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LUMINESCENCE DATING OF PREHISTORIC SITE OF SMINTHEION (GULPINAR) IN NW TURKEY

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ABSTRACT

This study aims to place the prehistoric settlement of Smintheion in northwestern Turkey in its temporal setting on the basis of the dating of the quartz from pottery and sediments collected from the site employing Optically Stimulated Luminescence and Thermoluminescence techniques. The site belongs to the problematic Middle Chalcolithic period in western Anatolia. This period represents a cultural upheaval in western Anatolia as it has a completely different material culture when compared to that of the preceding Early Chalcolithic period. The pottery and sediment samples were collected from two different locations of the Middle Chalcolithic settlement at Smintheion for dating study. The fact that this examined settlement is represented by a single cultural level provides an opportunity to obtain secure and reliable dates for the settlement. Results of this study show that the site can be dated to a period between 4800 and 4500 B.C.

KEYWORDS: Chalcolithic, Turkey, Archaeological pottery, Sediment dating, Smintheion (Gulpinar), OSL, TL

INTRODUCTION

The site of Smintheion (Sanctuary of Apollo Smintheus) is situated on the southwestern corner of the Troad in northwestern Turkey. It is also roughly located 1 km east of the ancient city of Chryse, mentioned in the first lines of the Iliad of Homer.

A team under the leadership of Coşkun Özgünel from Ankara University has been conducting archaeological excavations at Smintheion since 1980 to reveal information about the sanctuary (Özgünel 2001, 2003). Archaeological excavations undertaken at the sanctuary since 2004 have also yielded evidence for a single period prehistoric settlement, roughly dating to the first half of the 5th millennium B.C.

The prehistoric settlement identified below the Greek and Roman period remains at Smintheion, roughly falls into the vaguely understood transitional Middle Chalcolithic periods in western Anatolian chronology (Sperling 1976; Seeher 1985; Takaoğlu 2005). Because it is difficult to detect the sites of this period as they are represented by low level of cultural remains, the discovery of this prehistoric settlement at Smintheion is of great archaeological significance.

The prehistoric Smintehion (Gülpınar) is often considered to be a part of the so-called "Kumtepe A/Beşik-Siviritepe/Gülpınar" cultural horizon, which roughly defines the first half of the 5th millennium B.C. in northwestern Turkey. This Troadic cultural horizon, which is often considered contemporary of the Late Neolithic 1 of the Greek chronology, has often been characterized by small and short-term occupied villages.

Calibrated radiocarbon dates on archaeological finds from the site of Beşik-Sivritepe and Kumtepe A, and identical to those of Smintheion, yielded a chronology ranging from 4800 to 4500 B.C. (Korfmann and Krömer 1993; Krömer *et al.*, 2003).

Therefore, by demonstrating the contemporaneity of Smintheion with Beşik-Sivritepe and Kumtepe A we can acquire a better understanding of this cultural horizon and shed light on the 5th millennium's BC archaeological setting. The most distinguished feature of this period is probably finely gray-black or gray-brown burnished homogeneous pottery tradition.

This study aims to examine the samples selected among diagnostic clay vessels of prehistoric Smintheion using both thermoluminescence as well as optically stimulated luminescence techniques. In addition to pottery analyses, a total of seven sediment samples with quartz grains were also dated by luminescence techniques and compared with the results obtained from pottery samples.

This in turn helps us compare the two different datasets; the pottery analyses in one hand and luminescence ages from the sediments in the other.

SITE DESCRIPTION

Smintheion is located on a flat ground at an elevation of 60 m above the present sea level, nearly one kilometer far (east) from the Aegean seashore (Fig.1).

The site was founded on the edge of a valley floor located between two Miocene low plateau ridges, extending in east-west direction towards the Aegean Sea. This valley was originally a volcanic depression subsequently filled with the colluvial deposits. The natural resources and topography were probably important factors that led the prehistoric inhabitants of Smintheion to settle in this locality.

There are today fresh-water springs in the area that offers a year-round supply of water. The natural resources of their proximal environment favored the prehistoric settlers of the site to develop a self-sufficient mixed economy based upon farming, hunting, fishing and shellfish gathering.

