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Scientific Analysis of Ancient Bricks at Bukit Pendiat Temple (Site 17) and Pengkalan Bujang Temple (Site 23): A Comparative Study

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Abstract: Bukit Pendiat temple (Site 17) and Pengkalan Bujang temple (Site 23) are two temples in the Bujang valley, Kedah that used bricks as their main construction material. Based on relative dating, Bukit Pendiat temple (Site 17) was built in the 7 or 8th century AD while the Pengkalan Bujang temple (Site 23) was built in the 11 or 12th century AD. Site 17 is a temple with elements of Buddha based on the stupa structure while Site 23 is a temple with elements of Hindu based on the vimana and mandapa structures. Differences can also be seen in the size of the bricks used to build the structures of the two monuments. Based on the architectural features, it is believed that the two monuments were built by the local community of old Kedah. Therefore, this scientific study was conducted to scientifically prove the source of the raw materials used and to make comparisons between the two sites. This is based on the hypothesis made that the local community was involved in brick making by using local raw materials. It thus rejects the opinion of Quaritch-Wales based on the Colonisation Theory and supports the Indian Culture Indigenisation Theory by Nik Hassan Shuhaimi Nik Abdul Rahman. The material composition analysis involved two analysis techniques 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 results of the analysis show that the mineral content of the bricks in Site 17 consists of quartz, muscovite, microline and kaolinite while the bricks of Site 23 contain minerals such as quartz, muscovite, anorthite, orthoclase, kaolinite and minor minerals such as hydrobiotite dan biotite. Clearly there were differences in the mineral content between the two sites but the burning technique used was the same namely the open burning technique. The content of the major and trace elements in the brick samples of Site 17 and 23 is also different if comparison is made. Nevertheless, both the sites used local raw materials to produce the bricks.

Key words: Bukit pendiat, pengkalan bujang, X-ray fluorescence, X-ray diffraction, bujang valley, Malaysia

INTRODUCTION

Bukit Pendiat Temple (Site 17) and Pengkalan Bujang Temple (Site 23) are two temples in the Bujang valley, Kedah which used bricks as their main construction materials. Based on relative dating, Bukit Pendiat temple (Site 17) was built between 7th-9th century AD (Quaritch, 1940) while Pengkalan Bujang Temple was built between 11th-12th century AD. Site 17 is a temple with elements of Buddha based on the stupa structure while Site 23 is a temple with Hindu elements based on the vimana and mandapa structures. These differences can also be seen in the size of the bricks used to built the two monuments' structure. Based on the architectural features, it is believed that these two monuments were built by the local community of Old Kedah. Therefore, this scientific study was conducted to scientifically prove the source of raw materials used and to make comparisons between the two sites. This is based on the hypothesis made that the local community was involved in brick making by using local raw materials. It thus, rejects the opinion of Quaritch-Wales based on the colonisation theory (Quaritch, 1940) and supports the Indian Culture Indigenisation Theory by Nik Hassan Shuhaimi Nik Abdul Rahman (Abdul-Rahman, 1984).

The scientific study conducted involved material composition analysis of ancient bricks at both research sites where the analysis involved the use of X-ray fluorescence technique and X-ray diffraction technique that could determine the content of mineral and major elements as well as trace elements in the ancient bricks. Many composition analyses of clay based materials have

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been done before in proving that an artifact was locally made or not (Stephen, 1997; Muhamad, 1998; Ramli *et al*., 2011a, b, 2001). Analyses involved artefacts such as earthenware and bricks obtained from the pre-historic age, proto-historic age or historic age. Early studies have proven that the ancient bricks at the Sungai Mas Temple (Site 32/34) used local raw materials while studies of the composition of the monochrome glass beads in this site have also proven that the beads in Sungai Mas have its own chemical composition and different from the monochrome glass beads in India and this shows that Sungai Mas was one of the producer of this type of beads between the 6-13th century AD (Ramli *et al*., 2011a).

