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# CLAY MINERAL IDENTIFICATION FOR THE UTILIZATION OF THE BRICK INDUSTRY IN BUKIT RAYA, TENGGARONG SEBERANG, KUTAI KARTANEGARA

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## ABSTRACT

*Bricks as one of the main components in buildings are often made by clay contained material that supplied from the nearby resources, including in Bukit Raya, Tenggarong Seberang, Kutai Kartanegara. However, the type of clay minerals that utilized for the brick in the research area, is not identified in detailed analysis. The research is conducted to identify the clay mineral that consists in the lithology or material that used for the brick industries in the research area and its implication on the characteristic of the product. The analysis is carried out through field observation and laboratory analysis which included X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM), and X-Ray Fluorescence (XRF) analysis. The analysis resulting the lithology of the research area is predominantly sandstone interbedded with claystone and coal intercalation. The XRD analysis on claystone and soil that used for bricks showing that the samples are mainly composed by quartz, with clay minerals identified is kaolinite, montmorillonite, and illite. However, according to the SEM analysis, only kaolinite and montmorillonite that present in the samples. According to the geochemistry of the samples, the average $SiO_2$ content is ranging from 45.8% to 55.50%. The $Fe_2O_3$ content is measured from 2.02% to 5.96% which excess the SNI standard for pottery that set as 0.8 wt.%. CaO component varying from 0.117 to 0.221 wt.%, which still in the allowed value for the pottery materials which set to maximum 1 wt%. The high content of quartz ($SiO_2$) affect in decreasing plasticity of the material and montmorillonite might cause cracking due to drying process. These characteristics may lead to a decrease in product quality according to the National Standard of Indonesia.*

**Keywords:** *Brick, Clay Mineral, Quartz, X-Ray Diffraction, Sandstone*

## INTRODUCTION

Minerals which compose rocks in the earth are widely utilized according to their characteristics. One of the most common mineral that used in various products is clay mineral. Clay mineral is included as industrial mineral. The geological materials including mineral and rocks that obtained by mining and may be used in an industrial process directly due to its chemical/physical properties is defined as industrial minerals (Evans, 1993; Lehtinen, 2015; Schulze, 2005). Clay minerals can be formed by natural or synthetic process. These minerals are described as phyllosilicate minerals with plasticity characteristics that harden from drying and burning, generally have small grainsize (< 2 μm). Clay minerals can be formed by naturally or synthetic. The examples of the clay minerals are kaolin group, chlorite groups, smectite groups, illite groups and pyrophyllite (Bergaya, 2008; Guggenheim, 1995). The minerals can be used in a variety of industries such as ceramics, cosmetics, polymer coatings, and bricks. (Danish et al., 2022; Gonggo & Edyanti, 2013; Murray, 2007; T. Winarno, Kurniasih, Marin, & Kusuma, 2018). One of the most common used of clay minerals in Indonesia is as a bricks material, including in Bukit Raya, Tenggarong Seberang, Kutai Kartanegara (Balfas, Sasmito, Pangloro, & Wardana, 2019; Rahmi & Syarief, 2014). In

Bukit Raya, one of the utilization of the industrial minerals particularly clay mineral is bricks industry, which is produced in the level of home industry.

From the geomorphological characteristics, the research area is a part of Lower Kutai Basin that covered by Tertiary sedimentary rocks (Chambers et al., 2004). The location of the bricks Bukit Raya according to the regional geological map by (Supriatna, Sukardi, & Rustandi, 1995) is included in Pulau Balang Formation. The Pulau Balang Formation is composed by alternation of alternating greywacke and quartz sandstone, claystone, and coal. The greywacke has greenish grey color, compact, with thickness 50 – 100cm. the quartz sandstone has reddish gray color locally calcareous with the thickness of the layer is 15 – 60 cm. The claystone is blackish grey, thickness of the layer varies between 1 – 2 cm, in some place intercalating with coal, locally the lithology is found with 4 m thickness. The limestone has yellowish to light brown features which contained large foraminifera fossil including *Autrotrilina howchini*, *Borelis sp.*, *Lepidocylina sp.*, *Miogypsina sp*. The occurrences of the fossil indicates the age of formation is Middle Miocene and shallow marine depositional environment (Chambers et al., 2004; Supriatna et al., 1995; A. Winarno, Hendra Amijaya, & Harijoko, 2019). The regional geology structure controls the Bukit Raya Area is mainly folding, which identified as a part of Samarinda Anticlinorium elongated in North – South direction (Fig.1) (Supriatna et al., 1995; Witts, Davies, Morley, & Anderson, 2016).

The bricks in Bukit Raya is made from the clay which the source is from the surrounding lithology. However, the characteristics of the lithology which formed clay minerals and the species of the clay minerals in the research area is still limited by the X-Ray Diffraction (XRD) Analysis (Balfas et al., 2019). In fact, the identification of the minerals may provide information on the qualities of the minerals, which can provide information about how to use it efficiently, because each mineral has its own characteristics that lead to the recommendation of usage. (Bergaya, 2008; Kogel, 2009). Hence, the identification of the clay minerals in the research area are important to be done. The objectives of the research are to identify the clay minerals and its minerals associations in the lithology of the research area. Therefore, the effect on the clay mineral composition to the characteristic of the products can be determined.