The fertile alluvial and colluvial soils located on the flat and gently sloping hills, which retained water and were light enough to be easily tilled, were suitable for basic agriculture-based subsistence pursuits.

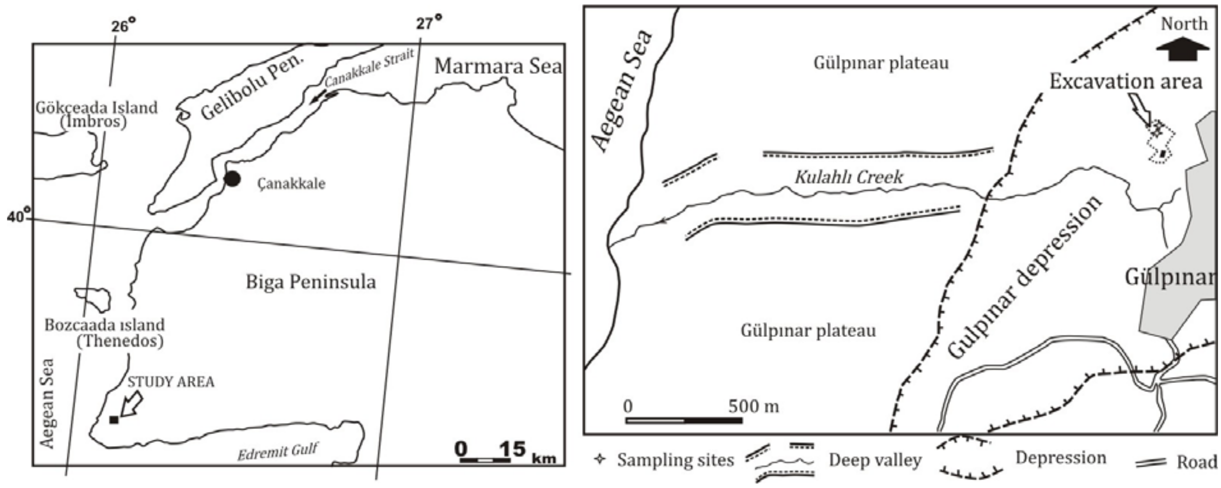

Fig. 1. Map showing Gülpınar where Smintheion (Sanctuary of Apollo Smintheus) is located.

The shallow waters located nearby were also rich in various edible species of mollusks and oysters, enabling the prehistoric settlers of Smintheion to support their subsistence base with marine resources. The cultural deposits of this prehistoric habitation rested upon the top surface of a yellowish marl layer just below the Roman structures. This marl layer in this area slightly undulates to the north towards a stream that once flew north of the site. A single cultural layer is documented above this virgin soil. Several houses with courtyards and storerooms have been identified in this prehistoric cultural level. Roman buildings such as a sacred road and houses were found above the remains of this prehistoric cultural level.

