***ORIGINAL PAPER***

# COMPARATIVE MORPHOLOGY AND COMPOSITION OF 13$^{th}$-14$^{th}$ CENTURIES POTTERY FROM INDIA AND SOUTHEAST ASIA

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***Abstract.*** *Fine-Paste Ware (FPW) was an evidence of trade routes connecting maritime Southeast Asia during 13$^{th}$ to 14$^{th}$ centuries. Beyond the present-day Thailand and Indonesia, FPW artifacts were also found at Otein Taung in Bagan in central Myanmar. Microscope images reveal fine cross-sectional texture of sample from such archaeological site. As a comparison, Coarse-Paste Ware (CPW) shreds of the approximately similar historical age from Tamil Nadu in southern India and Nakhon Si Thammarat in southern Thailand exhibit rough clusters with pores. In additions, the CPW samples from Thailand contain exceptionally high amount of carbon up to 36% suggesting the ash glazing in the manufacturing process. Iron contents in potshreds from Otein Taung in Myanmar are higher than that from Tamil Nadu in India, supporting the hypothesis that earthenware in Southeast Asia were locally produced and independent from the dominant India.*

***Keywords:*** *Maritime Southeast Asia, Fine-paste ware, Coarse-paste ware, SEM, EDS.*

## 1. INTRODUCTION

Archaeometric study of ancient pottery is a pathway to connect craftsmanship and technology of the past [1]. Unlike other precious materials, pottery was produced and used by common people all over the world. For this reason, pottery provides a unique route to understand the way of life and the technology of commoners. It is known that several European archaeological sites have a long history of pottery production. Examples include Sicily in Italy [2], Dorylaion in Turkey [3], Cassope in Greece [4], Alba Iulia-*Lumea Nouă* in Romania [5], Prokuplje, Nis and Belgrade in Serbia [6, 7]. The scientific characterizations on ancient earthenware of these different regions and eras have led to fascinating accounts and connections between places and times.

In Asia, Chinese glazed ceramics have dominated since the 9$^{th}$ century because of their strong bodies and sophisticated appearances [8, 9]. However, some types of indigenous unglazed earthenware were still produced in Southeast Asia because they were cheaper and had specific functions in the local context. For example, the Fine-Paste Ware (FPW) was still made after the 9$^{th}$ century. It had probably been the only type of earthenware that was widely traded in maritime Southeast Asia, including southern Thailand, northern Sumatra, Java,

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southern Philippines during $13^{th}$ to $14^{th}$ centuries or even earlier [10, 11]. Trade in maritime Southeast Asia continued to prosper as seen in the $17^{th}$ century as the spice trade in Molucca Island was extended to Europe [12].

FPW was wheel-made with very fine clay and sometime with Kaolin, without any visible temper. It was fired in an oxidizing atmosphere and, sometime, had slips. The clay composition has led to the classification into red-slipped FPW and Kaolin-rich white FPW with the probable production center in Java of Indonesia and Satingphra of Thailand, respectively. From the $10^{th}$ to $14^{th}$ centuries, the only form of FPW was *kendi*, which was a Malay word for ewer or globular vessel with a spout for pouring water out. FPW kendis were used in Hindu-Buddhist rituals for libation as well as in everyday life for containing drinking water. The unglazed, fine texture kept the water cool in the warm climate of this region.

In this paper, the studies of FPW and Coarse-Paste Ware (CPW) are extended beyond the maritime Southeast Asia. Interestingly, CPW vessels of different shapes were also distributed in Tamil Nadu, in southern India. As one of the world's oldest civilization, the origin of Indian pottery could be dated back to 2,000 BCE [13, 14] and Tamil Nadu has great historical significance [15, 16]. By contrast, the scientific reports on pottery on Myanmar are rare. In one of those reports by Ueda and co-researchers [10], Twante of Myanmar was identified as a kiln site whereas Otein Taung was regarded as a consumption site from the excavation of red FPW. Despite its historical contact with its neighbours in Indian Subcontinent, the FPW from Myanmar seems exhibit petrographic and chemical profiles unique to its own region [10]. The morphology and composition of red FPW Myanmar is also compared to those of CPW from southern Thailand and India in this study.