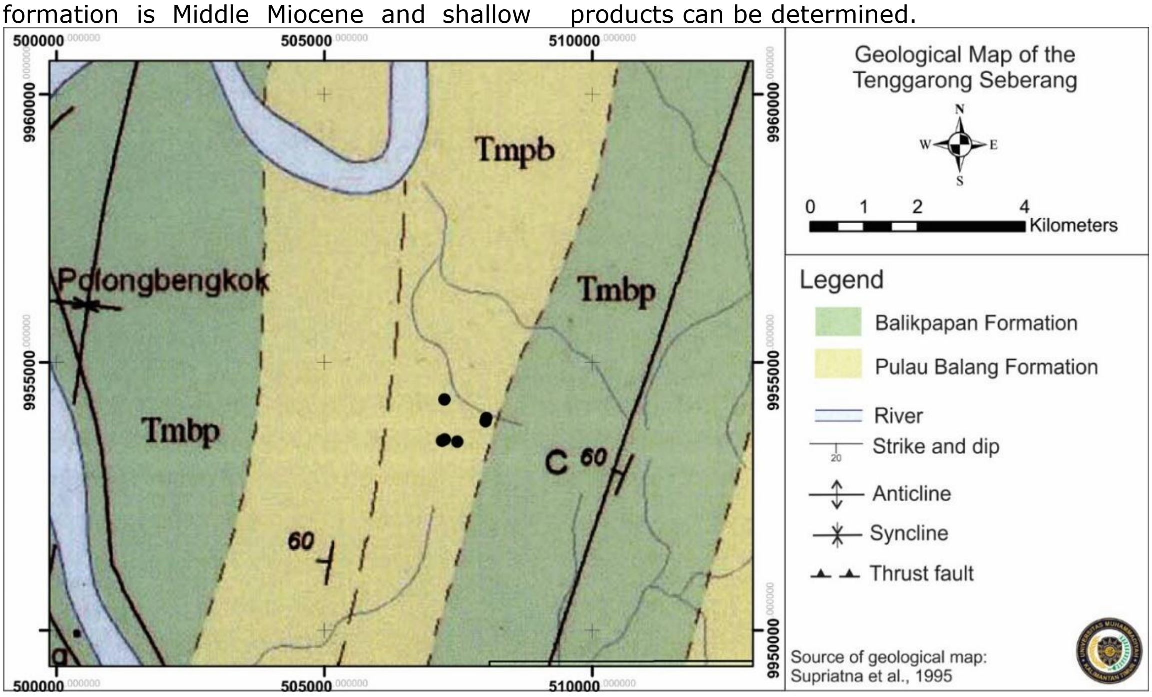


Fig. 1. The geological map of the research area which is a part of Pulau Balang Formation (black dots) (modified from Supriatna, Sukardi, & Rustandi, 1995).

**RESEARCH METHOD**

The research with topic identification of the clay minerals for bricks in industry in Bukit Raya was carried out in several steps. The location of the research is in the Bukit Raya area, Tenggarong Seberang, Kutai Kartanegara which according to regional geology map is included in Pulau Balang Formation (Supriatna et al., 1995) (Fig.1).

The research was carried out in several steps, including field observation, samples collection and laboratory analysis. Field observation was done to analyze geological features in the research area particularly the lithology or clay which used as the material for the bricks. Samples of the soil contained clay and the rocks underneath the clay.

The laboratory analysis that was used is X-Ray Diffraction (XRD). The samples were grinded become powder and analyze using Rigaku Miniflex II for initial 3.0-70° 2θ scanning angle. The Reference Intensity Ratio (RIR) is the method used for quantification to obtain mineral and phase estimation. Minerals/phases identification is carried out by using Jade9 software with ICDD database. The XRD analysis that was carried out in the research area is bulk and clay analysis. The bulk analysis is conducted to identify mineral associations of the samples. Clay analysis which includes air dried and ethylene glycol analysis is conducted to identify the specific clay mineral name in the samples which is utilized as clay bricks. Clay analysis was conducted by separating the clay soil samples with their clay fraction through centrifuge process. The clay fraction then placed to the glass and dried up in room temperature (*air dried*) and added ethylene glycol, and both of them analyzed using diffractometer to identify their peak (d and 2θ) value (Guggenheim, 1995; Moore & Reynolds, 1997; Rahmi & Syarief, 2014).

The second analysis is Scanning electron microscope (SEM) which has magnification up to 10000 times. The SEM analysis is conducted to identify the clay minerals through its morphology features. The identification of the clay minerals using SEM can describe the configuration (size and shape), fabric, texture and intergrowth of the clay minerals. Hence, the identification of the clay minerals in the research area can be done accurately (Di Remigio, Rocchi, & Zania, 2021; Islam, Khan, Hussain, & Uddin, 2022; Ural, 2021).