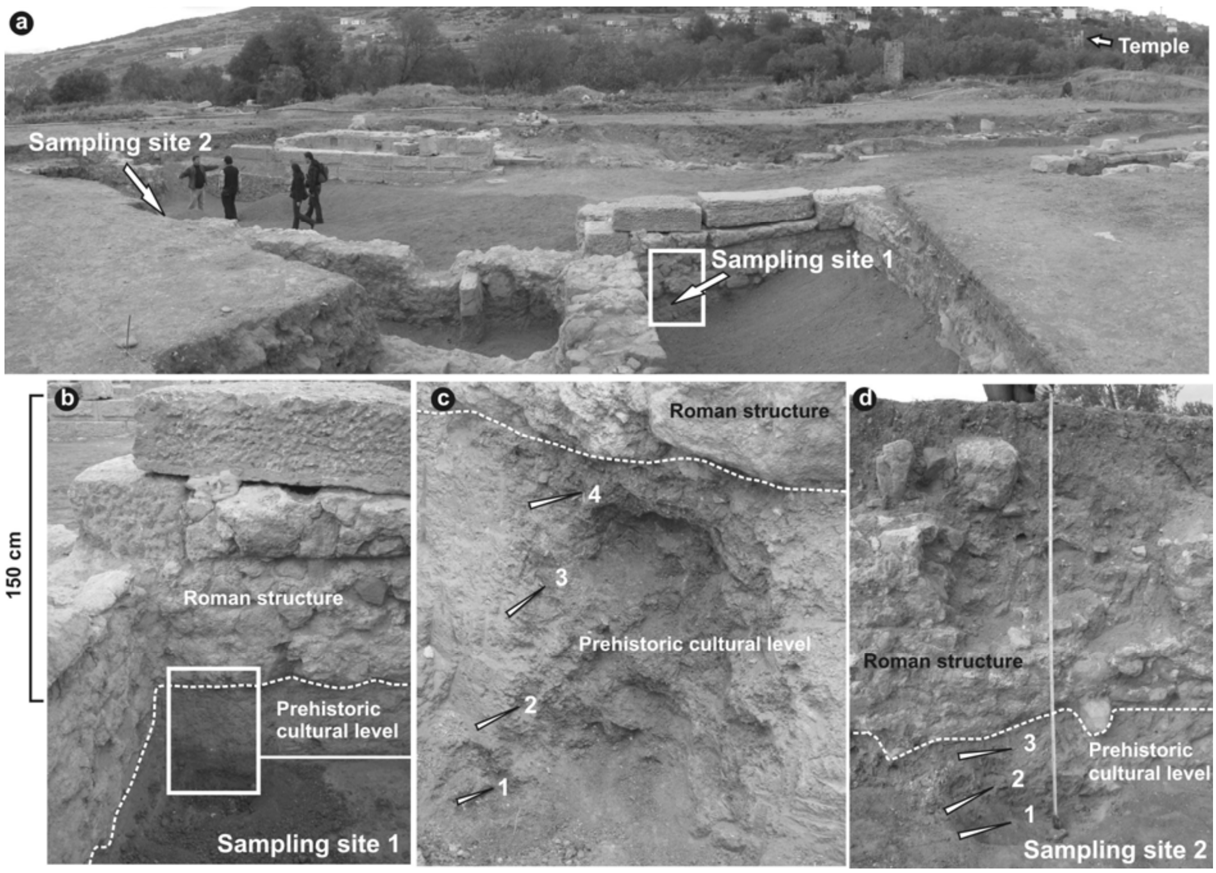

Fig. 2. Prehistoric sampling area (a). Sections from sampling sites 1 (b and c) and 2 (d).

MATERIALS & METHODS

Sampling

In the 2008 field fieldwork several pottery samples were collected from a cultural level below the foundation walls of Roman structures. Those samples have been subjected to both thermoluminescence and optically stimulated luminescence dating methods. This prehistoric cultural level has a thickness ranging from 10 to 60 cm over the virgin soil. Its uppermost surface is about 150 cm below the modern surface level. Sampling was carried out at two different locations within the settlement from a representative vertical section 100 meters north of the Apollo Temple. The positions of samples are shown in Fig. 2. Samples were collected from two different sections shown in Fig. 2c; (4 sediment, B1/01, B1/02, B1/03, B1/04 and 2 pottery samples, B1/S1 and B1/S2) and Fig. 2d; (3 sediment samples- B2/01, B2/22 and B2/03).

To confirm the dates obtained, 13 pottery samples were also collected from different parts of the prehistoric cultural deposit; 9 samples from site1 (coded from E1 to E9) and 4 samples from site2 (coded from S1 to S4). The pottery samples selected for analysis belong to pots similar to the ones illustrated in Fig. 3.

Fig. 3. Selected examples of pottery typical to Smintheion. Original materials and fragments of pattern burnished pottery from Smintheion. Two of the sherds analyzed are identical to these examples.

Sample preparation and luminescence measurements

The luminescence age can be simply defined as the ratio of equivalent dose accumulated in the sample during its burial time to the dose rate of the radiation environment in which the sample buried.