MATERIALS AND METHODS

A total of 17 brick samples were taken from the site of the Bukit Pendiat Temple (Site 17) and 19 brick samples taken from the Pengkalan Bujang temple (Site 23); these were then taken to the lab for cleaning and labelled with names BP17 (i)-BP17 (xvii) and PB23 (i)-PB23 (xix). Samples weighing 0.4 g that had been refined and heated for an hour at a temperature of 105°C were mixed until homogenous with flux powder of a type of Spectroflux 110 (product of Johnson and Mathey). These mixtures were baked for an hour in a furnace at a temperature of 1100°C. The homogenous molten was moulded into containers and gradually cooled into pieces of fused glass of 2 mm thick and 32 mm in diameter. These samples were of 1:10 dilution. Samples in the form of fused glass were prepared for analysis of major elements such as Si, Na, K,Ca, Fe, Al, Ti, Mn and Mg.

Pressed pallet samples were prepared for analysis of trace elements such as As, Ba, Ce,Co, Cr, Cu, Ga, La, Nb, Ni, Pb, Rb, Th, V, Zn dan Zr. These samples were prepared by mixing 1.0 g of sample with 6.0 g of boric acid powder and then pressure of 20 psi was applied by using hydraulic pressure equipment. The samples of fused pallets and pressed pallets were subsequently analysed using the Philips PW 1480 equipment. Samples in the form of very fine powder were placed in the pellets (sample holder) and then analysed by using an X-ray diffraction instrument (D500 Diffractometer SIEMEN Type). This analysis was conducted to determine the mineral content in the ancient brick samples.

Data obtained from the analysis of the major and trace elements will be analysed using the bi-plot graph method or scatter-plot graph. This method uses the Microsoft Excel software. Two graphs will be plotted based on the selected major and trace elements such as silica element with aluminium element, magnesium element with titanium element as well as lead element with copper element. The main purpose is to see the distribution of the samples in groups and subsequently to compare with the clay elements that have been done previously.

RESULTS AND DISCUSSION

The mineral content in the ancient brick samples of Bukit Pendiat temple (Site 17) and Pengkalan Bujang tsemple (Site 23) is shown in Table 1. The analysis

Table 1: Mineral content in the ancient brick samples of Bukit Pendiat temple (Site 17) and Pengkalan Bujang temple (Site 23)

Location	Sample	Mineral content
Bukit Pendiat temple (Site 17)	BP17 (i)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (ii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (iii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (iv)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (v)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (vi)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (vii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1
	BP17 (viii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1
	BP17 (ix)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (x)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (xi)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M $KAlSi_3O_8$ Microcline
	BP17 (xii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (xiii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (xiv)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (xv)	SiO_2 Quartz $Al_2Si_2O_5(OH)_4$ Kaolinite 1Md
	BP17 (xvi)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (xvii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	BP17 (xviii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
Pengkalan Bujang temple (Site 23)	PB23 (i)	SiO_2 Quartz low $Al_2Si_2O_5(OH)_4$ Kaolinite $KAlSi_3O_8$ Microcline
	PB23 (ii)	SiO_2 Quartz low $Al_2Si_2O_5(OH)_4$ Kaolinite
	PB23 (iii)	SiO_2 Quartz low $KAlSi_3O_8$ Microcline
	PB23 (iv)	SiO_2 Quartz low $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite
	PB23 (v)	SiO_2 Quartz low
	PB23 (vi)	SiO_2 Quartz low

Table 1: Continue

Location	Sample	Mineral content
		$KAlSi_3O_8$ Microcline
		$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite
	PB23 (vii)	SiO_2 Quartz low
		$Al_2Si_2O_5(OH)_4$ Kaolinite
		$KAlSi_3O_8$ Microcline
	PB23 (viii)	SiO_2 Quartz low
		$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite
	PB23 (ix)	SiO_2 Quartz low
		$KAlSi_3O_8$ Microcline
	PB23 (x)	SiO_2 Quartz low
	PB23 (xi)	SiO_2 Quartz low
		$KAlSi_3O_8$ Microcline
		$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite
	PB23 (xii)	SiO_2 Quartz low
		$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite
	PB23 (xiii)	SiO^2 Quartz low
		$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite
	PB23 (xiv)	SiO_2 Quartz low
		$KAlSi_3O_8$ Microcline
	PB23 (xv)	SiO_2 Quartz low
		$Al_2Si_2O_5(OH)_4$ Kaolinite
		$KAlSi_3O_8$ Microcline
	PB23 (xvi)	SiO_2 Quartz low
	PB23 (xvii)	SiO_2 Quartz low
		$KAlSi_3O_8$ Microcline
	PB23 (xviii)	SiO_2 Quartz low
		$Al_2Si_2O_5(OH)_4$ Kaolinite
		$KAlSi_3O_8$ Microcline
	PB23 (xix)	SiO_2 Quartz low
		$Al_2Si_2O_5(OH)_4$ Kaolinite

