Jurnal Teknologi

Full paper

The Formulation of Ceramic Bodies using the Toba Volcanic Ash of Lenggong

Salwa Ayob[a*], Hamdzun Haron[b]

[a]*Universiti Teknologi MARA (UiTM) Shah Alam, 40450 Shah Alam, Selangor, Malaysia*
[b]*Centre for General Studies, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia*

*Corresponding author: hh@ukm.my

Article history

Received :21 December 2013
Received in revised form :
12 January 2014
Accepted :30 January 2014

Graphical abstract

Abstract

The amalgamation of science and art is indisputable in the production of ceramic clay bodies for the creation of an artwork. It covers all stages of the production process starting from the formulation of raw materials (clay) to the final glazed products. This research observes the transformation of the clay body formulation by using alternative silica from Toba volcanic ash. Malaysia is located outside the ring of fire, but through the archaeological findings, there are volcanic ash deposits found at several places such as in Kedah, Perak, Selangor and Pahang. From previous studies, it is proven that this volcanic ash originated from the volcanic eruption of Toba in northern Sumatra around 74,000 years ago. Among all of these findings, volcanic ash in which situated at Lenggong, Perak is considered as the most suitable for this research because it is categorized as a primary and through the laboratory studies that has been conducted, it is found that it has sufficient amount of silica to be used as alternative material in producing ceramic bodies. Silica is one of the main ingredients in a glass formation. In the production of porcelain bodies, silica has been used at a rate of 15% to 25%. The success in producing ceramic bodies using volcanic ash opens up possibilities for diversifying the products made from volcanic ash, a material which has been wasted before and this will reduce the cost of raw materials. At the same time it is considered as an innovation of ceramic product with the specialties of its own including the historical values that come through the transformation process of the body to the creation of ceramic works displayed at galleries.

Keywords: The formulation of clay bodies; ceramics; Toba volcanic ash

Abstrak

Sains dan seni merupakan pencantuman yang tidak dapat ditolak dalam penghasilan jasad lampung seramik sehingga terhasilnya sesebuah karya. Ia merangkumi semua peringkat proses penghasilan bermula dari formulasi bahan mentah (tanah liat) sehingga produk akhir yang bergerlis. Penyelidikan ini melihat kepada transformasi formulasi jasad lampung yang menggunakan silika altenatif dari abu gunung berapi Toba. Malaysia merupakan negara di luar lingkaran api (ring of fire), namun melalui kajian arkeologi terdapat jumpaan abu gunung berapi (volcanic ash deposits) di beberapa buah tempat contohnya di Kedah, Perak, Selangor and Pahang. Dari kajian yang terdahulu membuktikan bahawa abu gunung berapi ini berasal dari letusan gunung berapi Toba di utara Sumatera pada kira-kira 74,000 tahun dahulu. Di antara semua jumpaan ini, debu gunung berapi di Lenggong, Perak didapati paling sesuai digunakan dalam penyelidikan ini kerana ia terdiri dari jenis prima dan melalui kajian makmal yang dijalankan, didapati ia mempunyai kandungan silika yang mencukupi untuk digunakan sebagai bahan alternatif dalam menghasilkan jasad seramik. Silika merupakan salah satu bahan utama dalam pembentukan kaca, dalam penghasilan jasad porselin silika digunakan pada kadar 15% hingga 25 %. Kejayaan dalam menghasilkan jasad menggunakan abu gunung berapi ini dapat membuka ruang bagi mempelbagaikan produk dari abu gunung berapi yang selama ini terbuang begitu saja serta dapat mengurangkan kos bahan mentah. Pada masa yang sama ia merupakan inovasi produk seramik yang mempunyai keistimewaan yang tersendiri termasuk nilai sejarah melalui proses transformasi jasad ini kepada karya seramik galeri.

