

## Research Article

### Scientific Studies of Candi Pengkalan Bujang (Site 19) Ancient Bricks: Knowledge of Old Kedah Community's in Usage of Local Raw Materials

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**Abstract:** The aim of this study is to determine whether the ancient bricks from Candi Pengkalan Bujang (Site 19) are made from local raw material or not. Candi Pengkalan Bujang (Site 19) is one of the temple sites that used bricks as the main construction material in addition to the usage of pillar bases made from granite stones and roof that are believed to have been made from wood and palm leaves. Relative dating proposed that this site was built between the 12<sup>th</sup> and 13<sup>th</sup> century AD. The architecture of the temple also indicates there was evolution toward the use of bricks that were smaller and of the same size as well as temple construction that revealed the lotus (padma) and upaphita structures. This study focuses on the material composition analysis of ancient bricks that were used to produce this temple of which the main purpose is to see whether the raw materials used to produce these bricks utilized local raw materials. Two analysis techniques were used, namely the X-Ray Fluorescence technique (XRF) and the X-Ray Diffraction technique (XRD) in determining the content of the major and trace elements as well as the mineral content in the ancient bricks. The findings of this study show that the major minerals found in the ancient bricks of the Candi Pengkalan Bujang (Site 19) are quartz, muscovite and microcline while other minerals that exist are leucite, mullite and geothite. The mineral content and physical observation of the bricks indicate that the open firing technique was used in producing these bricks. The major and trace element content also indicates that these bricks were produced from the same source and it is proposed that local raw materials were used in the production of the bricks. The involvement of the local community in producing the bricks should not be refuted, proving the Knowledge Transformation of the local community in Bujang Valley which had already started since the 4<sup>th</sup> century.

**Keywords:** Brick, bujang valley, candi pengkalan bujang (site 19), x-ray diffraction, x-ray fluorescence

## INTRODUCTION

Candi Pengkalan Bujang (Site 19) is one of the temple components located in the Temple Complex of Pengkalan Bujang Village together with the other temples which are Site 23, 21 and 22. In 1974, the Museum and Antiquity Department had carried out excavation work as well as rebuilding of the sites' temples except for Site 23. Archaeological research findings and report by Quaritch-Wales (1940) showed that Site 20 that is also located near to Site 21, 22, 23 and 19 suffered severe damages due to agricultural activities. These sites are located on a sand ridge of which its distance from Sungai Bujang is about 100 to 150 m.

Site 19 (Pengkalan Bujang Village) that has been rebuilt by the Museum and Antiquity Department does not have many records except for the ones reported by Quaritch-Wales. This temple uses bricks as the

construction material and is oblong shaped. This temple was also probably used as a place to store religious items or as a place of residence of the Bhiksu (Mohd Supian, 2002). Among the important finds of this site is the headless Ganesha Statue and reliquaries made from granite stones. Based on relative dating, the temple is estimated to have been built around the 11<sup>th</sup> and 12<sup>th</sup> century and represents the Hinduism. A new complex known as Sungai Batu also unearth several site which made from bricks (Zuliskandar, 2012).

Although the function of the monument is already known, that is a temple of the Siwa Hindu element, there are still questions of who built it and where did the bricks which were used to build this temple come from. Based on observations of the temple's architecture that has pillar bases, thus it is for certain that the structure at the top part of this temple used wood and roof made from palm leaves. The reason for the interpretation that palm leaves were used is because

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Fig. 1: Front side view of the Candi Pengkalan Bujang (Site 19)



Fig. 2: View from the front of the Candi Pengkalan Bujang (Site 19)

there was no finds of tiled roof while the archaeological excavations were carried out. The usage of construction materials from wood and the show that there are local elements in the architecture of this temple. The bricks used to build this temple are also bricks that have a small size and their measurements are almost similar or standard. This shows the development of the brick making technology at the time in Bujang Valley, Kedah. There are bricks with  $45^{\circ}$  angle of inclination and used on the sides of the temple (Fig. 1 and 2).

The source of the bricks' raw material, which is clay is still an unanswered question for the research at this site. Therefore, scientific studies particularly in the context of brick material composition were conducted. This is to find out whether the raw material used was obtained from the area around Bujang Valley. The area in Bujang Valley has a lot of clay resources that can be used to produce bricks.

