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Research Article

Composition Analysis of Ancient Bricks, Candi Bukit Kechil, Bujang Valley, Kedah

Zuliskandar Ramli and Nik Hassan Shuhaimi Nik Abdul Rahman
Institute of the Malay World and Civilisation (ATMA), Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

Abstract: Candi Bukit Kechil or Bukit Kechil Temple is one of the temples in Bujang Valley that was built on a hill apart from Candi Bukit Pendiat (Site 17), Candi Bukit Meriam (Site 26), Candi Bukit Penjara (Site 25) and Candi Bukit Gajah Mati (Site 7). On the whole, this temple was made from bricks and based on the north-south orientation and the construction of the lotus-like structure, it is believed that this temple is of Buddhist religion and was built between 9th to 10th century AD. Based on GPS reading, the temple's location is N5 37.129 E100 27.324. Analysis on the bricks of the temple was performed to determine whether the bricks used local raw material or otherwise, as well as to find out the physical condition of the bricks, particularly their burning method. As such, two analysis techniques were conducted, namely the X-Ray Diffraction and the X-Ray Fluorescence method that respectively determined the mineral content of the bricks as well as the major and trace element content of the bricks. Analysis shows that the minerals contained in the brick samples of Candi Bukit Kechil comprise of quartz, muscovite, albite and kaolinite. The presence of the kaolinite mineral shows that there are bricks that were baked at temperatures less than 550°C and this shows that open burning was used. The analyses of major and trace element content show that the raw material used are local raw material and the sources of the raw material were obtained from the area of the Bujang River basin and the areas around Mukim Merbok and Mukim Bujang.

Keywords: Bujang river, Bujang valley, candi bukit kechil, X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF)

INTRODUCTION

Candi Bukit Kechil or Bukit Kechil Temple is located in an area named Bukit Kechil that is situated in the Kampung Bukit area, about one kilometre from Kampung Telok Wang Kechil on the west and Kampung Masjid on the east. The position of this site based on GPS reading is N5 37.129 E100 27.324. The temple named Candi Bukit Kechil is made entirely of bricks and is perfectly situated on the summit of Bukit Kechil. This site was excavated by researchers from Universiti Kebangsaan Malaysia in the year 2007, where a total of 27 excavation squares measuring 2×2 m were uncovered (Fig 1 and 2). This Bukit Kechil area is also suitable for use as a guard post for the routes of boats or small ships that pass through Pasir River which is located about 1 km north of the temple site. It is believed that ancient monuments had been built on most of the hills or high areas at Bujang Valley, either as temples of guard posts. Among the hilly areas where remains of temples have been found are Candi Bukit Pendiat, Candi Bukit Gajah Mati, Candi Bukit Batu Pahat, Candi Telaga Batu, Candi Bukit Meriam, Candi Bukit Penjara and Candi Bukit Batu Lintang (Quaritch-Wales, 1940; Jacq-Hergoualc'h, 1992; Nik *et al*., 2008).

Fig. 1: The overall condition of candi bukit kechil

Fig. 2: The walls of candi bukit kechil

This ancient temple appears as if it has floor parts that seem to surround the walls that are on top of it. It is

Corresponding Author: Zuliskandar Ramli, Institute of the Malay World and Civilisation (ATMA), Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

believed that the walls and pillars of the temple were rectangular in shape and surrounding it there exist data of brick layers that serve as the part of the floor and round in shape. Based on the orientation of the temple that is toward the north-south direction, as well as the discovery of weaponry tools made from iron and the discovery of iron stones, this temple thus may have connection to Candi Sungai Batu. The physical characteristics of the bricks of both these sites are also found to be almost similar. Candi Bukit Kechil is believed to be a Buddhist temple and was built between the 9th to 10th century AD.

The objective of this study is to determine the sources of used for making the bricks which were used to build the temple. On the whole, Candi Bukit Kechil was built by using bricks as the main construction material. As such, material composition study of the temple bricks was carried out with the purpose of determining whether the raw material used is local raw material or otherwise. If local raw material was used, therefore indirectly this can corroborate the hypothesis that asserts the local community was the community responsible in producing the bricks and in building this temple. Previous research conducted on the bricks of Candi Sungai Mas (Site 32/34), Candi Pengkalan Bujang (Site 21/22), Candi Pengkalan Bujang (Site 23) and Candi Bukit Pendiat (Site 17) showed that local raw material was employed to produce the bricks used as the main temple construction material (Ramli *et al*., 2012a; Zuliskandar *et al*., 2011a, 2012) and the local community in Kedah Tua also produced their own glass beads (Zuliskandar and Rahman, 2009; Ramli *et al*., 2012b; Zuliskandar *et al*., 2011b). The research also showed that the raw materials were obtained from the basins of Muda River, Bujang River and Terus River.

