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THERMOLUMINESCENCE DATING OF MAENAM NOI KILN, CENTRAL THAILAND

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ABSTRACT

Maenam Noi kiln sites are located at Sing Buri, central Thailand. This study focused on Tawen Tawong remained kiln that is a part of the Maenam Noi kiln clusters. This investigated area can be divided into 2 geomorphologic units as the low river terrace and flood plain unit. This kiln is located on the low river terrace unit. Tawen Tawong kiln is the crossdraft kiln with a brick arch and used for firing earthenware during the Ayutthaya period (14^{th} to 18^{th} century AD). The age of the kilns were determined by using a regenerative thermoluminescence (TL) dating technique. The brick samples were collected from the remaining wall of the kilns. Quartz extracted from these bricks was the material dated by TL. The TL-dating results ranged 1419 to 1488 AD.

Keywords: *Maenam Noi kiln, Tawen Tawong kiln, Thermoluminescence dating*

1. INTRODUCTION

Mae Nam Noi kiln is the largest site for pottery production in the Ayutthaya period (14^{th} to 18^{th} century AD) [1]. It is located at Sing Buri Province, central Thailand (Figure 1). The kiln cluster is spanning two kilometers from the studying site and numbering over 200 kilns. However, some of them have decayed over time or destroyed due to irrigation canal digging and road construction. Apart from being a cultural heritage site, this archaeological site is also one of the world's study centers on ceramics. This work focused on one of the Maenam Noi kiln cluster called "Tawen Tawong" kiln. The first investigation began in 1985 by the Division of Archaeology of Thailand. Two kiln sites were designed to excavate in 1988 [2]. It was a crossdraft kiln with a brick arch, measuring 14 m in length, 5 m wide at fire-wall and 2.1 m in height.
It was known that geoarchaeology coupled with geomorphology had been used study the locations of ancient kilns. In this work, the geomorphology and thermoluminescence were carried out to study Mae Nam Noi Kiln to obtain more complete information.

2. METHODOLOGY

2.1. Geomorphology and sampling preparation

The geomorphological setting around the investigation area was divided into 2 units as the low river terrace (Lt) and floodplain (Fp) unit (Figure 2). The kiln cluster was on the lower river terrace at 7-12 m a.s.l., and scattered along the Noi River, locally called, Maenam Noi. This terrace was predominately composed of very fine to fine sand and clay.
Eight brick fragments were collected from the different remained chimneys and walls where the Tawen Tawong kiln was excavated (Figure 1). All samples were prepared with removing the outer surface (3-4 mm). The outer layer was discarded because it may reduce the level of luminescence due to the effect of sunlight and soil contamination on the brick surface [3]. The samples were crushed gently and sieved to obtain the grain size range of 74-250 μm. They were separated into magnetic and

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non-magnetic portion. The non-magnetic grains were washed in 35% HCl for 1 h and washed in distilled water. Afterwards the samples was etched in 24% HF for 40 min and washed in distilled water. After drying the samples in the 40-50 ^{o}C condition, the quartz quantity was checked by X-ray diffraction (XRD) analysis. The quartz samples contained more than 95% of mineral were accepted.