indicates that there are minerals such as quartz, muscovite, microline and kaolinite. Quartz mineral is rarely found separately from the other minerals. The quartz mineral is found in all the study samples and the results of the tests also show that PB23 (v), PB23 (x) dan PB23 (xvi) samples observed the readings of quartz mineral only. This does not mean that these samples do not have other minerals but the minerals from the mica and feldspar group have been decomposed due to the high combustion temperature.

Both these samples were baked at a temperature higher than the other brick samples. The estimated temperature achieved for both samples was as high as 1000°C. The kaolinite mineral present in BP17 (xv), PB23 (i), PB23 (ii), PB23 (vii), PB23 (xv) and PB23 (xviii) samples shows that the samples were baked at a temperature <550°C and indicates that the open burning technique was used.

Content of the major elements for the ancient brick samples of Bukit Pendiat temple (Site 17) and the Pengkalan Bujang temple (Site 23) can be shown in Table 2 and 3. The data obtained revealed differences in the content of the major elements in the bricks at both sites particularly in the content of the elements of iron, magnesium, calcium, sodium and potassium. The content

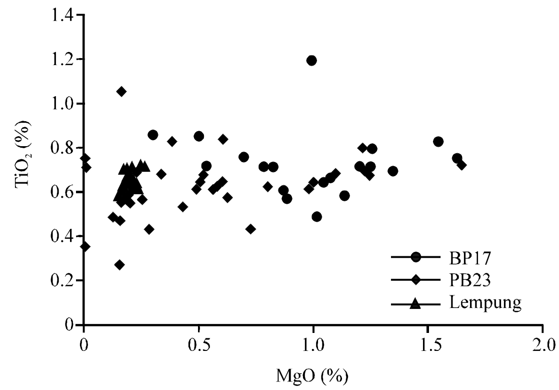

Fig. 1: Dry weight percentage (%) of MgO and TiO_2 elements for the brick samples of Pengkalan Bujang temple (Site 23), bricks of Bukit Pendiat temple (Site 17) and the clay of Bujang valley

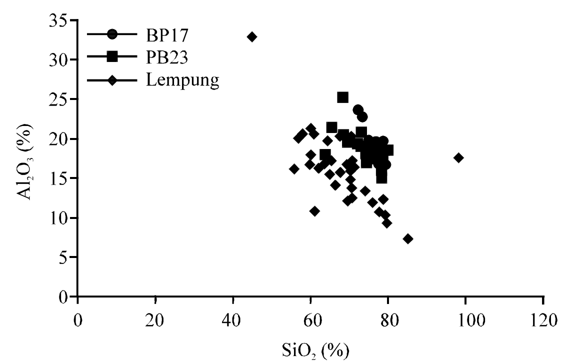

Fig. 2: Dry weight percentage (%) of SiO_2 and Al_2O_3 elements for the brick samples of Pengkalan Bujang temple (Site 23), bricks of Bukit Pendiat temple (Site 17) and the clay of Bujang valley

of these elements is higher in the ancient brick samples of Pengkalan Bujang temple (Site 23) compared to the ancient brick samples of Bukit Pendiat temple (Site 17).