MATERIALS AND METHODS

A total of 20 brick samples were taken from the site of Candi Bukit Kechil where these samples were labelled BK1, BK2, BK3, BK4, BK5, BK6, BK7, BK8, BK9, BK10, BK11, BK12, BK13, BK14, BK15, BK16, BK17, BK18, BK19 and BK20. These samples were then taken to the lab for cleaning and drying. The brick samples were later finely grinded and sifted. The sifted samples were then separated for analysis with the use of X-Ray Diffraction (XRD) method and the X-Ray Fluorescence (XRF) technique. The X-Ray Diffraction technique was used to identify the mineral content contained 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 major and trace element analysis will be analysed using the bi-plot graph or the 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 silica element with aluminium element, magnesium element with titanium element as well as lead element with copper element. The main purpose was to see the sample distribution in groups and subsequently to make comparison with clay elements.

Table 1: Mineral content of the ancient bricks of candi bukit kechil

Location	Sample	Mineral content
Candi bukit kechil	BK 1	SiO_2 quartz $K_2O._3Al_2O_3._6SiO_2._2H_2O$ muscovite $NaAISi_3O_8$ albite
	BK 2	SiO_2 quartz
	BK 3	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
	BK 4	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
	BK 5	SiO_2 quartz $Al_2Si_2O_5(OH)_4$ kaolinite 1Md
	BK 6	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M $Al_2Si_2O_5(OH)_4$ kaolinite 1Md
	BK 7	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
	BK 8	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
	BK 9	SiO_2 quartz
	BK 10	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
	BK 11	SiO_2 quartz
	BK 12	SiO_2 quartz
	BK 13	SiO_2 quartz $Al_2Si_2O_5(OH)_4$ kaolinite 1Md $NaAISi_3O_8$ albite
	BK 14	SiO_2 quartz
	BK 15	SiO_2 quartz
	BK 16	SiO_2 quartz $Al_2Si_2O_5(OH)_4$ kaolinite 1Md
	BK 17	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
	BK 18	SiO_2 quartz $Al_2Si_2O_5(OH)_4$ kaolinite 1Md
	BK 19	SiO_2 quartz $K_2O._3Al_2O_3._6SiO_2._2H_2O$ muscovite
	BK 20	SiO_2 quartz $KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M

RESULTS AND DISCUSSION

The details of the mineral content found in the ancient brick samples of Candi Bukit Kechil can be referred to in Table 1. Analysis showed that the mineral content found in the brick samples at Candi Bukit Kechil consists of quartz, Muscovite, albite and kaolinite. The mineral Kaolinite present in the samples of BK5, BK6, BK13, BK16 and BK18 shows that there are bricks baked at temperatures below 550°C. Meanwhile, samples BK2, BK9, BK11, BK12, BK14 and BK15 only contain the mineral quartz. This shows that there was uneven burning in the bricks. This happens when the open burning technique is used. The brick burning temperature at the site is believed to be no greater than 800°C. The X-ray diffraction patterns of

