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A mineralogical and geochemical investigation of archaeological pottery shards found at Bukit Komel, Sungai Tembeling, Pahang

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Abstract: This study presents the results of mineralogical and geochemical analyses carried out on prehistoric pottery of Bukit Komel in Sungai Tembeling, Pahang. The Bukit Komel archaeological site, which was excavated in 2022, has produced a significant number of earthenware potteries mainly in the form of body and rim shards. Since information on the prehistory pottery of Sungai Tembeling is limited, it was decided that morphological and analytical techniques should be performed in order to gain insights on pottery physical characteristics, technology and source. The morphological analysis technique used on Bukit Komel pottery involves the study of pottery shape, size, colour and design while the scientific analysis comprises X-ray diffraction (XRD), X-ray fluorescence (XRF), thin section petrography and image analysis methods. Based on geochemical and mineralogical results, this study concludes that the Bukit Komel pottery was locally made by using clay sourced from Sungai Tembeling. This was also confirmed by the findings of comparative study conducted between the Bukit Komel pottery and clay extracted from Sungai Tembeling. Similar minerals found amidst the pottery and clay are quartz, albite, muscovite and microcline. Technology-wise, the Bukit Komel pottery was hand-made using the paddle and anvil technique, and sand-tempered. Pottery shapes include flat- and round-bottomed vessels with plain, red-slipped, impressed and incised designs. Based on colour analysis, the Bukit Komel pottery was very likely fired using the open-firing technique at low temperatures, perhaps between 400 °C and 600 °C.

Keywords: Pottery, Bukit Komel, ancient, XRD, XRF, petrography

INTRODUCTION

Earthenware is the earliest type of pottery created by the human race. Basically, it is made with a combination of clay, water, air and fire (Suresh & Nasha, 2023). According to recent studies, the world's oldest pottery was discovered at Xianrendong site in Southern China, dating back to 20,000 years ago (Wu *et al*., 2012). The Xianrendong pottery is crudely made and tempered with crushed quartzite or feldspar. Technically, sheet-laminating and coiling with paddling are two main methods employed to form the vessel and the pottery is low-fired, probably baked at low temperatures in open fires. The Xianrendong pottery decoration appears to be very simple during the early period with some having parallel striations and cord-marked designs. Besides China, Japan and Russia have also reported early pottery dating from 15,000 to 17,000 years ago (Wu *et al*., 2012).

In Malaysia, archaeological research since the early 1900s had discovered several Neolithic sites with earthenware pottery. Some of these sites are Gua Harimau in Perak, Gua Berhala and Kodiang in Kedah, Bukit Tengku Lembu in Perlis, Gua Cha, Gua Peraling and Gua Chawas in Kelantan, Gua Sagu, Gua Tenggek, Kota Gelanggi and Lembah Tembeling in Pahang, Gua Taat in Terengganu, Jenderam Hilir in Selangor, Gua Niah, Gua Sireh, Gua Tupak and Lubang Angin in Sarawak, and Madai, Baturong, Tapadong, Segarong, Bukit Tengkorak, Melanta Tutup and Bukit Kamiri in Sabah (Linehan, 1928; 1930; Noone, 1939; Tweedie, 1940; 1953; Sieveking, 1954; 1956, 1962; Peacock, 1959; 1964; Harrisson, 1971; Theseira, 1976; Adi, 1983; 1985; 1987; 1989; 2007; Leong, 1986; 2001; 2003; Bellwood, 1988; 1989; Zolkurnian, 1989; 1998; Nik Hassan *et al*., 1990; Datan, 1993; Asyaari, 1998; Zuraina *et al*., 1998; Chia, 1997; 2003; 2016; Zuliskandar *et al*., 2001, 2006; 2011; Chia & Zolkurnian, 2005; Gani, 2010; Suresh, 2011; 2017; Goh *et al*., 2019). The Neolithic pottery of Malaysia has been radiocarbon dated to 4,000-2,000 years ago (Chia, 1997; 2003; 2007a; 2007b). Technology-wise, the pottery is hand-made using the paddle and anvil technique and is low-fired. Although the slow-wheel technique may have been employed in the past, substantial evidence of the use of wheel technology in Malaysian prehistory pottery-making is yet to be discovered. Other major forming techniques used include segmentation, coiling and joining. In terms of shape and form, prehistory pottery found in West Malaysia slightly differs from that found in East Malaysia. However, they likely

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serve the same purpose - cooking, storing, preserving and ceremonies (Suresh & Nasha, 2023).

Prior to 1980s, prehistoric pottery studies in Malaysia concentrated mainly on physical features such as pottery shape and design. However, in early 1990s and 2000s many researchers like Leong (1989; 1990; 2003), Mohd Kamaruzaman *et al*. (1991), Datan (1993), Chia (1997; 2003), Asyaari (1998; 2002), Vandiver & Chia (1997), Zuliskandar *et al*. (2001; 2006), Velat (2005; 2010) and Gani (2010) gave importance to pottery compositional studies. This has greatly benefited in determining prehistoric pottery source, technology and origin at national and regional levels. Continuous effort in studying the prehistoric pottery compositions can be seen in the works of Suresh (2011; 2014; 2017), Zuliskandar *et al*. (2011; 2014; 2021), Chia (2016), Zuraidah & Zuliskandar (2018), Mohd Hasfarisham & Mokhtar (2020), Shafiq *et al*. (2021; 2023).

The application of mineralogical and geochemical techniques in this study is anticipated to provide new and innovative insight into the compositions of prehistory pottery found recently at Bukit Komel in Sungai Tembeling, Pahang. In addition, physical analysis data provided in this study will further aid in strengthening the interpretation of pottery morphologies. By doing that, the source and origin of raw material used as well as the techno-cultural aspects of prehistory pottery production at Bukit Komel can be inferred.

THE SITE AND ITS GEOLOGICAL SETTING

Bukit Komel is an open site located in the interior part of Ulu Tembeling in Sungai Tembeling, Jerantut, Pahang. There are also other notable open sites in Sungai Tembeling namely Bukit Karim, Jeram Koi and Nyong. Located at an elevation of 117 metres above river level, Bukit Komel would have been a strategic location for the prehistoric people of Sungai Tembeling to use the site either for a temporary or permanent settlement. Our communication with locals in Ulu Tembeling revealed that Bukit Komel was never flooded during the massive flood which took place in the east coast of Peninsular Malaysia in 1923, 1926, 1971 and most recently in 2013 and 2020 (Linehan, 1928; Sinar Harian, 2023; Suresh & Nasha, 2023). This signifies that the site is very ideal for habitation, and it may have been occupied as early as the prehistoric era.

