Study of pottery materials in Muarojambi Temple complex and Batanghari River sediment in Jambi Province, Indonesia based on the mineralogical and petrographical analysis

D Savira¹, F M H Sihombing¹, D Sulistyowati² and T L Indra¹
¹Geoscience Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia
²Department of Archeology, Faculty of Humanities (FIB), Universitas Indonesia, Depok 16424, Indonesia

Corresponding author’s email: tito.latif@ui.ac.id

Abstract. Pottery is a ceramic which generally used as household utensils or religious necessities such as spiritual ceremonies. This object has been used by society since long time ago that make it has certain historical and cultural values. One problem with pottery that it is hard to define its source. We believe that mineralogy could help finding the source of the pottery by comparing mineralogy of pottery and mineralogy of alluvial sand that usually used for pottery. This study was carried out to analyze the pottery-forming material of pottery fragments in the Muaro Jambi Temple complex and compare them with the Batanghari River sediments on the opposite to the temple. Data retrieval is done by collecting pottery fragments in the excavation field and taking sand samples in the downstream of the Batanghari River. The fragments of pottery and river sands were separated based on their texture and analyzed using microscope. Each material will be described based on its physical appearance and frequency of existence. From the study we found that minerals found in the pottery fragments from Muaro Jambi have similarity with the mineralogy of alluvial sand from Batanghari River. Thus, it might be a good indication that there is a correlation between them. From this research, we also conclude that the mineralogy characteristic could be useful for identifying the source of pottery.

Keywords: Pottery materials, Muarojambi temple, Batanghari River, petrographical

1. Introduction
Pottery is a vessel made from fired clay which generally used as household utensils or religious necessities such as spiritual ceremonies. This object has been used by society since long time ago that make it has certain historical and cultural values [1]. From UNESCO profile, it mentioned that people in Muaro Jambi Village used to make potteries too. Muaro Jambi Temple Complex is one of Melayu Kingdom’s Buddhist heritage. The location of these temples is nearby Batanghari River, less than 40 kilometers from Jambi city (figure 1).
1.1. Geology of Muaro Jambi

Muaro Jambi Temple Complex is situated in Muara Enim Formation in Jambi Sub-Basin Region (Figure 2). This Region consist of some rock formations and surficial deposits as parts of South Sumatran Basin. They are Air Benakat Formation, Muara Enim Formation, and Kasai Formation [2].

Air Benakat Formation is composed by the intersections of fine-grained Miocene clastic rocks include shale with tuffaceous shale, sandstone, siltstone, and coal. Above this formation, deposited Muara Enim Formation, which consist of fine sand and siltstone-claystone intersection at the bottom. At the top of formation, there are siltstone and claystone deposit with some local coal seam inserted. This formation has age about Miocene-Pliocene. The top formation after Muara Enim is Kasai Formation which mainly consist of Pliocene-Pleistocene tuffaceous claystone. The surficial deposit in this region composed by sand, mud, some clastic fragments, and swamp deposits [3].

Figure 1. Maps of Muaro Jambi Temple compounds from satellite view.

Figure 2. Geological maps of Muarojambi research location in Muara Enim Formation.
Muara Enim Formation in the main coal bearing formation in South Sumatran Basin. This formation covers South Sumatera Province, Jambi Province, and little part of Riau and Lampung Province. There are some fold patterns in this region, including the anticlinorium and synclinorium. These folds formed by regional compression force in South Sumatran Basin. Some Andesitic intrusion also found in this formation. Muara Enim Formation has divided into 4 members; M1, M2, M3, and M4 based on the position of coal deposit in these members [4].

Archaeological Agency of Medan (2007) explained that Batanghari River is the longest river in Jambi Province which length is about 800 kilometres. The source of the water came from the Mount Rasan in West Sumatra Province. Some side rivers like Merangin, Asai, and Tebo, streams down passed the gold bearing rocks, and released it in heavy rain. People usually mine the gold alongside of the Batanghari river.

