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Research Article

Compositional Analysis of Ancient Bricks at Site 2211, Candi Pengkalan Bujang, Kedah

[1]Zuliskandar Ramli, [1]Nik Hassan Shuhaimi Nik Abd. Rahman, [1]Abdul Latif Samian,
[2]Adnan Jusoh, [2]Yunus Sauman and [3]Othman Mohd Yatim
[1]Institute of the Malay World and Civilisation (ATMA), Universiti Kebangsaan Malaysia
[2]Department of History, Faculty of Humanities, Universiti Pendidikan Sultan Idris
[3]Academy of Malay Studies, Universiti Malaya

Abstract: Archaeological research at Candi Pengkalan Bujang (Site 2211) which is located at Pengkalan Bujang, Kedah was conducted in 2008 and was carried out by researchers from the National University of Malaysia (UKM). The site is believed to be a new site because based on the Quaritch-Wales report, the site based on its location is not in the report that was published by Quaritch-Wales. Based on its orientation of northeast-southwest, which is the same orientation as Candi Pengkalan Bujang (Site 22), hence this Candi or temple was of the Buddhist religion and was constructed between the 11th century to the 13th century AD. Composition analysis of bricks at this site was conducted to determine whether the source of the raw material is local, namely clay or otherwise. The technique used is the X-Ray Diffraction (XRD) technique to determine the mineral phases of the bricks and also the X-Ray Fluorescence (XRF) technique to determine the major element and trace element content of the bricks. The mineral content found in the ancient bricks of Candi Pengkalan Bujang (Site 2211) consists of quartz, microcline, muscovite and minor minerals such as albite and geothite. Major element and trace element content also show that the raw materials used were derived from the basin of the Muda River, Bujang River and the surrounding areas of Kota sub-district. Indirectly, this study proves that local raw material was used to produce bricks at this site.

Keywords: Pengkalan Bujang, X-Ray Diffraction (XRD), X-ray Fluorescence (XRF), Ancient bricks, Muda River, Bujang River, Bujang Valley

INTRODUCTION

In 2008, a team of researchers from the National University of Malaysia headed by Nik Hassan Shuhaimi Nik Abdul Rahman and assisted by Adi Taha and Zuliskandar Ramli had conducted excavations at Site 2211 which is believed to be a ancient temple (candi). This excavation was assisted by a number of well-trained technical staff and also assisted by the locals. This newly excavated site is located at about 10 meters on the right side of Bujang River and about five hundred meters from the south-western part of Candi Pengkalan Bujang (Site 19). This temple was not disclosed in the report published by Quaritch-Wales (Quaritch Wales, 1940). The temples at Pengkalan Bujang consist of temples of the Buddhist element, namely Site 21 and Site 22 and temples of the Hindu element, namely Site 18, Site 19 and Site 23 (Quaritch Wales, 1940; Jacq-Hergoualc'h, 1992; Rahman and Yatim, 1990; Zuliskandar, 2012).

If seen from this structure, it is similar to the temple at Site 22. On the whole, this temple was built using bricks. The size of the bricks here is varied and most have a thickness of more than 6 centimetres. This site is named Site 2211 based on the location of the site which is located on the land lot numbered 2211 (Fig. 1 and 2). The structural orientation of this temple is believed to be inclined toward the northeast-southwest. No statues or inscriptions were found that may help to indicate which religious element was practiced at the temple. Excavation has revealed almost the entire site

Fig. 1: Overall Structure of Site 2211

Corresponding Author: Zuliskandar Ramli, Institute of the Malay World and Civilisation (ATMA), Universiti Kebangsaan Malaysia

Fig. 2: Structure of the inner and outer wall parts

and there are two walls on the outer and the inner parts of the structure; they are separated by a floor structure with 3 layers of bricks between them. It is believed that the inner wall is a structure devoted to placing sculptures.

Among the archaeological discoveries found at this site are earthenware and ceramic pottery of the Song Dynasty and Ming Dynasty. Ceramic artefacts of the Ming Dynasty were found in the upper layer but are not associated with the temple. The Chinese ceramics which are associated with this temple are the ceramics of the Song Dynasty. Among the ceramics found are such as mercury jars, and fragments of the celadon and Qing Pai bowls where these artefacts were produced between the 11th century to the 13th century AD and the temple is believed to have been built between the 10th century to the 11th century AD and its use continued until after the 13th century AD.