Bukit Komel and other archaeological sites like Kampung Bantal and Jeram Koi are situated near to the Lebir fault zone, one of the major lineaments in Peninsular Malaysia (Tjia, 1989; Harun, 2002; Figure 1). Geologically, the area is rich with sedimentary rocks from the Jurassic-Cretaceous period, Triassic volcanic rocks and intrusive rocks (Khor *et al*., 2017). In addition, early Paleozoic and Triassic limestone hills (a small part) have been identified in this area (Koopsman, 1968). According to recent mapping by Khor *et al*. (2023) rocks in the Kuala Tahan, Kampung Pagi and Kampung Bantal areas belong to the Mangking Formation of the Tembeling Group

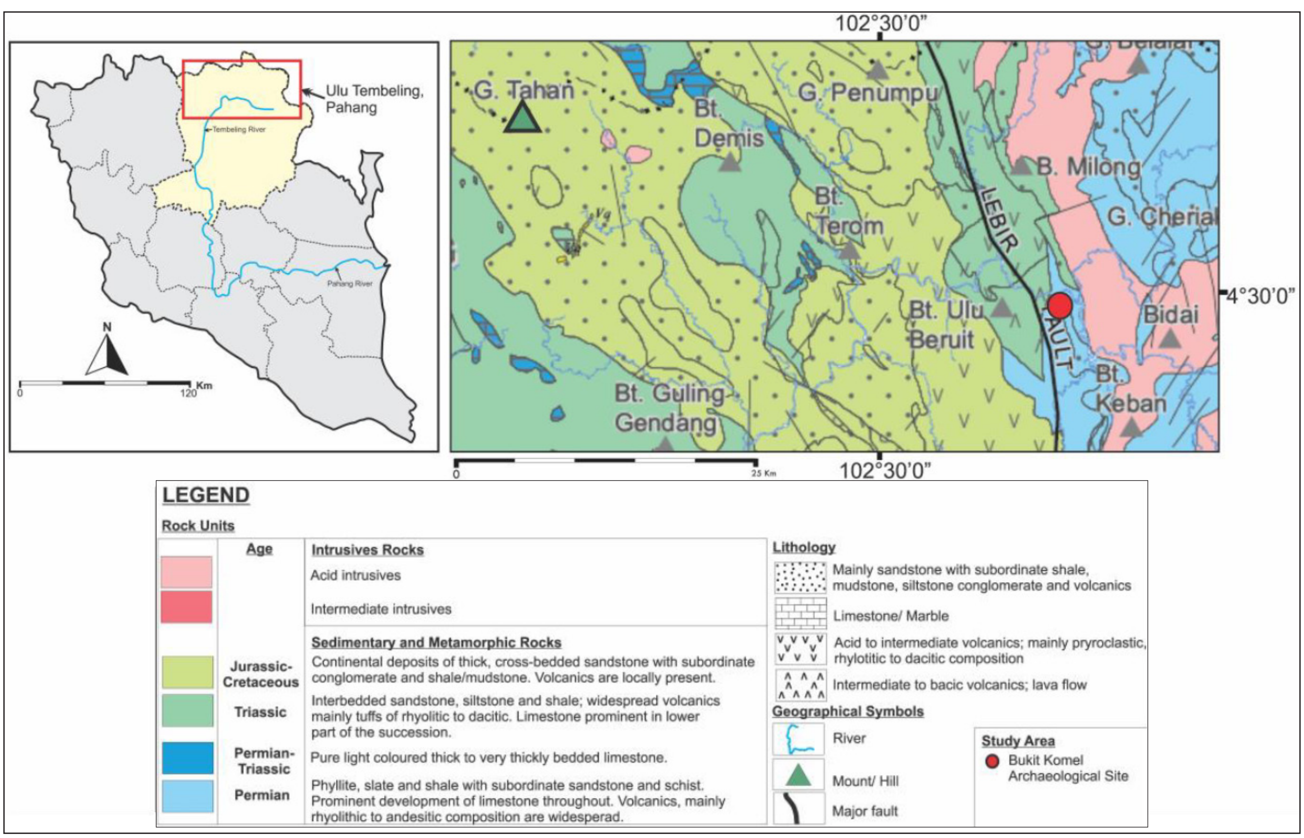

Figure 1: Geological map of Ulu Tembeling and the study area (modified after Suresh *et al*., 2020; Peninsular Malaysia Geological Map 9th Edition 2014).

which are sedimentary rocks from the Jurassic-Cretaceous period deposited in the terrestrial environment. The volcanic rocks, on the other hand, date back to the middle Triassic to Upper Triassic and are interpreted to have been deposited in deep sea settings (Ainul *et al*., 2005).

The Bukit Komel archaeological site was first investigated by Theseira (1976) in the mid-1970s where he reported on the discovery of earthenware pottery during a survey at Kampung Komel and Kampung Kucing. Subsequently, Adi (1983) from the Department of Museum and Antiquities Malaysia (now Department of Museums Malaysia) conducted an archaeological excavation at Bukit Komel in 1982. The findings of the 1982 excavation consisted mainly of stone adze and earthenware pottery. Also found were broken pieces of cylindrical-shaped clay moulds, similar to those reported at Jeram Koi, another open site excavated by Adi (1983; 1989) in Sungai Tembeling. According to Adi (1983; 1989) the Bukit Komel pottery is hand-made and sand-tempered as most of the shards had very coarse surface. A majority of them are plain with some decorated with cord-marked design. The upper layer of the site produced evidence for Metal Period where artifacts in the form of bronze bowl, green-coloured beads and Chinese ceramics (probably of Ming dynasty) as well as Thailand Swankhalok ceramics were recovered. Based on the findings, Adi (1983; 1987) postulated that Bukit Komel was occupied by Late Neolithic and Early Metal Age people. The ceramic vessels and metal objects are believed to have arrived at the Tembeling region through trade and exchange activities between the coastal and inland communities. No archaeological research was carried out in the Tembeling region after Adi's excavation at Bukit Komel and Jeram Koi except for some brief historical studies by Universiti Sains Malaysia and the Bujang Valley Archaeological Museum in 2009 (Suresh *et al*., 2020).

RECENT ARCHAEOLOGICAL RESEARCH AT BUKIT KOMEL

In 2022, archaeological research, involving survey and excavation, was carried out at Bukit Komel by the Centre for Global Archaeological Research (CGAR), Universiti Sains Malaysia (USM) for a period of 10 days. Prior to that, geophysical survey using ground penetrating radar (GPR) was conducted to identify any natural or man-made objects embedded under the soil at the study area. In total, six trenches were opened and all of them contained earthenware pottery shards. During the excavation, no pottery was found between spit 1 and spit 4. Basically, the upper layers of the site were disturbed. Pottery first appeared in spit 5 and was subsequently found in all lower spits until spit 9. The majority of the pottery shards appeared to be fragile and small in size. A preliminary analysis work including cleaning and sorting was carried out on-site before the pottery shards were packed and transported to USM for laboratory analysis.

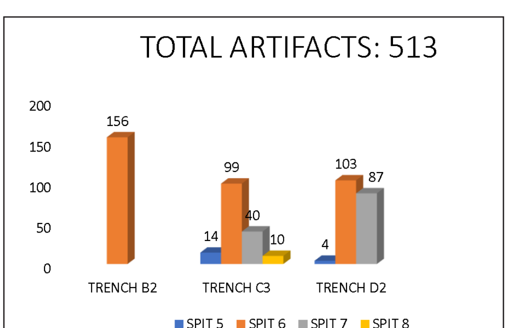

Figure 2: Quantity of pottery shards found in trench B2, C3 and D2 at Bukit Komel during the 2022 excavation by USM.

RESEARCH METHODOLOGY

For this study, pottery shards from three trenches namely B2, C3 and D2 were selected for mineralogical and geochemical analyses. In total 513 shards were found from all these three trenches (Figure 2). For instance, in trench B2 pottery was recovered from spit 6 (n=156) while in trench C3 (n=163) and D2 (n=194) pottery was found between spit 5 and spit 8. All of them were morphologically analysed to obtain information on pottery physical features such as colour, thickness, size, rim profile and decoration.

Of 513 shards, twelve shards were selected for scientific analysis. The samples were labelled S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11 and S12 (Table 1). Pottery shards from

Table 1: Mineral contents of earthenware pottery from Bukit Komel.