For equivalent dose estimation quartz grains (90-180 μ) from both sediment and pottery samples were extracted by usual chemical treatments. An outer 1-2 mm surface layer of the pottery samples was removed, gently crushed and then sieved of 90 μ grains before chemical treatments with 10% HCl (for the removal of carbonates) and then 10% H_2O_2 (for the removal of the organics). The minerals were etched using 40% HF treatment for 40 min and in this process feldspar grains were separated to yield pure quartz. The quartz grains were mounted on stainless-steel discs using silicone spray and then checked with infrared (IR) stimulation for the absence of feldspar contamination and no IRSL signal detected. All luminescence measurements were performed with an automated Risø TL/OSL 15 reader, equipped with an internal $^{90}Sr/^{90}Y$ beta-source (a dose rate of about 0.1 Gy s^{-1}). The OSL signal was detected through U-340 filter using blue light emitting diodes (LEDs) for stimulation (470 nm, 40 mW cm^{-2}). Aliquots of quartz grains from each sample were treated with a preheat temperature of 260^{o}C for 10 s to remove the unstable signals from shallow traps. Then OSL signals from natural and regenerative doses were recorded under blue light stimulation at 125 ^{o}C for 40 s. To monitor and correct the sensitivity change between the cycles a fixed test dose of 2 Gy, suggested to be 10-20% of natural dose, was employed prior to a cut-heat temperature of 190^{o}C, followed by the measurement of test dose OSL signal. For the palaeodose evaluation, the integral of the first 2 s data of the OSL signal was subtracted by the background signal (the integral of last 10 s). All samples were prepared under dim red light.

Dose rate estimation essential to dating is based on gamma spectroscopy for external dose rate and on the concentrations of the major radioactive isotopes of the uranium and thorium series and of potassium in the sample.

EXPERIMENTAL RESULTS

The equivalent dose was obtained from both sediment and pottery samples using the measurement sequence of single-aliquot regenerative-dose (SAR) protocol based on natural and regenerative dose OSL measurements (Liritzis et al., 1997; Murray and Roberts 1998; Murray and Wintle, 2000; Leung et al., 2005). Glow curves from a representative pottery sample are shown in Fig. 4a; in Fig. 4b natural and subsequent test dose decay curves are presented. A multiple-aliquot additive-dose method was used for Thermoluminescence (TL) evaluation of the pottery ages (Liritzis, 2000). The glow curves were measured at 3°C/s to 450°C and normalized using the luminescence signal induced from a test dose.

