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LUMINESCENCE DATING OF LIMESTONE WALLS AND POTTERY FROM ITHACA (SCHOOL OF HOMER); FIRST AGES

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ABSTRACT

Age estimation of two carbonate rock samples, using thermoluminescence (TL) technique, and two ceramic sherds using optically stimulated luminescence (OSL) was performed; all derived from School of Homer (Pelikata), on Ithaca Island, Greece. The first stone sample was collected from the east façade, the lower row of the Mansion (ITH-3), while sample ITH-4 derives from the outer circular wall of well-known archaeological age. The partial bleaching methodology of surface luminescence dating method using fine powder was applied for the equivalent dose determination. The ages given by the two carbonate rock samples (stairs and wall) were in the 2nd and 1st millennia BC; the two ceramics dated to late Byzantine era. Various experimental features concerning bleaching of the carbonate rock samples are discussed.

KEYWORDS: dose-rate, limestone, thermoluminescence, SAR-OSL, alpha counting, bleaching, plateau, equivalent dose.

1. INTRODUCTION

Ithaca was an important trading node during Bronze Age according to Papadopoulos and Kontorli-Papadopoulou, (2000). There is evidence for the presence of both the Minoans and the Mycenaeans on the island supported by the archaeological findings (Kontorli-Papadopoulou, 2000, 2002, Livitsanis, 2013). The archaeological site of "St Athanasios – School of Homer" is located in the Northern part of Ithaca, where the eastern slope of Exoghi mountain converge with the Pelikata hill, where the archaeological Museum of Ithaca is situated. The excavations were made under the supervision of the archaeologists of the Dept. of Archaeology, Univ. of Ioannina, Th. Papadopoulos and late L. Kontorli-Papadopoulou, in the years between 1994-2012 and they revealed findings, pottery shards, engraved with obvious characters that resemble linear writing symbols (Owens 1999; Kontorli-Papadopoulou et al., 2005; Kontorli-Papadopoulou, 2014-2015).

The entire region has been classified as having high archaeological significance, and the 750 square meter site contains the remnants of human habitation from the pre-Hellenistic and Mycenaean eras (Ferentinou 1976).

Under the direction of Professor W. A. Heurtley, the British School of Archaeology conducted in-depth investigations on what we previously knew to be significant archaeological sites in the island's north throughout the 1930s. His extensive and remarkable research (Heurtley 1939) served as the impetus for a more thorough analysis of this region's significance from an archaeological and historical standpoint. Professor Sarantis Symeonoglou and his team from Washington University in St. Louis, Missouri, headed the Odyssey Project, which involved further exploration of the southern regions of the island, including Aetos and Marmarospilia (Simeonoglou 1992). The Aetos series of vases and jars are the only examples of pre-geometric ceramic art in western Greece.

The Archaeological Museum in Vathy features several exhibits featuring this unique design, which has been dubbed the "Ithacan Pre-geometric style." The oldest settlement ruin in Aetos site is a circular structure that contains ceramic artifacts dated to 1400 BC. The Odyssey mentions the worship of Apollo at Ithaca, therefore it is likely that these foundation remnants and the surrounding area are connected to a sanctuary for him (Book 20, 277-278)[1]. A distinct image of an ancient, significant temple that is unmatched in the Ionian Sea is provided by S. Symeonoglou's reconstruction of the topographic data of the Aetos sanctuary.

Under the direction of late Professor Litsa Kontorli-Papadopoulou, a team from Ioannina University in Greece conducted excavations in the northern part of the island at Pelikata, or Homer's School. The British School of Archaeology's research from the 1930s revealed that human habitation continued at the location until the end of the Mycenaean period, or between 3000 and 12th century B.C. This group concluded that the location of Odysseus' kingdom's center was not far from what is now Stavros. She even describes the architectural setting of the site attributing them to the Homeric description of the palace on 'Terrace' or 'Andiron' the horizontal surface that was created, usually on the slopes of mountains, that supported a building or some other structure.

Based on the remains discovered nearby, archaeologists have inferred that the settlement was surrounded by a wall that dates back to the Mycenaean period. There are remnants of stone walls and a little stone road at the summit of Pelikata hill. However, a stockpile of sizable clay containers hidden beneath the stone floors of pre-Hellenistic homes was one of the site's most important finds (Ferentinou 1976; Heurtley 1939)

After discovering signs of human habitation here between 3000 and 2500 B.C., archaeologists are now convinced that this location formerly housed a walled pre-Hellenistic community. Ithaca's significance in the cultural and historical evolution of Western Greece is clear, since it is recognized as one of the very few pre-Hellenistic settlements on Greek territory.

According to W.A. Hartley, Ulysses' palace was located on the hill of Pelikata. Access to the site is not easy; a guide is necessary if someone wants to go to the remains of ancient walls (and fossilised bones) in what was once a cemetery. The artefacts from this site are on display in Stavros' archaeological collection (Heurtley 1939).

The Mycenaean presence in the Ionian Islands was early associated with Homeric epics, but at the time all references were thought to date to the Mycenaean period. However, after realizing that there are references to other periods, such as the Late Mycenaean period (1400-1411 B.C.). and the Protogeometric period (1100-800 B.C.), the debate inevitably widens and reconsideration was ought. Reliance on Mycenaean ruins was no longer sufficient, since the island called

[1] "So spoke Antinous, but Telemachus paid no heed to his words. Meanwhile the heralds were leading through the city the holy hecatomb of the gods, and the long-haired Achaeans gathered together beneath a shady grove of Apollo, the archer-god. But when they had roasted the outer flesh and drawn it off the spits,…", Perseus Digital Library (https://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0136%3Abook%3D20).

Ithaca by Homer had to show evidence of settlement from Protogeometric times.

Reliance on Mycenaean ruins was no longer sufficient, since the island called Ithaca by Homer had to show evidence of settlement from pre-Geometric times.

Ithaca is unique among the Ionian Islands in the sense that, ruins from the Mycenaean, Prehistoric, and Geometric periods can all be found here. There are numerous testimonies relating to all these periods, especially in the Loizos caves of Polis and Aetos. Ithaca is unique in offering such a witnessed proof, and in general the rich archaeological discoveries at Alarcomenes span two centuries from the 10th century BC[2] (Bikela 2010).

Early visits in Ithaca by antiquarian travelers have been reported (Livitsanis 2013 and references therein); the British geographer and antiquary William Gell, and the English Colonel William Martin Leake, in 1806 (Gell 1807, Leake, 1835) and Henry Schliemann in 1868 (Leake 2009). Some 60 years later, all include a full description of the inscription "ΟΔ". (Pazis-Danias, 2011). Today, visitors can easily identify the upper half of the letter O and the letter Δ. Each letter is around 27×33 cm. The rock is in the midst of the trail that begins at "Chordaki" in Aetos and leads to Agios Ioannis, a virtually horizontal road on Ithaca's western slopes between "Chani" and the coastal zone.

Moreover, the presence of two caves has fired even more the attribution to Ithaca as the island of the kingdom of Odysseus- Loizos cave and Marmarospilia or Nymphs Cave.

At the coast Loizos’ cave has been related to Odysseus. The first substantial activity in the cave occurred in the 1930s. Sylvia Benton led a team from the British School of Athens. The extensive collection of uncovered vessels revealed that the cave had been a place of worship from as early as 2500 B.C., through the Mycenaean period and into Roman times. Numerous engravings found on tiles, shells, and stones during the cave's excavations reveal that Artemis, Athena, Hera, and the Nymphs were among the deities worshipped there. Given that portions of a clay mask depicting a woman and containing the prayer to Odysseus—Efchin Odyssei/ευχην οδυσσει—that dates to the 2nd c BC were found here; it appears that Odysseus himself was exalted here. A 6th c B.C. clay Corinthian plate bearing an engraved image of a rooster is among the other noteworthy discoveries (Ferentinou, 1976). "Prayer to Odysseus" is the name given to this. It originates from a votive inscription that was discovered in a fragment during archaeological excavations at Polis's Cave of Loizos. As evidence that Odysseus was revered as a god for a considerable amount of time, the fragment, which was once a clay female bust from the second to the first century BC, is regarded as one of the most significant discoveries in Ithaca.

The Nymphs’ cave (Marmarospilia) between 1998 and 2001, was the site of excavations led by Saint Louis University professor and archaeologist S. Symeonoglou. Mounds of rocks filled a large portion of the cave floor, which may be a sign that an earthquake in 373 BC damaged the cave. The artifacts include two rings that may have belonged to adolescent priestesses, pots with dedicatory inscriptions, and figurines of Nymphs and their lover Pan and inscription bearing the name of Athena and Hera. When Odysseus got back to Ithaca, he concealed the gifts from Alcinous, King of the Phaeacians, in the Nymphs' grotto. The shape of that cave is thought to be Marmarospilia, which is located above the shore of Dexia, according to the description found in Book 13 of the Odyssey. However, others pinpoint to the cave Loizos at the coast. Indeed, the bronze tripods dated to the 9th c. B.C. from coastal Loizos cave are extremely significant; even in their poor state, they clearly represent the creation of a top-notch local workshop. Recall that the Odyssey states that Odysseus returned to Ithaca with gifts from the Queen of the Phaeacians including bronze, cauldrons, and gold that Odysseus gladly accepted (Odyssey, Book 13, 8-20). The exact number of tripods, though not stated in Odyssey, (Odyssey viii, 390-3) must be inferred to be thirteen, like the other gifts. Pieces of at least twelve were found in the cave, in addition to the complete tripod found earlier (Heurtley 1939).

Anyhow, the topic is still debated, and surely more research is required in Ithaca and other islands around. Within this fuzzy attribution of Odysseus palace, we offered to give some ages to samples and constructions invited by late Prof. Kontorli-Papadopoulou and late Prof Bucholtz back in 1999 (Buchholz, 2009).