## 2. MATERIALS AND METHODS

### *2.1. MATERIALS*

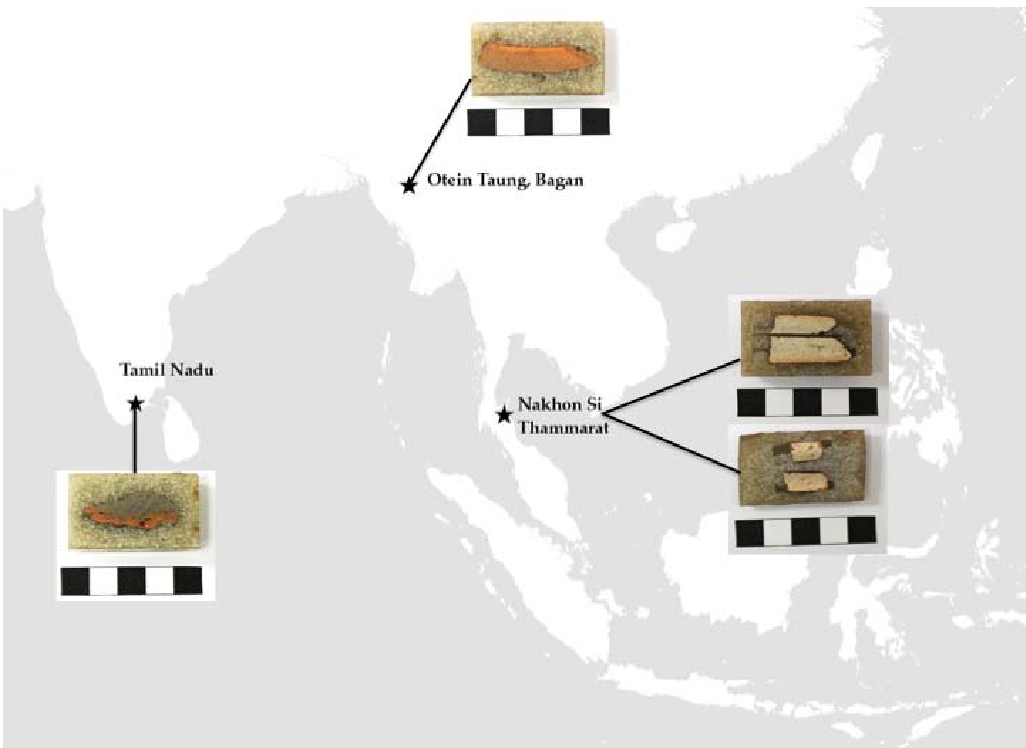


**Figure 1. Photographs of potsherds from Tamil Nadu in India (TND-010), Otein Tuang in Myanmar (OTT-011) and Nakhon Si Thammarat in Thailand (SL5-011, SL5-012).**

Four samples from three archaeological sites in three countries were investigated. The first site is Otein Taung in which sample OTT-011 was obtained. Otein Taung, which may be translated as “Pottery Hills,” is a part of ancient Bagan city in Myanmar. Secondly, Sample TND-010 was the surface collection from Periyapattinam of Tamil Nadu. The site was a major port on the eastern coast of the Gulf of Mannar in southern India. These two samples were collected by Professor John Miksic. Both red FPW samples were compared with two CPW shreds from present-day Thailand. Samples SL5-011 and SL5-012 were excavated from Suan Luang Temple in Nakhon Si Thammarat in southern Thailand by Dr. Wannasarn Noonsuk in 2009 [19]. They were from the same cultural layer with the Chinese ceramics dated to the Southern Song to Early Yuan Dynasties (approximately the $13^{th}$-$14^{th}$ century). All samples are mounted in blocks of resin as shown in Fig. 1.

### *2.2. METHODS*

A field emission scanning electron microscope (FESEM: Zeiss Merlin Compact) operating at 2-5 kV was used to visualize the texture of cross sectional surface. Elemental compositions of clay were characterized by Energy Dispersive Spectroscopy (EDS: Oxford Aztec connected Zeiss Merlin Compact) probe attached to the FESEM. Areas around 0.15 and 1 mm beneath the surface were measured.

