A REVIEW ON THE CURRENT SAMPLING REQUIREMENTS FOR THE ARCHAEOMAGNETIC DATING METHOD – A GUIDE FOR THE ARCHAEOLOGIST

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The aim of the article

The current article would like to present to the archaeology students and the field specialists the opportunities arising from the use of geomagnetic data for dating and analysis and to state the essential sampling requirements involved in collecting such data from archaeological features. It is our intent to provide certain basic details of the method in order to better explain to the archaeologists what features are adequate for this type of analysis and what is required from them to have these features, once found in excavations, sampled by our specialists. This article is also an appeal to all the institutions involved in archaeological excavations to announce the discovery of such features and to allow for their subsequent sampling. This will allow, in time, for the creation of a modern calibration curve for Romania and more precise dating of new contexts. It is very important that as many features as possible to be sampled in order to recover the current gap in the regional data and to create the premises of properly using this absolute dating method in Romania.

Introduction

The use of archaeomagnetism as a dating method for archaeological materials is practiced by a relatively large number of laboratories throughout Europe and now Romania is benefiting too of a well-equipped unit at the Systemic Archaeology Institute of the "1 Decembrie 1918" University in Alba Iulia. The creation of this laboratory was necessary in order to fill the current gap in the geomagnetic field data that characterizes the Eastern European region and Romania in particular, at this moment. A more recent approach on collecting data for our country was the implementation of a European Research Training Network, A.A.R.C.H. (Archaeomagnetic Applications for the Rescue of Cultural Heritage) resulting in an intensive specialist training programme and also large scale sampling scheme, with some results published already[1]. This project is aimed to be continued in the near future under finance from the National University Research Council. The aim of research in the field of archaeomagnetic dating for Romania is now focused on correcting the current gap in calibration data by sampling and analysing burnt archaeological

[1] C. A. Şuteu, C. M. Batt, I. Zananiri, „New developments in archaeomagnetic dating for Romania - A progress report on recent directional studies", in *Physics and Chemistry of the Earth*, 33 (2008), p. 557-565.

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features and sediments. A review on the current state and trends of archaeomagnetic studies in the Balkans is given by Mary Kovacheva (2003)[2]. There are only a few published data points for Romania, mainly due to the early work of Aitken and Hawley (1966)[3] and Bucur (1967)[4] on three 14th–18th century sites. More recently, Mantu (1988)[5] has published a review of archaeomagnetism in the region along with some isolated data points, but with no statistical information or indication of treatments applied.

Method and techniques

There is a lot of written material on the method and technique available today but it is not the scope of this article to go into much detail. One of the most succinct publication, also available on the internet, is the guideline document recently issued by English Heritage[6]. In the following parts we will briefly explain some of the physical phenomena involved in order to allow for the archaeologist to understand the particular issues concerning archaeomagnetic dating sampling.

Geomagnetic investigations on archaeological features have long been proven to be the best method available for revealing field variations during the historical past. These variations can be used for example to define models of climatic change but also to date archaeological features, a very important issue for archaeologists. The archaeomagnetic dating method is based on the determination of direction and intensity of the past geomagnetic field from baked clays and sometimes sediments found in archaeological sites. The processes involved in the mechanism of this dating method are simply defined onwards. Natural, unfired clays usually carry a weak, randomly oriented natural magnetization. These clays, when used in the manufacturing of kilns and hearths, are most often subjected to high temperatures, often over 700º C. As they cool down, the magnetization becomes much stronger as it is aligned to the (then) present geomagnetic field. As the direction and intensity of the geomagnetic field changes with time, this acquired thermoremanence (TRM) "fossilizes" this information for the time and place of this firing event and can

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[2] M. Kovacheva, "The Balkan Peninsula and archaeomagnetism – A brief review", in *Journal of the Balkan Geophysical Society*, 6 (3) (2003), p. 173-178.

[3] M. J. Aitken, H. N. Hawley, „Archaeomagnetic dating in Britain – IV", in *Archaeometry*, 3 (1966), p. 129-135.

[4] I. Bucur, „La variation de l'Inclinaison magnetique du XIVe au XVIIIe siècle, établie pour deux régions de la Roumanie", in *Revue Roumaine de, Géologie, Géophysique et Géographie – Série de Géophysique*, 11, (2) (1967), p. 105-111.

[5] C. M. Mantu, „Metoda arheomagnetică şi datarea siturilor arheologice", in *AM*, 12 (1988), p. 281-302.

[6] P. Linford, *Archaeomagnetic dating. Guidelines on producing and interpreting archaeomagnetic dates*, Swindon, UK, English Heritage Publishing, 2006; available on the internet at *http://www.english-heritage.org.uk/upload/pdf/Archaeomagnetic_Dating.pdf* (19/05/09).

be recovered from samples nowadays. It is important to know that the TRM resets at every firing that has reached these high temperatures, the event being dated being always the last firing. By analysing the oriented samples taken from these features, directional and intensity parameters that describe the ancient geomagnetic field at this last firing event can be recovered in the laboratory, following a complex set of procedures. These values can be used against a pre-existing calibration curve that shows the variation of the geomagnetic field through time for that area in order to derive accurate dates for the features investigated.