A large part of the temple was built of bricks; hence, the brick composition analysis was performed to determine whether these bricks used local raw material or otherwise. A similar study was done on the site of Candi Sungai Mas (Ramli *et al*., 2012), Candi Pengkalan Bujang (Site 23) and Candi Bukit Pendiat (Site 17) in which all of them used local raw material (Zuliskandar *et al*., 2011, 2012). The raw material was taken from the basin of Muda River, Terus River or the Basin of Bujang River. The objective of this study is to determine the mineral content, the major element content and trace element content that are in the bricks of Candi Pengkalan Bujang (Site 2211). The data obtained will be compared with the composition data of clay around Bujang Valley, Kedah. The initial hypothesis is that the temples at Bujang Valley were constructed using local resources and were built by the local community as a result of acculturation of the Indian culture and knowledge transformation of the Old Kedah Malay community (Zuliskandar, 2012).

MATERIALS AND METHOD

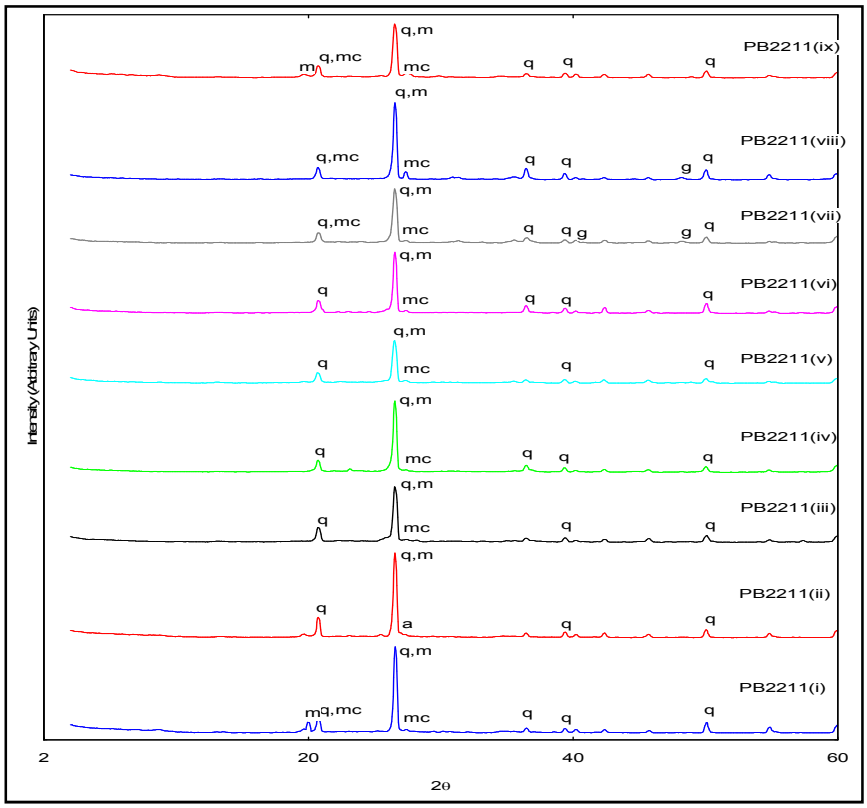
A total of 17 brick samples were taken from the Candi Pengkalan Bujang (Site 2211) where the samples were labelled PB2211 (i), PB2211 (ii), PB2211 (iii), PB2211 (iv), PB2211 (v), PB2211 (vi), PB2211 (vii), PB2211 (viii), PB2211 (ix), PB2211 (x), PB2211 (xi), PB2211 (xii), PB2211 (xiii), PB2211 (xiv), PB2211 (xv), PB2211 (xvi) and PB2211 (xvii). The samples were then taken to the laboratory to be cleaned and dried. The brick samples were then finely ground and sifted. The samples that had been sieved were then separated for analysis using the X-ray Diffraction (XRD) technique and the X-ray Fluorescence technique. The X-ray Diffraction technique (XRD) was used to identify the mineral content found in the brick samples while the X-ray Fluorescence technique was used to determine the major element and trace element content contained in the brick samples.