Sample	Mineral content
S1	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Illite [$KAl_2(Si_3AlO_{10})(OH)_2$], Albite ($NaAlSi_3O_8$), Microcline ($KAlSi_3O_8$)
S2	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$)
S3	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$)
S4	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$)
S5	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$), Microcline ($KAlSi_3O_8$)
S6	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Microcline ($KAlSi_3O_8$)
S7	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$), Kaolinite ($Al_2Si_2O_5(OH)_4$)
S8	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$), Microcline ($KAlSi_3O_8$)
S9	Quartz (SiO_2), Albite ($NaAlSi_3O_8$), Kaolinite ($Al_2Si_2O_5(OH)_4$)
S10	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$), Microcline ($KAlSi_3O_8$)
S11	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$), Microcline ($KAlSi_3O_8$)
S12	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Albite ($NaAlSi_3O_8$), Microcline ($KAlSi_3O_8$)

trench C3 (spit 5 and spit 8), and trench D2 (spit 5) was not included in this study due to small sample size. Four main scientific techniques used in this study were X-ray diffraction (XRD), X-ray fluorescence (XRF), thin section petrography and image analysis using 3D microscope. All these investigations were carried out at USM's Centre for Global Archaeological Research's Earth Material Characterisation Laboratory.

The XRD technique was employed to determine the mineral content while the XRF technique was used to determine the major and trace elements of the pottery shards (Papachristodoulou *et al*., 2006; Sarhaddi-Dadian *et al*., 2015; Zeinab, 2018). The pottery samples were first cleaned using soft brushes and ground into approximately 50μm grain size using a motorized grinding machine and was further ground manually to a finer grain size of 20μm using an agate mortar. For XRD analysis, the samples were analysed using the in-house method based on ASTM D934-80 (PPAG-MPBB-XRD-(007) (Qualitative Analysis). The machine used was a fully automated X-Ray Diffraction Model Bruker D8 Advance (Germany). The experimental parameters are as follows; Source of X-Rays: Kα, λ = 1.54060 Å, scanning range = 10◦ - 70◦ (2theta), scanning speed: 0.02◦ 2Θ/sec.

As for the XRF analysis, both press pallet and glass fused methods were employed. Samples analysed included excavated pottery shards and clay samples obtained from Bukit Komel and its surrounding areas. Each sample was ground into a fine powder using an agate mortar. The specimen for the XRF analysis was made by igniting 0.5g of sample and 5.0g of spectroflux at 1100 °C for 20 minutes, before it was cast into a glass disc, 32mm in diameter. The specimen was analysed for 10 major elements using a fully automated PanAlytical Axios Max (Holland) XRF spectrometer, with a standard elemental setup. The calibration technique was employed. The 10 element curves were constructed using 13 high quality international standard reference materials, comparable in composition to the unknown samples. Apart from elemental studies, the XRF results will be used to plot a ternary diagram and a three-dimensional scatter plot graph in order to see the differences between the elements in pottery and clay samples. Such attempts have successfully been applied in prehistoric pottery studies particularly in Peninsular Malaysia, for instance, by Shafiq *et al*. (2021), Suresh *et al*. (2022), and Shafiq *et al*. (2023). In this study, the ternary diagram was developed by using the XLSTAT 2019 edition software which was integrated into the Microsoft Excel format. The three-dimensional scatter plot, on the other hand, was made with the IBM SPSS Statistic 26 software.

In addition to XRD and XRF techniques, thin section petrography analysis was used to identify and classify the microstructure minerals in pottery fabrics. Past studies have shown that petrography analysis is very useful in studying pottery provenance and technology reconstruction (Petersen, 2009). In this study, petrography analysis was used to identify the mineralogical composition of inclusions used and its orientation, distribution, size and shape. Additionally, microscopy examination using 3D technology was applied to check for slips, cracks, impression marks as well as other peculiar types of marks and designs on pottery. Such analyses are believed to contribute essential data and understanding towards the Bukit Komel pottery technology as well as its source and provenance.

RESULTS AND DISCUSSION

As aforementioned, the Bukit Komel site yielded a total of 513 pottery shards during the 2022 excavation. All these shards were morphologically studied to obtain information on pottery colour, thickness and decoration. Of 513 pottery shards, 12 shards from different trench and spit were selected for compositional analysis. The following presents the results of morphological and compositional analyses conducted on the prehistory pottery of Bukit Komel in Ulu Tembeling, Pahang.

Morphological analysis

Physically, the Bukit Komel pottery is very fragile and coarse. The colour of the shards range from yellowish brown to dark grey or black. The core is either black or reddish brown in colour. The thickness of the shards was measured using the digital calliper, and it was found that most shards have thickness between 10mm and 20mm. Also found were some shards with thickness 25mm and above. According to Chia (1997) the prehistory pottery of Peninsular Malaysia, based on thickness analysis, can be formed into three main groups namely thin vessel (6mm and below), medium vessel (6mm to 10mm) and thick vessel (10mm and above) (Chia, 1997). Pottery with thick and medium

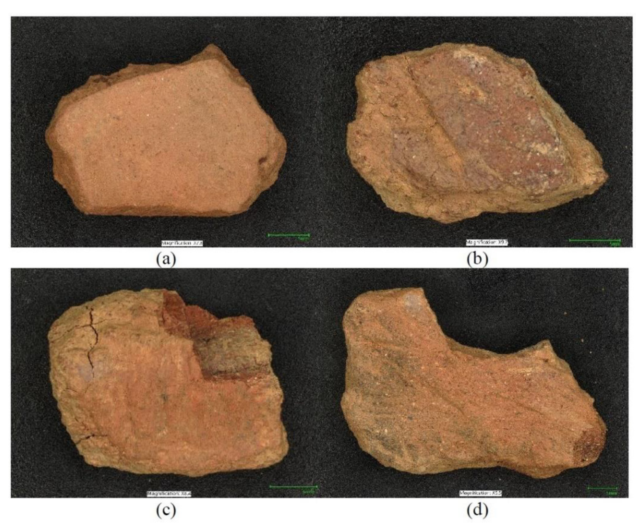

Figure 3: The Bukit Komel pottery designs (a) a fragment of plain pottery, (b) a piece of red-slipped pottery (partially faded), (c) a pottery shard with impressed design (faded parallel lines) and (d) a pottery shard with incised design (faded short and tiny lines).

walls is ideal for storing and cooking whereas pottery with thin walls is suitable for serving or ceremonial purpose. Therefore, it is reasonable to suggest that the Bukit Komel pottery was used for storing and cooking.

The Bukit Komel pottery decoration may be formed into two main groups namely plain and decorated. The decorated pottery consists chiefly of red-slipped, impressed and incised designs (Figure 3). In this study, the actual colour of pottery with red-slip coating was hard to determine because many of them are faded probably due to soil leaching and weathering. The impressed design includes parallel lines which was made by using the carved paddle while the incised designs consist of simple gouged marks or tiny lines. The incised designs could have been created with a sharp pointed tool when the pottery was still leather-hard. According to previous reports by Evans (1931), Theseira (1976) and Adi (1983) similar impressed and incised designs have been observed on potteries found at other archaeological sites in Ulu Tembeling such as Kuala Nyong, Bukit Karim and Jeram Koi. The Bukit Komel pottery rim profiles include both straight and everted rims.

Scientific analyses

In this study, XRD analysis was used to determine the mineralogical phase of all the pottery samples studied. The results of the study showed that the mineral contents of Bukit Komel pottery consist mainly of quartz, muscovite, albite and microcline (Table 1). Also found were clay minerals such as illite and kaolinite but limited to only several samples like S1, S7 and S9 (Table 1). The presence of such minerals indicates that the Bukit Komel pottery was fired at low temperatures, presumably between 400 °C and 600 °C. This is due to the fact that most of the clay minerals in the pottery will disintegrate at a firing temperature of 600 °C or above except for quartz mineral which has low thermal expansion (Suresh & Nasha, 2023). In addition, the presence of kaolin in S7 and S9 supports the use of low firing technology in Bukit Komel pottery production. Analytical studies have showed that kaolin decomposes at a temperature of 400 °C and is converted into meta-kaolin at temperature of 600 °C (Tiwari & Dasgupta, 2016; Yanti & Pratiwi, 2018). Also, the absence of carbonate minerals such as calcite in the pottery samples proves that the Bukit Komel pottery was made by using non-calcareous clay and such source is widely available in the Ulu Tembeling region.

