# *Archaeomagnetic dating: Examples from Euboea-Attica and the missing link between the central Greek mainland and the islands*

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***Περίληψη***

Ο αρχαιομαγνητισμός αποτελεί έναν κλάδο που συνδυάζει τη γεωφυσική με την αρχαιολογία και έχει διάφορες εφαρμογές, με πιο γνωστή τη χρονολόγηση θέσεων μέσω της μελέτης του γεωμαγνητικού πεδίου του παρελθόντος, όπως καταγράφεται στους ψημένους πηλούς που περιέχουν οξείδια του σιδήρου. Αφού θερμανθούν σε υψηλές θερμοκρασίες και στη συνέχεια ψυχθούν, αυτά τα οξείδια καταγράφουν την διεύθυνση και την ένταση του μαγνητικού πεδίου της γης στον τόπο και χρόνο της διαδικασίας. Αυτή η πληροφορία μπορεί να ανακτηθεί και έχει διπλή εφαρμογή: (1) εάν η χρονολόγηση του υλικού που μελετήθηκε βασίζεται σε ανεξάρτητες μεθόδους, τα αποτελέσματα μπορούν να χρησιμοποιηθούν ως σημεία αναφοράς για τη δημιουργία ή Καμπύλων Αιώνιας Μεταβολής (Secular Variation Curves (SVCs)) για την περιοχή, (2) εάν το υλικό είναι αβέβαιης χρονολόγησης, τότε αυτές οι καμπύλες, όταν είναι διαθέσιμες, μπορούν να χρησιμοποιηθούν για τη χρονολόγησή του, με μικρό κόστος και βαθμό φθοράς.

Η συστηματική έρευνα στην Ελλάδα κατά τις δύο τελευταίες δεκαετίες έχει προσφέρει σημαντικά δεδομένα και αρκούντως προσδιορισμένες SVC, οι οποίες ωστόσο έχουν ακόμη αρκετά κενά. Η άνιση κατανομή των μελετημένων θέσεων είναι συχνά ένα πρόβλημα που χρειάζεται επίλυση. Η μελέτη στις περιοχές της κεντρικής Ελλάδας, της Εύβοιας και των νησιών είναι ελλιπής και είναι αναγκαίο να καλυφθούν τα κενά αυτά. Δημοσιευμένα αποτελέσματα από προηγούμενες μελέτες στην ευρύτερη περιοχή προέρχονται από τον Evans[1], ο οποίος μελέτησε δύο κλιβάνους αμφίβολης χρονολόγησης από την Ερέτρια και την Αυλίδα. Με τη χρήση των προσφάτως ενημερωμένων SVC για την Ελλάδα, σε συνδυασμό με αυτές των Βαλκανίων και της Ευρώπης, στην παρούσα εργασία προχωρήσαμε στη χρονολόγηση των δύο αυτών θέσεων, με αποτέλεσμα ηλικίες που συγκλίνουν με τις προτεινόμενες αρχαιολογικές σε έναν ικανοποιητικό βαθμό. Νέα αποτελέσματα επακριβώς χρονολογημένου υλικού δημοσιεύθηκαν για τη Νεολιθική Θεσσαλία[2], ωστόσο μία συνέχεια μεταξύ της νοτίου Ελλάδος, των νησιών και της κεντρικής Ελλάδος πρέπει να δημιουργηθεί στο προσεχές μέλλον.

1. Evans 2006.
2. Aidona and Kondopoulou 2012; Fanjat et al. 2013.

## *Introduction*[3]

Nowadays, it is well known that the Earth is surrounded by a magnetic field, which acts as a natural shield against solar and cosmic radiation. The origin of this field lies in the Earth's outer, liquid core, and its properties have numerous applications in various disciplines.

Earth sciences interact considerably in studies in this field, intersecting through geomagnetism, and expanding also towards the study of the magnetic field of other planets.

Archaeomagnetism is a branch of geomagnetism which combines magnetic methods with archaeology in order to determine geomagnetic field elements (the angles of inclination and declination, and the strength or intensity) in historic and prehistoric times. This method is based on two fundamental principles:

1) Several archaeological artefacts (usually baked clay products) contain small quantities of magnetic minerals which can record the direction and the intensity of the geomagnetic field under certain conditions, such as, for example, the heating of the material at least to 500°- 600°C. During the cooling procedure, a thermal remanent magnetization is acquired, with the direction oriented parallel to that of the ambient Earth's magnetic field at that place and time.

2) The direction and the intensity of the geomagnetic field are not stable but change continuously chronologically and geographically.

By comparing the archaeomagnetic direction and intensity registered by an archaeological artefact with well-established reference curves (SVCs) for the same area, it is possible to determine the age of the studied structure. By the inverse procedure, well-dated by independent methods such as $^{14}C$ or Thermoluminescence/Optical Luminescence, artefacts can be used for the construction of the reference curves for a certain geographical area. Archaeological structures or artefacts that can be used for an archaeomagnetic investigation are mainly kilns, bricks, tiles, ceramics and generally all clay structures that have been heated in antiquity to high temperatures and subsequently cooled.