This scientific approach uses two techniques in determining the content of the brick material composition at this site. Two analysis techniques are used, namely the X-Ray Fluorescence technique (XRF) and the X-Ray Diffraction technique (XRD) in determining the major and trace element content as well as the mineral content in the ancient bricks. For example, analysis of the pottery in Peninsular Malaysia with the XRD and XRF method has given new information about the origin and the technology of pre-historic pottery making in Peninsular Malaysia (Treloar, 1978; Chia, 1997; Tykot and Chia, 1997; Zuliskandar *et al.*, 2001, 2007; Ramli *et al.*, 2011a) and also ancient bronze drums (Adnan *et al.*, 2012).

Studies on bricks and mortar have also been carried out where the mineral content and also the major and trace element content were performed. The study area was in Kota Kuala Muda, Kedah where physical studies were conducted such as tests of compression strength and the bricks' physical size (Asmah *et al.*, 2005; Ramli *et al.*, 2012). Similar studies were also conducted on the

Panggung Drama Building, Kuala Lumpur that involved composition and physical analysis of the construction materials (Mohd Zobir *et al.*, 2004).

Material composition analysis is also used to solve the problems that have long been in Bujang Valley, namely whether the bricks used to create the temples were produced using local raw materials and whether the local community were the ones responsible in producing them. Even though some archaeologists are indifferent as to whether it is necessary or not to conduct analysis on the bricks because they consider the archaeological discovery itself is enough to unravel the questions of the past and make interpretations based on their own understanding. We consider it very crucial to carry out the composition analysis of bricks in Bujang Valley because it can prove that the local community was the one who made Bujang Valley prosperous since the early centuries AD and simultaneously rejecting the notion put forward by Quaritch-Wales who proposed the theory of Indian colonisation in Bujang Valley (Quaritch-Wales, 1940) and also the opinion that the temples in Bujang Valley were built by merchants which was made based on the discovery of Buddhagupta inscriptions in Seberang Prai.

Apart from the discovery of archaeological artifacts, material composition analysis of artifacts is the best method to prove scientifically whether each specific artefacts was produced locally or obtained from outside (Abdulla, 2006). Analysis of the bricks found in Sungai Mas (Site 32/34), Candi Bukit Pendiak (Site 17) and Candi Pengkalan Bujang (Site 23) showed that the raw material used to produce the bricks were obtained from Muda River and Bujang River basin (Zuliskandar *et al.*, 2011; Ramli *et al.*, 2012) and also analyses on glass beads showed that there are locally made by Old Kedah community's (Ramli *et al.*, 2011b). This shows that since the 6<sup>th</sup> or 7<sup>th</sup> century AD, the society in Kedah Tua was already capable of producing bricks for building temples that were abundantly found in Bujang Valley. The objectives of this study are to determine the content of minerals and also the composition of major and trace elements in the bricks taken from Candi Pengkalan Bujang (Site 19). The data can show whether the bricks from Site 19 used local raw materials or not which the result is very useful to the archaeological research in Malaysia especially to identify the origin of the bricks.

## MATERIALS AND METHODS

This study used the scientific approach in determining whether the bricks in Site 19 used local raw materials or not. The scientific approach involved material composition analysis of the artefact to be studied which is bricks. A total of 16 fractions of ancient bricks were taken from the excavation site of Pengkalan Bujang (Site 19) and placed into plastic bags and recorded. These samples were taken to the

laboratory for sample treatment where each sample was cleaned using water and later dried at a temperature of 120°C for two days. These samples were then ground up into very fine powder and once again dried at a temperature of 120°C for one day. These samples were then sent for analysis where the two techniques used were the X-ray Fluorescence Technique and the X-ray Diffraction Technique. The X-ray Fluorescence Technique was used to determine the major element content while the X-ray Diffraction Technique was used to determine the mineral content in the brick samples. The data obtained were later compared with the data analysis of the clay around Bujang Valley that was carried out previously (Zuliskandar *et al.*, 2002).

### RESULTS AND DISCUSSION

The analysis involved the composition of mineral and major and trace elements content in the ancient brick samples at Site 19 (Pengkalan Bujang Village). The results of the analysis are expected to determine the raw material which is the clay used to produce the bricks.