During archaeological excavation at Bukit Komel, several clay heaps were found inside one of the excavated trenches at a depth of about one meter. This clay heap does not occur naturally at the site and we assume that it was brought in from elsewhere to make pottery at Bukit Komel. Sample of this clay heap was taken for laboratory testing and comparison. Additionally, clay from other villages in Ulu Tembeling namely Kampung Gusai, Kampung Berembang dan Kampung Salat were collected to examine and compare their mineral and chemical composition (Figure 4). The results of the study show that the composition of clay found in the excavation trench and those collected from Kampung Gusai, Kampung Berembang and Kampung Salat are similar. For instance, quartz, kaolin, muscovite, albite and microcline are the few common minerals found in clay from Bukit Komel and Ulu Tembeling (Table 1-2). Gibbsite was found in clay from Kampung Berembang while illite was found in clay found in the excavated trench at Bukit Komel. This finding confirms that clay in the Ulu Tembeling region is naturally rich in quartz with the presence of kaolin and other minerals like feldspar and mica. All these minerals are essential in clay for pottery production (Asyaari, 2002). By looking at this scenario, it is logical to conclude that the potting community of Bukit Komel must have been very skillful and knowledgeable artisans since they were aware as to where and how to procure suitable raw materials for making pottery.

The elemental composition of Bukit Komel pottery was determined by using the XRF method, and the results are shown in Table 3. It was observed that silica, alumina and iron formed the highest percentage in Bukit Komel pottery. The dry weight percentage of these three elements is between 50.79% to 69.69%, 11.95% to 20.32% and 5.4% to 12.86%, respectively (Table 3). The dry weight percentage of potassium ranged between 0.90% and 4.66% while elements

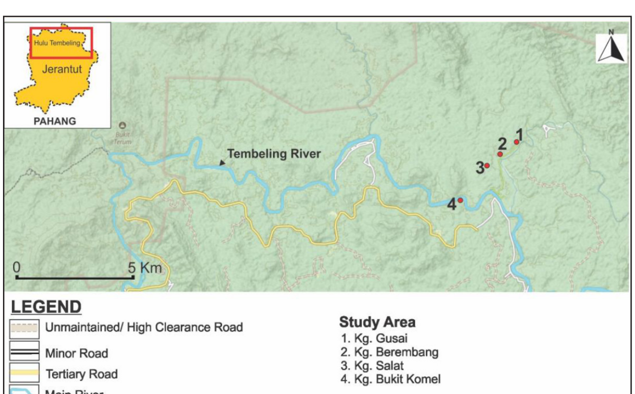

Figure 4: Location of clay samples collected in Ulu Tembeling.

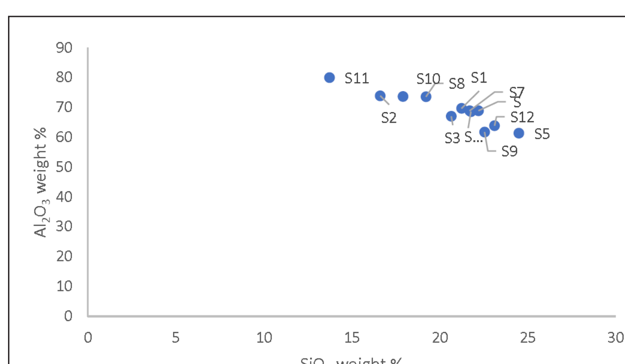

Figure 5: Percentage of dry weight content of Al_2O_3 against SiO_2 of Bukit Komel pottery.

like sodium, magnesium, calcium, titanium, manganese and phosphorus composed less than 2% (Table 3). The low dry weight percentage of phosphorus in the pottery indicated that the Bukit Komel clay paste was neither added with bone ashes nor contaminated by other sources like food stored or cooked in the pottery.

A scatter plot graph was made based on the dry weight percentage of silica against alumina and is presented in Figure 5. The graph specifies that all the pottery samples studied came from the same source and therefore they can be clustered in one group. However, some variation in the percentage of elemental composition between the pottery and clay samples can be observed (Table 3). For instance, dry weight percentage of silica in Bukit Komel pottery is relatively higher compared to clay because clay samples examined in this study has not been tempered with sand yet. Ethnographical studies from Peninsular Malaysia have shown that sand is often used as temper in traditional pottery production (Suresh, 2011; 2017). Similar technology is believed to have been employed in the past at Bukit Komel. Variation can also be seen in the dry weight percentage of iron where the iron content in clay is relatively lower compared to Bukit Komel pottery (Table 3). It is presumed that hematite powder was mixed into the clay during the pottery-making process in order to obtain red-coloured pottery. The discovery of anvil and hammerstone with traces of hematite during the 2022 excavation at Bukit Komel supports this theory. According to Adi (1985) similar tradition and technology have been observed and reported from other archaeological sites of Peninsular Malaysia.

Table 2: Mineral contents of clay from Bukit Komel and other villages in Ulu Tembeling.

Sample/ Name of Village	Mineral content
S13 (Kampung Gusai)	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Kaolinite ($Al_2Si_2O_5(OH)_4$), Albite ($NaAlSi_3O_8$), Microcline ($KAlSi_3O_8$)
S14 (Kampung Berembang)	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Kaolinite ($Al_2Si_2O_5(OH)_4$), Microcline ($KAlSi_3O_8$), Gibbsite [$Al(OH)_3$]
S15 (Kampung Salat)	Quartz (SiO_2), Muscovite ($KAl_2Si_3AlO_{10}(OH)_2$), Kaolinite ($Al_2Si_2O_5(OH)_4$), Microcline ($KAlSi_3O_8$)
S16 (Clay found in trench at Bukit Komel site)	Quartz (SiO_2), Illite [$KAI_2(Si_3Alo_{10})(OH)_2$] Kaolinite ($Al_2Si_2O_5(OH)_4$), Albite ($NaAlSi_3O_8$)

Comparative analysis between Bukit Komel pottery and clay

A comparative study based on the mineral content was conducted between the Bukit Komel pottery and clay samples. The results of mineral content comparison showed both clay and pottery makeup of the following minerals: quartz, muscovite, albite and microcline. Kaolin was identified mainly in clay from Bukit Komel, Kampung

Table 3: Dry weight percentage of major elements found in Bukit Komel pottery and clay samples.

Sample	Dry Weight (%)									
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3	MnO	P_2O_5
S1	0.576	0.489	18.785	61.667	1.329	0.224	0.982	8.019	0.004	0.127
S2	0.539	0.442	15.089	67.118	1.485	0.292	1.001	8.600	0.005	0.218
S3	0.933	0.383	18.302	59.437	1.136	0.470	1.148	10.888	0.008	0.370
S4	0.165	0.136	19.737	61.301	0.901	0.054	0.864	7.881	0.007	0.873
S5	1.111	0.469	20.324	50.954	4.655	0.327	1.658	11.706	0.028	0.285
S6	0.770	0.528	18.846	59.427	3.400	0.383	1.031	8.298	0.004	0.204
S7	0.801	1.311	18.725	59.463	1.019	0.380	1.177	8.121	0.007	0.148
S8	0.309	0.381	17.173	65.787	1.711	0.218	1.002	6.417	0.008	0.248
S9	1.190	3.345	18.524	50.785	1.825	1.317	1.213	12.864	0.021	0.193
S10	1.127	0.384	15.750	64.834	1.581	0.620	0.882	7.393	0.008	0.193
S11	0.486	0.460	11.949	69.693	1.589	0.240	0.949	5.404	0.004	0.062
S12	1.569	0.498	19.984	55.265	1.335	0.340	1.029	11.217	0.018	0.649
S13	0.172	0.307	20.379	45.052	1.772	0.031	0.759	5.370	0.031	0.046
S14	3.227	0.565	14.974	49.083	0.502	0.461	0.761	4.720	0.086	0.033
S15	0.261	0.449	16.835	48.161	0.044	2.214	0.163	5.243	0.693	0.087
S16	0.239	0.365	19.536	45.422	2.210	0.088	0.638	5.453	0.059	0.086