Systematic archaeomagnetic studies in Greece were initiated around the 1980s and provided abundant archaeointensity and fewer directional data, which allowed for the construction of reference SVCs for Greece.[4]

Apart from the local reference curves, which are built using data from a certain country or geographical area, e.g. Greek, Bulgarian, French, nowadays reference curves are also calculated through regional and global geomagnetic field modelling.

Over the last ten years several compilations and models have been published which describe the geomagnetic field variations on a global scale.[5] In some of them, sediment datasets have been tentatively used. Of these models, Korte et al.[6] suggest that the ARCH3K.1 (only archaeomagnetic data) global model is the most appropriate for Europe for the last 3000 years. For older times, the CALS7K.2 global model that covers the past 7000 years, from 5000 BC to AD 1950, is mostly used.[7]

An intermediate approach between global models and local SVCs is the calculation of regional mod-

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3. Over the almost 20 years of our archaeomagnetic research in Greece we have been guided and assisted by several people and teams. We mention particularly the Ephorates of northern Greece and Thessaly, whose contribution has been decisive, the Department of History and Archaeology at Aristotle University, the French School in Athens and the INSTAP Centre. S. Müller-Celka provided important information and bibliography about the archaeological context of the Eretria kiln. We further thank the Norwegian Institute at Athens, and the Ephorate of Antiquities for Euboea for organizing this scientific conference, their hospitality and the opportunity to disseminate our results. An anonymous reviewer is also acknowledged for comments and suggestions.

4. Evans 2006; De Marco 2007; De Marco et al. 2008 and references therein. See also Aidona and Kondopoulou 2012; Fanjat et al. 2013; De Marco et al. 2014; Spatharas et al. 2011; Tema et al. 2012 and references therein.

5. Donadini et al. 2009; Genevey et al. 2008; Korte and Constable 2005.

6. Korte et al. 2009.

7. Korte and Constable 2005.

els. Pavón-Carrasco et al. proposed a regional archaeomagnetic model, the SCHA.DIF.3K that calculates the geomagnetic field variations in Europe for the last 3000 years, modelling together the three geomagnetic field elements.[8] In order to extend this model's predictions backwards in time, Pavón-Carrasco et al. have proposed the SCHA.DIF.8K regional model, which is based on a selected compilation of both sedimentary and archaeomagnetic data and predicts the geomagnetic field variations from 6000 BC to 1000 BC.[9]

Recently, Tema and Kondopoulou monitored the secular variation of the geomagnetic field in the southern Balkan Peninsula and provided a complete pattern for the regional field evolution over the last 8000 years.[10] Nevertheless, and in spite of the above multiple achievements, building accurate SVCs on a local (country-wide) scale remains an important target. The improvement of the Greek reference curves for declinations and inclinations depends on the availability of adequate, well-dated archaeological materials, since their geographic and temporal distribution present important gaps, e.g. in central Greece and the islands of the eastern Aegean, but also in western Turkey, such data are almost totally missing (Fig. 1).

In the present study we attempt to date, based on the existing reference curves, two structures from the broader area of Euboea/eastern Attica, which were previously studied by Evans[11] but had a disputable archaeological age. The potential and the limitations of the method are discussed by presenting the archaeomagnetic dating of a Neolithic settlement in central Thessaly, where an accurate $^{14}C$ age is available, making a comparison of the two results possible.

The archaeomagnetic method is promising, and improvements are being made in order to provide the archaeological community with a sensitive and low-cost dating tool. These improvements are mostly related to the accuracy of the existing reference curves, and therefore the acquisition of new data remains an important target.

### *Methodology*

The geomagnetic field can be described as a vector defined at each specific place for a specific time.

The archaeomagnetic method deals with the definition of the three elements of the geomagnetic field vector (the angles of declination [D], inclination [I] and intensity [F]). In order to define the direction of the field (D, I), the studied material has to be *in situ*, a requirement which is not necessary for the calculation of the intensity. Sampling of *in situ* structures includes orientation with a magnetic and sun compass, and measurement of the dip with an inclinometer, and is followed by sample preparation in the laboratory in order to obtain cylinders of standard dimensions of 2.5 x 2.2 cm.

Measuring the 'archaeodirection' involves several steps, such as the initial measurement of the natural remanent magnetization, subsequent magnetic cleaning of possible secondary components, tests for the stability of the recorded magnetization and the calculation of the statistical mean direction. The dating of the structure based on the above elements is the final step and is performed by comparing the experimentally determined direction with a reference SV curve. In order to obtain the optimum dating, the calculation of the archaeointensity plays an important role. This calculation is related to a specific laboratory procedure, involving numerous heating/cooling cycles and the continuous monitoring of mineralogical transformations that are likely to severely reduce the experiment's success. For the two cases presented here, the archaeointensity value has not been calculated and dating is performed based only on the directional results.