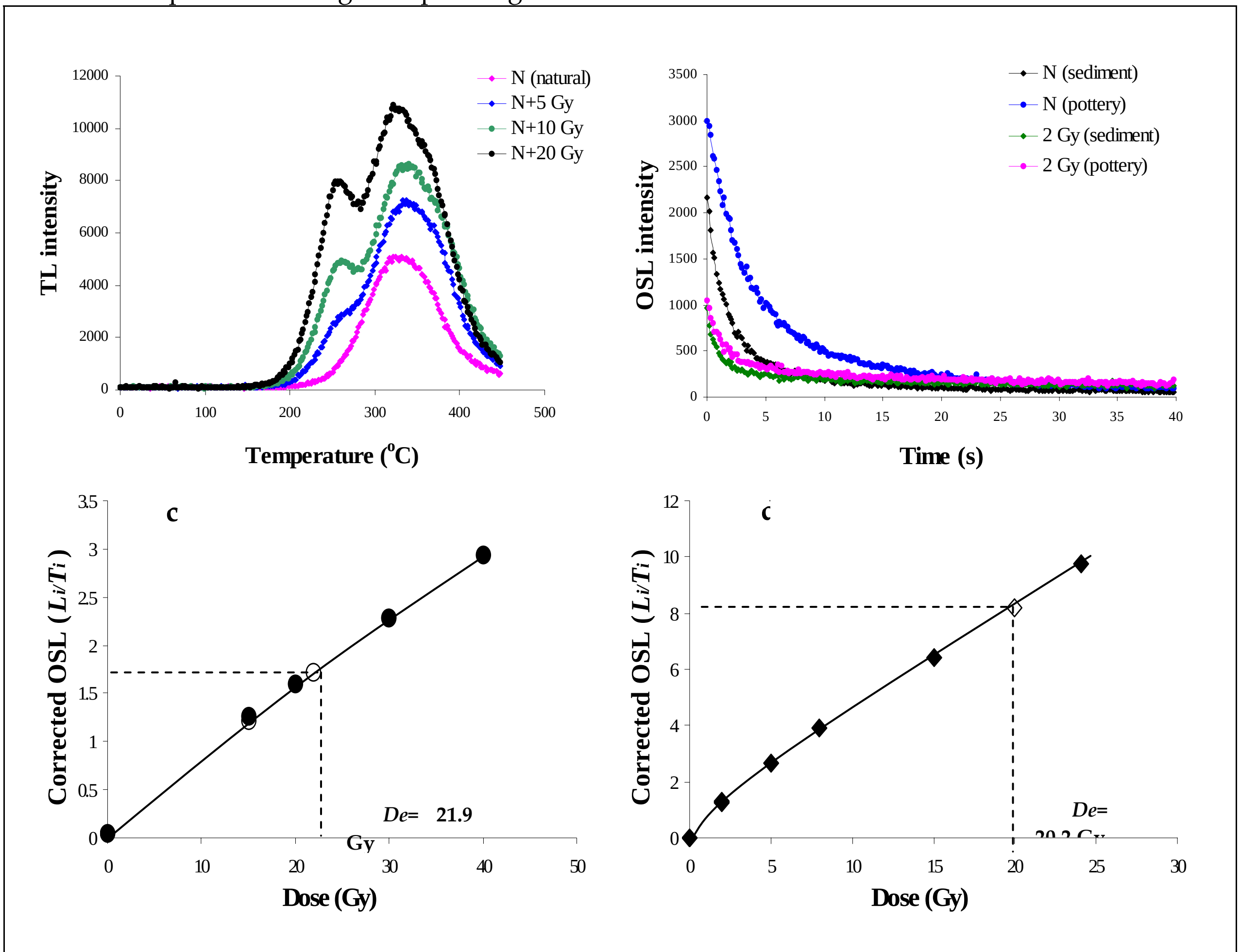

Fig. 4. a) Natural and additive dose glow curves from a representative pottery sample; b) Natural and test dose OSL decay curves from sediment and pottery samples; and comparison of growth curves obtained from c) sediment sample and d) pottery sample using single-aliquot regenerative-dose protocol.

For TL analysis, 15 aliquots were divided into four groups; the first group (6 samples) for measuring the natural TL (N), other groups (3 samples each) to be exposed to an additional beta doses (*N* + 5 Gy; *N* + 10 Gy; *N* + 20 Gy). Fig. 4a shows the glow curves of a representative sample. In case of OSL-SAR dose estimate, 10-16 aliquots from each sample were evaluated.

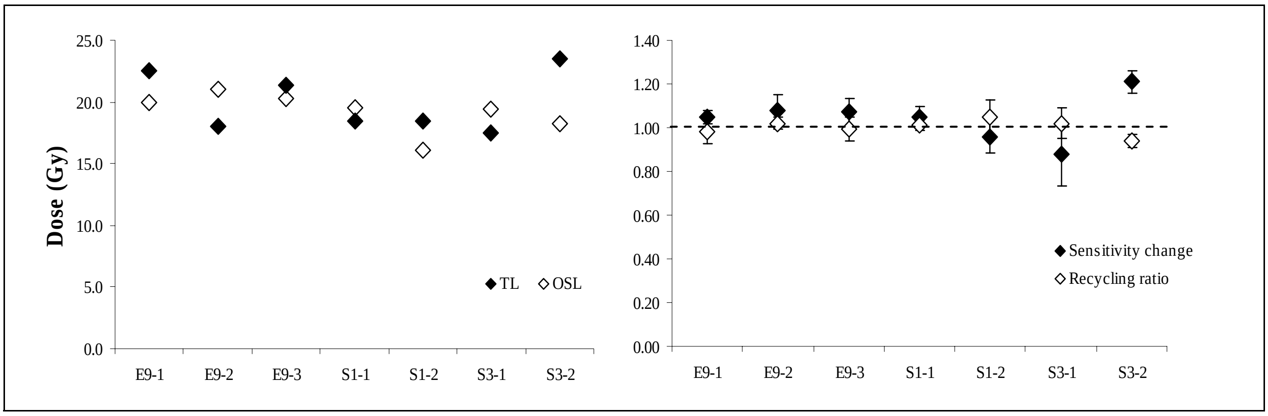

Fig. 5. This figure presents a) the D_e estimates of pottery samples by OSL and TL techniques from different fragments of representative samples for comparison. The OSL and TL palaeodoses obtained are relatively in accordance with each other and b) Sensitivity change and recycling ratio values in OSL measurements of the same samples.