## 3. RESULTS AND DISCUSSION

### *3.1. MORPHOLOGY*

In addition, to petrographic characterization, morphology visualized by FESEM lead to the understanding of the clay source and production process unique to each area. Fig. 2 reveals very fine texture of FPW shreds from Myanmar. There are small amounts of fine pores in nanoscale. By comparing micrographs at different depths, the morphology is very homogeneous. By contrast, all CPW shreds from India and Thailand in Figs. 3-5 exhibit rough cross-sectional surface. Interconnected linear pores and bloated round pores are also observed, suggesting that the firing was at a high temperature [17].

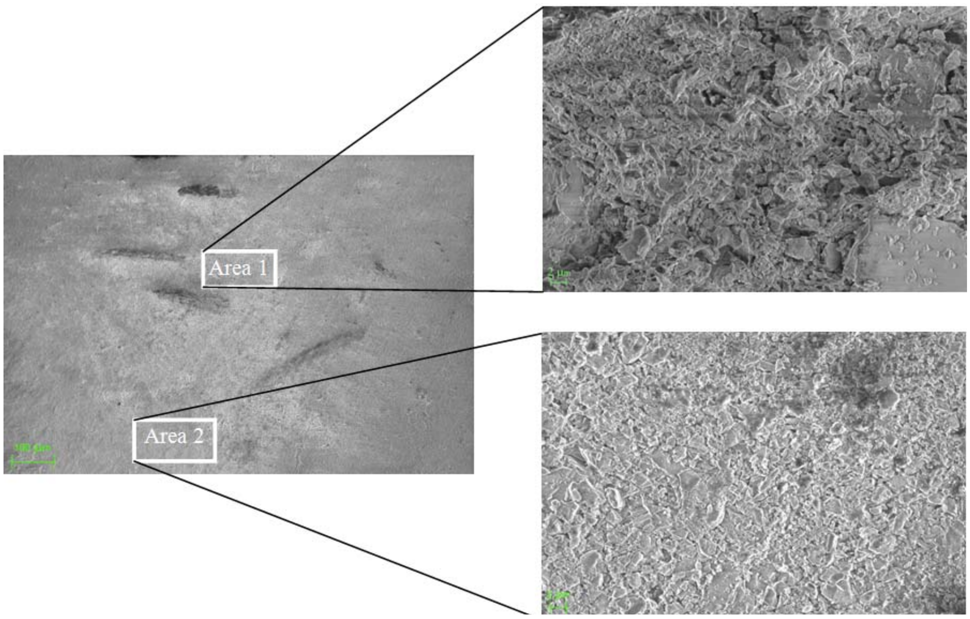


**Figure 2. FESEM images of Sample OTT-011 from Otein Taung in Myanmar.**

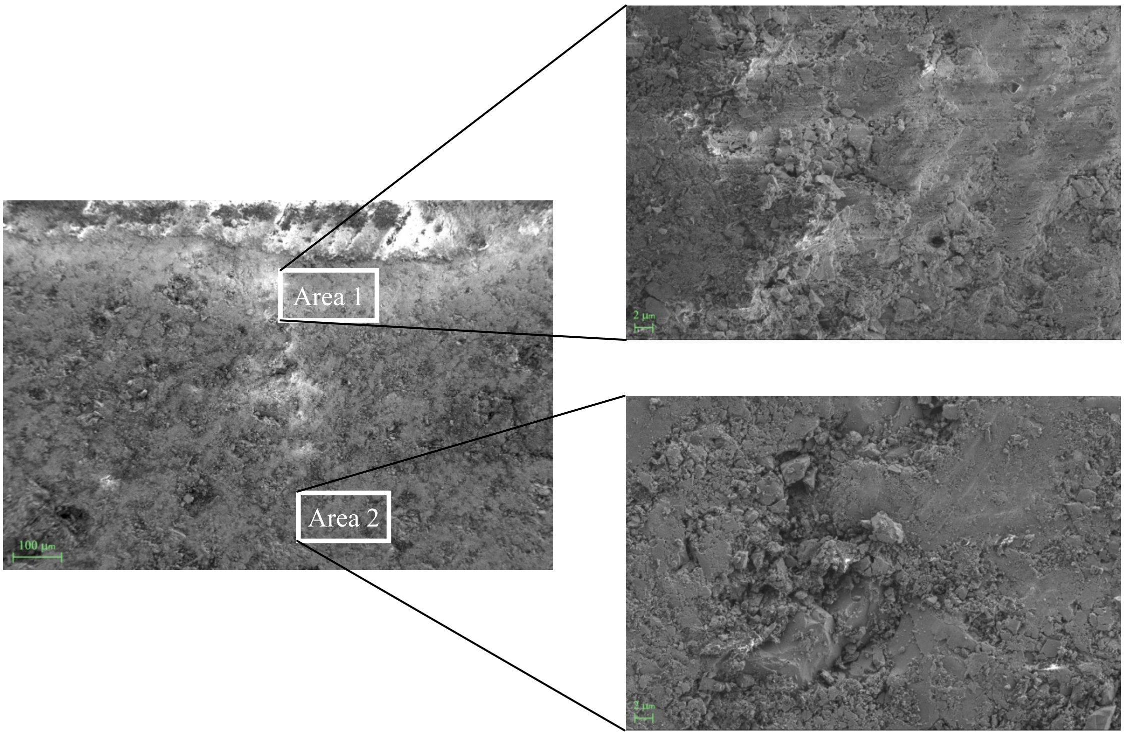


**Figure 3. FESEM images of Sample TND-010 from Tamil Nadu, India.**

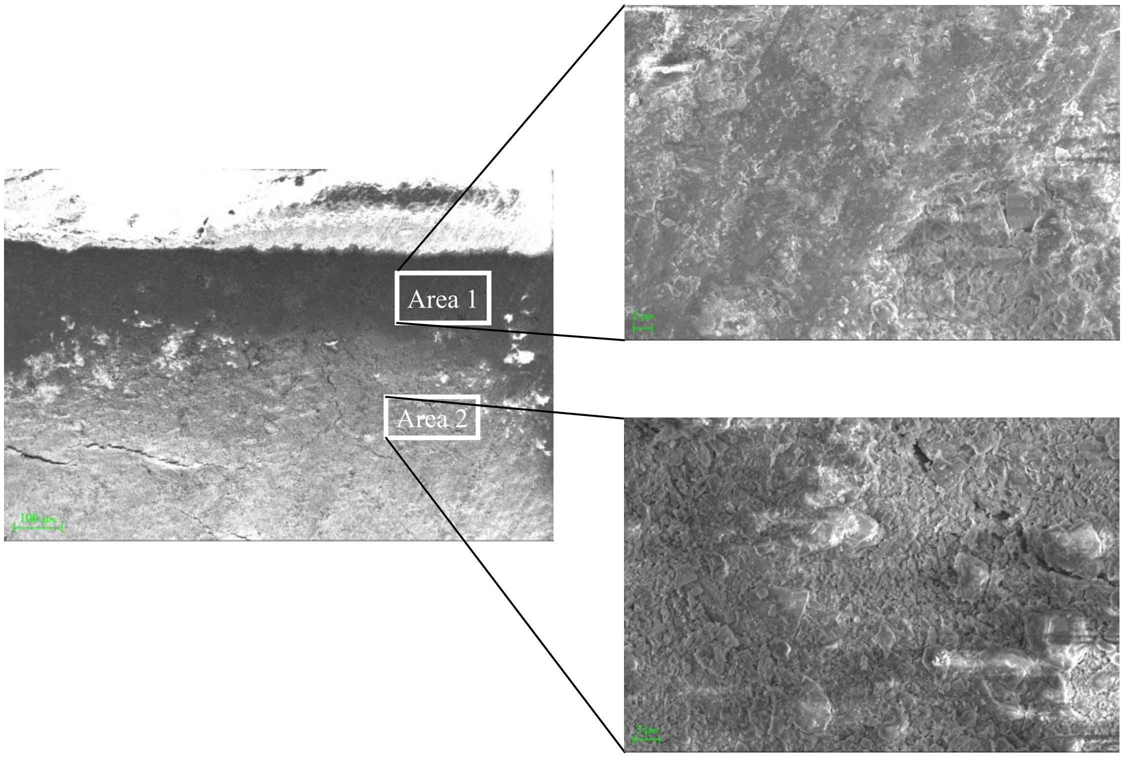