8. Pavón-Carrasco et al. 2009.
9. Pavón-Carrasco et al. 2010.
10. Tema and Kondopoulou 2011.
11. Evans 2006.

## *Data*

*Eretria*

This pottery kiln was excavated at Eretria, within the Bouratza plot, in the early 1980s and was restored and preserved in the museum's courtyard. It is an important finding of updraft combustion with a well-preserved *eschara* of about 95 cm in diameter. The kiln was found within an Early Bronze Age (EBA) II-III stratum, but in a disturbed context, in contact with a seemingly non-disturbed burial of Geometric date, and the excavator suggested an earlier age for the kiln.[12] According to recent archaeological information, the excavation record is more compatible with an Early Helladic (EH) III date—c.2300-2100 BC—although a later date is not to be completely ruled out.[13] Sampling was undertaken in 1992 and measurements reported by Evans[14] are as follows:

Inclination and declination reduced to Athens (lat.=37.96°; long.=23.79°):

| Site | Lat. (°) | Long. (°) | I site (°) | D site (°) | I Athens (°) | D Athens (°) | K/sI | N | $\alpha_{95}$(°) |
|---|---|---|---|---|---|---|---|---|---|
| Eretria | 38.44 | 23.79 | 58.0 | 0.6 | 57.6 | 0.6 | 406 | 5 | 3.1 |

Table 1: Inclination and declination (Eretria) reduced to Athens (lat.=37.96°; long.=23.79°).

*Avlis*

This ceramic kiln was unearthed in the late 1950s within a broader sector which included a temple dedicated to Artemis, built in the 5th century BC, but with Hellenistic and Roman rebuilding phases. The pear-shaped kiln with internal dimensions of 3 x 1.80 m lies within an important building with traces of clay processing. Several artefacts used for domestic purposes found inside the kiln were dated to the Roman period by early excavators, although an earlier phase has also been suggested. Non-fired whole pots were found within the firing chamber, implying that the kiln was abandoned before a firing happened.[15] In the following campaigns of 1960 and 1961, further evidence for the existence of an important potter's workshop was found. Numerous sherds dated to Hellenistic times, together with coins of the same period, better define the chronological use of the workshop.[16] Sampling was also undertaken by Evans in 1992 and the results reported by the author in 2006 are as follows:

| Site | Lat. (°) | Long. (°) | I site (°) | D site (°) | I Athens (°) | D Athens (°) | K/sI | N | $\alpha_{95}$ (°) |
|---|---|---|---|---|---|---|---|---|---|
| Avlis | 38.50 | 23.67 | 62.5 | 353.1 | 62.1 | 353.2 | 226 | 6 | 4.5 |

Table 2: Inclination and declination (Avlis) reduced to Athens (lat.=37.96°; long.=23.79°).

On the basis of the above results, the dating of the two structures was recently performed using the Bayesian approach.[17] For the Eretria kiln, this dating was modified in the present contribution to fit the new archaeological information, and is displayed in Fig. 2.

12. Krause 1981, 83-84; 1982, 158-160.
13. Müller-Celka 2010, and pers. comm. 2014.
14. Evans 2006.
15. Threpsiadis 1959.
16. Threpsiadis 1961.
17. De Marco et al. 2014.

Since the inclination and declination are acquired at the same time, during the last firing of the kiln, we can combine them to obtain the final dating rectangles plotted. Rectangles plotted onto the posterior density represent the highest posterior density (HPD) intervals at a 95% confidence level. The probabilities of each of the intervals are: [-2179; -1992] at 7%; [-1670; -1513] at 16%; [-1187; -734] at 10% [-190; 35] at 6% and [461; 1349] at 51%. The true dating solution is in one of these intervals. Evans[18] suggested that 'this kiln ceased operation in Late Helladic I/II times (~1500 BC)', and this restriction was taken into account by De Marco et al.[19] Therefore, the last two options were rejected, since the site was abandoned at the beginning of the 2nd century BC. The next interval [-1187; -734] could be compatible with the excavation information only if 'weight' is put on the possible installation of the kiln at a period contemporaneous or post-dating the necropolis of the Geometric age. The period [-1670; -1513] is very unlikely since the Bouratza plot did not provide a single sherd from this period. Considering the recent input about the archaeological context, as cited above, we adapted the choice of the time period covering our dating procedure. The best-fitting result indicates a shift to an earlier interval [-2179;-1992]. This, nevertheless, should be confirmed by an independent method, either thermoluminescence (TL) or optically stimulated luminescence (OSL), since the previously suggested dating by De Marco et al. cannot be rejected on the basis of statistics.[20]

For the Avlis kiln, the dating is displayed in Fig. 3. The probabilities of each of the dating intervals are: [-2180; -2103] at 1%; [-1592; -1115] at 35%; [-978; -281] at 52% and [726; 1074] at 7%. The true dating solution is in one of these intervals. Taking into account the archaeological information assuming a Hellenistic or at least 'post-Classical' date for its use, it is suggested that the kiln was used for the last time during the interval [-978;-281]. In this case, archaeomagnetism cannot be more precise because of a 'plateau' effect (little variation) in the inclination curve between 1500 and 400 BC, which seriously reduces the effectiveness of the dating.