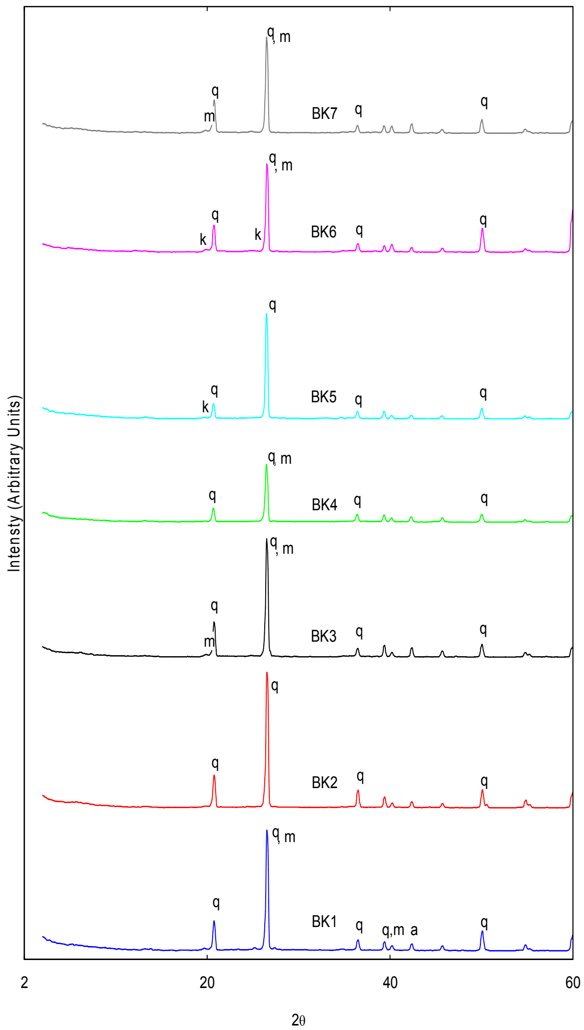

Fig. 3: The XRD diffraction pattern of candi bukit kechil bricks
q: Quartz; m: Muscovite; a: Albite

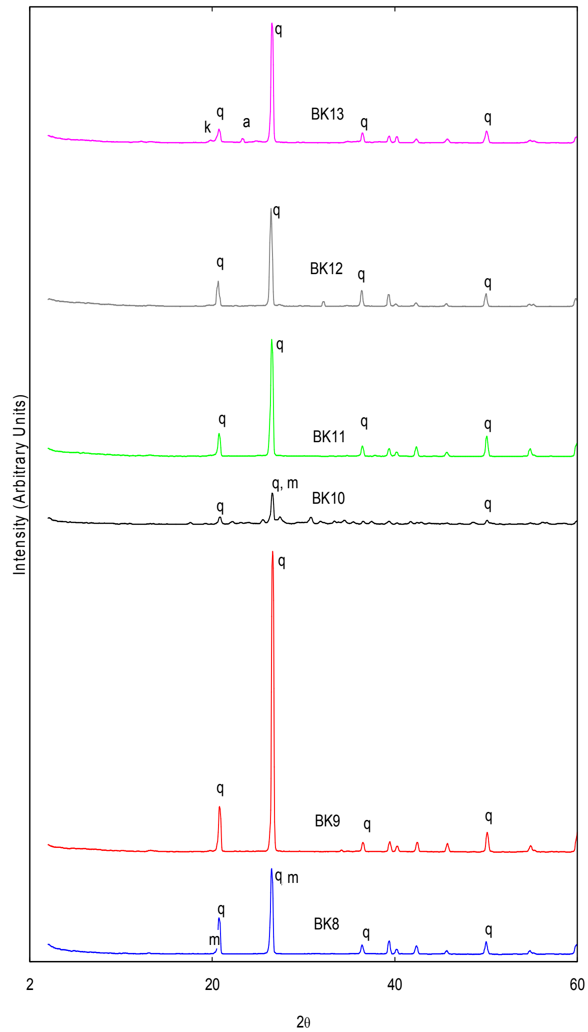

Fig. 4: XRD diffraction pattern of candi bukit kechil bricks
q: Quartz; m: Muscovite; a: Albite; k: Kaolinite

Candi Bukit Kechil's brick samples can be found in Fig. 3, 4 and 5.

The content of the major elements in the ancient brick samples of Candi Bukit Kechil can be referred to in detail in Table 2. The analysis shows that the ancient brick samples contain between 69.84 to 85.08% dry weight percentage of silica element. The dry weight percentage of titanium element ranges between 0.42 to 0.73%. Iron element contains dry weight percentage of between 1.14 to 4.43%. The dry weight percentage for aluminium element ranges between 12.26 to 26.02%. Manganese element contains the dry weight percentage of between 0.01 to 0.02% while calcium element contained the dry weight percentage of between 0.01 to 0.06%. The dry weight percentage of the magnesium and sodium element ranges between 0.11 to 0.26% and 0.04 to 0.07%, respectively. The elements of potassium and phosphorus contain the dry weight percentage of 0.07 to 0.36% and 0.01 to 0.03%, respectively.