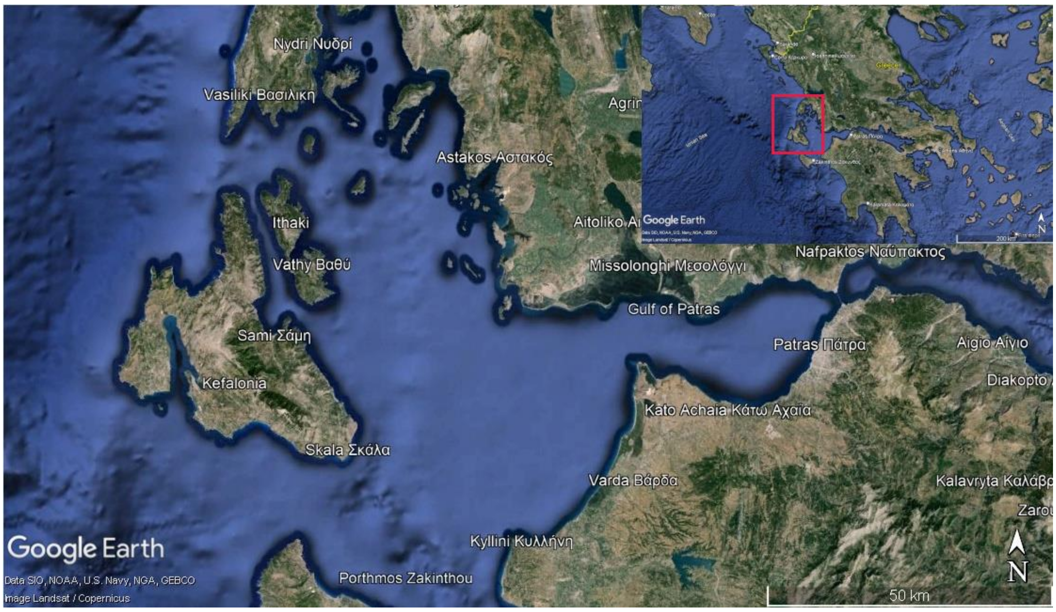
Our aim is to obtain the first trustworthy dates from Ithaca. These dates will shed light on, not only the dispute of Ithaca with the rival candidates islands of Lefkas and Kefalonia, but also the possible formation of joint islands during the LGM when the sea level subsidence would have reached 120 m below sea level (without referring to the insularity of the southern Ionian Islands), which is another matter beyond the purpose of the present article (Gaki-Papanastassiou et al., 2011; Ferentinos et al., 2012).

A view of the seaside from Pelikata is shown in Fig.1 (a-g) with views of the megalithic fortification and masonry.

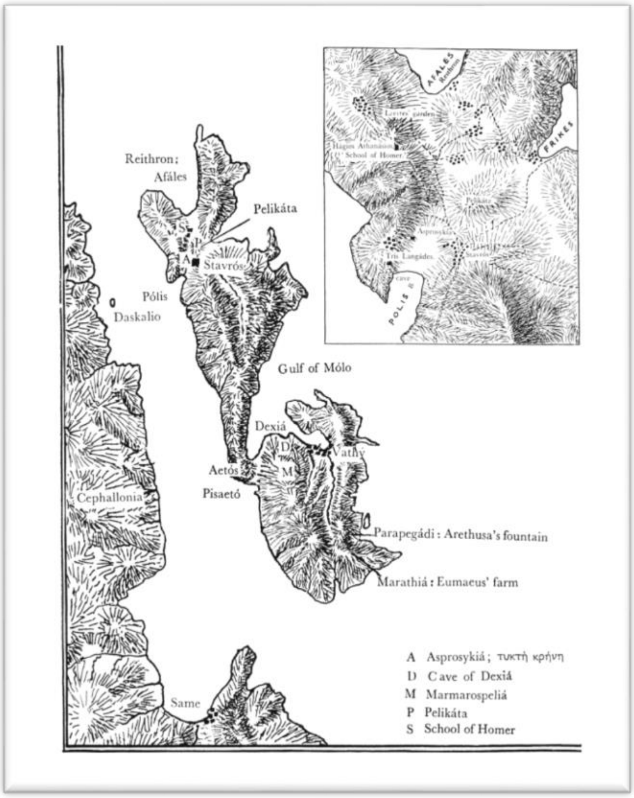
[2] http://odysseus.culture.gr/h/3/gh352.jsp?obj_id=18742

At the present research preliminary work aiming to the dating of some masonry structures and ceramics at the School of Homer at Pelikata was undertaken by means of luminescence signaling.

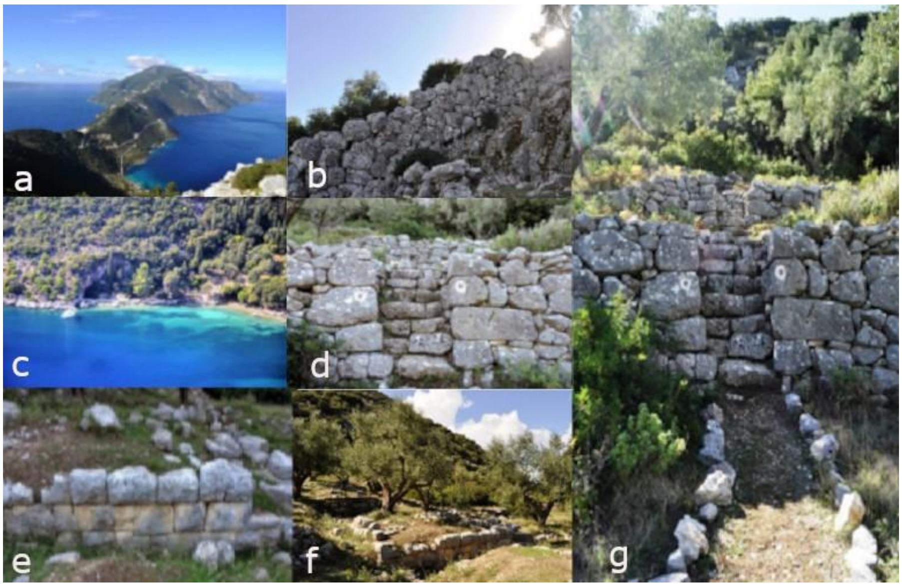
At Pelikata no sherds later than the LH III and until the 5th century and later burials (all outside the circuit wall) were found and it was inferred that the site was abandoned about the date at which the return of Odysseus to Ithaca is supposed to have taken place (Heurtley 1939).



(1)



(2)



(3)

Figure 1. 1 (Upper): Map of Ithaca and surrounding islands (Google Earth 2024), and (2) a sketch map of Ithaca with northern region (After Heurtley 1939, Plate 1). 3 (Lower) a) The site of Pelikata School of Homer from above; b) Fortified wall; c) the cave of Loizos is found at the northwestern corner of Polis Bay, which is also known as the harbour for Stavros.; d-g) views of masonry remnants in the site. (Photo credit: https://www.ithaca.gr/en/home/culture-environment/archaeological-sites/).

2. SAMPLES AND SAMPLING

Two carbonate rock samples[3] were collected from the archaeological site with great care, to prevent destruction of the surface layer, which was not exposed to sunlight after its positioning in the ancient monument; one from the east façade, the lower row of the Mansion (ITH-3), and sample ITH-4 from the outer circular wall. Two ceramic sherds from the surficial collection, samples ITH-2c and ITH-3c, were selected to be dated using OSL (Fig.2). As calcite is not sensitive in yielding useful optically stimulated luminescence (OSL) signal, the limestone samples were dated using thermoluminescence (TL). However, the pottery samples were dated using OSL.

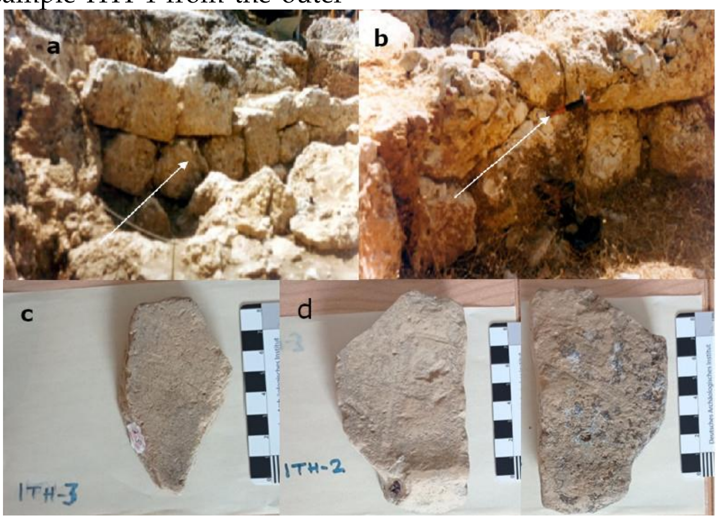


Figure 2. A: limestone ITH-3. School of Homer, Ithaca, Greece. East façade, lower row staircase of the Odyssey Mansion, B: ITH-4. School of Homer, Ithaca, Greece. Outer circular polygon wall of known archaic/classical age (Kontorli-Papadopoulou, 2000), C, ceramic sherd ITH3c, D: ceramic sherd ITH2c front and reversed, both from the School of Homer at Ithaca. Note an imprint design on ITH2c.

[3] Two carbonate rock samples from the so-called spring chamber were also collected; however, these did not pass the tests as they exhibited geological TL.

3. LUMINESCENCE DATING

Modern, hard-won data will eventually become a legacy of these data if it is not properly documented and preserved. This article provides details more than usual details for the reader to reproduce the results. (see Mahan et al., 2024).