The mineral content in the brick samples found at Candi Pengkalan Bujang (Site 19) shows the presence

of major minerals such as quartz, muscovite, microcline, while other minerals that exist in small quantities are minerals such as leucite, mullite and goethite (Table 1). Kaolinite is not present in the samples and this shows that the bricks were baked at a temperature exceeding 550°C. The mineral content of mullite in the PB19 (xii) and PB19 (xiii) samples also shows that the brick samples were exposed to high temperatures in which this mineral came about when the kaolinite mineral went through changes into mullite when struck by pressure of high temperature. PB19 (xv) sample only contained the mineral content of quartz and this shows that this sample was baked at high temperatures which probably exceeding 850°C. The firing technique of these brick samples is believed to have used the open firing technique if seen from the physical of the bricks and their mineral content. The size of the bricks used at the site is much smaller and had sizes that are almost the same. This clearly shows there was an evolution in the technology of brick making and also the architecture of the temples in Bujang Valley.

The content of the major elements in the ancient brick samples of Site 19 (Candi Pengkalan Bujang) can be referred to in Table 2. Analysis shows high silica content in the brick samples of this site, namely dry

Table 1: Mineral content in the ancient brick sample of site 19

Location	Sample	Mineral content
Candi Pengkalan Bujang (site 19)	PB19 (i)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 2M1 KAlSi <sub>3</sub> O <sub>8</sub> microcline
	PB19 (ii)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 1M
	PB19 (iii)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 2M1 Na <sub>2</sub> Al <sub>2</sub> Si <sub>2</sub> O <sub>7</sub> leucite
	PB19 (iv)	SiO <sub>2</sub> quartz K <sub>2</sub> O.3Al <sub>2</sub> O <sub>3</sub> .6SiO <sub>2</sub> .1H <sub>2</sub> O muscovite
	PB19 (v)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 2M1
	PB19 (vi)	SiO <sub>2</sub> quartz Fe <sub>2</sub> O <sub>3</sub> Geothite
	PB19 (vii)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 1M
	PB19 (viii)	SiO <sub>2</sub> quartz KAlSi <sub>3</sub> O <sub>8</sub> microcline
	PB19 (ix)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 2M1 KAlSi <sub>3</sub> O <sub>8</sub> microcline
	PB19 (x)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 1M
	PB19 (xi)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 1M
	PB19 (xii)	SiO <sub>2</sub> quartz Al <sub>2</sub> (Al <sub>2-8</sub> Si <sub>1-2</sub> )O <sub>9-6</sub> mullite
	PB19 (xiii)	SiO <sub>2</sub> quartz 3Al <sub>2</sub> O <sub>3</sub> .2SiO <sub>2</sub> mullite
	PB19 (xiv)	SiO <sub>2</sub> quartz KAl <sub>2</sub> Si <sub>3</sub> AlO <sub>10</sub> (OH) <sub>2</sub> muscovite 1M
	PB19 (xv)	SiO <sub>2</sub> quartz
	PB19 (xvi)	SiO <sub>2</sub> quartz KAlSi <sub>3</sub> O <sub>8</sub> microcline