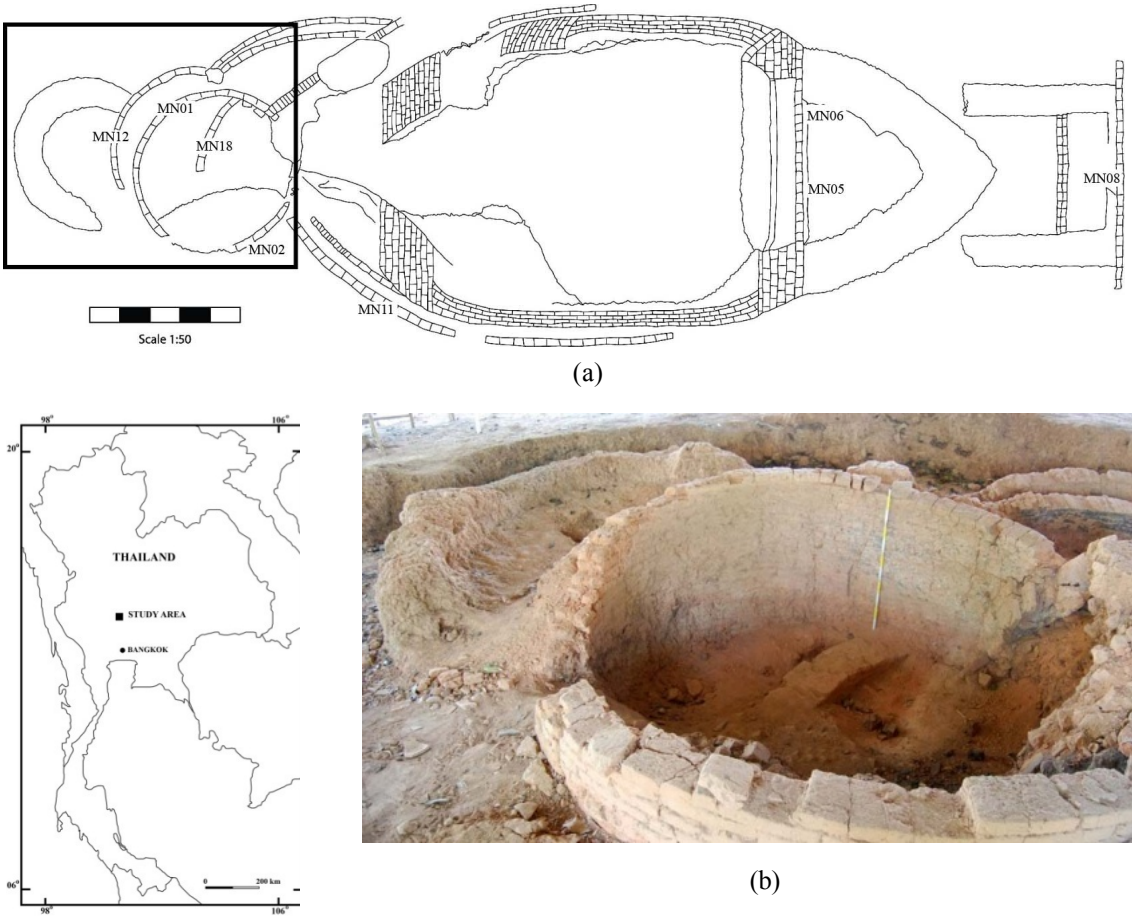

Fig. 1 Layout drawing of Tawen Tawong kiln excavation and the sampling locations (the multi-chimneys shown in the box) (a) and Four chimneys on Tawen Tawong kiln (b)