**Figure 4. FESEM images of Sample SL5-011 from Nakhon Si Thammarat, Thailand.**

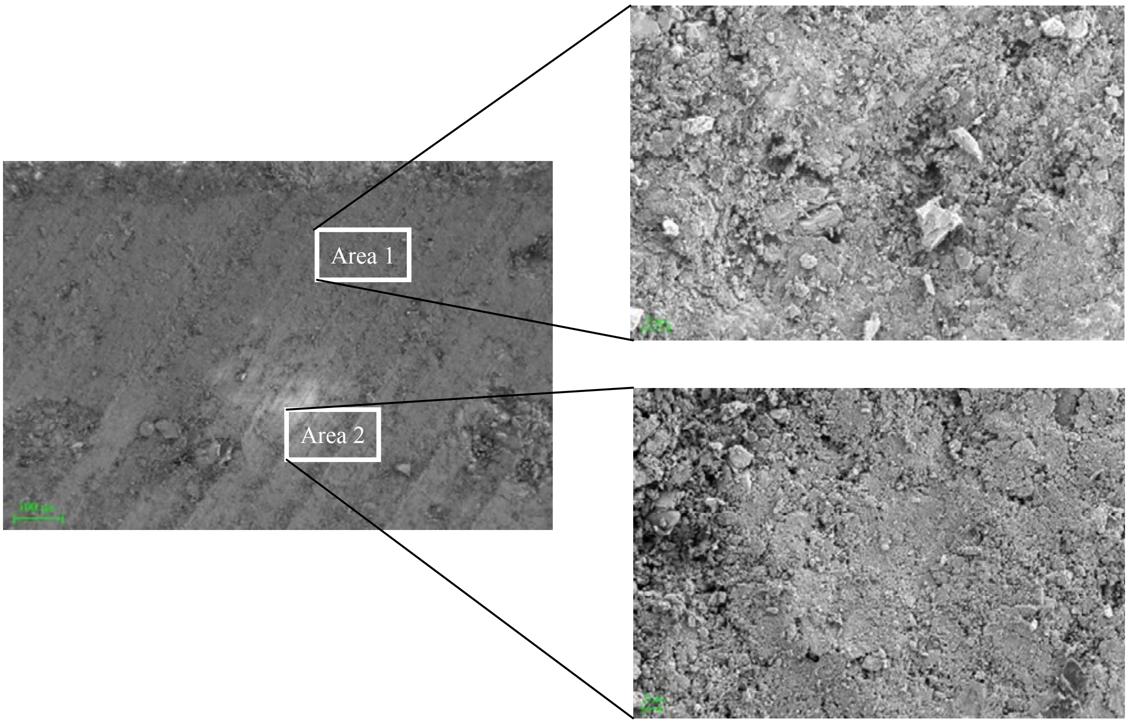


**Figure 5. FESEM images of Sample SL5-012 from Nakhon Si Thammarat, Thailand.**

## *3.2 ELEMENTAL COMPOSITION*

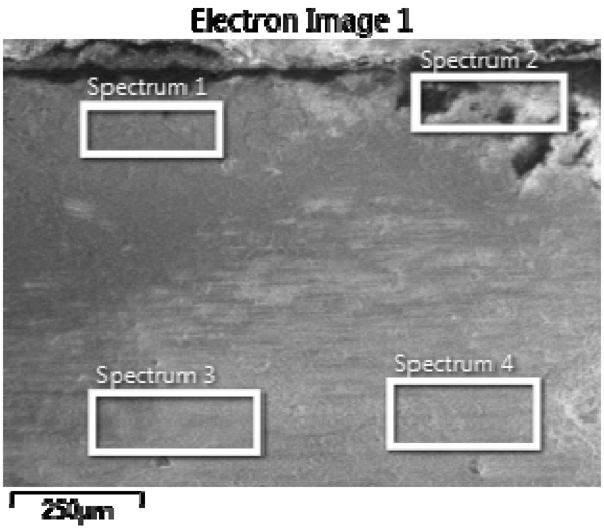


**Figure 6. Four regions of EDS measurements in Sample OTT-011 from Otein Taung in Myanmar.**

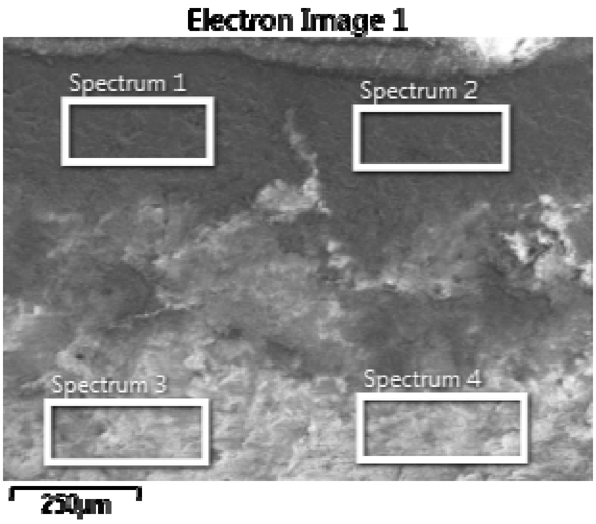


**Figure 7. Four regions of EDS measurements in Sample TND-010 from Tamil Nadu, India.**

**Table 1. Elemental composition of Sample OTT-011 from Otein Taung in Myanmar.**

| Elements | Composition (%) | | | |
|---|---|---|---|---|
| | Spectrum 1 | Spectrum 2 | Spectrum 3 | Spectrum 4 |
| **C** | 7.15 | 19.06 | 4.77 | 4.54 |
| **O** | 46.24 | 42.99 | 45.97 | 46.17 |
| **Na** | 0.46 | 0.33 | 0.70 | 0.57 |
| **Mg** | 1.32 | 1.12 | 1.02 | 1.31 |