The high content of the sodium, calcium and magnesium elements indicates that the raw materials used were obtained from areas near limestone formations. The areas might be located in the more upstream areas if steering along Sungai Muda. Based on the graph of the dry weight percentage of MgO dan TiO_2 (Fig. 1), it is shown that both of the brick samples used local raw materials. The graph also shows that the raw material source of the brick samples of Pengkalan Bujang Temple (Site 23) was obtained from the Sungai Muda basin while the bricks of Bukit Pendiat temple (Site 17) used raw materials from the Sungai Bujang basin. The dry weight percentage graph of the SiO_2 and Al_2O_3 elements (Fig. 2) also indicates that the content of silica and clay (based on

Table 2: Major element content of the ancient bricks of Bukit Pendiat temple (Site 17)

	Dry weight (%)									
Samples	Si	Ti	Fe	Al	Mn	Ca	Mg	Na	K	P_2O_3
BP 17 (i)	72.30	0.74	1.74	23.59	0.01	0.05	0.26	0.07	0.68	0.25
BP 17 (ii)	77.59	0.63	2.21	17.52	0.02	0.06	0.17	0.05	0.33	0.18
BP 17 (iii)	77.43	0.63	3.50	17.17	0.01	0.04	0.16	0.05	0.34	0.19
BP 17 (iv)	73.30	0.72	1.62	22.41	0.02	0.04	0.28	0.07	0.68	0.21
BP 17 (v)	76.01	0.70	2.90	19.44	0.01	0.04	0.15	0.05	0.29	0.14
BP 17 (vi)	78.32	0.60	2.14	17.40	0.01	0.04	0.16	0.05	0.32	0.20
BP 17 (vii)	76.13	0.64	3.53	18.32	0.03	0.04	0.21	0.06	0.37	0.19
BP 17 (viii)	77.70	0.61	2.88	17.24	0.01	0.04	0.17	0.06	0.33	0.18
BP 17 (ix)	73.57	0.73	1.63	22.67	0.01	0.04	0.19	0.06	0.62	0.22
BP 17 (x)	76.71	0.63	3.19	17.74	0.02	0.04	0.22	0.06	0.42	0.17
BP 17 (xi)	75.24	0.70	4.06	18.98	0.01	0.04	0.18	0.05	0.35	0.17
BP 17 (xii)	78.89	0.58	2.24	19.70	0.01	0.03	0.14	0.06	0.32	0.17
BP 17 (xiii)	77.47	0.61	2.71	17.79	0.01	0.04	0.16	0.07	0.28	0.17
BP 17 (xiv)	75.97	0.62	0.34	19.15	0.02	0.03	0.21	0.06	0.29	0.15
BP 17 (xv)	78.90	0.59	1.98	16.74	0.01	0.04	0.14	0.06	0.33	0.17
BP 17 (xvi)	76.88	0.71	3.10	18.39	0.03	0.03	0.16	0.05	0.34	0.20
BP 17 (xvii)	75.36	0.67	3.80	19.02	0.01	0.04	0.20	0.05	0.35	0.22
BP 17 (xviii)	75.03	0.71	3.55	19.65	0.01	0.04	0.19	0.05	0.35	0.17

Table 3: Major element content of the ancient bricks of Site 23

	Dry weight (%)									
Sample	Si	Ti	Al	Fe	Mn	Mg	Ca	Na	K	P_2O_3
PB23 (i)	74.35	0.64	17.01	4.54	0.12	1.04	0.69	4.82	1.70	0.12
PB23 (ii)	74.44	0.66	17.84	4.88	0.13	1.07	0.46	4.16	1.93	0.15
PB23 (iii)	73.20	0.82	20.70	5.33	0.04	1.54	0.26	3.45	1.72	0.08
PB23 (iv)	76.55	0.69	17.59	4.84	0.06	1.34	0.42	5.31	1.97	0.13
PB23 (v)	68.79	0.85	20.13	4.58	0.01	0.30	0.12	1.79	0.41	0.07
PB23 (vi)	72.66	0.58	19.07	4.35	0.02	1.13	0.25	3.65	2.53	0.05
PB23 (vii)	63.86	0.70	18.11	5.06	0.05	1.25	0.28	3.60	1.88	0.15
PB23 (viii)	73.05	0.75	19.15	5.78	0.02	1.62	0.27	3.10	1.69	0.09
PB23 (ix)	75.65	0.71	17.64	4.49	0.04	1.19	0.32	3.50	2.01	0.12
PB23 (x)	65.67	0.78	21.47	4.83	0.04	1.26	0.32	3.98	1.55	0.11
PB23 (xi)	70.49	0.71	19.62	4.61	0.01	0.78	0.19	3.70	2.05	0.14
PB23 (xii)	69.45	0.84	19.69	5.16	0.01	0.50	0.13	1.81	0.43	0.08
PB23 (xiii)	68.50	1.18	25.20	5.29	0.01	0.99	0.13	1.90	0.56	0.10
PB23 (xiv)	78.58	0.71	17.89	3.42	0.01	0.53	0.27	3.65	2.01	0.11
PB23 (xv)	72.28	0.75	19.11	5.19	0.01	0.69	0.18	2.51	1.14	0.09
PB23 (xvi)	79.86	0.70	18.65	4.69	0.01	0.83	0.14	3.44	1.30	0.08
PB23 (xvii)	78.37	0.56	15.88	3.27	0.06	0.88	0.33	4.01	2.25	0.26
PB23 (xviii)	78.22	0.48	15.09	3.01	0.03	1.01	0.35	4.76	2.43	0.87
PB23 (xix)	77.91	0.60	17.41	4.13	0.09	0.87	0.47	4.46	1.91	0.36