Gusai, Kampung Berembang and Kampung Salat, and some excavated pottery samples like S7 and S9 also show traces of kaolin. This finding affirms the use of local clay in the production of Bukit Komel pottery. Moreover, the presence of kaolin, feldspar and mica minerals verifies that the pottery was fired at low temperature, not more than 600 °C. This supports the XRD results of this study which also pointed to low firing temperature for Bukit Komel pottery. Interestingly, gibbsite was observed in clay from Kampung Berembang (S14) and this mineral was not found in any of the pottery samples excavated from Bukit Komel. This signifies that the Bukit Komel pottery was fired at a temperature of at least 100 °C or higher because according to a recent study the modification of gibbsite to amorphous minerals occurred at heating temperature between 70 °C - 110 °C (Sandeep *et al*., 2019).

A comparison of dry weight percentage between silicate, aluminium and iron of the pottery and clay samples was also made and the result is plotted and shown in Figure 6 (Table 4). The dry weight of silica between pottery and clay is between 63% - 80% while aluminium is about 15% - 28%. The dry weight of iron is between 6% - 18%. To further verify this, a three-dimensional scatter plot was made for three main trace elements with high qualitative values (Table 5). By looking at the three-dimensional scatter plot, it is plausible to conclude that the pottery was made by using clay discovered during excavation at Bukit Komel (Figure 7). Ethnography records showed that traditional potters would not travel very far (usually less than 7 kilometres) to obtain their clay (Arifin, 1991). For instance, in Kuala Tembeling, Malay potters from Kampung Pasir Durian collect clay customarily from a location just a few metres away from their village to manufacture pottery (Suresh, 2017; 2018). Therefore, in the case of Bukit Komel prehistory pottery production, the clay might have been exploited from Kampung Bukit Komel or its neighbouring areas within the Ulu Tembeling region.

The red-coloured pottery at Bukit Komel could be due to the presence of iron in the clay while the rough surface may be due to the use of quartz (sand) as temper during pottery manufacturing process. The angular and sub-angular shapes of quartz temper, as indicated by the results of thin section analysis, demonstrates that the sand was pounded

Table 4: Three major elements; alumina, silica and iron oxide selected for dry weight comparison.

Sample	Normalised by 100% Dry Weight Concentration		
	Al_2O_3	SiO_2	Fe_2O_3
S1	21.233	69.703	9.064
S2	16.617	73.913	9.471
S3	20.651	67.064	12.285
S4	22.197	68.940	8.863
S5	24.491	61.402	14.106
S6	21.769	68.645	9.585
S7	21.695	68.895	9.409
S8	19.214	73.606	7.180
S9	22.543	61.803	15.655
S10	17.902	73.694	8.403
S11	13.727	80.065	6.208
S12	23.112	63.915	12.973
S13	28.783	63.632	7.585
S14	21.772	71.365	6.863
S15	23.968	68.567	7.465
S16	27.746	64.510	7.745

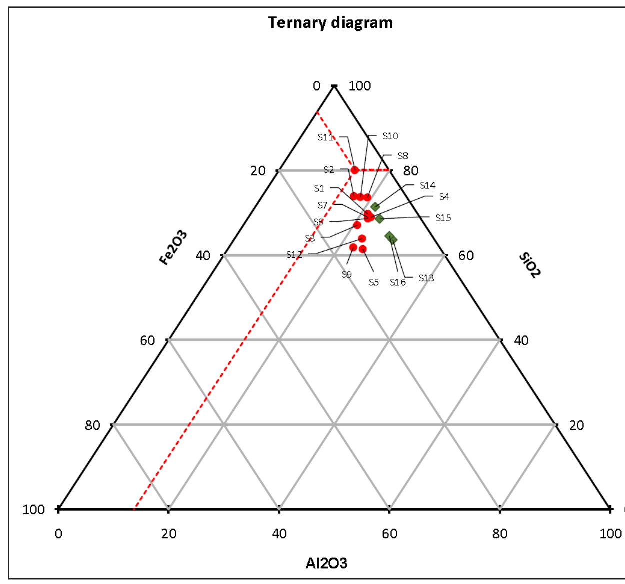

Figure 6: Ternary diagram of SiO_2, Al_2O_3 and Fe_2O_3 in Bukit Komel pottery and clay samples (dry weight normalised to 100%) (West, 2013; Stover, 2021).

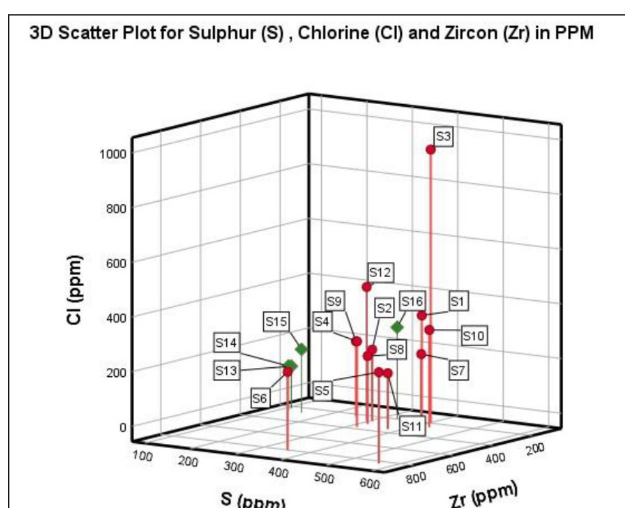

Figure 7: Three-dimensional scatter plot graph for S, Ci and Zr.

Table 5: The list of trace elements with qualitative values for Bukit Komel pottery and clay samples.

Sample	Dry Weight (ppm)															
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S-10**	**S-11**	**S-12**	**S-13**	**S-14**	**S-15**	**S-16**
S	324	202	939	253	274	227	183	189	215	296	145	432	97	107	175	277
Cl	367	299	394	310	560	347	367	309	247	419	369	292	107	118	149	325
Sc	64	bdl	69	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl
Cr	320	400	624	255	198	333	430	210	341	189	103	268	56	49	bdl	50
Co	197	171	227	bdl	170	13.8	bdl	bdl	bdl	135	bdl	210	bdl	195	bdl	bdl
Ni	108	951	126	bdl	61	64	126	66	160	89	bdl	112	bdl	54	46	bdl
Cu	115	135	547	94	528	bdl	198	105	640	634	490	113	bdl	30	30	51
Zn	117	92	146	101	108	91	103	131	157	155	72	155	78	30	71	92
Ga	28	30	25	23	36	31	45	34	29	29	30	47	24	30	29	29
As	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	30	bdl	46
Rb	77	120	74	79	172	145	75	149	83	112	109	84	147	30	160	192
Sr	62	58	93	28	192	147	84	47	115	121	53	76	27	30	33	43
Y	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	43	30	31	37
Zr	161	255	178	357	818	790	164	301	218	242	337	267	223	30	268	189
Nb	bdl	bdl	48	14	37	26	bdl	14	bdl	bdl	20	bdl	20	30	bdl	20
Ba	184	170	bdl	bdl	372	261	149	bdl	bdl	168	bdl	174	bdl	30	bdl	bdl
Ce	bdl	bdl	bdl	bdl	bdl	bdl	bdl	240	bdl	bdl	273	bdl	bdl	30	183	181
Br	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	30	bdl	bdl
W	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	30	106	bdl
Au	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	29	bdl	30	bdl	bdl
Pr	bdl	bdl	bdl	134	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	30	bdl	bdl
Pb	60	41	bdl	72	bdl	86	39	85	bdl	49	45	42	83	30	141	114
Th	bdl	bdl	bdl	49	bdl	bdl	bdl	50	68	bdl	24	bdl	46	30	68	54
Bi	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	59	bdl	bdl	30	bdl	bdl

before being added to the clay. This is in line with the ideas of previous researchers like Theseira (1976) and Adi (1983; 1989) who believed that sand was used as inclusion in the making of Bukit Komel pottery. Apart from sand, thin-section petrography analysis also disclosed the use of grog temper in Bukit Komel pottery production (Figure 8). The use of sand and grog as tempering materials in prehistoric pottery-making has been documented throughout Southeast Asia (Suresh, 2017).