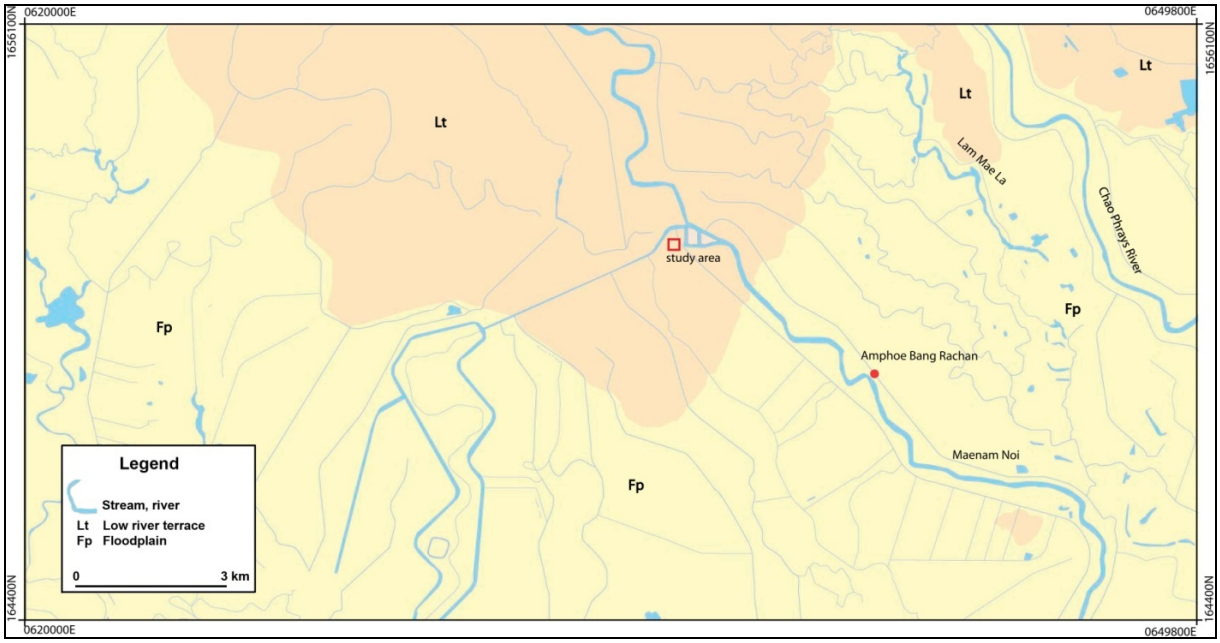

Fig. 2 Geomorphological map shown the study area was located on the low river terrace

2.2. TL measurement

The TL emission from the coarse-grained quartz is measured using the C123 photon counter (Hamamatsu Photonics), SU-11 Temperature controller (Chino Co. Ltd.) with heating rate 120°C per min in a well-equipped nitrogen purge condition. Only 10 mg of sample was placed on the molybdenum heater. A combination of the blue filter (Toshiba IRA-10) and a long wave pass filter (ESCO Products, OG-550) with bi-alkaline photomultiplier tube filtering is applied. The emitted wavelength of the system is around 550-650 nm.

Regenerative dose determination of the growth curve method was used for the determination of equivalence dose of coarse grained samples [4]. Both natural and gamma ray irradiated samples were measured. In the preheat condition at 320°C for 5 h, natural samples were irradiated at different dose. After irradiation, the unstable signals from the samples must be excluded by heating at 130°C for 1 day. The peak of the TL glow curve was selected by considering the plateau test [5]. A constant ratio between natural and artificial glow curves can give an indication throughout the plateau region. The 350-375°C peak height and non-peak of the TL glow curve (Figure 3a) for the coarse grain sample is selected for the determination of equivalent dose (ED) in Figure 3b.

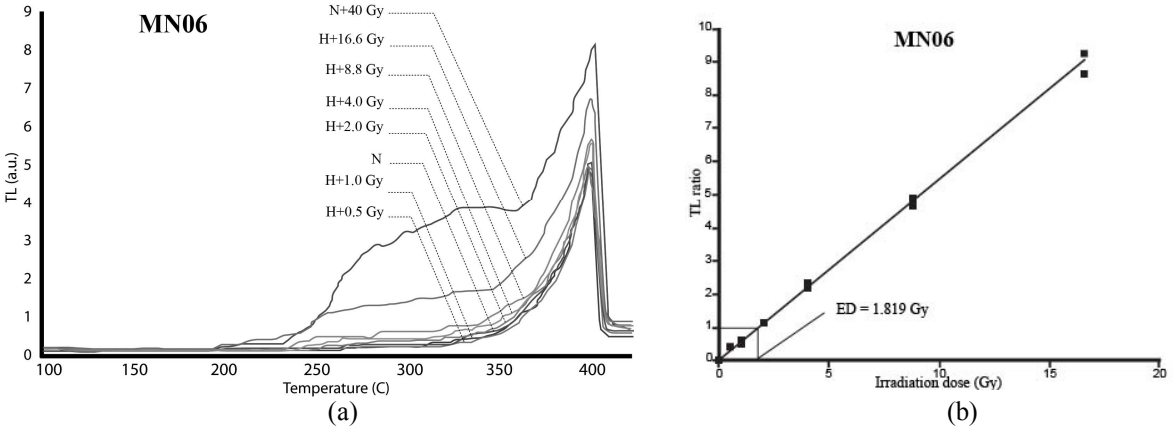

Fig. 3 TL glow curve of MN06 sample: N = natural quartz, H + 0.5 Gy = Heated quartz with additional artificial irradiation (a) and TL growth curve of MN06 for determination of equivalent dose (ED) (b)

The annual dose rate (AD) determinations were determined by gamma ray spectrometry. The 290 g sample was put in the 75 mm-diameter NaI scintillator unit with multi-channel analysis. Standard samples are NBL (0.5% U and 0.5% Th), chemical regent (K_2CO_3) and blank power (SiO_2:Fe_2O_3; 95:5 in weight). It was made by 50 ppm and 5% standards for U/Th and K_2O powder, respectively, and mix with blank powder. The annual dose rate is calculated from the chemical data of U, Th, K_2O and the water contents were calculated using the method propose by Aitken [5].

$$AD = D_{alpha} + D_{beta} + D_{gamma} + D_{cosmic\ ray} \quad (1)$$

Where AD = the total annual dose rate (mGy/year) including the doses of alpha, beta, gamma and cosmic ray irradiation contents from the surrounding environment.