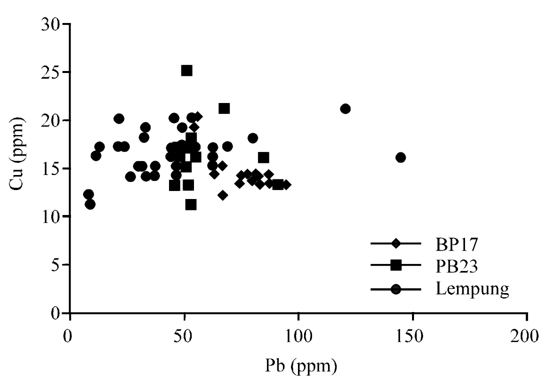

Fig. 3: Concentration of Pb and Cu elements in the brick samples of Site 23, bricks of Site 17 and the clay of Bujang valley, Kedah

the aluminium content) is similar between one another. The content of the trace elements contained in the brick samples of Site 23 and bricks of Site 17 can be shown in Table 4 and 5.

The graph of copper and lead element concentration for the brick samples of Site 23, bricks of Site 17 and the clay in the Bujang valley was plotted (Fig. 3) and it indicates that the brick samples of Site 23 have similarities that are closest to the copper and lead composition for the clay in Bujang valley while the bricks of Site 17 has slight differences as a result of the lead content that is a bit high compared to the bricks of Site 23 and the clay in the Bujang valley.

High concentrations of other elements in the brick samples of Site 17 are the cerium element where the

Table 4: Trace element content of the ancient bricks of Bukit Pendiat temple (Site 17)

	Trace element ($\mu g\ g^{-1}$)														
Sample	As	Ba	Ce	Co	Cr	Cu	Ga	La	Nb	Ni	Pb	Rb	Th	V	Zn	Zr
BP17 (i)	17	756	577	7	81	20	30	30	35	30	55	89	20	109	33	304
BP17 (ii)	27	690	549	8	89	12	22	29	31	25	66	44	19	114	27	301
BP17 (iii)	46	704	593	11	109	13	21	29	36	22	89	48	16	131	24	239
BP17 (iv)	16	756	633	7	82	20	29	30	36	33	55	86	20	108	34	285
BP17 (v)	35	707	576	9	111	14	23	29	34	24	76	41	23	128	25	268
BP17 (vi)	26	704	604	8	88	15	21	29	34	25	66	41	19	112	27	286
BP17 (vii)	44	680	571	11	118	14	21	29	33	23	86	46	18	128	28	247
BP17 (viii)	40	683	590	9	98	14	20	29	34	25	81	42	17	18	25	262
BP17 (ix)	16	735	608	7	79	19	29	30	33	32	54	74	20	108	33	301
BP17 (x)	39	679	583	10	109	13	22	29	33	25	79	51	20	125	26	266
BP17 (xi)	51	692	573	12	128	13	23	29	33	24	94	47	20	141	24	258
BP17 (xii)	32	684	550	8	90	13	20	29	29	25	73	39	16	127	25	265
BP17 (xiii)	35	656	554	9	92	14	21	29	28	23	75	38	23	117	26	300
BP17 (xiv)	27	668	536	8	89	15	22	29	28	26	65	32	17	110	27	295
BP17 (xv)	24	726	586	8	80	14	20	30	34	26	63	40	15	107	27	264
BP17 (xvi)	37	696	587	9	95	14	23	29	35	24	77	44	23	20	25	268
BP17 (xvii)	46	705	590	11	121	13	23	29	34	23	87	47	19	136	25	254
BP17 (xviii)	43	676	577	11	115	13	23	29	32	27	83	47	23	135	26	276