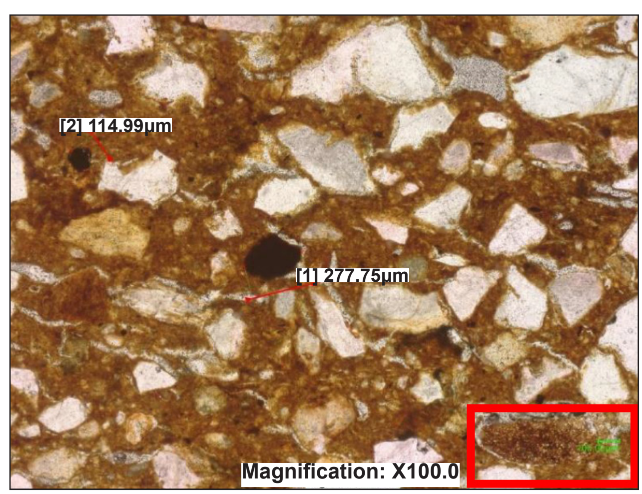

Figure 8: Quartz mineral with grog inclusion found in Bukit Komel pottery (trench B2).

CONCLUSION

The primary aim of this study was to attempt the morphological and compositional characterisation of pottery excavated at Bukit Komel in Ulu Tembeling, Pahang. The findings of this study are very significant and valuable to the archaeology of Ulu Tembeling and Pahang. This is because previous archaeological research in Ulu Tembeling provided minimal information on prehistoric pottery morphologies and compositions. In addition, details on ancient pottery source and origin were not available. The results of the 2022 pottery study appear to be promising and convincing where the study has provided important data and information on Ulu Tembeling prehistoric pottery technology and culture. By integrating both morphological and scientific approaches, the study revealed that the Bukit Komel pottery was made by using raw materials sourced from Sungai Tembeling. The clay could have been derived from Kampung Bukit Komel or other villages in Ulu Tembeling as all of them share similar mineral properties. Other materials like fuels for pottery firing, for instance, firewood and bamboo were probably obtained from the forest of Ulu Tembeling while sand from the riverbank of Sungai Tembeling. Technologically, the Bukit Komel pottery is hand-made and the use of the paddle and anvil method is highly possible. Designs like impressed and gouged marks represents the use of carved paddle and sharp implements possibly made of wood or stone. The two types of temper used in Bukit Komel pottery production are sand and grog, and the pottery is fired using the open-firing technique at low temperatures. Uniformity in surface and core colours showed that the pottery was fired uniformly in an oxidising atmosphere. However, the presence of black cores in some pottery shards confirmed that the pottery received less oxygen supply during firing. All these elucidate that the open-firing method was employed with firing temperature ranging between 400 °C and 600 °C. At this point, all evidence signify that the Bukit Komel pottery were utilitarian vessels used for domestic purpose, feasibly for storing. It is unsure if the pottery was used for cooking because no evidence of soot marks was observed. It is suspected that the pottery was made by the pre-Malay community who lived in the interior region of Tembeling valley during the Neolithic Period, circa 4,000 to 4,500 years ago. However, as of now, we do not have radiocarbon or any type of chronometric dating results to prove this. To determine the absolute age of Bukit Komel pottery, one shard sample has been sent to Korea Basis Science Institute in South Korea while another one to USM in Penang for Optically Stimulated Luminescence (OSL) dating and we are still awaiting the results. Future study using ethnography data of traditional Malay pottery-making from Kuala Tembeling and other parts of Peninsular Malaysia will be very useful in understanding the ancient pottery technology of Bukit Komel, Pahang.

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AUTHORS CONTRIBUTION

All the authors except for NRK and NMG were involved in the archaeological survey and excavation at Bukit Komel in 2022. At USM, ES, ASZ, AFJ and NMG carried out the morphological and scientific analyses of pottery while SN, NRK and NKT prepared and edited the final draft of the manuscript.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare that are relevant to the contents of this article.

REFERENCES

Adi, T., 1983. Recent Archaeological Discoveries in Peninsular Malaysia 1976-1982. Journal of the Malaysian Branch of the Royal Asiatic Society, 56(1), 47-63.

Adi, T., 1985. The Re-excavation of the Rockshelter of Gua Cha, Ulu Kelantan, West Malaysia. Federation Museums Journal, 30 (New Series), 1-134.

Adi, T., 1987. Recent Archaeological Discoveries in Peninsular Malaysia. Journal of the Malaysian Branch of the Royal Asiatic Society, 60(1), 27-44.

Adi, T., 1989. Archaeological, Prehistoric, Protohistoric and Historic Study of the Tembeling Valley, Pahang, West Malaysia. Malaysia Journal of Archeology, 2, 47-69.

Adi, T., 2007. Archaeology of Ulu Kelantan. Department of Museums Malaysia and Ministry of Culture, Art and Heritage Malaysia, Kuala Lumpur. 278 p.

Ainul, R.A., Sharifah, S.W.S.K.W., Saiful, A. & Uyop, S., 2005. Sedimentological and Palaeontological Study along the Kuala Tekai-Kuala Tahan Stretch of Tembeling River, Jerantut Pahang. Bulletin of the Geological Society of Malaysia, 51, 77-82.

Arifin, K., 1991. Social aspects of pottery manufacture in Boera, Papua New Guinea. Bulletin of Indo-Pacific Prehistory Association, 11(2), 373-387.

Asyaari, M., 1998. Historical Art of Pottery in Perak. Thesis M.A., Universiti Kebangsaan Malaysia (Not Published).

Asyaari, M., 2002. Determining the Origin of Earthenware from Scientific Perspective. Collection of Academic and Archaeological Journals, 8, 79-83.

Bellwood, P., 1988. Archaeological Research in Southeastern Sabah. Sabah Museum Monograph, 2, 1-282.

Bellwood, P., 1989. Archaeological Investigations at Bukit Tengkorak and Segarong, Southeastern Sabah. Bulletin of Indo-Pacific Prehistory Association, 9, 122-162.

Chia, S., 1997. Prehistoric Pottery Sources and Technology in Peninsular Malaysia based on Compositional and Morphological Studies. Monograph of Malaysia Museums Journal, 33, 1-155.

Chia, S., 2003. The Prehistory of Bukit Tengkorak as a Major Pottery Making site in Southeast Asia. Sabah Museum Monograph, 8, 1-157.

Chia, S., 2007a. Neolithic Culture in Malaysia. Malaysia Journal of Archeology, 20, 1-13.

Chia, S., 2007b. Scientific Studies of Prehistoric Pottery in Malaysia. In: M. Saidin & S. Chia (Eds.), Archaeological Heritage of Malaysia. Centre for Archaeological Research Malaysia, Universiti Sains Malaysia, Penang. 81-95.

Chia, S., 2016. The Archaeology of Bukit Tengkorak, Sabah. Universiti Sains Malaysia Press, Penang. 110 p.