1.2. Pottery Classification
Potteries are made by clay materials which mixed with rock and mineral fragments then fired at specific temperatures. American Society for Testing and Materials (ASTM) define pottery as ceramic wares with clay contain when formed that were burned at certain temperature. There are 3 main types of clay-based potteries; earthenware, stoneware, and porcelain [5].

Earthenware is the first product of pottery in around 10,000 BC, starting in Japan. People used clay as the raw material for earthenware production because of its plasticity. But, sometimes in drying process, clay forms a shrinkage that results cracking because of non-plastic inclusions, so those inclusions must be removed first [6].

Stoneware, as one of China’s Shang Dynasty (1700-1027 BC) products, is also made from clays. These clays are burned at higher temperature than earthenware, produce green to grey colour bodies with low porosity [6]. The chemical composition of stoneware can be recognized by the colour of glaze on its surface. The initial stoneware which is unglazed and doesn’t have much range of colours, were used in industrial and society’s daily life. Time after time, people started to make new decorating system for these porcelains to improve the economic value in market [7].

Porcelain itself is made from refractory clays, which is burned under very high temperature and produce a very different physical appearance from another pottery. The products tend to have a vitrified and hard body with very low porosity [6].

2. Methodology
This research was carried out to analyze the resource of pottery fragments in Muaro Jambi Temple Complex. The sample was taken in a field between Astano Temple and Gumpung Temple in Muaro Jambi Village. This location was chosen as a former residential area to look for people's lifestyle in the era of the kingdom where this temple was built. Data retrieval is done through excavation methods and direct sediment extraction in the Batanghari river.

In archaeology, excavation defined as a fieldwork program with specific research objects. The objects can be artefacts, ecofacts, or another archaeological stuffs which interprets archaeological deposits [8]. With spit excavation method, we made four holes sized 1x1m and took some pottery fragments inside (figure 3).

For the sediment samples, sand and granules were collected along the sand bar in Batanghari River (figure 4). Those samples were separated based on physical appearance before washed and sorted by the grain size. The washed sand will be observed under loupe to describe mineral and rock materials inside. The same method of analysis was also carried out on pottery samples, but those pottery samples were taken in excavation field. After the macroscopic description, sediment and pottery samples are taken to laboratory to be observed further under microscope.
3. Results and discussion

3.1. Batanghari River Sediment
The sediments along Batanghari River have a lot of different material. These sediments are taken in sand bar area in the downstream and mixed with little soil. After washed and sorted, the sediments show different mineral and another colored material (figure 5 and table 1).

Black minerals look very similar in appearance, but they can be identified by some specific properties of each mineral like luster, hardness, scratches color, and magnetism. Hudson Institute of Mineralogy explains that magnetite has metallic luster with a high magnetism, its scratches color is black. Goethite has silky-metallic luster with very low magnetism and yellowish-brown scratch, its hardness is lower than magnetite. Hornblende has vitreous luster and no scratches color, it has no magnetism but has high hardness. Lithic fragment luster is dull, its hardness is low, it has black scratches but no magnetism.

3.2. Stoneware Sample

3.2.1. MJB/ABH/E2/1/2018. From macroscopic view, the first sample tends to have massive structure. In microscopic observation, there is no crack inside with fine grained minerals and lithic fragments. The fine-sized paste between materials are greyish white with components mentioned below. The second sample has a little crack inside even though overall structure is still massive. The paste is
fine-grained and has a bright brown colour. The components of this pottery fragment are also mentioned below (figure 6).

3.3. Earthenware Sample

3.3.1. MJB/ABH/E2/2/2018/A. This earthenware sample has more little cracks than stoneware fragments. The size of materials is also coarser with brownish paste. The texture of sample surface shows that it used the coarse paste. The components of this sample are mentioned below (figure 7).

3.3.2. MJB/BH/E2/2/2018/B. The second earthenware sample shows a similar characteristic. It has some little cracks between coarse materials. The paste also has a similar coarse texture but with a darker brownish colour. The components of this fragment are mentioned below (figure 8).