Luminescence dating is based on the principle that minerals like quartz and feldspars have the capability of preserving a record of irradiation dose received through time. This dose results mainly from the decay of certain natural radionuclides, i.e., ^{232}Th, ^{40}K and natural U, along with cosmic radiation, which provide a constant source of low-level ionizing radiation and is stored as trapped charge in the crystal's defects. This charge remains stable over time and can be released and measured by either heating (TL) or exposure to light (OSL). It is assumed that in the case of sediment dating, any prior trapped charge is usually emptied by exposure to daylight during transport and deposition, a process known as resetting, zeroing or bleaching, depending on the level of the released charge. In the case of materials of archaeological origin, such as ceramics, heating at high temperatures for prolonged times releases the trapped charge. The age of the material is given by the following equation:

AGE = equivalent dose (ED) / annual dose-rate (DR) (1)

Thus, the amount of trapped charge is equivalent to a "clock" that starts measuring time from the moment the mineral is buried and shielded from light (Liritzis, 1994; Liritzis et al., 2020; Wallinga, 2002).

During recombination, a part of the trapped charge releases energy in the form of light, called luminescence. The brightness of the luminescence signal reflects the amount of trapped charge. Consequently, it is also proportional to the total irradiation dose accumulated to the sediment since its burial.

In the case of stone structures and artifacts, during the construction of the building and while carving the stones their surface will have been exposed to sufficient daylight to be "zeroed" providing thus a reasonably accurate chronometer, as introduced by Liritzis methodology (Liritzis 1994) and later development (Laskaris & Liritzis, 2011; Liritzis et al., 1997b; 2010; 2013, 2015, 2020; Aitken, 1998; Liritzis, 2001; Greilich et al., 2002; 2005; Theocaris et al., 1997).

In the present work we attempt to apply surface luminescence dating protocols in stone samples from the archaeological site of "St Athanasios – School of Homer", Ithaca island, western Greece.

4. INSTRUMENTATION

A Littlemore type 711 setup was used for the TL measurements at the nuclear physics laboratory of the Physics Department at Aristotle University of Thessaloniki, Greece. The thermocouples used were 90/10 Ni/Cr and 97/03 Ni/Al, with a filter transmitting in the 320–440 nm range, and the P/M tube was an EMI 9635QA bialkali (Sb K–Cs). A ^{90}Sr/^{90}Y beta source that delivered 1.72 Gy/min was used in each case to administer a beta dosage. To prevent considerable temperature lag, all TL measurements were carried out in a nitrogen environment at a continuous heating rate of 2 ◦C/s, up to a maximum temperature of 500 ◦C. Every sample's mass repeatability was maintained at ± 5%.

OSL measurements were measured at the Laboratory of Archaeometry, at ATHENA - Research and Innovation Center in Information, Communication and Knowledge Technologies (former Cultural and Educational Technology Institute, CETI), Xanthi, Greece, using a Risø TL/OSL system equipped with blue light-emitting diodes (~40 mW/cm^2 at 470±30 nm) and an Infrared laser (~500 mW/cm^2 at 830 nm). OSL measurements were performed using a using a 9 mm thick Hoya U-340, and a 0,088Gy/s beta ray source ^{90}Sr/^{90}Y (Bøtter-Jensen et al., 2000). Blue LEDs were operated at 36 mW/cm^2 maximum intensity at the sample position (90% of the maximum stimulation intensity) were used for stimulation. Preheating was carried out in a nitrogen atmosphere using a slow heating rate of 2 ◦C/s, to avoid significant temperature lag (Kitis et al., 2015).

The annual dose rates were computed following a combination of techniques.

A portable XRF, TN Spectrace 9000 with a mercuric iodide HgI2 detector and three excitation sources of radioisotopes within the probe unit—Am-241 (26.4 keV K-line and 59.6 keV L-line), Cd-109 (22.1 keV K-line, 87.9 keV K- and L-line), and Fe-55 (5.9 keV K-line)—were used to measure K and Rb for the stone samples (Liritzis and Zacharias, 2011).

The chemical analysis of the two ceramics were measured by a NEX CG ED-XRF performed at the Laboratory of Electron Microscopy and Microanalysis, School of Natural Sciences, University of Patras, Greece.

In the Laboratory of Archaeometry, Department of Mediterranean Studies, University of the Aegean, Greece, alpha counting using the pairs technique assuming U-equilibrium and neutron activation analysis (NAA) for U and Th were employed. A Littlemore Sci. Eng Co. Oxford 7286 Low-Level Alpha Counter with a PM tube type EMI 6097B was used to calculate the measurements. The counter was calibrated in accordance with established conversion factors and pertinent computations (Aitken, 1985; Liritzis & Vafiadou, 2012). The study of Liritzis et al. (2013) served as the foundation for the conversion to dosage rates.

All combined methods were compared, and values were critically assessed.

Environmental gamma ray dose rates were also measured by a portable 2"× 2" NaI(Tl) scintillometer (model PSR6 supplied by Nuclear Enterprises Ltd., Sighthill, Edinburgh) (Liritzis and Galloway, 1980, 1981) and to calculate the radioactivity of the surrounding soil a high resolution Canberra gamma-spectrometry counting system at Risoe (Murray et al., 1987) and beta ray dose rate by a beta counting measurements were made on a total beta counting system at Riso GM-25-5; with plastic scintillator using a 2″×2″ crystal scintillator NaI(Tl) NE102A and a PM of EMI 9814B 5 where used (Bøtter-Jensen and Mejdahl, 1985, 1988).

5. EXPERIMENTAL PROCEDURES AND PROTOCOLS

The stone samples were collected from the archaeological site with great care, preserving the original surface which was not exposed to sunlight after its positioning in the ancient monument. Fine powder was used to study the bleaching properties and finally calculate the equivalent doses. These were taken from closely joined carved cobbles. Samples were collected from the east façade, the lower row of the Mansion (ITH-3, Fig.2a), and from the outer circular wall (ITH-4, Fig.2b), with the aid of a hammer and chisel, exerting care to remove pieces of around 2×2 cm, preserving the original surface. Samples were immediately wrapped in black plastic bags in order to avoid exposure to daylight. The un-exposed to light side of the original carbonate rock sample was immersed in HCl (10%) for a few seconds in order to remove any secondary product, dust, and organics present. From the cleaned surface, the outer layer of about of 200 μm was removed. The selected powder was sieved and grains of dimensions less than 40μm were separated. The deposition procedure was that of fine grains of Zimmerman, (1971). In order to improve the repeatability a normalization procedure was adopted, which is based on the TL induced to each sample by a test beta dose. XRD analysis on sample ITH3 has shown that it consists of 100% calcite.

For pottery, a 2-mm layer was removed from all sample surfaces to eliminate the light-subjected portions, followed by gently crushing in an agate pestle and mortar. Grain sizes 4 - 12 microns were collected in acetone suspension (Fleming 1979).

Treatment and preparation for all carbonate rock samples in the laboratory were undertaken in subdued red-light conditions.

For sample ITH3, (Fig. 1a), the Partially Bleached TL Dose-Temperature Plateau approach was applied, used in earlier applications (Liritzis et al., 1997). Calculation of the equivalent dose involves subtracting this residual by extrapolating the dose response curve to the TL intensity of a natural aliquot that has received the total bleach. Specifically, the systematic of the dating procedure consists of the measurement of:

1. Natural TL (NTL)
2. Geological TL (GTL)
3. Natural TL plus an additive b-dose (NTL+b)
4. The bleaching versus time of exposure to daylight

For the evaluation of the equivalent b-dose (ED), the glow-curves were separated in intervals of 10 °C. A dose Calibration Factor (CF) for each interval was obtained, according to the equation:

$$CF = \frac{TL_x - NTL}{\beta} \tag{2}$$

TL_x is the NTL+β built up curve and β is the added dose.

The equivalent dose (ED) is calculated by the equation:

$$ED = \frac{NTL(1 - \frac{h_x}{GTL})}{CF} \tag{3}$$

Assuming that the bleaching properties of the NTL and the GTL are similar, the solar bleaching is obtained by the factor R of the GTL.

h_x is the built-up curve of geological plus following *h* hours exposure to daylight.

For sample ITH4 the alpha to beta response (k-value) was measured and the procedure consist of the following measurements:

1. Natural thermoluminescence (NTL)
2. Natural plus an additive beta dose
3. Natural plus an additive alpha dose
4. The bleaching versus time of exposure to sunlight.

The equivalent doses were obtained by fitting the TL(NTL+β) and the TL(NTL+α), as a function of β and α dose respectively, to a linear equation of the form

$$TL(D) = NTL + \beta \cdot Dose \tag{4}$$

Where NTL is the level of the experimentally obtained NTL and B the slope of the calibration TL versus dose line.

The NTL is not treated as free parameter during the fitting. It was kept constant and equal to the experimentally obtained NTL value. The Equivalent Dose (ED) were then evaluated by the equation:

$$ED = \frac{NTL}{\beta} \tag{5}$$

Considering the bleaching curves were evaluated, the ED results using the equation:

$$ED = \frac{NTL - TL_{bleaching}}{\beta} \tag{6}$$

where $TL_{bleaching}$ is the TL from the glow-curve obtained by the bleaching to sunlight measurements.

A test dose of 6 Gy was applied to each aliquot; a background signal measurement, also known as reheat, was measured for each aliquot and thus subtracted from each glow curve.

In the case of the ceramic sherds, the ED was estimated by applying the Single Aliquot Regenerative OSL (SAR OSL) protocol (Murray and Wintle, 2000), using solely blue stimulation, and only this aforementioned luminescence signal is being used. In the SAR OSL protocol, the signal intensity of an aliquot of extracted grains is recorded at first without attributing any dose in step 1 (called natural OSL, NOSL hereafter); then the same aliquot is subjected to a series of subsequent laboratory irradiations with a calibrated radiation source and OSL measurements. Besides the natural OSL measurement, the protocol incorporates 3 regenerative steps with incremental doses (between 3 and 9 Gy, in steps of 3 Gy), one recycling and one recuperation measurement steps. Sensitivity changes were both monitored and corrected with the aid of a test dose (3 Gy), delivered after each regenerative, natural, and zero dose OSL measurement following a cut-heat temperature of 180 °C for the same reason as the preheat treatment. Infrared stimulation was used in order to check the presence of quartz signal only. All OSL signals are dominated by the fast OSL component. The contribution of this latter component over the entire OSL signal is of the order of 40% (Saleh et al., 2024), making the quartz samples ideal for OSL dating applications. More details on the experimentally applied protocol can be found in Table 1.