Chia, S. & Zolkurnian, H., 2005. Gua Harimau, A Prehistoric Cemetery in Lenggong, Perak. In: Z. Majid (Ed.), The Perak Man and Other Prehistoric Skeletons of Malaysia. Universiti Sains Malaysia Press, Penang. 363-383.

Datan, I., 1993. Archaeological Excavations at Gua Sireh (Serian) and Lubang Angin (Gunung Mulu National Park), Sarawak, Malaysia. Sarawak Museum Journal, 45(66), 1-192. (Special Monograph No.6). Sarawak Museum Department, Kuching.

Department of Mineral and Geoscience Malaysia, 2014. Geological Map of Peninsular Malaysia. 9th Edition, 2014.

Evans, I.H.N., 1931. Excavation at Nyong Tembeling River, Pahang. Federated Malay States Museums, 15(2), 51-62.

Gani, N., 2010. The Archaeology of Gua Tupak from 1,190 B.P. to 170 B.P. in Bau, Sarawak. Thesis M.A., Universiti Sains Malaysia (Not Published).

Goh, H.M., Shaiful, S., Mokhtar, S., Curnoe, D., Mendoza, R., Adler, L., Saw, C.Y., Eng, K.K., Velat, B., Suresh, N. & Jeffrey, A., 2019. Revisiting the 3000-year-old Neolithic Burial Ground of Gua Harimau, West Malaysia. Archaeological Research in Asia, 18, 120-129.

Harrisson, B., 1971. Prehistoric Double-Spouted Vessels Excavated from Niah Caves, Borneo. Journal of Malaysian Branch of Royal Asiatic Society, 44(2), 35-78.

Harun, Z., 2002. Late Mesozoic-Early Tertiary faults of Peninsular Malaysia. Geological Society of Malaysia Annual Geological Conference, 26-27 May 2002, Kota Bharu, Kelantan, Malaysia.

Khor, W.C., Mohd Shafeea, L., Muhammad, A.D., Kamal, R.M., Che Aziz, A. & Jasmi, A.T., 2017. Gagau Group (Early Cretaceous) Sedimentary Rock Deposited at Sungai Chichir Upstream, Terengganu Darul Iman, Malaysia. Sains Malaysiana 46(12), 2315-2323.

Khor, W.C., Kamal, R.M., Mohamed, S.L. & Che Aziz, A., 2023. Sedimentary Logs and Facies Characterization Dataset of Tembeling Group from the Vicinity Area of Kuala Tahan, Pahang, Malaysia. Available at SSRN: https://ssrn.com/abstract=4504343 or http://dx.doi.org/10.2139/ssrn.4504343 (Accessed 30 October 2023).

Koopmans, B.N., 1968. The Tembeling Formation-A Litho-stratigraphic Description (West Malaysia). Bulletin of the Geological Society of Malaysia, 1, 23-43.

Leong, S.H., 1986. A Tripod Pottery Complex in Peninsular Malaysia. Paper presented at First Conference of the Association of Southeast Asian Archaeologists, Western Europe, Institute of Archaeology, London.

Leong, S.H., 1989. A tripod pottery complex in Peninsular Malaysia. In: I. Glover & E. Glover (Eds.), Southeast Asian Archaeology 1986. British Archaeological Reports International Series, 561, 65-76.

Leong, S.H., 1990. Jenderam Hilir and the mid-Holocene prehistory of the west coast plain of Peninsular Malaysia. Bulletin of the Indo-Pacific Association, 10, 150-160.

Leong, S.H., 2001. Chinese Pottery from Archaeological Sites in Malaysia – Typology and Chronology. In: M.S. Senik & M.Z. Abdullah (Eds.), Tembikar dari Warisan ke Wawasan. Lembaga Muzium Selangor, Shah Alam. 83-98.

Leong, S.H., 2003. Tripod Pottery in Mainland Southeast Asia. In: John Miksic (Ed.), Earthenware in Southeast Asia. Singapore University Press, Singapore. 173-186.

Linehan, W., 1928. Some Discoveries on the Tembeling. Journal of the Malayan Branch of the Royal Asiatic Society, 6(4), 66-77.

Linehan, W., 1930. Notes on Some Further Archaeological Discoveries in Pahang. Journal of the Malayan Branch of the Royal Asiatic Society, 8(2), 314-317.

Mohd Hasfarisham, A.H. & Mokhtar, S., 2020. X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and Scanning Electron Microscopy (SEM) Analysis of Potsherds, Sungai Batu Complex, Bujang Valley, Kedah. Warta Geologi, 46(3), 204-209. DOI:10.7186/wg463202006.

Mohd Kamaruzaman, A.R., Mohamad, D., Ramli, J. & Mohd. Al Sufi, 1991. Scientific Study on the Discovery of Earthenware Pottery in Pulau Kalumpang, Perak. Preliminary Results. Malaysia Journal of Archeology 4.

Nik Hassan, S.N.A.R., Mohd Kamaruzaman, A.R. & Mohd Yusof, A., 1990. Prehistoric Site of Gua Ta'at, Hulu Terengganu (8,920 ± 120 BP to 2,630 ± 80 BP). Malaysia Journal of Archeology, 3, 1-14.

Noone, H.D., 1939. Report on a New Neolithic Site in Ulu Kelantan. Journal of the Federated Malay States Museums, 15, 170-174.

Papachristodoulou, C., Oikonomou, A., Ioannides, K. & Gravani, K., 2006. A Study of Ancient Pottery by means of X-Ray Lluorescence Spectroscopy, Multivariate Statistics and Mineralogical Analysis. Analytica Chimica Acta, 573-574, 347-353. DOI:10.1016/j.aca.2006.02.012.

Peacock, B.A.V., 1959. A Short Description of Malayan Prehistoric Pottery. Asian Perspectives, 3, 121-156.

Peacock, B.A.V., 1964. A Preliminary Note on the Dong-Son Bronze Drum from Kampong Sungai Lang. Federation Museums Journal, 9, 1-3.

Petersen, S.E., 2009. Thin-Section Petrography of Ceramic Materials. INSTAP Academic Press, Pennsylvania. 29 p.

Sandeep, S., Ninu, J.M. & Sreejith, K.A., 2019. Mineralogical Transformations under fire in the Montane Grassland Systems of the Southern Western Ghats, India. Current Science, 116(6), 966-971. DOI:10.18520/cs/v116/i6/966-971.

Sarhaddi-Dadian, H., Zuliskandar, R., Nik Hassan, S.N.A.R. & Mehrafarin, R., 2015. X-Ray Diffraction and X-Ray Fluorescence Analysis of Pottery Shards from New Archaeological Survey in South Region of Sistan, Iran. Mediterranean Archaeology and Archaeometry, 15(3), 45-56. DOI:10.5281/zenodo.18357.

Shafiq, M.A., Zuliskandar, R. & Nur Sarahah, M.S., 2021. Geochemistry and Mineralogy of Prehistoric Pottery Shards found at Gua Jaya, Nenggeri Valley, Kelantan, Malaysia. Bulletin of the Geological Society of Malaysia, 72, 205-213. DOI:10.7186/bgsm72202116.

Shafiq, M.A., Zuliskandar, R. & Nur Farriehah, A., 2023. Geochemistry and Mineralogy of Prehistoric Pottery Shards found at Gua Kelew, Nenggeri Valley, Kelantan, Malaysia. Bulletin of the Geological Society of Malaysia, 75, 85-99. DOI:10.7186/bgsm75202308.

Sieveking, G.de G., 1954. Excavations at Gua Cha, Kelantan. Federation Museums Journal, I & II, 75-143.

Sieveking, G.de G., 1956. Pottery Cons from Kodiang, Kedah. Journal of the Malayan Branch of the Royal Asiatic Society, 29(1), 189-194.