3.3.3. MJB/ABH/E2/2/2018/C. This sample has some finer-sized materials beside the coarser ones. It also has more cracks inside with darker colour paste. From the surface texture, it also has a coarse paste. The components of this pottery fragment are mentioned below (figure 9).

![Figure 5. Batanghari River's sediment sample.](image)

| Table 1. Composition and occurrence of sediment sample. |
|---------------------------------|-----------------|
| Material                        | Occurrence      |
| (Red) Quartz                    | Ubiquitous      |
| (Transparent) Quartz            | Common          |
| (Smoky) Quartz                  | Ubiquitous      |
| (Milky) Quartz                  | Common          |
| Plagioclase                     | Uncommon        |
| Lithic Fragment                 | Very common     |
| Muscovite                       | Uncommon        |
| Hornblende                      | Common          |
| Red Chalcedony                  | Uncommon        |
| Magnetite                       | Common          |
| Goethite                        | Common          |
Figure 6. Stoneware sample and it's microscopic view.

Figure 7. Earthenware sample (MJB/ABH/E2/2/2018/A) and it's microscopic view.

Figure 8. Earthenware sample (MJB/BH/E2/2/2018/B) and it's microscopic view.
3.3.4. MJB/ABH/E2/2/2018/D. This sample has many small, elongated cracks. The size of materials is so fine so it can’t be seen so clearly at 0.8x magnification but can be quite visible after 4x magnification. From the surface texture, the sample used fine paste coloured bright cream. The components of this fragment are mentioned below (figure 10).

3.3.5. MJB/ABH/E2/2/2018/E. The last earthenware sample has rounded coarse materials inside with some little cracks between them. The colour of paste is dark, and the texture is coarse. The components of this pottery fragment are mentioned below (figure 11).

3.4. Fireplace sample
This fireplace fragment has a lot of cracks inside. The materials are coarse and some of them are rounded. The colour of paste is bright brown with mixture of red brick fragments inside. From the surface texture, this sample used a coarse-grain paste. The components of this fireplace fragment are mentioned below (figure 12).

The total composition of each pottery material with the occurrence are mentioned in the table 2. One of the stoneware samples has a massive structure with greyish white paste, while the other one has little cracks with a bright brown coloured soft paste. Earthenware samples have some different

Figure 9. Earthenware sample (MJB/ABH/E2/2/2018/C) and it's microscopic view.

Figure 10. Earthenware sample and it's microscopic view with addition of magnification 4 times (in the right picture).
variations. The sample A and B have little cracks with bright cream and dark cream coloured coarse paste. The sample C and E have more cracks with dark cream coarse paste. The sample D’s cracks have a bigger size and bright cream coloured soft paste. The fireplace earthenware has a lot of little cracks with brownish coarse paste.

Similarities that appear differ in each type of pottery. The same component and occurrence can be seen from italicized text in table 3. In stoneware type, we found some abundance of minerals such as plagioclase and black minerals, also basaltic lithic fragments. In earthenware pottery, some variations of quartz like transparent quartz, smoky quartz, and milky quartz are found commonly, also the other materials like lithic fragments and red lithic fragments. The most common material found in fireplace is rock lithics. Those red lithic fragments possibly come from brick fractions. The mica minerals mostly can be found in some kind of pottery with high degree of combustion.

The structure of stoneware ceramics tends to be massive meanwhile those on earthenware and stoves type with coarse paste have more cracks. Cracks in earthenware can differ depending on the type of paste. Earthenware with fine pasta generally forms more cracks than those with coarse paste.

