying global models. *Geochemistry Geophysics and Geosystems 10* (Q06008). doi:10.1029/2008GC002297.

Kosterov, A. A., Perrin, M., Glen, J. M., Coe, R. S. 1998. Paleointensity of the Earth's Magnetic Field in Early Cretaceous Time: The Parana Basalt, Brazil. *Journal of Geophysical Research, 103(B5)*, 9739–9753, doi:10.1029/98JB00022.

Levi, S. 1977. The Effect of Magnetite Particle Size on Paleointensity Determinations of the Geomagnetic Field. *Physics of the Earth and Planetary Interiors, 13*, 245-259.

McCabe, C., Jackson, M., Ellwood, B. 1985. Magnetic Anisotropy in the Trenton limestone: Results of a New Technique, Anisotropy of Anhysteric Susceptibility. *Geophysical Research Letters, 12*, 333-336.

Morales, J., Goguitchaichvili A., Urrutia-Fucugauchi, J. 2007. Cooling Rate Effect as a Cause of Systematic Overestimating of the Absolute Thellier Paleointensities: A Cautionary Note. *Studia Geophysica and Geodaetica, 51, 315-326.*

Pavón-Carrasco F. J., Rodríguez-González, J., Osete, M. L. Torta, J. M. 2011. A Matlab tool for archaeomagnetic dating. *Journal of Archaeological Science 38,* 408-419.

Riisager, P. & Riisager, J. 2001. Detecting Multidomain Magnetic Grains in Thellier Palaeointensity Experiments. *Physics of the Earth and Planetary Interiors, 125, 111-117.*

Selkin, P.A., Gee, J. S., Tauxe, L., Meurer, W.P., Newell, A.J. 2000. The Effect of Remanence Anisotropy on Paleointensity Estimates: A Case Study from the Archean Stillwater Complex. *Earth and Planetary Science Letters, 183*, 403-416.

Thellier, E. & Thellier, O. 1959. Sur l'intensité du Champ Magnétique Terrestre dans le Passé Historique et Géologique. *Annales Géophysique, 15, 285-376.*

Zijderveld, J. D. A. 1967. A. C. Demagnetization of Rocks: Analysis of Results. In D. Collinson, K. Creer, & S. Runcorn (Eds.), *Methods in Paleomagnetism, 254-286. Amsterdam: Elsevier.*