The data obtained from the analysis of the major and trace elements will be analyzed using the bi-plot graph or 'scatter plot' graph method. This method uses Microsoft Excel software. Two graphs will be plotted based on the selected major elements and trace elements such as magnesium with titanium and copper with lead. The main purpose is to see the distribution of samples in groups and in turn compare them with the clay element (Ramli *et al*., 2011a, b).

RESULTS AND DISCUSSION

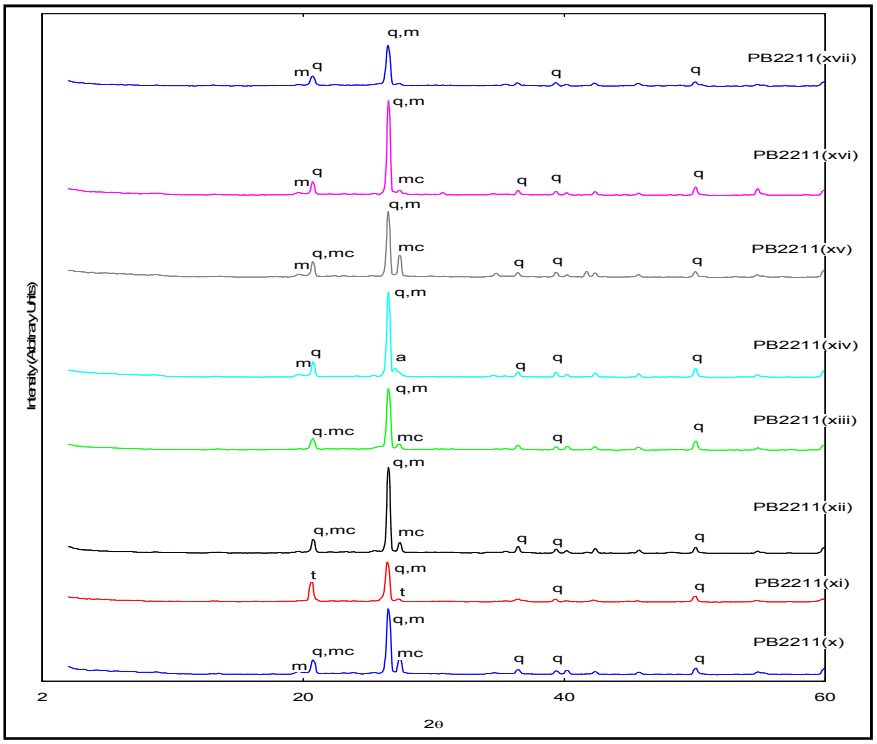
The mineral content found in the ancient bricks of Candi Pengkalan Bujang (Site 2211) consists of quartz, microcline, muscovite and minor minerals such as albite and geothite (Refer to Table 1). The absence of the kaolinite mineral shows that the bricks at this site were baked between the temperatures of 600ºC to 800ºC. Therefore we suggest that open firing technique was used to produce the bricks. Albite mineral is present in the PB2211 (ii) and PB2211 (xiv) samples while geothite mineral containing iron element is present in the PB2211 (vii) and PB2211 (viii) samples. X-ray diffraction pattern of the Site 2211 brick samples can be referred to in Fig. 3 and 4.

The major element content in the ancient brick samples of Candi Pengkalan Bujang (Site 2211) can be referred to in detail in Table 2. The analysis showed that the brick samples contained between 75.54% to 81.88% of dry weight percentage of silica element. The dry weight percentage of the titanium element ranged between 0.44% to 0.59%. The dry weight percentage of iron element is between 1.95% to 3.22%. The dry weight percentage of the aluminium element ranged between 11.60% to 15.90%. The manganese element contained dry weight percentage of between 0.01% to 0.03%, while the calcium element contained dry weight percentage of between 0.13% to 0.43%. The dry weight percentage of the magnesium and sodium element ranged between 0.05 to 1.09% and 0.15 to 0.24% respectively. The potassium and phosphorus element contained dry weight percentage of between 1.46 to 2.00 and 0.17 to 0.76%, respectively. Silica and