Kata kunci: Formulasi jasad; seramik; Abu Gunung Berapi Toba

1.0 INTRODUCTION

Ceramic is originally refers to the pottery in which has been made of clay, a medium of art with plasticity that makes the clay malleable and it can be shaped into any forms or copying the semblance of other mediums such as metal, wood, paper, leather and etcetera. The original characteristic of clay has long been identified by the ancient people who used it in the production of figurines and potteries because it is quite easily found in various parts of the world, whether on the surface or dug in the ground. According to Rawson;

> "Clay is found in beds and strata in the ground, produced naturally by decomposition from the granite and gneiss rocks which contribute about 85% of the earth's surface."
>
> (Rawson: 1971)

The same situation happened in Malaysia, and the tropical rainforest climate has been aiding the process of accumulation the natural clays and gives us various types of clays and colours to be explored. But in the context of traditional Malay potteries in Malaysia, the focus is only towards the earthenware clay because the plasticity of the clay allows its workability without going through any treatment. Jin Leng in his writing interprets the types of clay in Malaysia as follows:

> "Primary clays, know as kaolinite and with a chemical formula of AL^2O^3, SiO^2, and $2H^2O$, are usually free of contaminants such as iron and give a clay cast which is white. They withstand high temperatures and are use to make porcelain ceramic. Other uses include the manufacturing of floor and wall tiles, sanitary ware and tableware. Huge deposits are found in the Bidor area in Peninsular Malaysia and they are processed for the domestic consumption and export. Secondary or sedimentary clays are lined with impurities. The verdant and luxurious Malaysian rain forest exude decomposed organic liquor into stream, giving most secondary clay deposit distinctive colours of buff-brown to grey to black, but this organic material is burnt off when the clay is fired. The lateritic content of Malaysian soil discolour clays from pink to iron red dust when fired, because of the fine iron particles collated and mixed with the clay on its journey down stream. These clay are plastic than the primary clay and are used in Malaysia's pottery and ceramics industries, from brick making to the manufacture of products like floor tiles, sanitary ware, tableware and fine ceramics"
>
> (Yeoh Jin Leng: 1986)

With the rapid growth and variety of demands, ceramic field has been fully explored until it can be divided into different usages that require more advanced knowledge such as the high-tech ceramics used in electronic engineering, medical, aerospace, motoring and many more.

The word ceramic according to Zainal Abidin Safarwan (1995) refers to 'tembikar, temberek, porselin and tembereng'. In Malay word 'tembikar' is most commonly used to describe items made of clay. 'Porselin' also has been used to describe ceramic because it is usually produced from a type of clay and goes through the same conventional processes of ceramic production, and it is even fired at a higher degree of temperature (1200ºC-1300ºC). High firing temperature in ceramic refers to a temperature above 1000°C. In archaeological term, ceramic is referred to the items that have been fired at a high temperature, thus items fired at lower temperature is called pottery.

The development of ceramic products such as ceramic tiles, and the artistic development of ceramics will continue to be given more attention in order to enrich the ceramic term. Nevertheless in a three-dimensional creation, ceramic art should has been translated into the art and techniques of producing items made of clay either the earthenware, stoneware, porcelain, bone china and so on.

According to Professor Zainal Arifin, the definition of ceramic has slightly changed when the inclusion of refractory material (a material hardly molten and retains its shape when it is being fired at a temperature reaching 1300°C without warping) to melt iron, steel and other metals is taken into account. After the World War II, the definition of ceramic changed once again with the presence of the new terms such as cement, glass, magnet, optical fibre, insulating materials, electro ceramic, bio ceramic, and others.

From the etymological perspectives, 'Keramikos' refers to the clay which has been used by the ceramic creators. Pottery refers to item that is made of clay, dried and fired inside a kiln. Even though the history of ceramics began with potteries, but the ceramic term is more specific in representing the pottery and all products in the same group (Mohd. Khalil bin Imran: 1992). The same term has been explained by Horslay in the 'Concise Encyclopedia', ceramic is a broad field of knowledge covering the areas of pottery, porcelain, refractory, clay structure, abrasives, cement, glass, non-metal magnetic material, ferro-electric and other organic materials. In short, nowadays ceramic can be defined as "any non-organic material that is non-metal and non-polymer product which goes through firing temperature exceeding 540ºC (basically 1000ºF) during the manufacturing process or the usage, and consists of oxides, borides, carbide or nitride, or a mixture of those materials" (Somiya: 1989)

2.0 THE BACKGROUND OF STUDY

The transformation of working with ceramic clay bodies has started since the pre-historic age. Starting as a colorant mixed with an animal fat for cave paintings and as a medium to make relief sculptures, figurines and functional items, the medium has been explored incessantly up until now. The discovery of the earliest pottery dated around 7000 years ago at Gua Teluk Kelawar, Lenggong significantly proven the existence of the culture of ancient pottery design in Malaysia. The perfection of its processes, the mixtures of grog and the uniformity of thickness clearly shows the knowledge of the makers and the creators were at eminent level, especially after Stephen Chia (1997) has further clarified that the items were made from local raw materials.