| **Al** | 9.19 | 7.28 | 10.33 | 9.30 |
| **Si** | 25.33 | 21.26 | 26.08 | 28.01 |
| **P** | 0.56 | - | - | - |
| **Cl** | - | 0.15 | - | - |
| **K** | 1.86 | 1.41 | 4.90 | 1.98 |
| **Ca** | 1.83 | 0.88 | 0.52 | 0.63 |
| **Ti** | 0.43 | 0.38 | 0.43 | 0.43 |
| **Fe** | 5.62 | 5.14 | 5.29 | 7.07 |
| **Total** | 100.00 | 100.00 | 100.00 | 100.00 |

Nine elements, namely C, O, Mg, Al, Si, P, K, Ti and Fe are present in all pottery shreds from three countries in Tables 1-3. High Si around 20% in every sample is due to siliceous clay but the FESEM images in Figs.2-5 suggest that there are not in forms of coarse Quartz grains. Si, K and Al are main components in Feldspar and K compounds with the low melting point act as the flux during earthenware firing. Al also exists in forms of free Alumina which reduces the plasticity in fine clay. Na and Ca are also detected in the samples from Myanmar and India but conspicuously absent from the sample from Thailand. With the maximum content in sample TND, Ca is mostly in Calcite which decomposes during the firing. Interestingly, carbon content is the highest and highly uneven in the same shred in this sample. Two measurements near the surface indicate particularly high carbon contents over 30% which is likely attributed to the ash glazing process. In such process, carbon is introduced either in the mixing or firing stage. Along with a large amount of C is Cl which is found in only one area in the sample from Myanmar and entirely absent in the sample from India. Fe, mostly existing in forms of hematite, is maximum in the FPW from Myanmar and the lowest in CPW from Thailand. The Fe content in the CPW from India is approximately 3%, consistent with the previous report on clay components from several sites in India [14].