What can be sampled?

There are various features associated to human habitation that require combustion and very often rather high temperatures to accomplish their designated functions. Most of these are highly suitable for archaeomagnetic sampling if they are reasonably well preserved. The list includes fireplaces and domestic hearths, temporary campfires and accidental (intense) firing of the soil, intense heat in situ incineration burials and burnt clay houses. For the more recent period in time suitable features are: any combustion structures like the hypocaust burning chamber or various industrial use kilns (for the production of pottery, glass, bricks and tiles, lime etc), metal smelting furnaces, baking ovens and burnt pits for the storage of cereals and various other structures. If any of the archaeologists currently excavating in Romania finds any such feature it is imperative that he announces the archaeomagnetic facility in Alba Iulia via email or telephone, as soon as possible, sometimes even before completely excavating the feature in question. Any opportunity to sample suitable features should be taken whenever possible.

It is very important to remember that not all fired features are suitable for this analysis. There are numerous factors, natural or human, that can render the magnetic information retained in the fired clay unusable. The most important characteristics to be found in such a usable feature will be detailed bellow, with the note that this information applies only to thermal remanence, more reliable and often found on archaeological features.

The presence of relevant magnetic minerals

Ferromagnetic minerals are found naturally in the constitution of almost all clays present in archaeological soils. Therefore when this material is used to build combustion features the presence of natural magnetic minerals is ensured. It is important to identify the presence of such magnetic carriers, like haematite and magnetite, because they have rather different behaviours in retaining the characteristics of the past geomagnetic field. This can be done by means of magnetic mineralogy in the laboratory.

High temperatures of firing

Another important issue is the acquisition of a remanence by these minerals as a result of a sustained firing event. A good, strong remanence is often acquired if the firing has been sustained over the blocking temperatures (Curie points) of the magnetic minerals contained, for magnetite around 585ºC and for haematite around 675ºC. The presence of such high temperatures at a feature can be directly derived by analysing the colour of the burnt clay. If high temperatures, over 675ºC, were reached in an oxidizing atmosphere, the changes in the coloration of clay are towards orange, pink and red. This states that haematite was formed and the TRM is most likely strong and stable. If high temperatures, over 585ºC, were reached in the absence of air (reducing conditions) a darkly coloured mineral is most likely to have formed, magnetite, also a good carrier of TRM. High temperatures and repeated burning will also render the clay hard and sometimes vitrified. It is important to mention that, in certain conditions, two firing events can be identified and dated. This is possible if the second firing has not reached the high temperatures needed to reset the previous high temperature remanence completely. It is acknowledged that for a TRM to be properly acquired temperatures over 300ºC must be met, any magnetization acquired under these values being unstable and most often unusable for dating. It is sometimes the case of temporary hearths and accidental firings.

Integrity of feature since the last firing event

Another crucial requirement is that the feature or large areas of it have not sustained major integrity altering events such as destruction, bioturbation, post-interference, natural tilting etc. It is important to realise that the magnetic information recovered from each sample is a vector composed of direction (inclination and declination angles) and intensity of the ancient magnetic field. Any such physical or mechanical perturbation will render this information unusable as the feature has lost the primary position in which it obtained this TRM. As the nowadays precision of the technique revolves around decimals it is essential that the feature has been very well preserved and "truly" in situ from the last firing event. The suitability of a feature from this point of view is a complex on site analysis process that will take into account geoarchaeological factors and the data available from the excavation of that particular context. Natural tilting can be identified visually and so can most of the factors mentioned here. Sometimes the specialist is able to identify on site suitable sampling areas in features even if they have not been well-preserved during time. But, overall, only in the laboratory the specialist can, based on statistical analysis, finally determine that a feature has accurate, stable and valuable magnetic information.

Basic feature characteristics

The sampling process involves the collection of many samples per feature (at least 14 for directional dating alone – even more for intensity studies, including bulk, un-oriented material), and therefore the suitable area must be of an appropriate size. It is important that several areas of a burnt feature be sampled in order to identify issues related to a possible variation of values due to refraction and other phenomena. The archaeologist has to realise that the process of sampling is a destructive one, important portions of the feature being removed for laboratory analysis. If that feature is to be preserved in situ or later removed for museum display the archaeomagnetist can negotiate a particular sampling strategy (micro-sampling etc) to allow for the preservation of the visual integrity of the feature. The on-site visit of a specialist is crucial to determine the final suitability of a feature, or of parts of it, for sampling.

Date relevance issues

There is also the issue of the relevance of archaeomagnetic dating on the objectives of the archaeological dig. It is important for the archaeologist to realise that the event dated by this method is particularly associated with certain moments in the evolution of the feature and only sometimes can be extrapolated to the whole site. For example, while dating a Roman kiln, the archaeomagnetic date given can be only representative of the last firing of that particular kiln and may bear no importance to the beginning of the site's habitation or its demise. The date is to be associated with the evolution of this feature alone and only further archaeological data from associated contexts can (and often do) give a more complex meaning to it.