Table 5: Trace element content of the ancient bricks of Pengkalan Bujang temple (Site 23)

	Trace element ($\mu g\ g^{-1}$)														
Sample	As	Ba	Ce	Co	Cr	Cu	Ga	La	Nb	Ni	Pb	Rb	Th	V	Zn	Zr
PB23 (i)	11	839	343	8	83	17	18	37	21	30	51	194	21	114	102	231
PB23 (ii)	13	783	363	9	83	18	17	38	23	30	53	187	22	111	109	207
PB23 (iii)	10	664	456	10	100	16	23	37	24	27	48	156	30	132	94	227
PB23 (iv)	12	757	442	10	85	15	18	39	26	29	51	184	28	115	92	255
PB23 (v)	33	661	540	8	139	16	22	39	31	25	84	45	19	181	35	258
PB23 (vi)	12	764	473	11	93	21	17	39	28	36	67	170	19	125	89	175
PB23 (vii)	9	641	389	12	95	13	21	37	20	25	45	158	25	126	85	261
PB23 (viii)	9	718	495	7	70	11	16	38	27	25	52	196	18	107	62	202
PB23 (ix)	9	736	495	8	97	17	16	39	28	30	51	141	17	122	104	163
PB23 (x)	12	741	448	9	91	16	19	38	26	28	55	190	22	117	94	189
PB23 (xi)	39	631	425	10	137	13	13	38	28	22	91	49	21	194	37	267
PB23 (xii)	9	568	483	10	118	18	18	38	24	29	52	62	32	184	65	425
PB23 (xiii)	8	724	470	3	65	15	15	38	24	23	50	215	20	109	70	216
PB23 (xiv)	6	705	482	8	96	17	17	38	27	24	47	97	19	124	483	239
PB23 (xv)	11	680	408	9	80	16	19	37	23	25	48	193	23	115	83	205
PB23 (xvi)	10	780	417	12	95	25	20	38	22	34	51	163	25	130	125	226
PB23 (xvii)	10	744	481	7	78	15	18	39	26	25	50	198	21	107	73	211
PB23 (xviii)	10	699	467	6	70	13	16	38	27	25	51	219	17	93	144	200
PB23 (xix)	13	887	395	12	92	18	19	39	30	34	53	179	22	127	111	198

concentration of the element is between 536-633 ppm. The bricks in Site 23 have higher content of rubidium and zinc elements where the concentrations of the two elements are between 49- 219 and 35-483 ppm, respectively.

CONCLUSION

The study on material composition conducted on the bricks at Pengkalan Bujang temple (Site 23) and bricks at Bukit Pendiat temple (Site 17) has successfully proven that both brick samples had used local raw materials in the production of their bricks. The comparison of the brick samples with the clay samples in Bujang valley, Kedah indicates that the raw materials for the bricks of Bukit Pendiat temple (Site 17) were obtained from the basin of Sungai Bujang while the bricks of Pengkalan Bujang temple (Site 23) were obtained from the basin of Sungai Muda which was near the formation of the limestone hills. The use of local raw materials since the 7th century AD shows the role played by the local community in the production of bricks and also in building temples by using bricks based on their knowledge and the supervision from the Brahmans versed in the silpasastra scripture. Therefore, the Colonisation Theory proposed by Quaritch-Wales is rejected while the Indian Culture Indigenisation Theory proposed by Nik Hassan Shuhaimi is more relevant in discussing about the Malay community of Old Kedah.

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