For the brick samples in Candi Bukit Kechil, elements such as silica, aluminium and iron are the elements that contain high dry weight percentage. The dry weight percentage graph for the elements SiO_2 and Al_2O_3 (Fig. 6) as well as the dry weight percentage graph for the elements MgO and TiO_2 (Fig. 7) for the brick samples of Candi Bukit Kechil and the clay in Bujang Valley were plotted to see the results of the comparison between the brick samples and clay based on their major elements. Based on the graphs, it was found that the composition of the major elements of the brick samples of Candi Bukit Kechil was similar with the major element composition of the clay from Bujang Valley. The raw material for the bricks was sourced from the basin areas of Bujang River and the areas around Mukim Merbok and Mukim Bujang.

The content of trace elements of the brick samples in Candi Bukit Kechil (Table 3, 4 and 5) shows content of more than 100 ppm for elements such as barium,

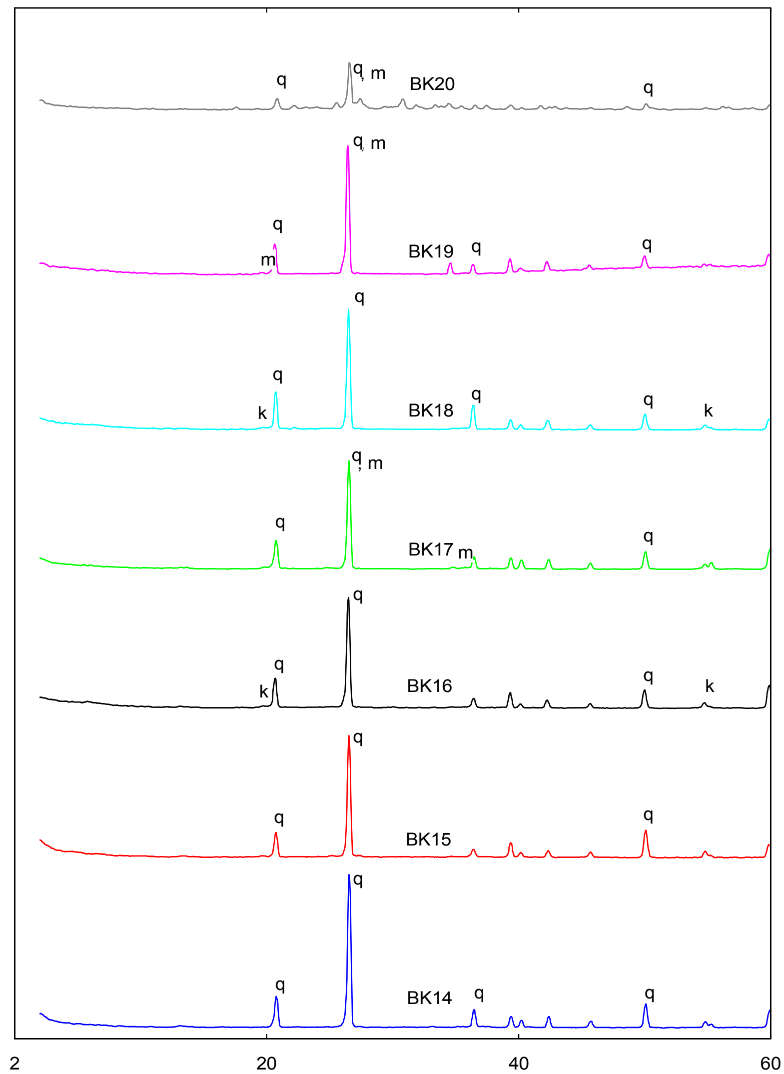

Fig. 5: XRD diffraction pattern of candi bukit kechil bricks
q: Quartz; m: Muscovite; k: Kaolinite

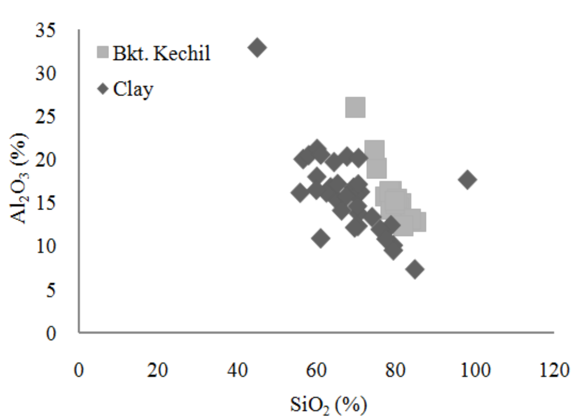

Fig. 6: Dry weight percentage (%) of the elements SiO_2 and Al_2O_3 for the brick samples of candi bukit kechil and clay at Bujang valley