In order to further investigate the possibilities of the method, we repeated the dating of these two structures using the regional reference curves: first, that proposed for the Balkans by Tema and Kondopoulou[21] and second, that proposed for Europe by Pavón-Carasco et al.[22] For easier comparison we chose the same time intervals for both, which are compatible with the archaeological constraint, [-1000; -5900] for Eretria and [-1000; 1000] for Avlis.

Using the Balkan SV curve, we obtained several time spans for Eretria, two of which are likely to be retained (Fig. 4a). One indicates an age between 2415 BC and 2023 BC and the second one between 1628 BC and 1239 BC. Given the archaeological context, the first one (2415 BC-2023 BC) is favoured by us. On the other hand, dating with the SCH.DIF.8K geomagnetic field model (Fig. 4b) results in a much wider dating interval (2790 BC-1172 BC), but includes the period recently supported by archaeologists. These results demonstrate that the regional reference curves for time periods earlier than 1000 BC are not detailed enough for dating purposes, and all need new data from the periods before that age.

For the site of Avlis, the dating results from the Greek and Balkan SV curves are comparable—(978 BC-281 BC) and (699 BC-248 BC), respectively (Fig. 5)—though the Balkan dating reduces the time span by almost 250 years. If we observe all probabilities in Fig. 3 and Fig. 5a, we notice that none lies within 248 BC to AD 621. Therefore, on the basis of this model, the kiln's last use could not be dated to Roman times.

On the other hand, the SCHA.DIF.3K model in Fig. 5b results in a date of 492 BC-59 BC. This is narrower by 400 years than the one obtained by the Greek curves and fits in a satisfactory way with

18. Evans 2006, 94.
19. De Marco et al. 2014
20. De Marco et al. 2014.
21. Tema and Kondopoulou 2011.
22. Pavón-Carasco et al. 2010.

the dating suggested by the Balkan curves, though the present one gives an age which has shifted to later (younger) chronological periods. It is noteworthy that again in this model, no probability appears between 59 BC and AD 528. Thus, we can safely exclude a clear Roman age for this kiln and suggest that its last use was during the Hellenistic or possibly the beginning of Roman times. The fact that during 600-100 BC the declination of the Earth's magnetic field exhibits very small variations and is mainly characterized by stable values for more than five centuries, could have affected the dating. We claim that the very uncertain age for the Avlis kiln is now better constrained by situating it chronologically before the Roman period. The excavation information provided by Threpsiadis converges with this result.[23] In such cases, the calculation of the archaeointensity can provide a decisive contribution. Unfortunately, both samplings cited above were performed long ago and no available material exists any more.

***Discussion/conclusions***

The archaeomagnetic method has continuously developed over the last decade, and applications, both geophysical and archaeological, are now being established. Nevertheless, there is still ground for further improvements, and a demonstration of the potential and limitations is provided in this contribution. To start from the first step of such a study—the sampling—the two sites presented here were sampled more than 20 years ago, under severe restrictions. Hence, the quantity of the material did not allow for the study of the full geomagnetic vector, since it was not possible to perform archaeointensity experiments. At the same time, there was little or no interaction with archaeologists, leading to uncertain dating constraints. The next step for successful dating would be the establishment of more precise reference curves and, to achieve this, the use of well-dated material by independent methods is crucial.

The conclusions to which this presentation points are as follows: the archaeomagnetic dating of the Eretria kiln suggests that with the present state of knowledge and quality of the reference curves it is impossible to firmly posit the best time span for the last use of this kiln. The earlier age favoured by the archaeologists 2300-2100 BC is likely, but the interval 1187-734 BC cannot be excluded.

For Avlis, the contribution of archaeomagnetism is more substantial, since it leads to a better definition of the kiln's last use, and the more recent Roman period is excluded in terms of the kiln's functioning. There is a time period in which all three datings overlap, between 492 BC and 281 BC. This includes Hellenistic times, as supported by archaeological findings. Given that there is evidence of an abrupt interruption in its use, we may suggest that a violent event was responsible, occurring at the latest around 59 BC.

It is clear that there is much more to be undertaken in our discipline, but for improvements to be made the contribution of the archaeological community is of paramount importance. As an example, we cite the result of a similar dating for two Neolithic structures in central Thessaly (at Vassili): these were sampled with the guidance of the excavator (G. Toufexis) and his team, who allowed us to take a considerable amount of material, leading to a successful study and dating.

The dating of the studied Neolithic site was performed using the Bulgarian reference curves of the full geomagnetic vector (declination, inclination, intensity), which almost cover the last eight millennia.[24] The archaeomagnetic dating for Vassili was calculated at 4970-4680 BC at a 95% confidence level. According to archaeological information and $^{14}C$ dating of the same structures, their expected age is estimated at c.4750 BC, and thus the archaeomagnetic dating converges very well with this independent-

23. Threpsiadis 1961.
24. Kovacheva et al. 2009.

ly calculated age.[25] The result from this Neolithic site in Thessaly is the only one to be published for this period, but also for the broader area of central Greece. It is clear that there is an important 'missing link' between the islands of southern Greece, which have provided numerous archaeomagnetic directional results, and central Greece, which lacks such data. Satisfactory coverage also exists further to the north. Our target is to fill this gap with the support of the archaeological community, Greek and foreign, which has been active in the area for many decades.