For the selection of the appropriate preheating temperature, a typical preheating plateau test was applied for OSL measuring temperatures 130, 160, 200, 230 and 260 °C. A total of 25 aliquots was used, dividing them into 5 groups each one corresponding to one preheating temperature and containing 5 aliquots each. For the majority of the aliquots for the SAR analysis, linear expressions were used for fitting dose response curves. For each ceramic sherd, an individual preheat plateau test was applied; thus, the ED was calculated as the average over all values that form the plateau (namely at lower preheating temperatures). Table 1 presents all important required aspects of the applied SAR protocol in the resent study.

Sensitivity change and anomalous fading was checked. The difference of about 8% of the sensitivity change from the signal change is within the framework of the systematic error, so we can say that the signal change is due to the sample sensitivity change, so the phenomenon is not observed.

Table 1. Steps, actions, comments, and technical specifications on the SAR protocol of the present study.

Step no	Action	Comments & Technical Specifications
1	Regenerative dose, D_i	*D_1=0 Gy (Natural), D_2-D_4 Regenerative doses (3, 6 and 9 Gy), D_5=0 Gy (Recuperation test), D_6= D_2 (Recycle point)*
2	Preheat	*Duration 10 s, Temperature Ti °C*
3	CW-OSL measurement	*Duration 70 s, Temperature 125 °C: Natural & regenerative OSL measurement* $\mathbf{L_i}$ *from quartz*
4	Give test dose, D_i	*D_t=1.5 Gy*
5	Cut-heat	*Duration 0 s, Temperature 180 °C*
6	CW-OSL stimulation	*Duration 70 s, Temperature 125 °C: Test dose OSL measurement*
7	Return in 1 for a fresh sample	Each measurement cycle at the same stimulation temperature was repeated for 5 different aliquots of the same sample.

6. MEASUREMENTS AND RESULTS

6.1 Equivalent Dose Measurements

A major problem in the TL dating of stones (here carbonate rock), is the lack of information concerning the degree of bleaching that took place in the past. Incomplete bleaching will leave a residual dose in the material, which is a significant fraction of the dose accumulated, and therefore will provide a highly erroneous age result if it is not subtracted from the archaeological dose. Thus, the correct ancient residual TL level, and consequently ED value, had to be sought. Based on earlier results the interesting observation is the variation of residual TL shapes as a function of exposure time to sunlight. The different parts of the TL glow curve—that is, TL intensity versus temperature— are not bleached in a similar manner, as they correspond to a number of individual TL traps, that are differentially/variably affected by the different solar wavelengths (Liritzis et al., 1996). Therefore, plots of residuals of both samples should be studied after exposure of the geological TL within the temperature range of the stable traps (200–340°C). Variations in general shape are apparent mainly between 280 and 350°C. During bleaching, the TL intensity of the natural signal decreases until an unknown bleaching level is reached, which presumably corresponds to the ancient residual threshold level and upon which the environmental dose is added till today. The TL curves in the course of time would give variable doses in the temperature range of interest, because the difference between unbleached signals and bleached ones is only dose dependent. In this case, due to the different bleaching rates of different parts of glow curves, the plot of (nat. *minus* bleached nat.) TL signals, versus, temperature, expressed in terms of archaeological dose (ED), should give a plateau (dose plateau plot), which is the longest if the right ancient residual TL is subtracted (Liritzis et al., 2015).

For both the limestone samples this partial solar bleaching methodology was applied (Liritzis et al., 1997, 1996).

ITH3 limestone (East façade, lower row, section B)

For sample ITH3 the natural glow-curves of three samples were measured in order to check the repeatability of the measurements (Fig.3a). Fig.3b shows the same glow-curves, only in this case we present the results from the integration every 10°C across the glow-curve. The curve (abc) in Fig.3b is the average of the three samples.

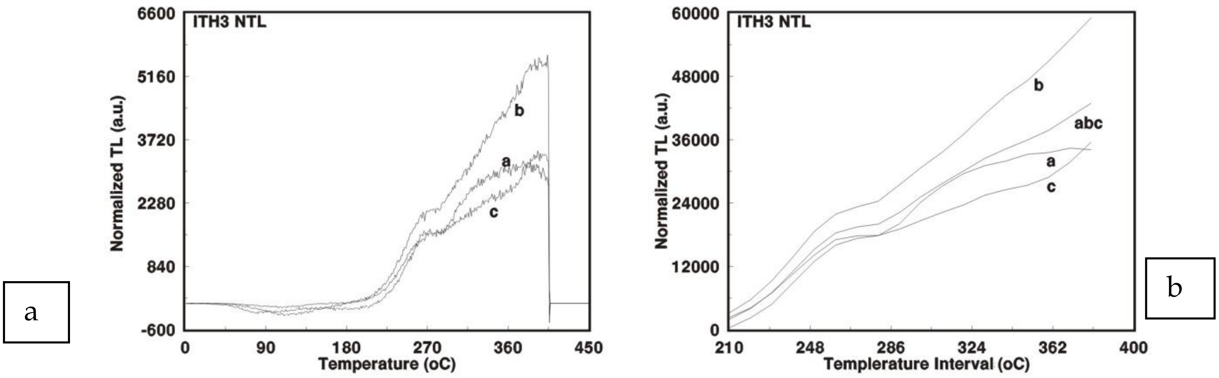


Figure 3: a) Three Natural glow – curves of sample ITH – 3. b) The Natural glow – curves of sample ITH – 3 presented as the intervals every 10 ℃ across the glow – curve. Curve (abc) is the average of curves (a), (b) and (c).

Fig.4 shows the geological glow curves on four samples. In Fig.4b glow-curve (abc) is the averages of curves (a), (b) and (c), and curve (abdc) is the average of curves (a), (b), (c) and (d).

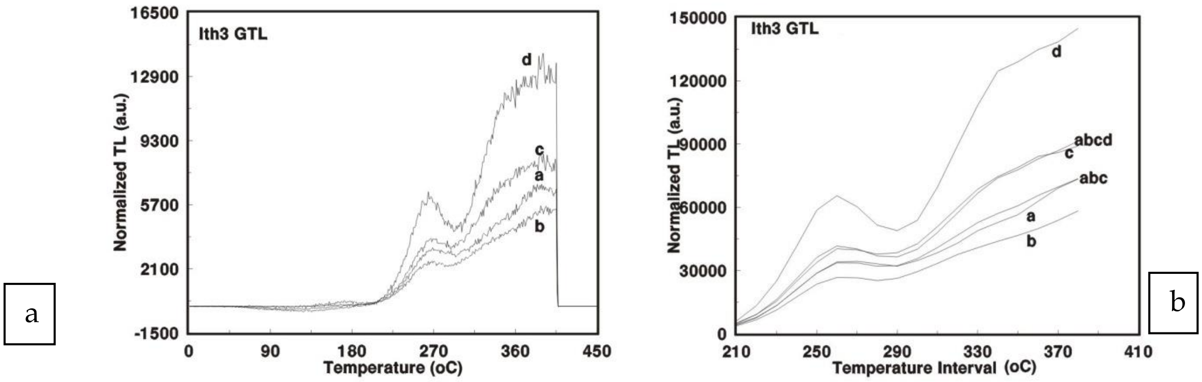


Figure 4. a) Four Geological glow – curves of sample ITH – 3. b) The Geological glow – curves of sample ITH – 3 presented as the intervals every 10 ℃ across the glow – curve. Curve (abc) is the average of curves (a), (b) and (c), and curve (abcd) is the average of curves (a), (b), (c) and (d).

The additive doses applied to the aliquots were curve (b) 17.5, curve (c) 23.3, curve (d) 32.05 and curve (e) 52.4 Gy. Fig. 5a shows the glow curves and Fig.5b as the intervals every 10 °C across the glow – curve.

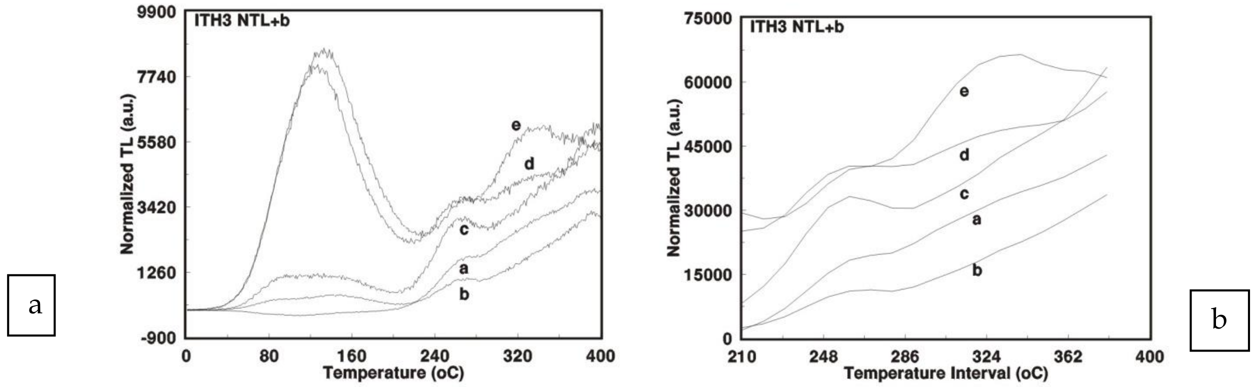


Figure 5. a) Natural TL glow – curves of sample ITH – 3 plus a laboratory beta dose. Curve (a) is the Natural TL, curve (b) is the Natural+17.5 Gy, (c) is the Natural+23.3 Gy, (d) is the Natural+32.05 Gy and (e) the Natural+52.4 Gy. The Natural TL is curve (abc) from Fig. 3. b) Natural TL glow – curves of sample ITH – 3 plus a laboratory beta dose presented as intervals every 10 °C across each glow – curve. Curve (a) is the Natural TL, curve (b) is the Natural+17.5 Gy, (c) is the Natural+23.3 Gy, (d) is the Natural+32.05 Gy and (e) the Natural+52.4 Gy. The Natural TL is curve (abc) from Fig. 3.