![Earthenware sample (MJB/ABH/E2/2/2018/D) and it's microscopic view.](image1)

![Earthenware sample (MJB/ABH/E2/2/2018/E) and it's microscopic view.](image2)
| Type       | Sample               | Material            | Occurrence |
|------------|----------------------|---------------------|------------|
| Stoneware  |                      | (White) Plagioclase  | Common     |
|            |                      | Lithic Fragment     | Very common|
|            | MJB/ABH/E2/1/2018/A  | Black Mineral       | Common     |
|            |                      | Red Lithic          | Uncommon   |
|            | MJB/ABH/E2/1/2018/B  | (White) Plagioclase  | Common     |
|            |                      | Lithic Fragment     | Uncommon   |
|            |                      | Black Mineral       | Uncommon   |
|            |                      | Red Lithic          | Uncommon   |
|            | MJB/ABH/E2/2/2018/A  | (Transparent) Quartz| Very common|
|            |                      | (Smoky) Quartz      | Common     |
|            |                      | Muscovite           | Uncommon   |
|            |                      | Lithic Fragment     | Very common|
|            |                      | Red Lithic          | Very common|
|            | MJB/ABH/E2/2/2018/B  | (Transparent) Quartz| Common     |
|            |                      | (Milky) Quartz      | Common     |
|            |                      | (Smoky) Quartz      | Common     |
|            |                      | Muscovite           | Uncommon   |
|            |                      | Lithic Fragment     | Common     |
|            |                      | Red Lithic          | Very common|
|            | MJB/ABH/E2/2/2018/C  | (Transparent) Quartz| Common     |
|            |                      | (Smoky) Quartz      | Very common|
|            |                      | Plagioclase         | Uncommon   |
|            |                      | Muscovite           | Uncommon   |
|            |                      | Lithic Fragment     | Very common|
|            |                      | Red Lithic          | Common     |
|            | MJB/ABH/E2/2/2018/D  | (Transparent) Quartz| Common     |
|            |                      | (Smoky) Quartz      | Very common|
|            |                      | Plagioclase         | Uncommon   |
|            |                      | Mica                | Uncommon   |
|            |                      | Lithic Fragment     | Very common|
|            |                      | Red Lithic          | Very common|
|            | MJB/ABH/E2/2/2018/E  | (Transparent) Quartz| Common     |
|            |                      | (Smoky) Quartz      | Very common|
|            |                      | Plagioclase         | Common     |
|            |                      | Muscovite           | Common     |
|            |                      | Lithic Fragment     | Very common|
|            |                      | Red Lithic          | Very common|
|            | MJB/ABH/E2/3/2018/A  | (Transparent) Quartz| Very common|
|            |                      | (Milky) Quartz      | Common     |
|            |                      | (Smoky) Quartz      | Very common|
|            |                      | Plagioclase         | Common     |
|            |                      | Hornblende          | Common     |
|            |                      | Muscovite           | Uncommon   |
Table 3. Comparison between river sediment and pottery materials.

| Materials          | River Sediment | Stoneware | Earthenware | Fireplace |
|--------------------|----------------|-----------|-------------|-----------|
| Quartz             | Ubiquitous     | Rare (very minor) | Very common | Very common |
| Lithic Fragments   | Very common    | Common    | Very common | Very common |
| Muscovite          | Uncommon       | Absent    | Uncommon    | Uncommon  |
| Plagioclase        | Uncommon       | Very common | Uncommon    | Uncommon  |
| Black Minerals     | Common         | Common    | Rare (very minor) | Absent    |
| Red Lithics        | Rare (very minor) | Uncommon | Very common | Very common |

4. Conclusion
The sand materials in Batanghari River have a lot of correlation with pottery materials in Muaro Jambi Temple Complex. Those materials include minerals like quartz, muscovite, and black minerals. The other materials are lithic fragments and red rocks. The quartz mineral group that has been seen also has several variations, namely quartz, milky quartz, smoky quartz, and red quartz. This variation may appear due to the effect of weathering and sedimentation process in Batanghari River. Through this study, we can identify similarities between river sand and pottery. Some stoneware materials may not come from Batanghari River but the other pottery materials from Earthenware and Fireplace have a high similarity with river sediments, both from the type of materials and its occurrence.

This similarity shows that it is most likely that pottery in Muaro Jambi Region is locally made in Jambi region with material sources from the Batanghari River. We see that this method will be useful in sourcing local pottery in the future.

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