To check the reliability in OSL measurements, the first regenerative dose was repeated in the last cycle, defined as the ratio of the first and last repeated doses- namely recycling ratio- was found in a range of acceptability from 0.90 to 1.10 for all sediment and pottery samples. Recuperation, the percent ratio of recuperated signal to the natural dose signal (should not be above 5%) was obtained from a zero Gy dose application in the fifth cycle of SAR (Murray and Wintle, 2000). Disregarding the two pottery samples all recuperated values were found below 5%. As another indicator for the reliability in OSL dose evaluation, previously bleached aliquots by subjecting to light were given a known laboratory dose, close to the natural dose, namely dose recovery test, and then measured using the SAR protocol (Murray and Wintle, 2003, Vafiadou, et al., 2007).

The ratio of given dose to measured dose was found between 0.90 and 1.10, as suggested. The TL palaeodose estimates were obtained from the evaluation of additive dose glow curves. The main difference between these two protocols is that the SAR protocol gives number of individual dose estimates for each aliquot and palaeodose D_e is averaged, whereas TL additive procedure produces only single dose value from multiple aliquots.

The annual dose rate calculation relevant for dating was estimated from the concentrations of radioactive elements in the sample and its surroundings. For the sediment samples gamma dose rate was measured at site using a field gamma spectrometer. Beta dose rate was obtained from relative contribution of U, Th and K from gamma spectra recorded at site and using conversion factors as presented by Olley et al., 1996. In case of pottery samples the annual dose rate is estimated from external and internal dose rates calculated independently. The external dose rate is generated by gamma rays from the sediment within a radius of about 30 cm around the sample and cosmic rays. The contribution of alpha and beta doses to external dose rate was eliminated because the outer 2 mm layer of pottery samples was removed. Thus the external dose rate was measured in situ with a portable gamma spectrometer, as 1.95 mGy/a in average ranging from 1.71 to 2.26 mGy/a. Internal dose rate was derived from the concentrations of radioactive elements in the sample. The concentrations of relevant isotopes in pottery sample were measured about 1.6 ppm U, 16.6 ppm Th and 0.99 % K. The maximum water uptake of all pottery and sediment samples was determined in the laboratory in the range between 7.3 and 16.3, and used for the corrections to dose-rates (Aitken, 1998). Cosmic dose rate was estimated between 0.15-0.19 mGy/a using the depth of sample location 150 cm below ground, and on altitude and geographic latitude (Prescott and Hutton 1994).

The OSL ages from site1 (4 sediment and 2 pottery samples) and site2 (3 sediment samples) are presented in Fig. 6a. All samples from site1 gave ages in a range between 6.8 and 6.3 ka, whereas the age from location 2 was found relatively younger. The ages obtained for pottery samples with errors estimated, equivalent OSL-SAR doses and dose rates relevant to OSL dating are presented in Table 1.