Since, the zeroing in the calcite samples is through the exposure in sunlight, the necessary bleaching study as a function of exposure to sunlight is performed. For the bleaching experiment the glow-curves are shown in Figs. 6. Curve (a) is the GTL, curve (b) is the glow-curve after 2h exposure to daylight, curve (c) is the result of 4h exposure to daylight, curve (d) the glow-curve after 7h, curve (e) after 11h, curve (f) after 21h, and, finally, curve (g) is the glow-curve after 40h exposure to daylight. the GTL is the curve (abc) in Fig.4.

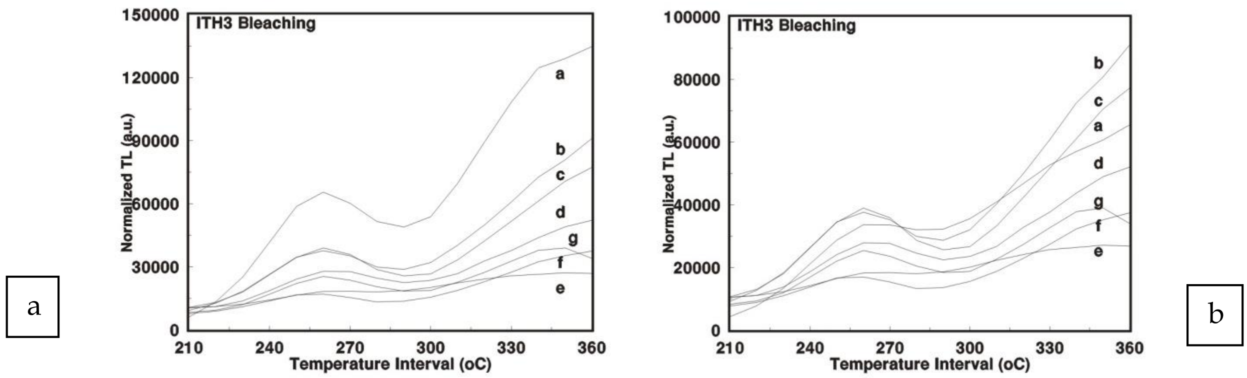


Figure 6. a) Glow – curves of ITH – 3 sample after exposure to daylight. Curve(a) is the Geological TL, curve(b) the glow – curve after 2h exposure, (c) after 4h, (d) after 7h, (e) after 11h, (f) after 21h and curve(g) after 40h exposure to daylight. The Geological TL is curve(d) from Fig. 2. b) Glow – curves of ITH – 3 sample after exposure to daylight. Curve (a) is the Geological TL, curve (b) the glow – curve after 2h exposure, (c) after 4h, (d) after 7h, (e) after 11h, (f) after 21h and curve (g) after 40h exposure to daylight. The Geological TL is curve (abc) from Fig. 4.

We decided to consider more than one curves for NTL as well as GTL for the calculation of the ED, because the reproducibility of the natural glow-curves and the geological glow-curves weren't satisfactory enough (Figs.3a and 4a). Using the equations 2 and 3, and several combinations of natural and geological glow curves, we reached at several plateaus. Indicative of the process presented charts Figures 7 and 8 show the plateau resulted from NTL+β after the subtraction of the bleaching curves. Some cases of NTL+β or of hours exposure to daylight may be missing, because there wasn't any plateau observed.

In Figs 7 for the calculations we used NTLc (curve (c) in Fig.4b) and GTLd (curve (d) in Fig.4b) and in Fig. 8 for the calculations we used NTLabc (curve (abc) in Fig.1b) and GTLabc (curve (abc) in Fig.4b). There are shown the plateau from NTL+23.3 Gy after 7h exposure (curve (a)), 11h exposure (curve (b)), 21h exposure (curve (c)) and 40h of exposure to daylight (curve (d)).

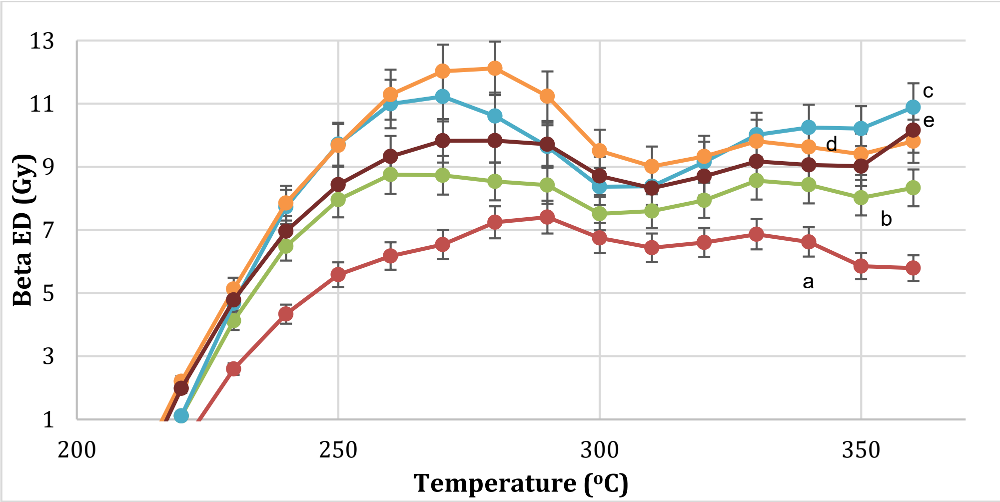


Figure 7. Glow – curve Natural+23.3 Gy after 4h of exposure to daylight (curve (a)), 7h exposure (curve (b)), 11h exposure (curve (c)), 21h (curve (d)) and 40h of exposure to daylight (curve (e)). For the calculation of ED the Natural TL is curve (c) (from Fig. 2b) and the Geological TL is curve (d) (from Fig. 3b). Best plateau curve(a), 4h exposure to daylight, region temperature 300-340 ℃. ED=(6.60±0.06) Gy.

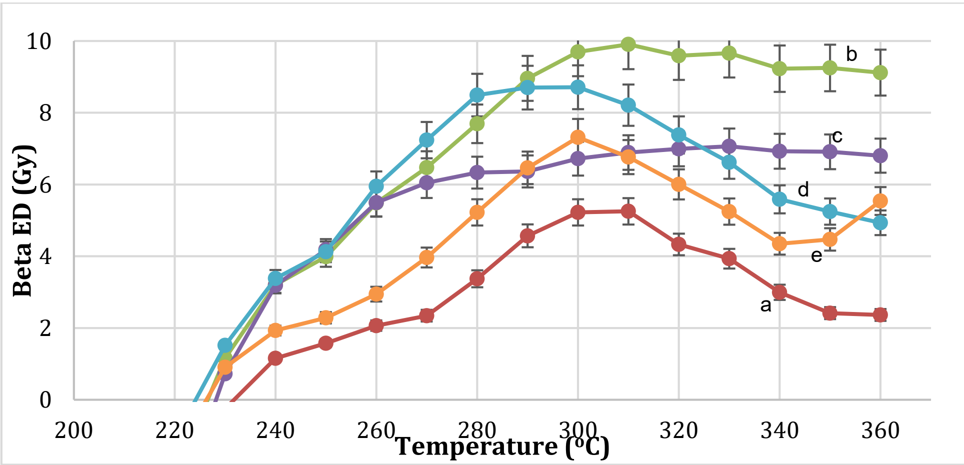


Figure 8. Glow – curve Natural+17.5 Gy after the subtraction of 4h of exposure to daylight (curve (a)), 7h exposure (curve (b)), 11h exposure (curve (c)), 21h (curve (d)) and 40h of exposure to daylight (curve (e)). For the calculation Natural TL is curve (c) from Fig. 2b and the Geological TL is curve (abc) from Fig. 3b. Best plateau curve (c), 11h exposure to daylight, region temperature 310-360 ℃. ED=(6.39±0.04) Gy.

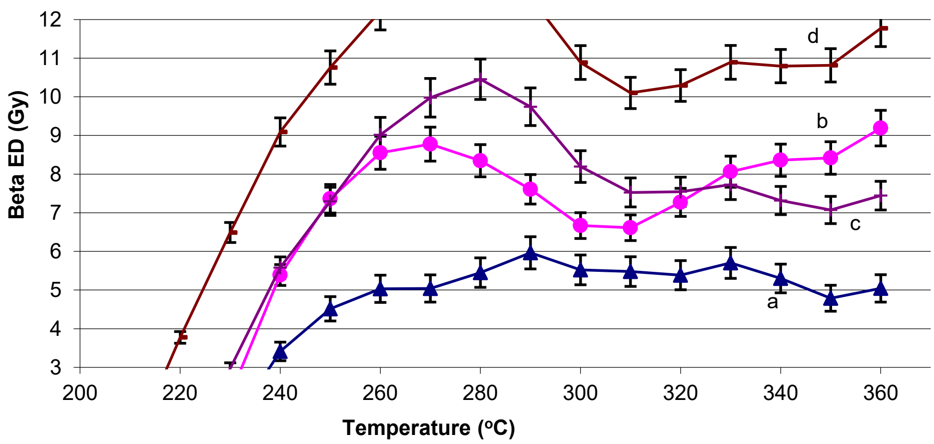


Figure 9. Glow – curve Natural+23.3 Gy after the subtraction of 7h of exposure to daylight (curve (a)), 11h exposure (curve (b)), 21h exposure (curve (c)), and 40h (curve (d)) of exposure to daylight. For the calculation Natural TL is curve(c) from Fig. 2b and the Geological TL is curve (abcd) from Fig. 3b. Best plateau curve (a), 7h exposure to daylight, region temperature 280-340 ℃. ED=(5.54±0.08) Gy.