Legend: q= quartz, m= muscovite, mc = microcline, g = geothite

Fig. 3: XRD Diffraction pattern of bricks at Candi Pengkalan Bujang (Site 2211)



Legend: q = quartz, m = muscovite, mc = microcline, t = tridymite, a = albite

Fig. 4: XRD diffraction pattern of bricks at Candi Pengkalan Bujang (site 2211)

Table 1: Mineral content of the ancient bricks of Candi Pengkalan Bujang site 2211

Location	Sample	Mineral content
Pengkalan Bujang valley (site 2211)	PB2211 (i)	SiO_2 Quartz $KAlSi_3O_8$ Microcline $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1
	PB2211 (ii)	SiO_2 Quartz$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1 $NaAISi_3O_8$ Albite
	PB2211 (iii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	PB2211 (iv)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M $K_2O.Al_2O_{3\cdot 6}SiO_2$ Microline
	PB2211 (v)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M $K_2O.Al_2O_{3\cdot 6}SiO_2$ Microline
	PB2211 (vi)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1 $KAlSi_3O_8$ Microcline
	PB2211 (vii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1 $K_2O.Al_2O_{3\cdot 6}SiO_2$ Microline $Fe_2O_3.H_2O$ Geothite
	PB2211 (viii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1 $K_2O.Al_2O_{3\cdot 6}SiO_2$ Microline $Fe_2O_3.H_2O$ Geothite
	PB2211 (ix)	SiO_2 Quartz$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M$KAlSi_3O_8$ Microcline
	PB2211 (x)	SiO_2 Quartz$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M$KAlSi_3O_8$ Microcline
	PB2211 (xi)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	PB2211 (xii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 2M1 $K_2O.Al_2O_{3\cdot 6}SiO_2$ Microline
	PB2211 (xiii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M $KAlSi_3O_8$ Microcline
	PB2211 (xiv)	SiO_2 Quartz$KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M $NaAISi_3O_8$ Albite
	PB2211 (xv)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M
	PB2211 (xvi)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M $KAlSi_3O_8$ Microcline
	PB2211 (xvii)	SiO_2 Quartz $KAl_2Si_3AlO_{10}(OH)_2$ Muscovite 1M

Table 2: Major element content of Candi Pengkalan Bujang (site 2211) ancient bricks

	Dry weight (%)									
Sample	Si	Ti	Fe	Al	Mn	Ca	Mg	Na	K	P_2O_3
PB 2211 (i)	76.65	0.57	3.10	15.32	0.02	0.17	0.98	0.16	1.70	0.18
PB 2211 (ii)	78.45	0.51	2.39	12.72	0.01	0.15	0.68	0.15	1.46	0.25
PB 2211 (iii)	76.24	0.53	3.12	14.67	0.02	0.32	0.05	0.20	1.91	0.22
PB 2211 (iv)	77.24	0.54	3.02	13.49	0.04	0.43	1.12	0.22	1.70	0.58
PB 2211 (v)	77.49	0.50	2.79	13.65	0.01	0.21	0.81	0.17	1.76	0.27
PB 2211 (vi)	80.24	0.50	1.95	11.48	0.01	0.18	0.64	0.18	1.67	0.26
PB 2211 (vii)	76.36	0.55	3.32	14.97	0.03	0.14	1.09	0.24	1.83	0.17
PB 2211 (viii)	80.51	0.47	2.49	12.07	0.02	0.20	0.90	0.18	1.67	0.19
PB 2211 (ix)	76.79	0.55	3.06	14.92	0.02	0.17	0.95	0.21	1.74	0.30
PB 2211 (x)	76.60	0.56	3.00	15.50	0.02	0.18	0.76	0.16	1.66	0.21
PB 2211 (xi)	81.88	0.44	2.36	11.60	0.02	0.23	0.08	0.19	1.80	0.21
PB 2211 (xii)	77.62	0.50	2.77	13.85	0.02	0.19	0.93	0.24	1.87	0.19
PB 2211 (xiii)	75.54	0.59	3.22	15.90	0.02	0.23	0.87	0.22	1.98	0.23
PB 2211 (xiv)	78.10	0.50	2.95	13.85	0.01	0.13	0.63	0.22	1.76	0.28
PB 2211 (xv)	77.32	0.53	2.99	14.45	0.03	0.23	0.60	0.17	1.80	0.41
PB 2211 (xvi)	76.81	0.58	2.92	14.79	0.03	0.15	0.97	0.21	2.00	0.18
PB 2211 (xvii)	77.04	0.53	3.01	14.17	0.03	0.23	0.65	0.18	1.79	0.76