Table 2: Major element content in the brick sample of site 19

Sample	Dry weight (%)									
	Si	Ti	Fe	Al	Mn	Ca	Mg	Na	K	P <sub>2</sub> O <sub>5</sub>
PB19 (i)	77.01	0.48	2.74	15.48	0.02	0.09	0.61	0.13	1.07	0.02
PB19 (ii)	65.49	0.97	3.30	28.01	0.01	0.11	0.35	0.10	1.52	0.01
PB19 (iii)	78.95	0.35	2.00	11.88	0.02	0.19	0.56	0.20	1.03	0.01
PB19 (iv)	76.99	0.50	3.13	15.03	0.01	0.13	0.77	0.17	1.60	0.01
PB19 (v)	71.80	0.63	3.64	21.69	0.01	0.11	0.33	0.11	1.51	0.01
PB19 (vi)	68.01	0.82	6.41	21.42	0.01	0.04	0.86	0.08	1.03	0.01
PB19 (vii)	78.29	0.42	2.56	13.94	0.02	0.14	0.41	0.17	1.88	0.02
PB19 (viii)	72.49	0.75	4.59	18.61	0.01	0.09	0.60	0.09	1.02	0.01
PB19 (ix)	69.82	0.77	5.11	21.80	0.05	0.10	0.53	0.11	1.41	0.01
PB19 (x)	65.90	0.95	3.74	26.62	0.02	0.10	1.03	0.13	0.85	0.01
PB19 (xi)	71.11	0.77	4.48	20.75	0.01	0.09	0.72	0.09	1.33	0.01
PB19 (xii)	73.81	0.41	2.34	13.33	0.01	0.14	0.44	0.18	1.78	0.01
PB19 (xiii)	72.53	0.55	2.92	21.46	0.01	0.12	0.54	0.12	1.68	0.01
PB19 (xiv)	69.82	0.77	5.11	21.80	0.05	0.10	0.53	0.11	1.41	0.01
PB19 (xv)	70.68	0.79	3.80	20.99	0.01	0.10	0.76	0.09	1.12	0.02
PB19 (xvi)	68.86	0.79	4.16	22.91	0.01	0.11	0.65	0.11	1.42	0.01

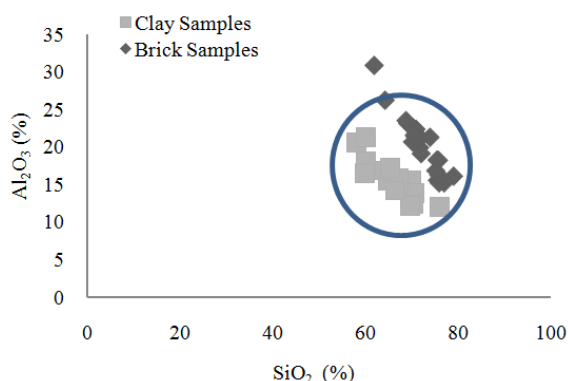


Fig. 3: Dry weight percentage content of silica and aluminium in the brick sample of site 19 and the clay sample in Lembah Bujang, Kedah

weight percentage of between 65.49 to 78.95%. The aluminium content representing the clay mineral also shows high content that is between 11.88 to 28.01%. The calcium content is low that is between 0.09 to 0.14%. This gives some indication that the raw material used was obtained not from areas near limestone. It was found that the raw material has high iron content which is between 2.00 to 6.41%. The presence of geothite mineral in one of the samples confirms this. Figure 3 and 4 were plotted to determine the distribution of the brick samples based on the content of silica, aluminium, magnesium and titanium elements and compared with the distribution of clay elements in Bujang Valley, Kedah. Data of the major and trace elements of clay in Bujang Valley were obtained from previous analyses (Zuliskandar *et al.*, 2002). Analysis from both the

Table 3: Trace element content in the brick samples of site 19

Element (ppm)	Sample							
	PB19i	PB19ii	PB19iii	PB19iv	PB19v	PB19vi	PB19vii	PB19viii
As	19	16	14	15	14	15	18	16
Ba	804	721	784	782	717	562	676	598
Ce	593	565	530	571	554	485	545	529
Co	12	12	9	12	13	20	16	16
Cr	72	87	56	79	83	121	101	101
Cu	69	85	30	19	25	11	24	19
Ga	17	26	15	17	25	27	22	27
Hf	7	7	7	7	7	7	7	7
La	29	29	29	29	29	27	28	28
Nb	28	29	29	33	31	23	27	25
Ni	29	26	26	28	27	19	21	22
Pb	48	47	45	45	44	31	42	38
Rb	203	152	198	165	141	97	118	114
Sr	42	13	47	33	12	23	12	24
U	9	9	9	9	9	9	9	9
Th	25	24	17	20	20	31	27	32
V	88	96	71	92	98	121	116	114
Y	27	20	26	17	20	10	12	19
Zn	63	56	63	58	62	55	82	61
Zr	252	219	179	261	220	223	210	236