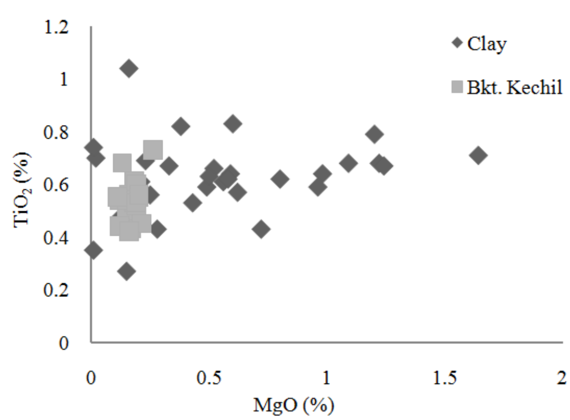

Fig. 7: Dry weight percentage (%) of the MgO and TiO_2 elements for the brick samples of candi bukit kechil and clay at Bujang valley

Table 2: Major element content of the brick samples at candi bukit kechil

	Dry weight (%)									
Sample	Si	Ti	Fe	Al	Mn	Ca	Mg	Na	K	P_2O_3
BK 1	79.82	0.56	2.43	15.16	0.01	0.06	0.20	0.05	0.25	0.01
BK 2	79.77	0.50	2.16	14.89	0.01	0.02	0.15	0.06	0.26	0.01
BK 3	81.31	0.52	1.98	14.89	0.02	0.02	0.19	0.06	0.27	0.01
BK 4	79.96	0.55	4.01	13.80	0.01	0.02	0.15	0.05	0.19	0.01
BK 5	75.12	0.68	4.33	18.93	0.01	0.02	0.13	0.05	0.34	0.01
BK 6	79.22	0.53	2.26	14.78	0.01	0.03	0.18	0.05	0.28	0.01
BK 7	85.08	0.43	1.57	12.71	0.02	0.02	0.17	0.05	0.20	0.01
BK 8	77.25	0.61	3.51	15.67	0.01	0.01	0.18	0.04	0.07	0.01
BK 9	78.88	0.56	2.53	16.34	0.01	0.02	0.16	0.05	0.26	0.02
BK 10	80.78	0.54	2.41	14.37	0.01	0.02	0.12	0.05	0.24	0.02
BK 11	83.84	0.44	1.14	13.06	0.01	0.02	0.12	0.06	0.23	0.01
BK 12	74.66	0.60	2.17	21.07	0.02	0.03	0.19	0.08	0.81	0.03
BK 13	78.63	0.55	2.18	15.38	0.01	0.02	0.20	0.06	0.33	0.01
BK 14	78.67	0.45	1.84	14.24	0.02	0.02	0.21	0.05	0.09	0.01
BK 15	69.84	0.73	1.63	26.02	0.01	0.02	0.26	0.07	0.48	0.02
BK 16	79.85	0.54	2.22	14.82	0.01	0.02	0.15	0.05	0.27	0.02
BK 17	81.79	0.42	2.42	12.26	0.02	0.02	0.16	0.06	0.23	0.01
BK 18	78.28	0.53	2.25	16.25	0.01	0.02	0.19	0.06	0.36	0.02
BK 19	80.22	0.55	1.87	15.42	0.01	0.02	0.11	0.06	0.28	0.01
BK 20	79.82	0.56	2.43	15.16	0.01	0.06	0.20	0.05	0.23	0.01

Table 3: Major element content of the brick samples at candi bukit kechil

	Sample						
Element (ppm)	BK 1	BK 2	BK 3	BK 4	BK 5	BK 6	BK 7
As	18	27	23	39	52	27	17
Ba	716	693	696	656	689	697	697
Ce	643	624	596	610	592	620	646
Co	13	13	16	16	12	8	6
Cr	72	84	72	121	139	93	57
Cu	18	14	14	12	12	16	15
Ga	22	18	18	19	20	19	13
Hf	8	8	8	7	7	8	8
La	29	29	29	29	29	29	29
Nb	32	33	32	33	33	32	35
Ni	27	24	25	21	21	26	24
Pb	55	66	61	77	94	70	56
Rb	72	39	41	23	35	38	28
Sr	2	3	6	1	2	7	3
U	9	9	9	9	9	9	9
Th	13	14	15	14	17	14	5
V	102	104	99	119	153	111	83
Y	2	0	0	0	0	0	0
Zn	29	25	27	26	23	27	23
Zr	272	213	230	191	223	202	160