Most of the ceramic artworks in Malaysia were made from earthenware and stoneware bodies. Earthenware bodies are often used because they are readily available or can be purchased in the market at relatively cheaper price. As known, ceramic art in Malaysia is still new and not deeply explored. In fact in almost every contemporary ceramics exhibition, this issue will be raised, especially in the topic of promoting the ceramic artists at the international level.

Porcelain is one of the ceramic bodies that have always been prioritized and it is of high-grade in ceramic field. Nevertheless only few people in Malaysia are using this medium for their works. This is probably due to the lack of this material in the market and the fact that it is expensive will also be a hindrance. The technical nature of porcelain that requires highly skilled person in handling it also contributes to this exclusion.

On the contrary, in ceramic art abroad there are many artists who use porcelain as a medium for their works; among them are Peter Lane, Evan Staffle, Angela Mellor, Sasha Swindle, Geoffrey Sindell and many more. They are not only using this medium; they even created a body formula to fulfill the requirements of the works to be produced. The ceramic artists in USA, UK, Japan, Germany, Finland etc. use different bodies for their works such as earthenware, stoneware or porcelain but they always strive to create the clay bodies with their own formulae. Whereas in Malaysia, there are only few local artists using porcelain for their works, among them is Associate Professor Faridah Yusuf who has been

involved in this field for over 30 years. There are three key ingredients needed for the production of ceramic clay bodies namely kaolin, feldspar and silica. Malaysia has high-quality kaolin and the purity rate is 99.9 % while feldspar can only be found in Kelantan and it is exported to Singapore to be processed.

3.0 TOBA VOLCANIC ASH AT LENGGONG

Volcanic ash found at the region is said to be originated from the Toba eruption around 74,000 years ago that has been triggered by the fourth aftershock of a previous bigger earthquake. It is similar to every major earthquake aftershocks occurring at smaller or almost at similar scale. Volcanic ash from the Toba eruption was deposited to the Malay Peninsula and to several countries in the Middle East. The location of the volcanic ash fall depends on the wind speed. Most of Lenggong was covered with volcanic ash, but due to the rainfalls combined with the major flood events in 1926, most of the volcanic ash was washed out to the rivers and lakes. However there are ash deposits categorized as primary found in some areas; the most exposed and easily accessible is at Bukit Sapi.

Picture 1 The Toba Eruption: Illustration by European artist

According to the locals, the volcanic ash was used by the people in the past to be eaten with betel leaf. The ash will be parched before it can be eaten. According to their beliefs, by eating the parched ash it can eliminate a type of worm in human beings. Goats also favour the volcanic ash because they are often seen licking it. Lenggong at one time has a very huge lake; the lake area is estimated to be as huge as the entire Lenggong Valley and the Toba volcanic ash settled to the bottom of the lake. The thickness of the volcanic ash at Lenggong is between three to five meters. Volcanic ash deposits are also found at several other places in Malaysia including Kedah (Baling), Selangor (Serdang and Ampang) and Pahang (Bentong dan Raub).

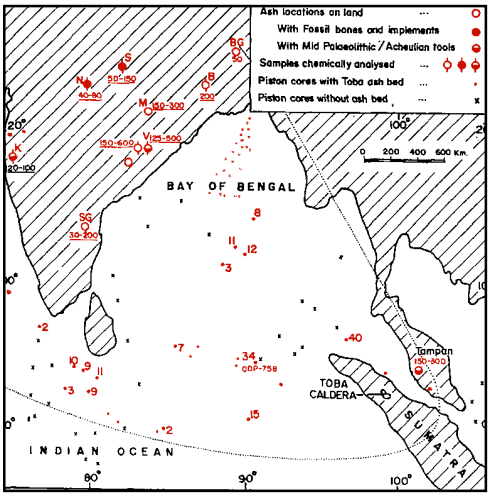
Volcanic ash deposits have been found in many areas of Kedah, Perak, Selangor and Pahang. These are believed to have been most likely derived from volcanic explosion which created Lake Toba in the Northern Sumatra. (Nik Hassan Shuhaimi (2006)

Through the research done by the University Malaya researchers in 2008, there was also Toba ash deposit found at the bottom of the South China Sea during the oil exploration conducted by Petronas. Apart from Bukit Sapi area, through archaeological research conducted by the Centre for Global Archaeological Research of USM, there was also a finding of volcanic ash in the ground with fossil of leaf.