Fig. 9 presents another set of glow-curves for Glow – curve Natural+23.3 Gy subtracting remaining TL after various bleaching times in hours.

According to Fig 6-8 the longer temperature plateau are at 4hr bleaching time (300-340 ^{o}C) with average ED of (6.60±0.06) Gy (Fig. 6), at 11hr (310-360 ^{o}C), with average ED of (96.39±0.04) Gy (Fig. 7) and at 7hr bleaching time (280-340 ^{o}C), with average ED of (5.54±0.08) Gy (Fig. 8), giving average ED ED_{ITH3}=(6.18±0.06) Gy.

6.2 ITH4 limestone (Archaic/Classical wall)

The TL glow-curve shapes of ITH4 calcite are shown in Fig.10a. Curve (a) is the NTL and curves (b), (c), and (d) are NTL+β for doses 9, 18 and 30 Gy respectively. Fig. 10b shows the NTL+a dose glow-curves from alpha doses. Curve (a) is the NTL and curves (b), (c) and (d) are NTL+a for doses 194, 301 and 430 Gy respectively.

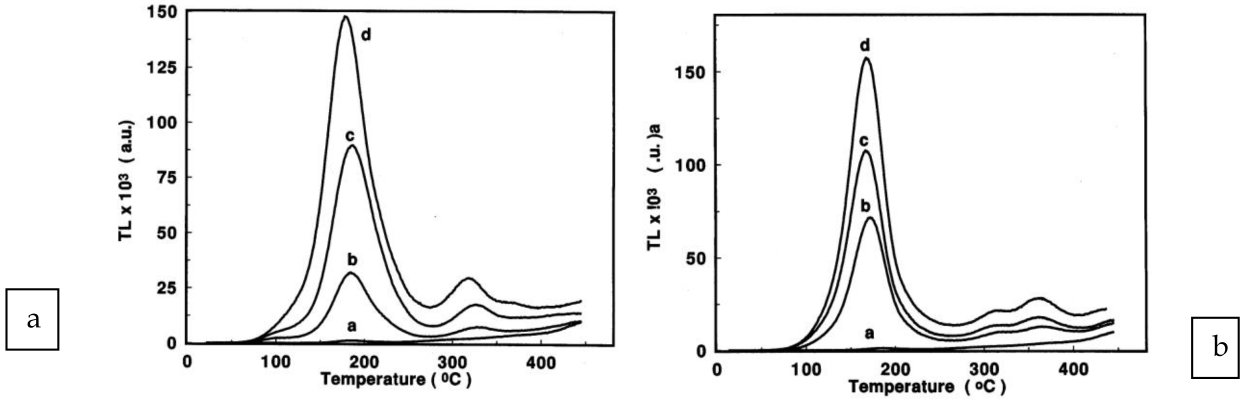


Figure 10. a) Natural TL glow – curves of sample ITH – 4 plus a laboratory beta dose. Curve (a) is the Natural TL, curve (b) is the Natural+9 Gy, (c) is the Natural+18 Gy and (d) is the Natural+30Gy. b) Natural TL glow – curves of sample ITH – 4 plus a laboratory alpha dose. Curve (a) is the Natural TL, curve (b) is the Natural+194 Gy, (c) is the Natural+301 Gy and (d) is the Natural+430 Gy.

Examples of glow-curves are shown in Fig. 11. Curve (a) is the NTL, curve (b) is the glow-curve after 6 hrs exposure to sunlight, curve (c) 20hrs exposure and curve (d) after 3 days exposure. A number of exposures between 20hrs and 3 days gave glow-curves between curves (c) and (d). This means that curve (d) represents the limit of the bleaching possibility.

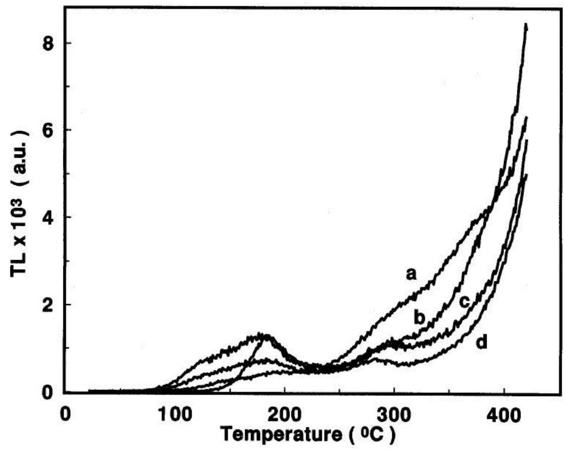


Figure 11. Glow – curves of ITH – 4 sample after exposure to daylight. Curve (a) is the N-TL, curve (b) is the glow-curve after 6 hrs exposure, curve (c) 20hrs exposure and curve (d) after 3 days exposure. A number of exposures between 20hrs and 3 days gave glow-curves between curves (c) and (d).

For the evaluation of EDs, the glow-curve from 200 up to 430 °C was used. As a measure of the TL, temperature interval of 10 °C each, across the glow-curve, were used. The Eds were evaluated using eq.5. Since the NTL in the equation was kept constant and equal to the experimental value of NTL, the procedure was performed to each one of the four experimentally obtained NTL glow-curves. This means that the data evaluation results in four series of EDs from which a mean value can be obtained.

The resulting β-EDs as a function of the glow-curve temperature for the case of the first NTL are shown in Fig. 10a. Curve (a) corresponds to the EDs without taking account the bleaching. Curve (b) taking account the bleaching of 20hrs curve, (c) considering bleaching of 2 days. Curve (d) corresponds to a bleaching of 6hr and is an example of the behaviour of ED for too less bleaching. Figs. 12b, c, and d show the β-EDs for the rest three NTL glow-curves. The notation is the same. In all cases it is obvious that the best plateau is obtained for bleaching of two days in the region between 350-420 °C.

In one-to-one correspondence Figs 11, 12 and 13 show the alpha dose-EDs. As in the case of βeta dose-EDs the best plateau is obtained for bleaching time of two days in the glow-curve region between 350-420 °C.

Except from this region, in Fig. 10b, a plateau can be observed in the temperature region 280-330 °C. The EDs in Grays are: 3.054, 2.79, 1.697 and 1.796, that is, ED_{mean}=2.33±0.34. Then k-value=0.132.

To calculate the beta equivalent dose to be used for dating the other sample ITH4 we considered the temperature range 280-330^{o}C, which gave an average of all four physical glow-curves of 2.33 Gy. For bleaching, powder was used from the one intended for dating and for the natural light experiment. Exposure times to the sun are from 6 hours to 3 days. The exposure times of the sample between 20 hours and 3 days fall between the corresponding curves of Fig 12, 13 (curves c and d), which shows that the phenomenon stops developing after 20 hours.

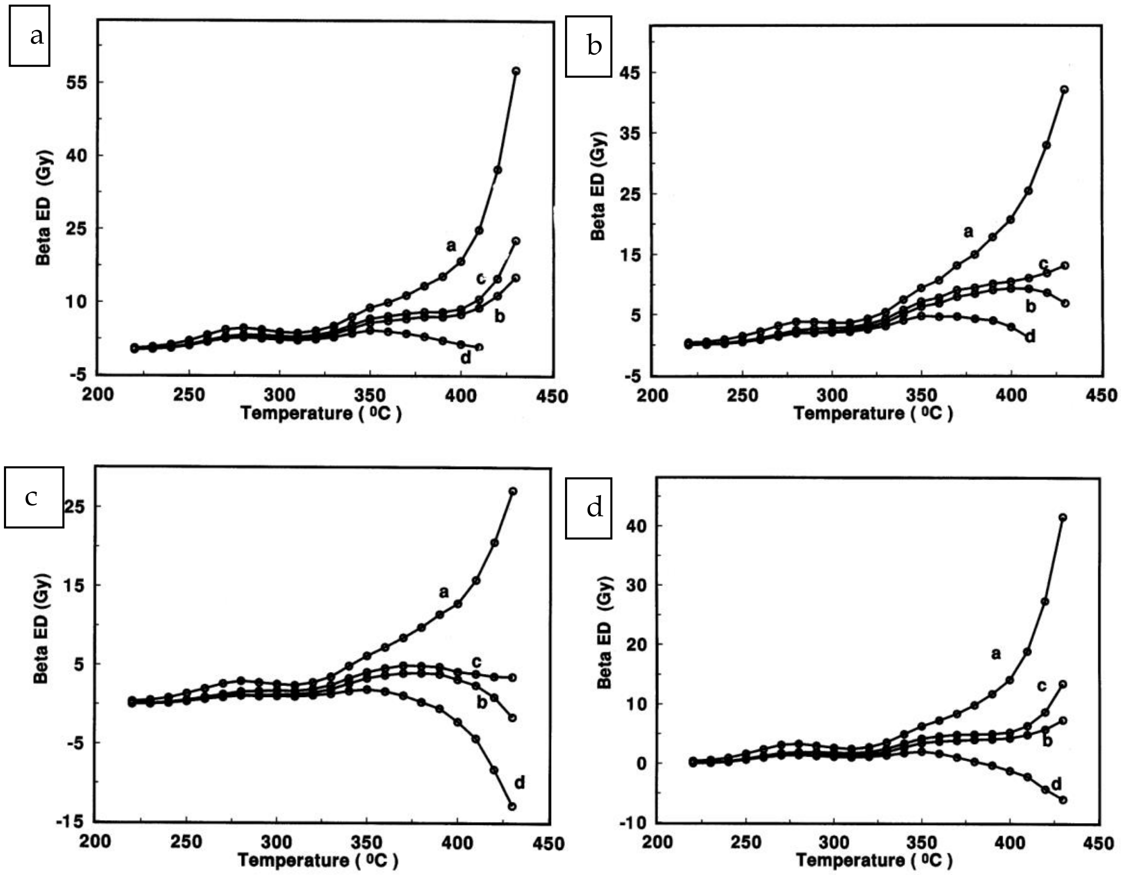
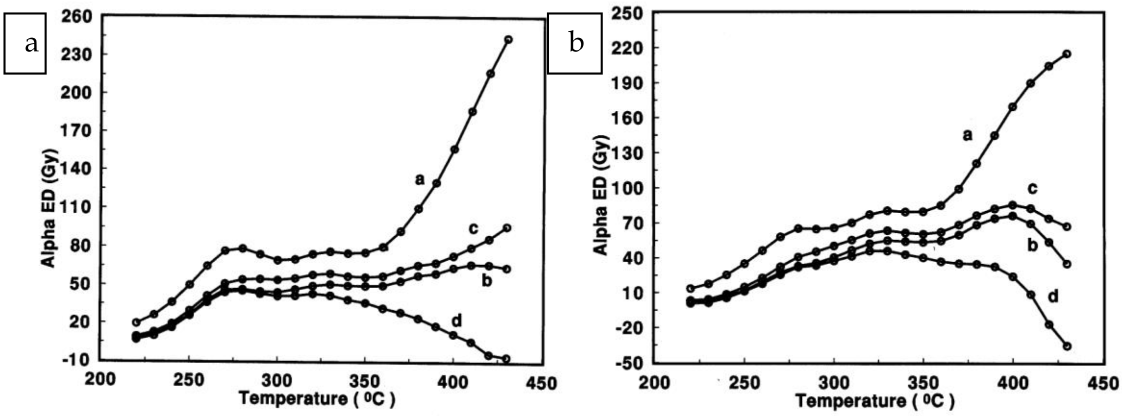