25. Fanjat et al. 2013.

## *Bibliography*


Aidona, E. and D. Kondopoulou (2012) 'First archaeomagnetic results and dating of Neolithic structures in northern Greece'. *Studia Geophysica et Geodaetica* 56, 827-844: doi:10.1007/s11200-011-9006-8.

De Marco, E. (2007) 'Complete magnetic and archaeomagnetic measurements in archaeological sites: contribution to the SVC for Greece'. PhD thesis. Aristotle University of Thessaloniki, Greece.

De Marco, E., V. Spatharas, M. Gómez-Paccard, A. Chauvin and D. Kondopoulou (2008) 'New archaeointensity results from archaeological sites and variation of the geomagnetic field intensity for the last 7 millennia in Greece'. *Physics and Chemistry of the Earth* 33, 578-595.

De Marco, E., E. Tema, P. Lanos and D. Kondopoulou (2014) 'An updated catalogue of Greek archaeomagnetic data for the last 4500 years and a directional secular variation curve'. *Studia Geophysica et Geodaetica* 58, 121-147.

Donadini, F., M. Korte and C. G. Constable (2009) 'Geomagnetic field for 0-3 ka: 1. New data sets for global modelling'. *Geochemistry, Geophysics, Geosystems ($G^3$)* 10, Q06007: doi:10.1029/2008GC002295.

Evans, M. E. (2006) 'Archaeomagnetic investigations in Greece and their bearing on geomagnetic secular variation'. *Physics of the Earth and Planetary Interiors* 159, 90-95: doi:10.1016/j.pepi.2006.06.005

Fanjat, G., E. Aidona, D. Kondopoulou, P. Camps, C. Rathossi and T. Poidras (2013) 'Archaeointensities in Greece during the Neolithic period: New insights into material selection and secular variation curve'. *Physics of the Earth and Planetary Interiors* 159, 29-42: doi:http://dx.doi.org/10.1016/j.pepi.2012.10.011.

Genevey, A., Y. Gallet, C. Constable, M. Korte and G. Hulot (2008) 'ArcheoInt: An upgraded compilation of geomagnetic field intensity data for the past ten millennia and its application to recovery of the past dipole moment'. *Geochemistry, Geophysics, Geosystems ($G^3$)* 9, Q04038: doi: 10.1029/2007GC001881.

Korte, M. and C. G. Constable (2005) 'Continuous geomagnetic field models for the past 7 millennia: 2.CALS7K'. *Geochemistry, Geophysics, Geosystems ($G^3$)* 6, Q02H16: doi: 10.1029/2004GC000801.

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

Kovacheva, M., Y. Boyadziev, M. Kostadinova-Avramova, N. Jordanova and F. Donadini (2009) 'Updated archaeomagnetic data set of the past 8 millennia from the Sofia laboratory, Bulgaria'. *Geochemistry, Geophysics, Geosystems ($G^3$)* 10, Q05002: doi: 10.1029/2008GC002347.

Krause, C. (1981) 'Eretria: Ausgrabungen 1979-1980'. *Antike Kunst* 24, 83-84.

Krause, C. (1982) 'Eretria: Ausgrabungen 1981'. *Antike Kunst* 25,158-160.

Lanos, P. (2004) 'Bayesian inference of calibration curves: application to archaeomagnetism'. In *Tools for Constructing Chronologies, Crossing Disciplinary Boundaries*, edited by C. E. Buck and A. R. Millard, 43-82. London: Springer-Verlag.

Müller-Celka, S. (2010) 'Avant la cité'. In *Cité sous Terre. Des archéologues Suisses explorent la cité grecque d'Erétrie,* edited by C. M. Prouvot, 50-55, 86-88. Gollion: Infolio editions.

Pavón-Carrasco, F. J., M. L. Osete and J. M. Torta (2010) 'Regional modelling of the geomagnetic field in Europe from 6000 BC to 1000 BC'. *Geochemistry, Geophysics, Geosystems ($G^3$)* 11, Q11008: doi: 10.1029/2010GC003197.

Pavón-Carrasco, F. J., M. L. Osete, J. M. Torta and L. R. Gaya-Piqué (2009) 'A regional archaeomagnetic model for Europe for the last 3000 years, SCHA.DIF.3K: applications to archaeomagnetic dating'. *Geochemistry, Geophysics, Geosystems ($G^3$)* 10(3), Q03013: doi:10.1029/2008GC002244.

Spatharas, V., D. Kondopoulou, E. Aidona and K. Efthimiadis (2011) 'New magnetic mineralogy and archaeointensity results from Greek kilns and baked clays'. *Studia Geophysica et Geodaetica* 55, 131-157.