External (modern) interferences

The presence of a modern magnetic interference on site and close to the feature to be sampled can render it unusable for archaeomagnetic dating. Alteration of the initial TRM can be significant in the presence of such strong magnetic fields (like those found in the vicinity of high voltage underground or aerial power lines). Also, on site orientation using a high accuracy magnetic compass is not possible near strong magnetic fields generated by modern pipelines, heavy machinery specific to modern construction sites and so on. Not least, the destructive nature of an archaeological dig can render a feature unusable, like the common half sectioning procedure normally applied to such a structure. It is often the case that the removed half contained more viable material or that this removal and the actual excavation by archaeologists has altered the feature's "true" in situ position. The preservation of such a structure after it has been revealed from the soil matrix until the specialist arrives and the prevention of rapid drying processes (by avoiding prolonged exposure to sun heat and atmospheric conditions) are crucial to the success of the later sampling visit. It is therefore very important that the archaeologist informs the specialist early on, and allows for a proper detailed study of the entire feature, sometimes making full use of the experience of an archaeomagnetist on such features, upon his arrival on site.

Construction of the Romanian calibration curve

For the current state of research it is imperative that most of the features that provided viable archaeomagnetic data to have been previously dated by other methods, as precisely as possible. This existent date (scientific or archaeological) is absolutely necessary in the process of building the calibration curve for future dating purposes. The curve is constructed from such well-dated magnetic references until the whole data set acquired allows for an appropriate estimation of the evolution of the geomagnetic field through time, with as little as possible error. It is also essential that this type of magnetic data, already dated by other means, to cover as much as possible all periods in time and to be as evenly spread as possible, avoiding gap periods. A summary of the essential conditions for the suitability of a feature is found at the end of this article, as a table.

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Important note: In the event of finding such suitable features please contact the Systemic Archaeology Institute at tel. 0258/817071 int. 208, facsimile 0258/818459 or the Archaeomagnetic Dating Laboratory researcher directly, at mobile 0768844465 and email: calinsuteu@yahoo.com to arrange a site visit or a discussion on the topic. If a feature was found please attach to your email several digital pictures of the feature(s) in question for an informed discussion. Please feel free to advertise among colleagues the benefits of this cooperation. The services provided are free of charge for the moment (external funding) but accommodation arrangements on site are needed for the specialist for the entire duration of sampling visit. A provisional dating can be made on the feature if reliable magnetic data is retrieved, based on the calibration curves of Bulgaria and/or Hungary, at a later date and depending on the laboratory scheduled priorities.

	Good	Acceptable	Unacceptable
Features	hearths, fireplaces, industrial kilns (pottery, glass, brick and tile, lime), baking ovens, smelting furnaces etc	temporary campfires, in situ incineration burial, burnt pits for cereal storage, combustion chambers (hypocaust)	tilted burnt clay walls, dislocated parts of hearths, kilns, non-in situ cremations, dislocated burnt soil
Magnetic mineralogy and temperature indicators (colour, hardness)	Strong oxidation / reducing firing shown by strong orange, pink, red and black colourings; deeply hardened and coloured clays, over 5 cm in depth; sometimes surface vitrification is present.	Medium oxidation / reducing firing shown by brownish to red coloured clays, with penetration of colour in the soil, up to 4 cm; hardened surface crust with fine but compacted red soil underneath.	Slightly burnt and locally red speckled soil, lots of charcoal and ashes with no smooth hard surface; penetration of colour in soil is less than 2 cm.
In situ position of feature from last firing event; size and state of preserved remains	Large, contiguous and level surfaces, compacted material – no significant surface cracks; no cutting contexts nearby; feature is to be fully excavated (to be removed).	Partial remains of features with slightly compacted material displaying cracks and tilted areas; partially cut context; features built on uncertain beds (river stones); feature to be preserved in situ / museum.	Dislocated parts of burnt features, tilted areas, reused materials; cutting contexts present.
Association of interest date with event; use as calibration data	Scientifically dated on directly associated contexts, coin dating; date looked after represents the last firing event/use of the feature.	Archaeologically dated context based on typology of pottery/ metal artefacts and relation to scientifically dated nearby similar sites; event to be dated can be associated to last firing.	No available archaeological context information; uncertain age, isolated contexts.
External modern interferences; archaeological intervention	Remote sites with one deep habitation layer; not half- sectioned and protected from atmospheric conditions; systematic excavation and informed archaeologists.	Multi-layered sites with deep layers; rural area; preventive and rescue excavations; informed archaeologist supervisor.	Multi-layered, deeply cutting upper strata, deep ploughing; mechanical excavation; construction site above or nearby; pipe and power lines nearby.
Solution	contact archaeomagnetic lab for a urgent site visit	contact archaeomagnetic lab for a discussion / site visit	contact archaeomagnetic lab for discussion and future cooperation
Possible outcome	dating of feature, use for calibration curve	dating of feature, probable use for calibration curve	not usable for calibration curve