Figure 12. The β-EDs as a function of the glow-curve temperature for the case of the (a) first NTL, (b) the second NTL, (c) the third NTL and (d) the forth NTL. Curve (a) corresponds to the EDs without considering the bleaching. Curve (b) taking account the bleaching of 20hrs; curve (c) considering bleaching of 2 days. Curve (d) corresponds to a bleaching of 6hr.



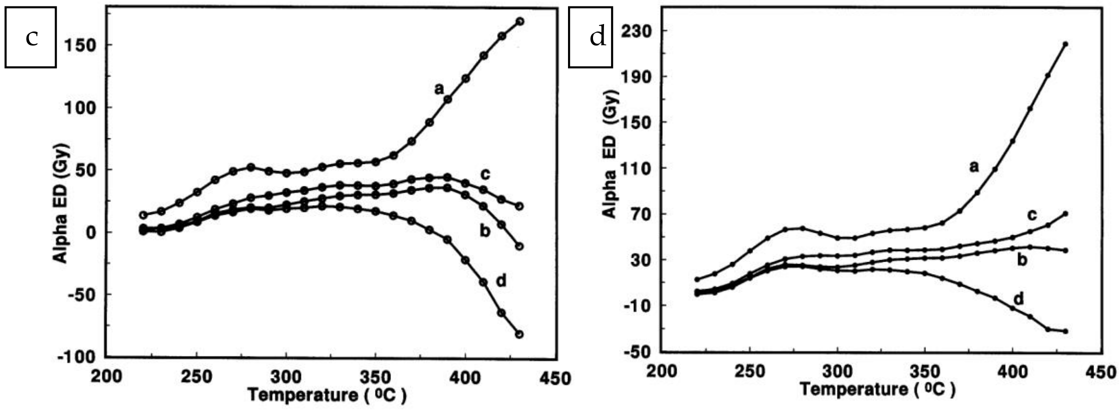


Figure 13. The a-EDs as a function of the glow-curve temperature for the case of (a) the first NTL, (b) the second NTL, (c) the third NTL and (d) the forth NTL. Curve (a) corresponds to the EDs without considering the bleaching. Curve (b) taking account the bleaching of 20hrs, curve (c) taking account of bleaching for 2 days. Curve (d) corresponds to a bleaching of 6hr.

The final values of the EDs series are shown in Table 2.

Table 2. ED values in Gy and relative β to a response values

Region between 350-420°C			
N-TL	β-Eds	α-EDs	Relat. Resp.
1	7.416±0.6	56.13±1.85	0.13
2	9.740±0.6	61.53±1.18	0.15
3	4.550±0.37	40.10±3.01	0.11
4	4.786±0.36	34.19±1.53	0.14

6.3 Dose rates and Estimation of Ages

Limestones

The results for the isotopic concentration by three methods are shown in Table 3. Further detailed notes on DR can be found at the inset for "Notes on DR".

The annual dose rate measurements for the calcitic samples and the surrounding soil and the total Dose Rate estimation for the samples are summarized in Table 4, 5 and for the ceramics in Table 6. All radioisotope geochemistry data were transformed to dose rates using the conversion factors of Liritzis et al. (2013). Zimmerman's formulas (1971) were used for water uptake corrections:

Dg, wet = Dg, dry / {[(W/D) -1]*1.14 + 1]}, (7)

Db, wet = Db,dry /{[(W/D) -1]*1.25 + 1]}, (8)

Da, wet =Da,dry/{[(W/D) -1]*1.50 + 1]}, (9)

where, (W/D) = (wet / dry) by weight (W/D=1.20), coefficients are 1.14 for gammas, 1.25 for betas and 1.50 for alphas.

Table 3. The isotopic data U, Th, K, Rb and the calculated dose rate per method for stone samples ITH3 and ITH4.

Sample	U (ppm)		Th (ppm)		K (%)		Rb (ppm)		Water content
ITH3	a counting CalibFact[1]	0.22±0.03	a counting (CalibFact)	0.24±0.11	XRF	0.06±0.03	XRF	0	-
	a counting (Aitken)[2]	0.17±0.04	a counting (Aitken)	0.19±0.09					
	NAA	0.127	NAA	0.449	NAA	0.0722	NAA	4.75	
Average ITH3		**0.17**		**0.29**		**0.067**		**2.5**	
ITH4	a counting CalibFact	0.14±0.03	a counting CalibFact	0.40±0.12	XRF	0	XRF	10.7	-
	a counting (Aitken)	0.10±0.04	a counting (Aitken)	0.33±0.10					
	NAA	0.106	NAA	0.237	NAA	0	NAA	3.76	
Average ITH4		**0.12**		**0.36**		**0**		**7.23**	

Surrounding soil [3]	-	-	-	-	20%
1. CalibFact: Calibration factor from Liritzis & Vafiadou (2005) 2. Calibration factor from Aitken (1985) 3. For the dose rate calculations the environmental soil beta and gamma dose rate was used db_{soil} = 1.65±0.04Gy/ky, at Riso by proportional beta counter dg_{soil}=1.08±0.03Gy/ky, at Riso by high resolution Ge-counter $dg_{portable}$ = 0.488±0.048Gy/ky, by portable GM Geiger for ITH3 and 0.377 ±0.035 for ITH4. The reading does not represent a spherical geometry.					

The a-efficiency factor is taken 0.132 ± 0.02 for stone applied after experimental data (Table 2). For medium to coarse-grained quartz, a dose of 0.1 is added (Olley et al.,1998). No acid treatment was performed. Attenuation coefficients for alpha and betas per isotope are taken from Durcan et al., 2015 (their Figs. 2 and 3).

For the calculation of the total dose rates, the following assumptions were made: For the beta dose rate, for sample ITH3 half of the beta dose rate from the stone and half from the soil was used. At the excavation site a dusty soil layer was observed between the two blocks. In the case of sample ITH4, the contact between the two blocks was firm and no plaster was used. Some dust from soil must have been introduced during cover. Thus, half beta dose arises from the stone.

For gamma dose rate and for the measurement from the portable device and half the gamma from the soil, for sample ITH3, corrected for 20% of water content. This is happening because one side of the stone was covered by the soil during time. For the gamma portable measurement, no water uptake correction was applied because surrounding soil was unearthed during excavation and any contribution for the distant soil is small and any correction insignificant. The dg,port GM from soil was 0.377±0.035 includes cosmic and everything else but not the covered soil that the wall was buried until the excavation.

For the soil and ceramic samples, it was assumed 20% water uptake, the total beta dose from the sherds and the gamma dose from the surrounding soil, using Zimmerman's (1971) formulas.

Thus, ages calculated in some details are as follows:

ITH3 limestone

Table 4 gives the dose rate components for stone and soil and the age (see Eq.1).

Hence, Age = ED / DR, ED=equivalent Dose in Grays; Plateau with longer Temp at 7hr bleach (60 °C, 280-340), 5.54 Gy; 4hr (40 °C, 300-340) 6.60 Gy; 11hr (310-360, 50 °C), 6.4 Gy; give average 6.18 Gy.

DR = Dose Rate in mGy/yr= k*Da,st + Db,st + Dg,st +Dg,so + Dc; k= alpha to beta efficiency factor = 0.132 (measured, see Table 2).

Table 4. ITH 3. DR components and calculated age for the polygon wall. (Da,b, st the alphas and betas from stone, Dg, so the gammas from the soil, Dc the cosmic radiation).

Da,st (mGy/yr)[1]	**Db,st[2] (mGy/yr)**	**Db,so[3] (mGy/yr)**	**Dg,st[4] (mGy/yr)**	**Dg,so[5] (mGy/yr)**	**Dc (mGy/yr)**	**Total (mGy/yr)6**	**Total Dose, (Gy)**	**AGE years, BC**
0.122	0.045	0.82	0.02	0.41	17±2	1.59	6.18±0.5	880±300
1. the alphas from stone after multiplied by 0.132 and attenuation coefficient 0.90 2. the beta ray dose rate from betas of stone, 0.09mGy/yr halved as between the blocks dusty thus not full 2π geometry, 0.09/2=0.045 3. the beta ray dose rate from betas of dusty space between blocks 1.65mGy/yr halved, as between the blocks was dusty, thus not full 2π geometry, 1.65/2=0.824. 4. the gamma contribution from the stony block face that is half of total gamma ray dose rate, 0.04 /2=0.02 5. the sediment gamma dose rate that covers the half of the buried wall environmental context (after abandonment soon the lower wall is covered by sediment), 1.08, (Riso by high resolution Ge-counter) which after correction for water uptake becomes 0.87 and finally halved to 0.41.								