Table 4: Trace element content in the brick samples of site 19

Element (ppm)	Sample							
	PB19ix	PB19x	PB19xi	PB19xii	PB19xiii	PB19xiv	PB19xv	PB19xvi
As	13	15	17	12	9	18	17	15
Ba	750	606	773	730	693	689	656	716
Ce	583	521	607	585	578	495	552	580
Co	12	17	13	13	13	15	13	14
Cr	67	100	111	72	72	106	109	104
Cu	81	18	57	19	23	59	27	19
Ga	20	23	28	22	23	29	31	29
Hf	7	7	7	7	7	7	7	7
La	29	28	29	29	29	28	29	29
Nb	31	28	31	35	32	29	28	35
Ni	27	21	28	26	26	27	27	26
Pb	45	37	46	41	37	44	43	43
Rb	159	113	153	144	117	160	124	141
Sr	11	23	26	15	15	15	25	21
U	9	9	9	9	9	9	9	9
Th	12	29	32	14	17	26	33	28
V	84	104	120	86	85	117	117	114
Y	16	13	23	16	13	25	24	23
Zn	82	52	73	51	54	84	93	58
Zr	203	209	220	213	207	243	252	246

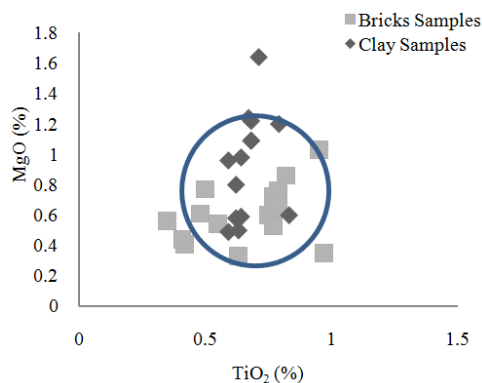


Fig. 4: Dry weight percentage content of titanium and magnesium in the brick samples of site 19 and the clay samples in Lembah Bujang, Kedah

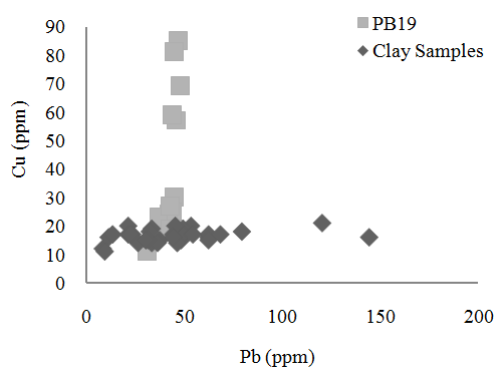


Fig. 5: Lead and copper concentration in the brick samples of Site 19 and the clay samples in Lembah Bujang, Kedah

graphs show that the raw material used to produce the bricks to build the temple at Site 19 used local raw material. The raw material was obtained from one or two similar sources.

The trace element content (Table 3 and 4) shows content that is slightly high for elements such as barium, cerium, rubidium and zircon. Other elements are at a relatively low level which is less than 100 ppm. Content of barium element is between 562 to 804 ppm while cerium element is between 485 to 593 ppm. Content of rubidium and zircon element is between 97 to 203 ppm and 179 to 261 ppm, respectively. Figure 5 was plotted to see the distribution of copper versus lead element for the brick samples of Site 19 and the results show that there is a major raw material source that was used as well as five samples with anomalies and possibly from other raw materials. Graph 3 also shows that the raw material used was obtained from local clay.

### CONCLUSION

The scientific study conducted on the ancient bricks of Site 19 (Pengkalan Bujang Village) has

successfully proven that the raw materials used were obtained from the clay found in the vicinity of the river basin in Bujang Valley, Kedah. The physical and size of the bricks that are smaller and almost similar indicated developments in terms of brick making technology and temple architecture. Based on the mineral content contained in the bricks, it was found that the temperature used to bake the bricks is high but it is still proposed that open firing was used to bake the bricks. The firing temperature proposed is between 800 to 950°C, respectively. Based on the continuity in the technology of brick production in Sungai Mas since the 6<sup>th</sup> century AD, hence it can be concluded here that the local community in Pengkalan Bujang still maintained the knowledge in the process of producing bricks to build temples. The knowledge transformation in the technology of brick production can be seen in the apparent changes toward the usage of smaller and standard sized bricks in comparison to the temples built earlier. The architecture used also showed changes with the presence of padma and upaphita structures.

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