Picture 2 Fossil of leaf on Toba volcanic tuff. *Source:* Zuraina: 2003

Facts of the Toba eruption

- Has erupted four times in 1.2 million, 840,000, 450,000 and 74,000 years ago.
- Causes strong tremors like a meteor explosion and it is felt throughout the entire world.
- The ash fall about 2800 km³ reached India, East Africa and Middle East.
- Human population was nearly extinct, creating the 'Out of Africa' and 'bottleneck' theory.
- Malaysia was in the dark around 14 days
- Resulted in a drop of the global mean surface temperature by 3–15 C
- Recreated the ice age.
- Takes about six months to deposit the ashes through the air.



Picture 3 The distribution of the Toba ash fall. *Source:* Oppenheimer: 2008

4.0 DEFINITION OF BONE CHINA

Most products which have been made by volcanic ash are based on volcanic rocks (tuff). Borobudur is among the best examples; tuffs have been used to make various craft products, in construction field and also as a garden decoration up until today. In addition, it is also been used as a foot scrubber/pumice stone for beautifying the skin, especially on the crack heels. Volcanic ash from Mount Pinatubo

in Philippines is made as souvenirs. The items were made by mixing the ash with resin and moulded using rubber moulds.

Picture 4 Product made of Mount Pinatubo volcanic ash

■5.0 THE METHOD OF PRODUCING THE TOBA VOLCANIC ASH CERAMIC BODY

The location of Toba volcanic ash has been identified as the area at Kampung Bukit Sapi with the help from the Centre for Global Archaeological Research of USM. To obtain the raw materials from the site, one needs to get the permission from the Archaeological Museum of Lenggong. In this research, the museum party also helped to obtain raw materials at selected locations; this assistance was much needed because the selected locations were far away from the main road and they were located within the rubber and oil palm plantation. In the process of obtaining the raw materials, tools such as a hammer and a small hoe were needed because the ash deposit was quite hard, but after a knock it will get loose and easy to filter in order to get fine dust

Picture 5 Researcher gets the raw materials with helps from staff of Lenggong Archaeological Museum

■6.0 THE ANALYSIS OF MINERAL CONTENT OF TOBA VOLCANIC ASH

The analysis of mineral content of Toba Volcanic Ash has been carried out in the laboratory of the School of Material and Mineral Resources Engineering (Ceramic) USM.

Table 1 The mineral content of Toba Volcanic Ash

No.	Component	Result
1.	SiO2	50
2.	Al O3	40
3.	K2O	1.9
4.	Fe2O3	1
5.	TiO2	0.6
6.	MgO	0.43
7.	SO3	0.16
8.	CaO	0.15
9.	P2O5	0.089
10.	Rb2O	0.023
11.	ZrO2	0.016
12.	PbO	0.016
13.	ZnO	0.011
14.	MnO	traced
15.	Ni O	traced
16.	Ga2O3	traced
17.	SrO	traced
18.	Nb 2O5	traced
19.	WO3	traced
20.	ThO2	traced
21.	LOI	5.6

A pilot test for the production of the products was carried out in advance to identify the potential of producing the ceramic body by following a basic recipe used for the porcelain body in the Ming Dinasty that uses three main ingredients:

Kaolin
Feldspar
Silica (Toba Volcanic Ash)

The results from the conducted pilot test showed that the product can be fired up to 1200°C without warping. Laboratory methods are carried out using the triaxale blending as shown on the figure below:

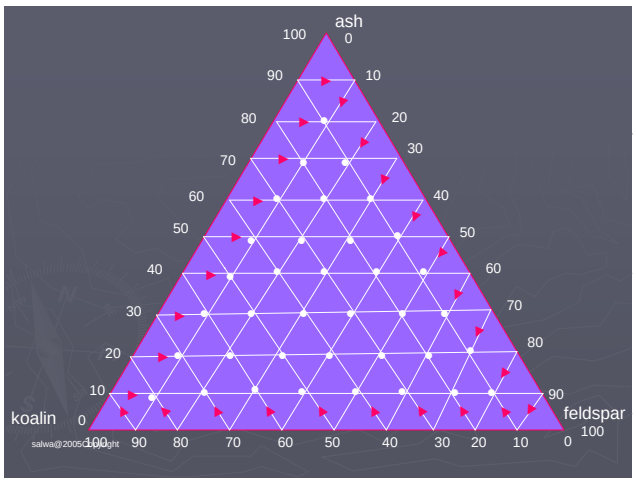


Figure 1 Triaxale blending

■7.0 THE FLOWCHART OF THE PROCESS

Identify the location
↓
Obtaining the raw material
↓
Grind the clay
↓
Mixing the materials
↓
Ageing Process
↓
Forming (Press mould and throwing)
↓
Greenware product
↓
Bisque firing (900°C)
↓
Glaze firing (1200°C)
↓
Final period

■8.0 THE FORMING OF PRODUCT

To produce the product, the researchers used three methods that are using the press mould with plaster of Paris, slip casting and throwing using the potter's wheel (Table 2).

■9.0 THE FIRING OF THE FINAL PRODUCT

The final product is fired at 900°C for bisque firing and 1080°C & 1200°C for glaze firing. The glaze firing is separated into two that are using commercial glaze and self-prepared glaze. Both glazes can be used in accordance with their maturity temperature. Firing at 1200°C did not affect the body and also the glaze. Examples of glaze use are like the Pictures 6.

Table 2 The method of producing the products

No.	Method	100% Toba bodies	The formulation of Toba porcelain bodies	Glaze
1.	"Press mould"	√	√	√
2.	"Slip Casting"	√	√	√
3.	"Throwing"	×	√	√

Picture 6 Testing of the final product

10.0 CONCLUSION

It is proven that products made of Toba volcanic ash found at Lenggong can be produced by either using 100% Toba ash or used as an alternatif to silica in the formulation of porcelain bodies with a rate of 25%. Ceramic products also responded well and can be glaze fired up to 1200°C. The usage of 100% Toba volcanic ash also allows the production of ceramic products, whether in the form of tiles (press mold) or tableware (slip casting and throwing) by the local community. With its historical values, it can also be used as craft items with Lenggong identity and it has potential to be marketed. Furthermore, Lenggong has been declared as a UNESCO World Heritage site recently and this will add value to the craft products. This research is also a pioneer in the production of other ceramic products that can be produced from Toba Volcanic Ash of Lenggong and other raw materials that are available in the vicinity.

References

[1] Zainal Abidin Safarwan, 1995. *Kamus Besar Bahasa Melayu Utusan*. Utusan Publications & Distributors Sdn. Bhd. Percetakan KUM Sdn Bhd.
[2] Zainal Ariffin Ahmad, 2004. *Seramik: Tamadun, Sains Teknologi, Kejuruteraan dan Hala Tuju: Siri Syarahan Umum Perlantikan Profesor, USM*. Penerbitan Universiti Sains Malaysia, Pulau Pinang.
[3] Oppenheimer, S., 2007. *The Importance of the Southeast Asian Archaeological Heritage: From a Genetic Perspective: Sharing Our Archaeological Heritage*. International Seminar Johor, Malaysia, November 11th–15th, 2007
[4] Zuraina Majid, 2003. *Arkeologi di Malaysia*. Pusat Penyelidikan Arkeologi Malaysa, Universiti Sains Malaysia.
[5] Philip Rawson, 1971. *Ceramics*. London, Oxford University Press.
[6] Nik Hassan Shuhaimi Nik Abdul Rahman, 2004. *Early History: The Encyclopedia of Malaysia*. Volume Editor, Archipelago Press.
[7] Yeoh Jin Leng, 1986. *Katalog Pameran Tanah Liat Sebagai Bahan Ekspresi Seni*. Balai Seni Lukis Negara.
[8] Stephen Chia Ming Soon, 1997. Monograph, Prehistoric Pottery Sources and Technology in Peninsular Malaysia Based on Compositional and Morphological Studies, Volume 33 New Series, ISSN 0126–561X.

‘’