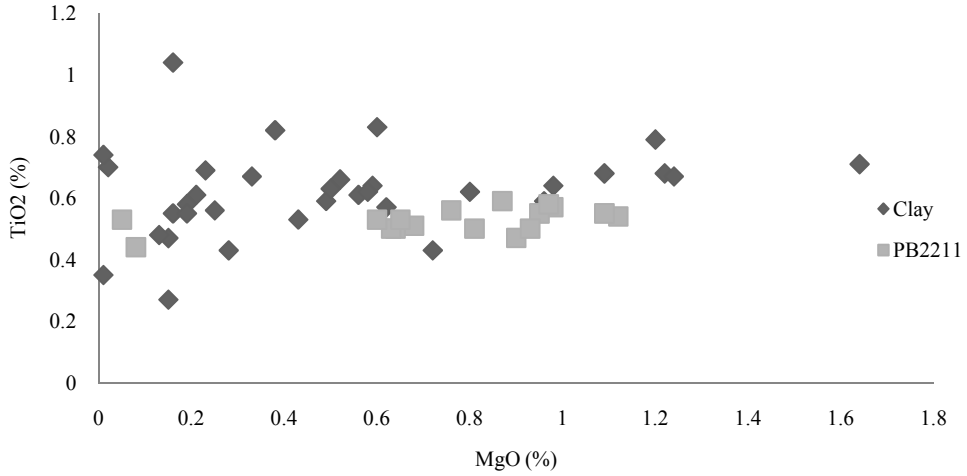


Fig. 5: Dry weight percentage (%) of MgO and TiO_2 element for Candi Pengkalan Bujang (site 2211) brick samples and clay in Bujang valley

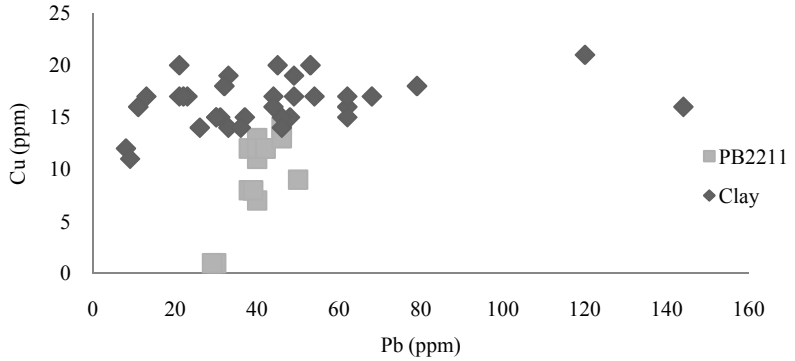


Fig. 6: Graph of copper and lead concentration (ppm) for the brick samples of Candi Pengkalan Bujang (site 2211) and clay at Bujang valley

Table 3: Trace element content of Candi Pengkalan Bujang (site 2211) ancient bricks

	Sample					
Element (ppm)	PB 2211 (i)	PB 2211 (ii)	PB 2211 (iii)	PB 2211 (iv)	PB 2211 (v)	PB 2211 (vi)
As	15	14	14	13	12	11
Ba	721	719	671	721	650	701
Ce	475	538	533	560	526	547
Co	12	10	11	11	14	11
Cr	78	67	74	77	72	60
Cu	12	13	11	12	8	7
Ga	18	16	18	17	14	12
Hf	7	7	7	7	7	7
La	28	28	28	29	28	28
Nb	26	31	29	31	27	33
Ni	32	28	32	33	36	38
Pb	42	40	40	38	38	40
Rb	174	155	183	158	168	166
Sr	41	33	57	54	42	40
U	9	9	9	9	9	9
Th	22	18	20	21	16	11
V	90	83	84	85	81	73
Y	32	24	29	26	22	17
Zn	69	81	66	70	46	26
Zr	203	198	175	228	167	167