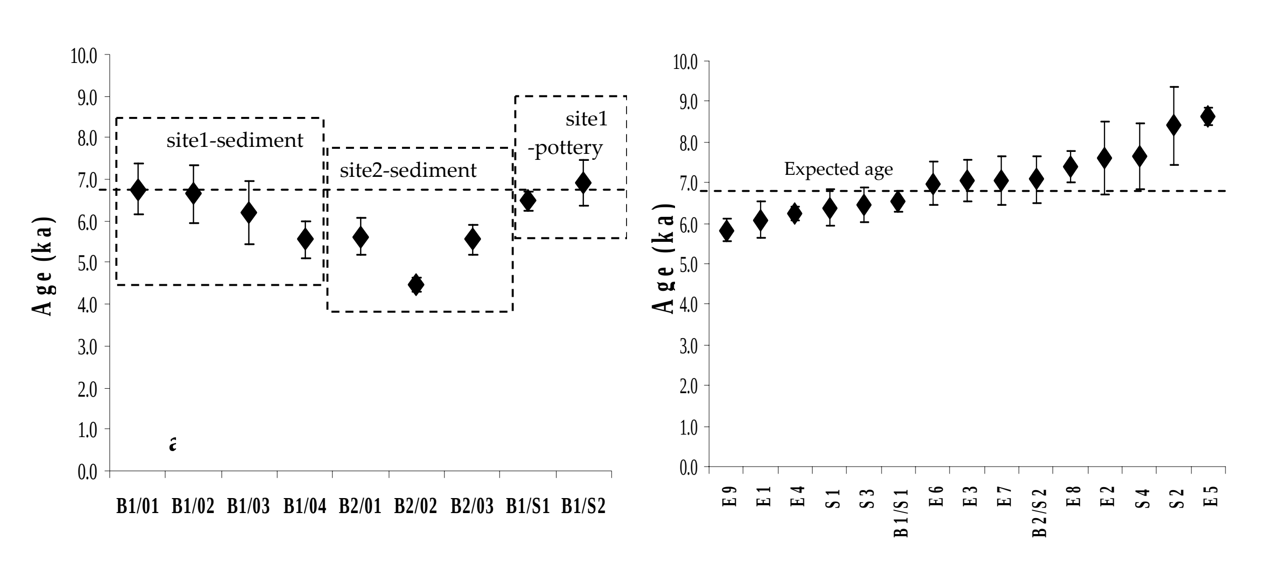

Fig. 6. a) OSL ages for sediment samples from site1 and site2, and OSL ages of pottery samples from site1. Dashed straight line indicates the expected age. b) OSL ages with standard errors for pottery samples collected from prehistoric cultural deposit. Dotted line presents the expected age.

Table 1. OSL ages for all pottery samples evaluated, equivalent SAR doses and dose rates

Lab Code	Age (ka)	Dose (Gy)	n*	Dose rate (Gy/ka)
E1	6.08 ± 0.44	22.20±1.60	6	3.65
E2	7.61 ± 0.89	28.35±3.28	8	3.73
E3	7.04 ± 0.52	26.14±1.89	6	3.71
E4	6.25 ± 0.18	22.96±0.59	8	3.67
E5	8.64 ± 0.22	32.25±0.73	6	3.73
E6	6.98 ± 0.54	23.67±1.81	10	3.39
E7	7.05 ± 0.61	25.70±2.21	7	3.65
E8	7.39 ± 0.38	26.83±1.33	6	3.63
E9	5.83 ± 0.29	20.66±1.01	9	3.54
B1/S1	6.55 ± 0.25	22.11±0.75	12	3.38
B2/S2	7.08 ± 0.57	24.01±1.90	7	3.39
S1	6.38 ± 0.44	21.10±1.43	10	3.31
S2	8.40 ± 0.98	28.35±3.28	8	3.38
S3	6.47 ± 0.43	20.63±1.34	6	3.19
S4	7.64 ± 0.83	25.68±2.76	10	3.36

* The number of aliquots evaluated.

The OSL ages from 15 pottery samples are summarised with ascending order in Fig. 6b, where seven OSL age values are almost overlapped with expected ages. Overall errors in optical age estimates contain systematic and random errors from beta-source calibration and dose-rate estimate in addition to luminescence measurements.

CONCLUSIONS

The dates obtained for pottery of Smintheion through OSL and TL techniques are in accordance with the relative dates obtained by stylistic analysis. Seven OSL dates from 15 pottery samples are well satisfactory compared to the expected ages. Prior to analyses, dates ranging from 4800 to 4500 BC were being expected as the sites such as Kumtepe A and Beşik-Sivritepe with materials remains closely comparable to those of Smintheion yielded these dates after radiocarbon dates. Now, OSL and TL analyses of pottery samples and OSL analyses of sediment samples from Smintheion provided us with similar dates. This promising preliminary study shows a potential for more precise dating for the Middle Chalcolithic settlement when additional detailed sampling is undertaken at the site. The reliability of these dates can be tested when they will be compared with the forthcoming radiocarbon analysis expected for the charcoal and bone samples from the site. This will in turn help us to obtain a closer date within the nearly 500 years long Middle Chalcolithic period. This is because documenting to what centuries Smintheion belonged to between about 5000 B.C. and 4500 B.C. could be an important contribution to the archaeology of western Turkey. The dates from both sediment and pottery samples indicate a homogenous cultural level below the ancient Greek and Roman remains of Smintheion. This homogeneity in pottery also confirms that this prehistoric site is indeed represented by a single cultural level.

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