Sieveking, G.de G., 1962. The Prehistoric Cemetery at Bukit Tengku Lembu, Perlis. Federation Museums Journal, 7, 25-54.

Sinar Harian, 2023. Five Major Floods in Pahang. Retrieved from https://premium.sinarharian.com.my/article/154442/sinar360/multimedia/lima-banjir-besar-pernah-melanda-pahang.

Stover, C., 2021. Ternary Diagram. Retrieved from MathWorld – A Wolffram Web Resource, created by Eric W. Weisstein. https://mathworld.wolfram.com/TernaryDiagram.html.

Suresh, N., 2011. The Past and Present Pottery in Semporna, Sabah. Thesis MA, Universiti Sains Malaysia (Not Published).

Suresh, N., 2014. The Past and Present Pottery-Making in Semporna Sabah: A Comparative Study between the Bukit Tengkorak and Bajau Pottery. In: Mokhtar Saidin & Jeffrey Abdullah (Eds.), Sabah's Contribution to Southeast Asian Archaeology: 20 years of research (1993-2013). Sabah Museum Monograph, 12, 243-259.

Suresh, N., 2017. Past and Present Pottery Making Traditions in Malaysia: An Ethnoarchaeological Perspective. Thesis PhD, Universiti Sains Malaysia (Not Published).

Suresh, N., 2018. The Heritage of Traditional Pottery in Kuala Tembeling, Jerantut, Pahang: Issues and Challenges. In: M. Saidin & J. Abdullah (Eds.), Etnoarkeologi di Malaysia: Cerminan Budaya Material Masyarakat Peribumi. Penerbit UTHM (Universiti Tun Hussein Onn Malaysia), Johor, 61-71.

Suresh, N., Nasha, R.K., Esnita, S., Nurulamani, R., Nor Hidayah, A., Fadly, J. & Sairul, R., 2020. A Study on Traditional Pottery in Hulu Tembeling, Pahang: Early Ethnographic Data. Jurnal Persatuan Muzium Malaysia (PURBA), 39, 1-26.

Suresh, N., Nasha, R.K., Ahmad, F.J. & Ahmad, S.Z., 2022. Tracing the Source and Origin of Earthenware Stove in Kelantan State Museum by means of Geochemical and Mineralogical Methods. Bulletin of the Geological Society of Malaysia, 73, 53-65. DOI:10.7186/bgsm75202205.

Suresh, N. & Nasha, R.K., 2023. Traditional Earthenware Cooking Stove (Tuku) at Kampung Mambong, Kelantan: History, Production Tradition and Challenges. Kajian Malaysia, 41(1), 288-310.

Theseira, O.A., 1976. Preliminary Report of Archaeological Sites along the Tembeling River, Pahang. Federation Museums Journal, 21, 35-39.

Tiwari, J.N. & Dasgupta, S., 2016. High Temperatures Reactions of Kaolin. ResearchGate.

Tjia, H.D., 1989. Major Faults of Peninsular Malaysia on Remotely Sensed Images. Sains Malaysiana, 18, 101-114.

Tweedie, M.W.F., 1940. Report on Excavation in Kelantan. Journal of the Malayan Branch of the Royal Asiatic Society, 18(2), 1-22.

Tweedie, M.W.F., 1953. The Stone Age of Malaya. Journal of the Malayan Branch of the Royal Asiatic Society, 26(2), 1-90.

Vandiver, P. & Chia, S., 1997. The Pottery Technology from Bukit Tengkorak, a 3,000-5,000 year-old site in Borneo, Malaysia. In: P. Vandiver, J. Druzik, J. Merkel & J. Stewart (Eds.), Material Issues in Art and Archaeology V, 462, 269-277. Symposium Proceedings of the Materials Research Society, Warrendale, PA1997 USA.

Velat, B., 2005. The Culture of Prehistoric Community (860BP to 420BP) at Lobang Batu Puteh, Bukit Sarang, Ulu Kakus, Bintulu, Sarawak. Thesis M.A., Universiti Sains Malaysia (Not Published).

Velat, B., 2010. The Late Neolithic Pottery at Lobang Batu Puteh, Bukit Sarang, Ulu Kakus, Bintulu. Malaysia Journal of Archeology, 23, 82-102.

West, D., 2013. Ternary Equilibrium Diagrams. 2nd ed. Springer, New York. 160 p.

Wu, X., Zhang, C., Goldberg, P., Cohen, D., Pan, Y., Arpin, T. & Bar-Yosef, O., 2012. Early Pottery at 20,000 years ago in Xianrendong Cave, China. Science, 336, 1696-1700.

Yanti, E.D. & Pratiwi, I., 2018. Correlation between Thermal Behavior of Clays and their Chemical and Mineralogical Composition: A Review. IOP Conf. Series: Earth and Environmental Science, 118, 1-4. DOI:10.1088/1755-1315/118/1/012078.

Zeinab, J., 2018. Chemical and Mineralogical Analysis for Provenaning of the Bronze Age Pottery from Shahr-I-Sokhta, South Eastern Iran. Scientific Culture, 4(1), 83-92. DOI: 10.5281/zenodo.1048247.

Zolkurnian, H., 1989. Gua Harimau: An Early Report. Jurnal Persatuan Muzium Malaysia, 9, 41-52.

Zolkurnian, H., 1998. Chronology of Prehistoric Culture in Lembah Lenggong, Hulu Perak, Perak during Holocene Period. Thesis M.A., Universiti Sains Malaysia (Not Published).

Zuliskandar, R., Mohd Zobir, H., Asmah, Y. & Zulkifli, J., 2001. Chemical Analysis of Prehistoric Pottery Sherds Found at Gua Angin, Kota Gelanggi Complex, Jerantut, Pahang, Malaysia. Malaysia Journal of Archeology, 14, 1-25.

Zuliskandar, R., Mohd. Zobir, H., Asmah, Y. & Kamaruddin, Z., 2006. Preliminary Analysis of Prehistoric Pottery Sherds Excavated at Gua Peraling and Gua Cha, Ulu Kelantan, Malaysia. Malaysia Journal of Archeology, 19, 27-36.

Zuliskandar, R., Muhammad Nu'man, M.N. & Muhamad Shafiq, M.A., 2021. Geochemical Characterization of Pottery Shards Unearthed from Kampung Baru Archaeological Site, Kedah, Malaysia. Warta Geologi, 47(1), 9-18. DOI:10.7186/wg471202102.

Zuliskandar, R., Nik Hassan Shuhami, N.A.R., Abdul Latif, S., Muhammad, R.R., Sharifah, Z.S.Z., Adnan. J., Yunus, S. & Hossein, S., 2014. X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) Analysis of Proto-historic Votive Tablets from Chawas Cave, Hulu Kelantan, Malaysia. Research Journal of Applied Sciences, Engineering and Technology, 7(7), 1195-1201.

Zuliskandar, R., Nik Hassan Shuhaimi, N.A.R., Adnan, J. & Yunus, S., 2011. X-Ray Diffraction and X-Ray Fluorescent Analyses of Prehistoric Shards from Ulu Kelantan. American Journal of Applied Science, 8(12), 1337-1342. DOI:10.3844/ajassp.2011.1337.1342.

Zuraidah, H. & Zuliskandar, R., 2018. Analysis of Prehistoric Pottery Shards in Kedah. Asian Journal of Environment, History and Heritage, 2(1), 223-252.

Zuraina, M., Ang, B.H. & Jaffrie, I., 1998. Late Pleistocene Sites in Pahang: Excavations of Gua Sagu and Gua Tenggek. In: Z. Majid (Ed.), Malaysia Museums Journal, 34 (New Series), 65-115. Special Issue: Archaeological Research and Museums in Malaysia. Department of Museums and Antiquities Malaysia, Kuala Lumpur.

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