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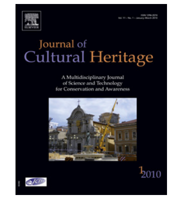

Original article

Dating of ancient kilns: A combined archaeomagnetic and thermoluminescence analysis applied to a brick workshop at Kato Achaia, Greece

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ABSTRACT

We present here the results of a detailed archaeomagnetic and thermoluminescence investigation performed on bricks from two ancient kilns excavated at Kato Achaia, Greece. Magnetic mineralogy measurements have been carried out to determine the main magnetic carrier of the samples. The directions of the characteristic remanent magnetization of each structure have been obtained from standard thermal demagnetisation procedures and the absolute archaeointensity has been determined with the Thellier modified by Coe method, accompanied by regular partial thermoremanent magnetization (pTRM) checks. The full geomagnetic field vector was used for the archaeomagnetic dating of the two kilns, after comparison with the reference secular variation curves calculated directly at the site of Kato Achaia. Independent dating has also been obtained from thermoluminescence (TL) analysis on four brick samples from each kiln. The dating results obtained from the two methods have been compared and the last firing of each kiln has been estimated from the combination of the two techniques. Using the independent date offered by TL dating, the new archaeomagnetic data have been compared with other data from the same time period and they can further be used as reference points to enrich our knowledge about the past secular variation of the Earth's magnetic field in Greece.

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1. Introduction

Dating of archaeological remains is essential in archaeological research, in order to place in chronological order findings and civilizations. Inscribed objects sometimes bear an explicit date, or preserve the name of a known individual (e.g. a king or an emperor). However, this is not always the case and often the contribution of a scientific dating technique is necessary. During the last decades, several dating methods such as radiocarbon dating, obsidian hydration, dendrochronology, potassium-argon, archaeomagnetic and luminescence dating have been increasingly used in archaeology. Each one of these dating techniques however has its own advantages and limitations, mostly related to the availability of appropriate material, the type and characteristics of the studied samples, their preservation conditions and the chronological period. For this reason, when possible, the combination of more dating techniques together with the available archaeological evidence may offer the best approach for obtaining a more precise chronological framework for an archaeological site.

Archaeomagnetic dating is based on the principle that the magnetic minerals contained in many baked clay archaeological artefacts (e.g., kilns, hearths, bricks, pottery), when heated at high temperatures and cooled in the presence of the Earth's magnetic field, may acquire a thermal remanent magnetization (TRM) with direction parallel and magnitude proportional to the ambient magnetic field. For the regions where a detailed reference secular variation (SV) curve is available, archaeomagnetic dating is possible after the comparison of the remanent magnetization measured on the undisturbed archaeological artefacts with the reference SV

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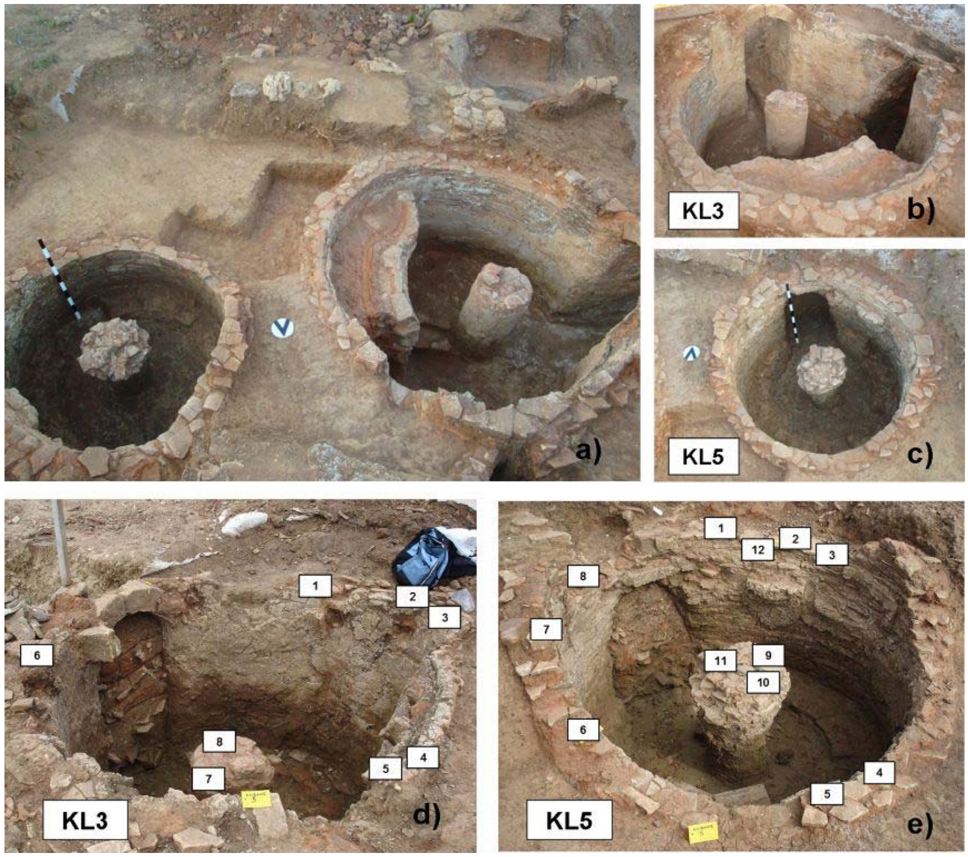