Tema, E. and D. Kondopoulou (2011) 'Secular variation of the Earth's magnetic field in the Balkan region during the last eight millennia based on archaeomagnetic data'. *Geophysical Journal International* 186, 603-614: doi: 10.1111/j.1365-246X.2011.05088.x.

Tema, E., M. Gómez-Paccard, D. Kondopoulou and Y. Almar. (2012) 'Intensity of the Earth's magnetic field in Greece during the last five millennia: New data from Greek pottery'. *Physics of the Earth and Planetary Interiors* 202-203, 14-26: doi:10.1016/j.pepi.2012.01.12.

Threpsiadis, I. (1959) 'Ανασκαφαί Αυλίδος'. *Πρακτικά της εν Αθήναις Αρχαιολογικής Εταιρείας* 1959, 26-33.

Threpsiadis, I. (1961) 'Ανασκαφαί Αυλίδος'. *Πρακτικά της εν Αθήναις Αρχαιολογικής Εταιρείας* 1961, 39-44.

## *Figures*

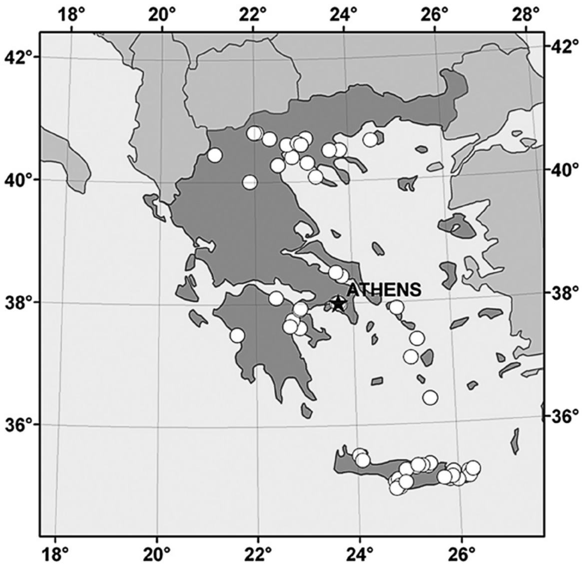


*Figure 1.*
Geographic distribution of the Greek archaeological sites with available directional data (De Marco et al. 2014).

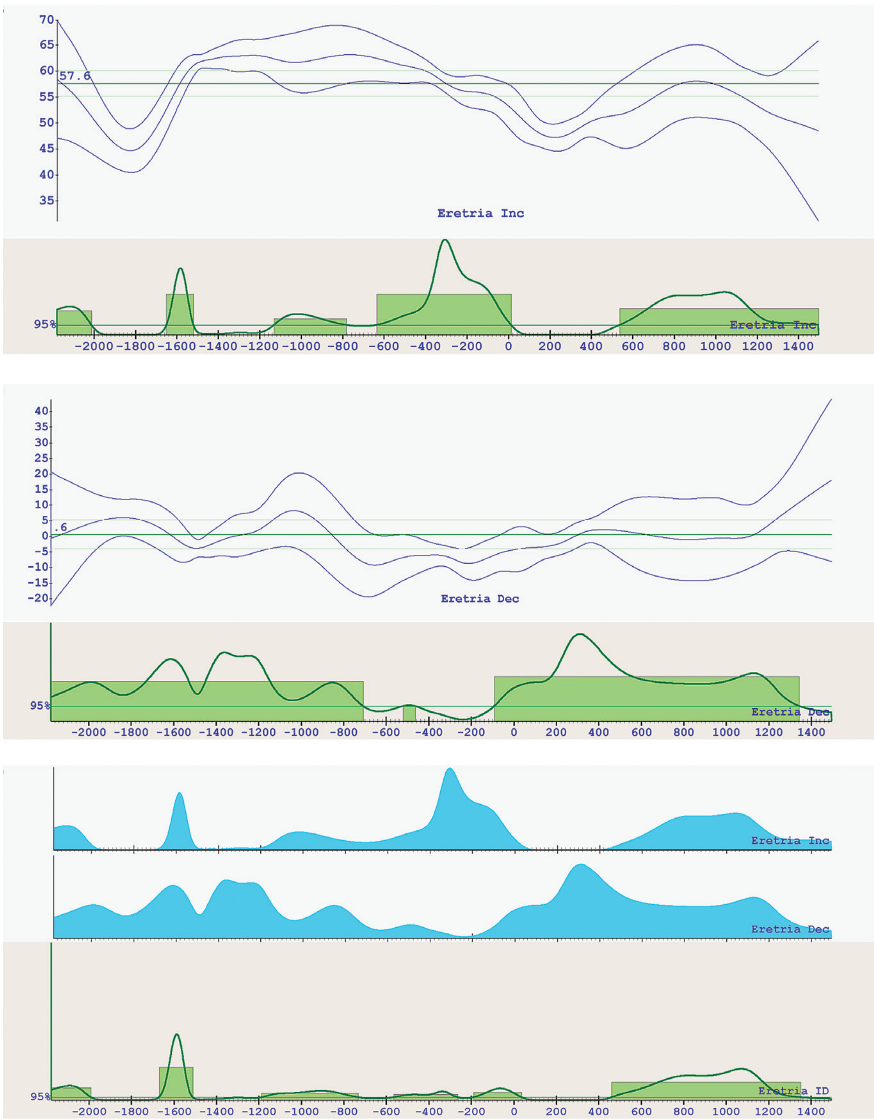


*Figure 2.*
Dating results obtained for the Eretria kiln with the Greek reference SV curve (Adapted from De Marco et al. 2014).