Table 4: Trace element content of Candi Pengkalan Bujang (site 2211) ancient bricks

	Sample					
Element (ppm)	PB 2211 (vii)	PB 2211 (viii)	PB 2211 (ix)	PB 2211 (x)	PB 2211 (xi)	PB 2211 (xii)
As	7	8	17	13	7	13
Ba	744	477	755	663	496	663
Ce	543	345	526	508	395	508
Co	6	19	11	15	22	15
Cr	95	70	78	72	69	72
Cu	9	1	14	8	1	8
Ga	27	11	18	14	9	14
Hf	7	8	7	7	8	7
La	42	26	29	28	26	28
Nb	29	18	30	30	21	30
Ni	26	54	33	36	56	36
Pb	50	30	46	39	29	39
Rb	48	141	177	173	141	173
Sr	13	39	48	42	38	42
U	8	9	9	9	9	9
Th	26	15	21	16	10	16
V	191	76	92	81	73	81
Y	18	16	34	26	15	26
Zn	41	6	74	49	0	49
Zr	495	169	216	178	173	178

Table 5: Trace element content of ancient bricks (site 2211)

	Sample				
Element (ppm)	PB 2211 (xiii)	PB 2211 (xiv)	PB 2211 (xv)	PB 2211 (xvi)	PB 2211 (xvii)
As	14	14	17	17	17
Ba	686	736	750	755	722
Ce	547	538	541	526	537
Co	12	12	11	11	15
Cr	84	69	73	78	72
Cu	12	12	13	14	13
Ga	19	15	17	18	15
Hf	7	7	7	7	7
La	28	29	29	29	28
Nb	29	29	32	30	30
Ni	34	32	33	33	39
Pb	40	42	46	46	46
Rb	194	167	165	177	169
Sr	52	34	40	48	42
U	9	9	9	9	9
Th	23	18	20	21	22
V	91	82	84	92	83
Y	32	28	26	34	29
Zn	63	63	73	74	72
Zr	228	207	193	216	198

aluminium content showed that these bricks have a high sand content compared to clay. The dry weight percentage graph of MgO and TiO_2 element (Fig. 5) for the brick samples of Candi Pengkalan Bujang (Site 2211) and the clay in the Bujang Valley were plotted to see the result of the comparison between the samples of brick and clay based on their major elements. Based on the graphs, it appears that the major element composition of the brick samples of Site 2211 was found to have a similarity with the major element content of the clay in Bujang Valley, Kedah. Based on Fig. 5, the raw material that has similarity of magnesium and titanium element composition is the one in the area around the Basin of Muda River and the area around the Kota sub-district and some in the Bujang Valley basin.

The trace element content of the brick samples of Candi Pengkalan Bujang (Site 2211) (Refer to Table 3, 4 and 5) showed content of more than 100 ppm for the elements such as barium, cerium, rubidium, vanadium and zirconium. Other elements are at a relatively low concentration, namely less than 100 ppm. The content of barium element is between 477 ppm to 755 ppm while the cerium element is between 345 ppm to 560 ppm. The content of rubidium and vanadium element is between 48 ppm to 194 ppm and 73 ppm to 191 ppm respectively whereas zircon element has a concentration of between 167 ppm to 495 ppm. Figure 6 is a graph that was plotted to see the distribution of the lead element against the copper element for the brick samples at Candi Pengkalan Bujang (Site 2211) in which the concentration of these two elements is between 1-14 and 29-50 ppm, respectively. The results show that the lead and copper trace element content of the bricks at this site is almost similar to the trace element content of the clay around Bujang Valley, particularly in the Muda River basin area.

CONCLUSION

Brick material composition analysis has successfully proven that the bricks used to build Candi Pengkalan Bujang (Site 2211) used local raw materials obtained from the Muda River and Bujang River basin which indirectly supports the initial hypothesis which stated that the temples in the Bujang Valley used local raw material and that the local community built the temple, based on the archaeological and architectural evidence. Based on the mineral content of the brick, it can be estimated that its combustion temperature was between 600ºC to 800ºC because there is no kaolinite mineral in the bricks.

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