**Table 2. Elemental composition of Sample TND-010 from Tamil Nadu, India.**

| Elements | Composition (%) | | | |
|---|---|---|---|---|
| | Spectrum 1 | Spectrum 2 | Spectrum 3 | Spectrum 4 |
| **C** | 15.72 | 15.17 | 15.04 | 13.05 |
| **O** | 45.89 | 47.00 | 45.09 | 45.99 |
| **Na** | 0.69 | 0.43 | 2.41 | 0.96 |
| **Mg** | 0.47 | 0.33 | 0.42 | 0.76 |
| **Al** | 7.47 | 6.85 | 8.13 | 7.79 |
| **Si** | 21.77 | 23.53 | 22.47 | 22.08 |
| **P** | 0.17 | 0.16 | - | 0.14 |
| **K** | 1.80 | 1.55 | 1.45 | 2.42 |
| **Ca** | 1.28 | 1.06 | 1.88 | 1.40 |
| **Ti** | 0.42 | 0.31 | 0.21 | 0.53 |
| **Fe** | 4.31 | 3.61 | 2.92 | 4.87 |
| **Total** | 100.00 | 100.00 | 100.00 | 100.00 |

Ancient potteries contain more varieties of elements than Tables 1-3 and over 30 elements were detected in samples dated back to 600-300 BCE from the Holtun archaeological site in Guatemala [18]. In the previous reports on FPW from Thailand and Indonesia [10, 11], X-ray Fluorescence (XRF) also detected 30-600 ppm trace elements including S, Cr, Cu, Zn, Rb, Sr, Zr and Pb in addition to the major clay components in Table 3. Similar to the CPW from the same area (samples SL5-011 and SL5-012), they had low alkali and alkali earth contents. Na was also missing from the clay components. This finding, as well as the different Fe content between Tables 1 and 2, suggests that the FPW products in Thailand and Myanmar were not imported from India. They were locally produced with unique clay components and techniques.

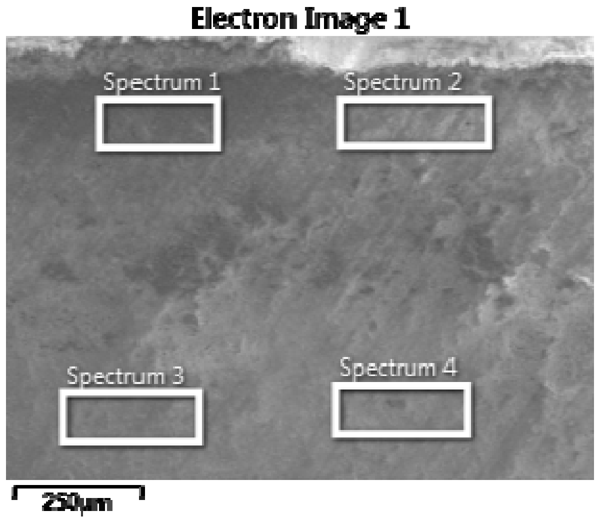


**Figure 8. Four regions of EDS measurements in Sample SL5-012 from Suan Luang temple, Thailand.**

**Table 3. Elemental composition of Sample SL5-012 from Suan Luang temple, Thailand.**

| Elements | Composition (%) | | | |
|---|---|---|---|---|
| | Spectrum 1 | Spectrum 2 | Spectrum 3 | Spectrum 4 |
| C | 36.40 | 36.01 | 15.58 | 14.16 |
| O | 37.75 | 37.23 | 45.89 | 46.51 |
| Mg | 0.14 | 0.16 | 0.28 | 0.20 |
| Al | 8.45 | 9.19 | 13.20 | 12.97 |
| Si | 13.34 | 12.11 | 19.09 | 20.24 |
| P | 0.67 | 0.76 | 0.73 | 0.69 |
| Cl | 0.28 | 0.35 | 0.13 | 0.12 |
| K | 0.69 | 0.82 | 1.52 | 1.44 |
| Ti | 0.35 | 0.43 | 0.59 | 0.50 |
| Fe | 1.95 | 2.93 | 2.99 | 3.17 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

## 4. CONCLUSIONS

As its name suggested, the FPW sherd from Otein Taung in Myanmar has very fine cross-sectional texture compared to CPW sherds from Tamil Nadu in India and Nakhon Si Thammarat in Thailand. The elemental composition reveals the clay composition as well as production technique unique to each region. The high carbon in CPW from Thailand and high iron in FPW from Myanmar confirm the previous suggestion that Southeast Asian sites had their own earthenware productions which are different from the neighbouring India.

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