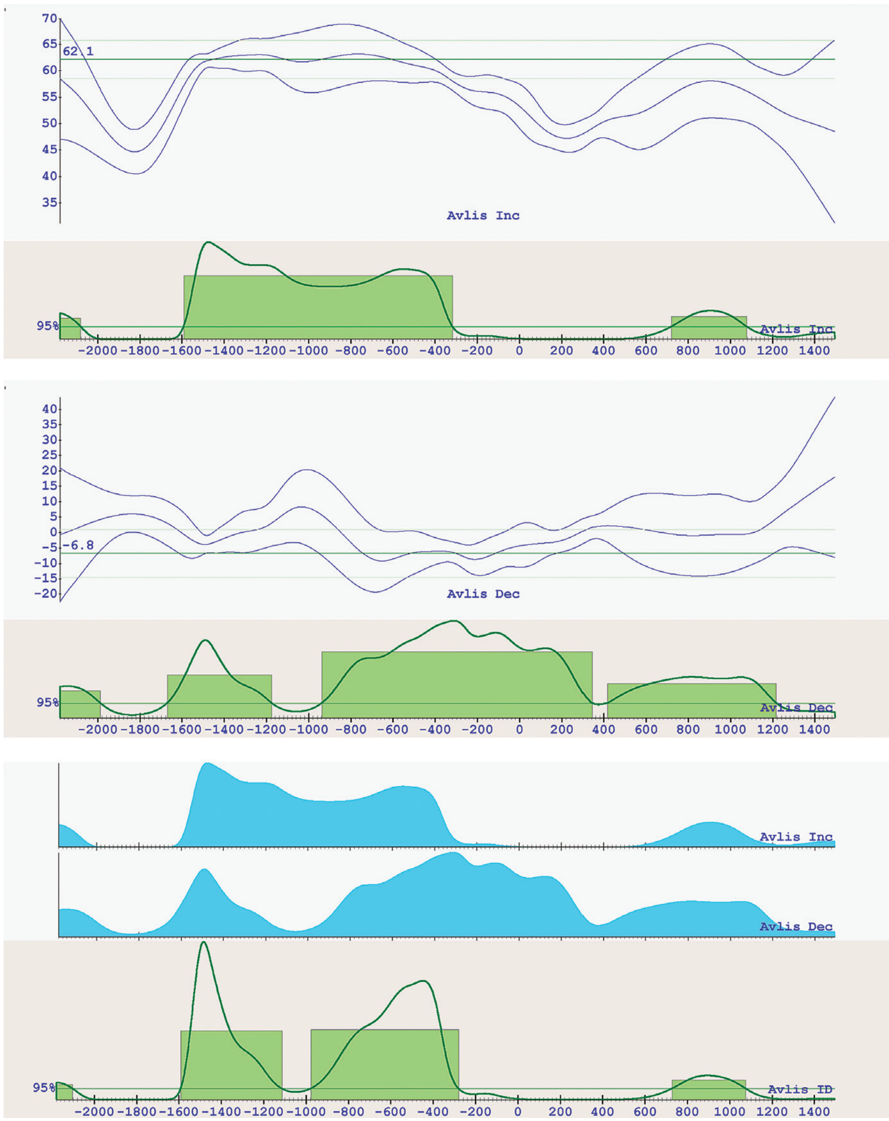


*Figure 3.* Dating results obtained for the Avlis kiln with the Greek reference SV curve (De Marco et al. 2014).