Fig. 1. a: General view of the studied kilns; b, c: kilns KL3 and KL5; d, e: location of the collected brick samples respectively.

curve. During last decades, important progress on archaeomagnetic dating has been done and it has been successfully applied in several case studies in the Mediterranean area, mainly involving the study of the direction of the geomagnetic field vector (e.g. [1–7]).

In an analogous way, luminescence dating is based on the fact that naturally-occurring minerals like quartz and feldspars act as natural dosimeters and preserve a record of irradiation dose, i.e. energy per unit mass, received through time. This dose results mainly from the decay of natural radionuclides, i.e., ^{232}Th, ^{40}K and natural U, along with cosmic rays, which provide a constant source of low-level ionizing radiation. The accumulated dose is stored by means of trapped charge in crystal defects, which is stable over long periods of time but can be released either by heating or exposing the crystal to light. This release can take place accidentally in a natural way or alternatively artificially, at the laboratory, giving thus rise to thermoluminescence (TL) and optically stimulated luminescence (OSL) respectively [8–10]. The brightness of the luminescence signal reflects the amount of trapped charge. Consequently, it is also proportional to the total irradiation dose accumulated and thus to the total age. The number of trapped electrons is increasing as long as the material is irradiated. However, every time that the material is subjected to prolonged heating (as in the case of firing pottery) or intense light exposure (as in the case of sunlight), electrons are evicted and traps are emptied. In that case, the signal is totally zeroed. Then, energy starts to accumulate in the form of trapped electrons in order to refill the empty traps once again. The total number of trapped electrons forms a luminescent "clock" which starts measuring from the beginning ($t = 0$) every time that these traps are zeroed. Therefore, light-exposed materials could be dated to their last exposure to light, while burnt materials to their last heating. Kilns belong to the latter case and TL can effectively date their last use.

Archaeomagnetic and TL dating techniques share the same rationale, dating exactly the same event that is the last heating of baked clay artefacts. Therefore, simultaneous application of both techniques to the same archaeological materials, such as bricks from kilns, yields the important advantage of crosschecking ages. Even though their combination can offer a powerful tool for dating of archaeological artefacts during Holocene, up to now such combined studies are extremely limited [6,11–13]. We present here the results of a detailed archaeomagnetic and TL investigation performed on bricks collected from the structure of two ancient kilns excavated at Kato Achaia, Greece. The dating results obtained from the two methods have been compared and the last firing of each kiln has been estimated from the combination of the two techniques. Using the independent date offered by TL dating, the new archaeomagnetic data can be further used as reference points at the construction of the secular variation of the Earth's magnetic field in the past.

2. Archaeological site and sampling

The studied kilns were discovered during the works for the establishment of the fundamentals of a new building in the corner of Parodos Ag. Ioannou and Papaflessa, Kato Achaia, and are part of the extensive ceramic workshop found in the west part of the ancient city of Dyme, situated at the same wide plateau of the modern city of Kato Achaia (38.15° N, 21.55° E), Peloponnese, Southern Greece. The archaeological research in this plot revealed a cluster of ceramic kilns of various dimensions with additions and modifications which denote the timeframe of function and activity of the workshop during the whole Hellenistic period. For the present study, two circular kilns were sampled, named KL3 and KL5 (Fig. 1).

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