Table 4: Major element content of the brick samples at candi bukit kechil

	Sample						
Element (ppm)	BK 8	BK 9	BK 10	BK 11	BK 12	BK 13	BK 14
As	20	29	30	14	15	62	27
Ba	623	704	676	686	693	714	622
Ce	634	599	604	573	585	639	541
Co	11	8	8	14	8	8	16
Cr	114	94	90	55	75	91	85
Cu	12	16	13	13	16	15	12
Ga	18	18	17	15	21	19	19
Hf	7	8	8	8	8	8	7
La	28	29	29	29	29	29	29
Nb	33	33	33	32	34	37	28
Ni	22	23	23	26	24	26	25
Pb	51	69	71	52	52	67	63
Rb	14	37	36	33	77	42	17
Sr	0	3	3	2	2	7	1
U	9	9	9	9	9	9	9
Th	13	15	15	9	14	12	14
V	103	121	112	81	101	115	89
Y	0	0	0	0	2	0	0
Zn	26	25	25	28	26	26	26
Zr	201	208	224	241	254	201	237

Table 5: Major element content of the brick samples at candi bukit kechil

	Sample					
Element (ppm)	BK 15	BK 16	BK 17	BK 18	BK 19	BK 20
As	13	26	32	25	23	30
Ba	686	700	737	698	706	702
Ce	610	609	645	615	600	591
Co	11	8	9	8	7	8
Cr	83	90	88	92	88	84
Cu	16	15	16	15	15	14
Ga	27	17	16	18	17	18
Hf	8	8	7	8	8	8
La	29	29	30	29	29	29
Nb	35	35	37	35	35	35
Ni	32	24	23	25	25	24
Pb	52	66	73	64	63	70
Rb	40	39	35	46	32	46
Sr	2	4	5	6	1	7
U	9	9	9	9	9	9
Th	15	14	9	9	12	15
V	99	107	105	106	104	107
Y	0	0	0	0	0	0
Zn	33	28	24	27	26	23
Zr	251	201	177	187	206	229

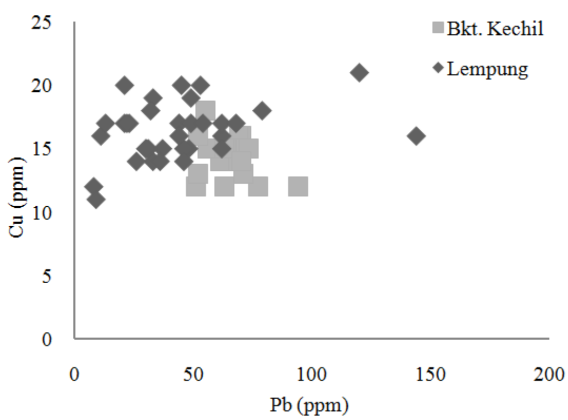

Fig. 8: Graph of lead and copper element concentration for the brick samples of candi bukit kechil and clay at Bujang valley

cerium, chromium, vanadium and zirconium. Other elements are at a relatively low concentration which is less than 100 ppm. The content of the element barium is between 622 to 737 ppm while the element cerium is between 541 to 646 ppm. The content of the elements chromium and vanadium is between 55 to 139 ppm and 81 to 153 ppm, respectively while the element of zircon has the concentration of between 160 and 272 ppm.

Figure 8 is the graph plotted to see the distribution of lead versus copper element for the brick samples in Candi Bukit Kechil where the content of the concentration of these two elements is between 14 to 20 ppm and 41 to 57 ppm, respectively. The result shows that there is one major source of raw material that was used and the graph also shows that the raw material used was obtained from the local clay.

CONCLUSION

The archaeological study conducted on Candi Bukit Kechil shows that this temple is believed to have been built in the 9th or 10th century AD based on the ceramic findings that are associated with the temple's site and the brick size used. The material composition study carried out showed that local raw material was employed to produce the bricks used in the construction of the temple. This raw material was obtained from the Bujang River basin and the areas around Mukim Merbok and Mukim Bujang. The analyses also show that the minerals contained in the brick samples of Candi Bukit Kechil consist of quartz, muscovite, albite and kaolinite. The presence of the kaolinite mineral shows that there are bricks that were baked at temperatures below 550ºC and this indicates that open burning was used.

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