The age of the brick fragments were determinate by

$$Age = ED/AD \quad (2)$$

Where ED = the equivalent dose accumulated during the age of the brick.

3. RESULTS AND DISCUSSION

The evaluation of the equivalent dose was calculated by the natural TL intensity from the natural sample and comparing with the artificial TL intensity from the irradiated sample. The TL age results were shown in Table 1.

Results from regenerative dose thermoluminescence showed that MN01, MN02, MN05, MN06, MN08, MN11 and MN12 were dated to 522 ± 53, 528 ± 50, 588 ± 51, 591 ± 51, 535 ± 47, 535 ± 46, 534 ± 45 and 563 ± 52 years, respectively.

The structure of Tawen Tawong kiln was a crossdraft kiln which was similar as the kilns that found at Sawankalok site. It was superimposed on the used kilns. From archaeological excavations (Figure 1) showed at least four of thermal chimney stack. It was assumed that the newer kilns of Tawen Tawong kiln were rebuilt and recovered on the first one which was broken or intended to overlap to take advantage of heat flow through from the bottom of the top of the kiln.
Results from TL dating and construction of the kiln, it was expected to be used from 1417 AD. The chimney was then reconstructed on the original kiln and operated together. TL reported that the bricks from the chimney wall (MN 01, MN02 and MN12), external of fire-wall (MN11) and rim of kiln entrance (MN08) were dated around 1475 to 1488 AD.
It was found that the Tawen Tawong kiln was operated between the middle of 14th century AD to the beginning of 15th century AD., which corresponded with the archaeological resources from the other [1].

Table 1 TL ages determination of brick samples from Tawen Tawong kiln remain. Wt is water content, AD is annual dose, and ED is equivalent dose

Sample	Wt (%)	U (ppm)	Th (ppm)	K_2O (%)	AD (mGy/a)	ED (Gy)	TL age (a)
MN01	0.880	2.685	17.71	0.465	2.468	1.289	522±53
MN02	0.610	2.466	18.32	1.118	3.027	1.600	528±50
MN05	0.140	1.592	17.58	0.535	2.257	1.327	588±51
MN06	nil	3.251	20.44	0.775	3.077	1.819	591±51
MN08	0.490	2.823	17.74	0.666	2.679	1.434	535±47
MN11	1.490	1.771	16.10	0.533	2.188	1.171	535±46
MN12	nil	2.036	15.36	0.648	2.296	1.225	534±45
MN18	0.200	2.106	16.42	0.542	2.230	1.294	563±52

Note: nil equals to less than 0.1 wt%

4. CONCLUSIONS

The result of TL dating of the brick fragments indicated that the Tawen Tawong kiln consisted of at least four remaining chimneys which were constructed and reconstructed during the middle period of the Ayutthaya Kingdom (15th to 16th century AD).
Finally, the results of this study demonstrated the usefulness and potential advantages of thermoluminescence measurements to the understanding of ancient kiln.

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REFERENCES

[1] Grave P. and Maccheroni M. (2009) Characterizing Asian stoneware jar production at the transition to the early modern period. In: *Proc Scientific Research on Asian Ceramics 4th Forbes Symposium*, 1550-1650.
[2] Prishanchit S. (1988) The archaeological survey and excavation report of Maenam Noi kiln, Tambol Choeng Klat, Amphoe Bang Rachan, Changwat Singburi, Central Thailand. Division of Archaeology, Department of Fine Art of Thailand (in Thai language).
[3] Meric N., Atlihan M. A., Kosal M., Yuce U. R. and Cinaroglu A. (2009) Infrared stimulated luminescence and thermoluminescence dating of archaeological samples from Turkey. *Journal of Geochronometria* 34: 25-31.
[4] Takashima I. and Watanabe K. (1994) Thermoluminesence age determination of lava flows/domes and collapsed materials at Unzen Volcano, SW Japan. *Bull. Volcano. Soc. Japan* 39: 1-12.
[5] Aitken M. (1985) *Thermoluminescence Dating*. Academic Press, London.