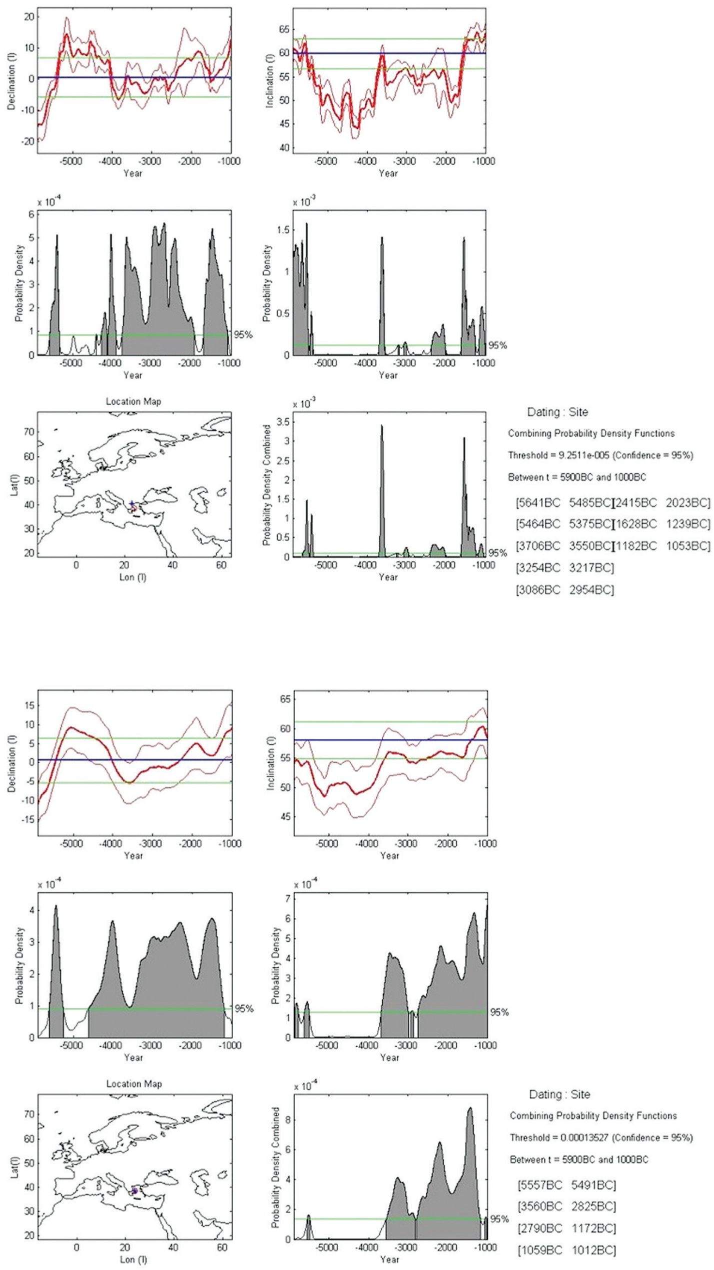


*Figure 4.* Dating of the Eretria kiln with the Balkan and European Regional reference curves.

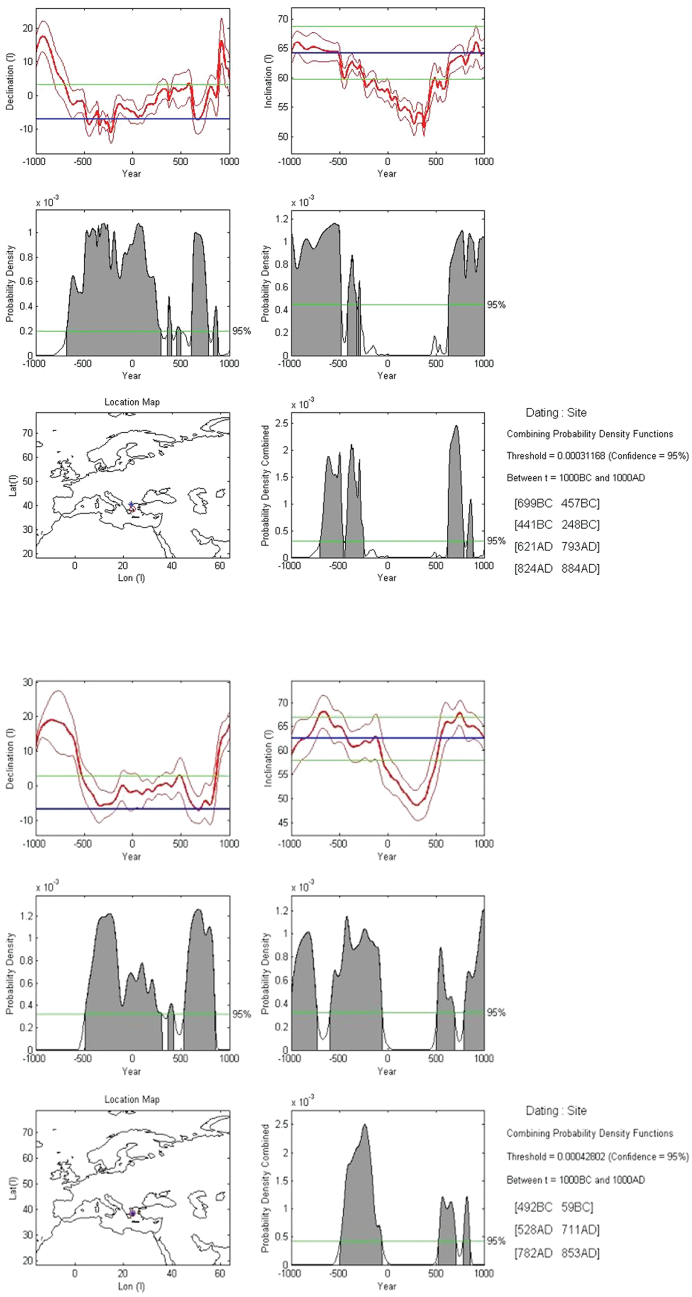


*Figure 5.* Dating of the Avlis kiln with the Balkan and European regional reference curves.