Notes on DR
1.the intrusion of sediment from minute cracks occurred during the time it was found between the overlapping space of blocks, and assumed an additional 50% Db,so, making Db,so 0.82 mGy/yr. 2. Large dig across the stairs profile, forms an empty space, preferred the dg,stone+dg,soil as 50-50 The Dg, GM =0.488 measures the context without sediment fil and includes cosmic. The not so straightforward radiation geometry leads us to accept with more confidence the added radiation fields from inhomogeneous context. 3.From some experiments, UNSCEAR assumes the cosmic ray dose rate at sea level from muons and electrons to be 32 nGy / h. This indicates a total yearly dose of 0.28 mGy. The geomagnetic latitude effect is about 10%. (Since in this case

the radiation weighting factor is by ICRP set to 1, the equivalent dose is also 0.28 mGy.) We also have to include the neutrons at ground level. Based on this, the effective annual dose from neutrons at sea level and at 50° latitude is estimated to be 0.08 mGy. The latitude variation for the neutron contribution is from 0.05 – 0.11mGy/year. For latitudes higher than 35°N the assumed dose for a depth of 100gr/cm², is 25-30 mGy/yr (see also, Prescott & Hutton 1994; Prescott J. R. and Stephan L. G. (1982) The contribution of cosmic radiation to the environmental dose for thermoluminescence dating. PACT 6, 17-25; https://www.unscear.org/docs/reports/annexb.pdf. For a depth of a couple of meters and 39°N the 17±2 is assumed.

4. Dose rate conversion factors: Potassium, 1% natural K: Db,K = 0.8011, Db,K= 0.2498 0; Rb: 50 ppm of nat. Rb, Db,Rb=0.0185; Thorium-232: Da,Th=0.7375, Db,Th=0.0275, Dg,Th=0.0481; Uranium-238/235: Da,U=2.793, Db,U=0,1459, Dg,U=0.1118. %K = %K_2O x 0.83 (Liritzis et al., 2013).

5.Attenuation coefficients for alpha and betas per isotope are taken from Durcan et al., 2015 (their Figs. 2 and 3). For average size 20μm: betas from potassium, Dbx0.97; betas from U, Th: Dbx0.95, and for alphas from U, Th, Dax0.90.

ITH4, limestone

Table 5 gives the dose rate components for stone and soil and the age.

Hence, Age = ED / DR, DR= ED=equivalent Dose in Grays; Plateau with longer Temp at 280-330 °C give average 2.33 Gy; DR= Dose Rate in mGy/yr.

DR = k*Da,st + Db,st + Dg,st +Dg,so + Dc, K= alpha to beta efficiency factor = 0.132 (measured, see Table 2).

Table 5. ITH 4 DR components and calculated age for the polygon wall. (Da,b, st the alphas and betas from stone, Dg,so the gammas from the soil, Dc the cosmic radiation.

Da,st(mGy/yr)	Db,st[1](mGy/yr)	Dg,st[2](mGy/yr)	Dg,so[3] (mGy/yr)	Dc (mGy/yr)	Total (mGy/yr)[4]	Total Dose, (Gy)	AGE years, BC
0.27	0.045	0.02	0.44	17	0.97	2.33±034	350 ±250

1. the beta ray dose rate from betas of stone, 0.09mGy/yr halved as between the blocks dusty thus not full 2π geometry, 0.09/2=0.045.
2. the gamma contribution from the stony block face that is half of total gamma ray dose rate, 0.04
3. Preferred to GM portable value of 0.463; the sample near the floor, has 1/2nd dg,stone and 1/2nd soil. The separate dg component is close to 0.463, so, Dg,so=the sediment gamma dose rate that covers the half of the buried wall environmental context (after abandonment soon the lower wall is covered by sediment), 1.08, which after correction for water uptake becomes 0.87 and finally halved to 0.44.
4. Coversion factors see (4) from Table 5.

Table 6. The estimated ages of the two stone samples

Sample	ED (Gy)	Dose Rate (Gy/ky)	TL Age (BC)
ITH3	9.03±0.12	1.89±0.06	1814±500
ITH4	2.33±0.34	0.97±0.05	740±200

Ceramic OSL ages, ITH2c and ITH3c

Figure 14 presents the results of this preheat plateau test for the ED (upper plot), the recycle ratio (middle plot) and the recuperation value (lower plot) of the pottery with laboratory code name ITH2. Open squares represent the independent measurements while circles represent the averages for each preheating temperature. For each ceramic sherd, an individual preheat plateau test was applied; thus, the ED was calculated as the average over all values that form the plateau (namely at lower preheating temperatures). After all, the estimated EDs are 5.63±0.11 Gy for ITH2c and 4.43±0.51 Gy for ITH3c.

The ceramic Age equation is given by:

TL Age = ED / DR, ED the total dose in Gy and DR the dose rate.

DR= Da,ce + Db,ce + Dg,so +Dc +0,1, (Da,ce alphas from the ceramic, Db,ce betas from the ceramic, Dg,so gammas from the soil, Dc cosmic ray dose rate and 0.1 mGy/yr assumed from quartz grains (Table 7).

Both ceramic finds provided by late excavator were of early Byzantine period (Patricios 2002).

Table 7. Ceramic ages for grain size on average 20 micron.

Sample	ED (Gy)	U	Th	K_2O (K%)	Rb	Dose Rate (Gy/ky)	TL Age (BP)
ITH2c	5.63±0.11	1.5±0.4	16±1.4	2.09 (1.73)	91.17	4.16±0.15	1350±60
ITH3c	4.43±0.51	1.3±0.5	13.5±1.7			3.79±0.18	1170±150

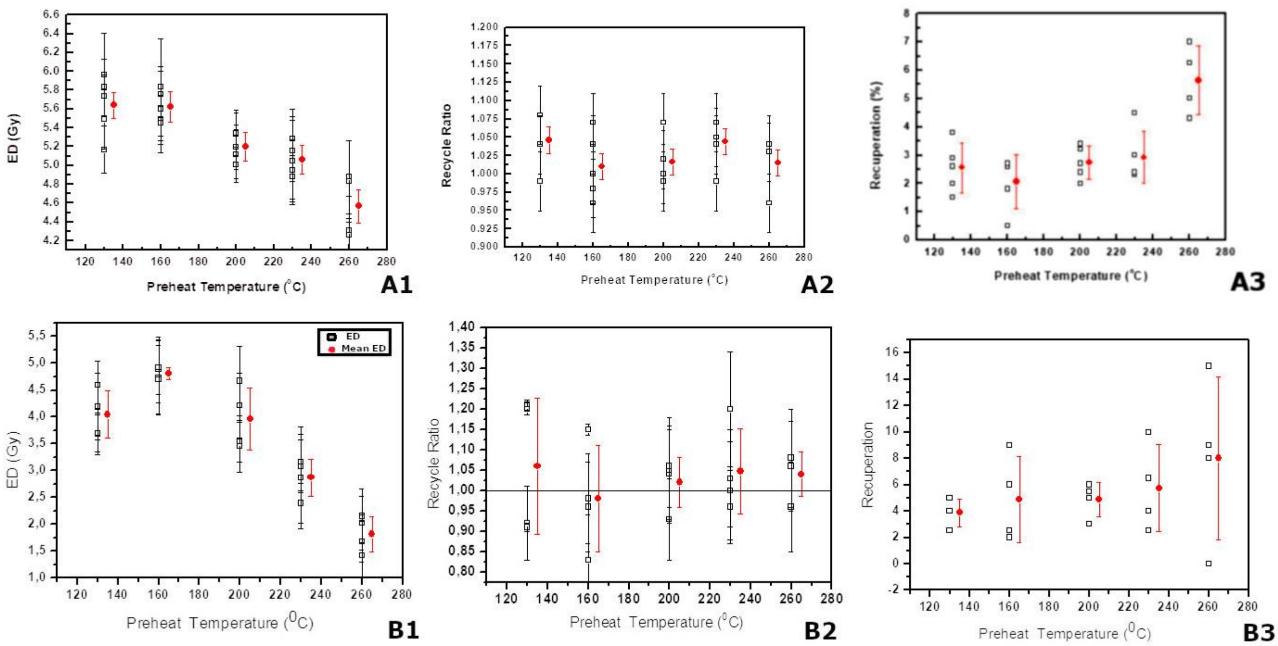


Figure 14. Reliability Test of the two ceramics. ITH2c; ED (A1), the recycling ratio (A2) and the recuperation value (A3) of the pottery with laboratory code name ITH2. ITH3c; ED (B1), the recycling ratio (B2) and the recuperation value (B3) of the pottery. Open squares represent the independent measurements while circles represent the averages for each preheating temperature.

7. CONCLUSIONS

Age estimation of two limestone samples from School of Homer, on Ithaca Island, Greece, was performed using thermoluminescence (TL). They dated the upper east façade, the lower row of the Mansion (ITH-3), of a stony walkway, while sample ITH-4 was collected from the outer circular wall of well-known age during archaic/Classical period. The obtained TL age was within the error bars in the 2nd millennium BC and the mid millennium BC respectively. The latter satisfies the archaeological estimation of the wall.

For the two ceramic ages they were of early byzantine period. The site was occupied during Bronze, later to Hellenistic era and Byzantine as well.

The earlier age is consistent with the Middle/Late Bronze Age phase. The low row from where the sample was taken must have been the prehistoric foundation of the wall.

The present study verifies experimentally the previous suggestion of Papadopoulos (2022) that the archaeological site has been subjected to various occupational phases throughout its history.

The limitation regarding reliability of the obtained TL age at least for the stone, lies with the limited number of samples measured. Yet the one age agrees to the archaeological expectation, and this alone provides credit to the higher age sample even within a large error still falls within the 2nd millennium BC. If this age is related to the Odysseus palace cannot be confirmed as more archaeological evidence is sought.

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