The third analysis is geochemistry analysis using *X-Ray Fluorescence* (XRF) using Rigaku Supermini200. The XRF analysis is carried to identify the composition of major elements in oxide form. XRF analysis is analyzed from rock samples that have been prepared into powder form. The results of the XRF analysis are in the form of data on the major oxide, namely $SiO_2$, $Al_2O_3$, FeO, CaO, MgO, MnO, P2O5, $Na_2O$, $K_2O$, and $TiO_2$, which are expressed in the form of percent (%) by weight (Rollinson & Pease, 2021). The research aims to determine the chemical composition of clay minerals in the research area which is then compared with the geochemical content of clay minerals in other research areas. So, the feasibility of utilization of clay minerals and recommendations for other uses can be determined. The data from the field observation and laboratory analysis then integrated and analyzed to determine the species of the minerals and interpret the source of the clay minerals which used as the bricks in the research area.

## RESULT AND DISCUSSION

### Lithology

The lithology in the Bukit raya is mainly composed by the sandstone interbedded with claystone and coal intercalation. The sedimentary rock is formed in bedding structure and in the sandstone the cross-bed structure with coal lenses is identified. The sedimentary rocks in the research area is controlled by structural geology event, which cause it to have strike/dip N 744 °E/ 24°. The material of the bricks is taken from sandstone lithology mixed with the clay (**Fig.2**.).

Fig.2. (left) The outcrop in the research area containing the soil that used as bricks (right) the close up view of the soil containing clay.

### Clay Minerals

According to the bulk XRD analysis in the four samples of the lithology containing clay grainsize which used the material of brick, the minerals that detected are quartz and plagioclase as primary mineral. While the according to XRD clay analysis (air dried and ethylene glycol) the clay minerals which formed in the research area is predominantly kaolinite, illite, montmorillonite, with addition in some minerals identified as sepiolite and scolecite. The proportion of each mineral that identified in the research area is written in (Table 1).

**Table 1**. Table the result of XRD analysis on the 4 samples in the research area.

| Id Sample | Minerals Composition | Chemical Formula | Minerals Composition Estimation (%) |
|---|---|---|---|
| STA1B Bukit Raya_ claystone | Quartz | $SiO_2$ | 90 |
| | Montmorillonite | $(Ca,Na)_{0.3}Al_2(Si,Al)_4O_{10}(OH)_2xH_2O$ | 3 |
| | Kaolinite | $Al_2(Si_2O_5)(OH)_4$ | 3 |
| | Scolecite | $CaAl_2Si_3O_{10}3H_2O$ | 2 |
| | Illite | $(K,H_{30})Al_2(Si_3Al)O_{10}(OH)_2xH_2O$ | 2 |
| | | **TOTAL** | 100% |
| STA2 Bukit_ Raya_ Clay | Quartz | $SiO_2$ | 85 |
| | Kaolinite | $Al_2(Si_2O_5)(OH)_4$ | 9 |
| | Illite | $(K,H_{30})Al_2(Si_3Al)O_{10}(OH)_2xH_2O$ | 6 |
| | | **TOTAL** | 100% |
| STA5 Bukit Raya_ Clay | Quartz | $SiO_2$ | 59 |
| | Kaolinite | $Al_2(Si_2O_5)(OH)_4$ | 12 |
| | Sepiolite | $Mg_4Si_6O_{15}(OH)_26H_2O$ | 10 |
| | Illite | $(K,H_{30})Al_2(Si_3Al)O_{10}(OH)_2xH_2O$ | 8 |
| | Montmorillonite | $(Ca,Na)_{0.3}Al_2(Si,Al)_4O_{10}(OH)_2xH_2O$ | 7 |
| | Albite | $Na(AlSi_3O_8)$ | 4 |
| | | **TOTAL** | 100% |
| STA6 Bukit Raya_ Clay | Quartz | $SiO_2$ | 59 |
| | Albite | $Na(AlSi_3O_8)$ | 13 |
| | Kaolinite | $Al_2(Si_2O_5)(OH)_4$ | 11 |
| | Illite | $(K,H_{30})Al_2(Si_3Al)O_{10}(OH)_2xH_2O$ | 9 |
| | Montmorillonite | $(Ca,Na)_{0.3}Al_2(Si,Al)_4O_{10}(OH)_2xH_2O$ | 8 |
| | | TOTAL | 100% |

From the result of the clayey soil analysis which utilized as the material of the bricks in research area still dominated with quartz. The clay minerals which dominated by kaolinite, illite, and montmorillonite in the research area is interpreted to be result of the weathering process experienced in the lithology of the research area. The chemical weathering process alter some of the plagioclase which identified as albite $Na(AlSi_3O_8)$ into clay minerals. Kaolinite ($Al_2(Si_2O_5)(OH)_4$) is identified by its peak which is in 2θ value 7A and its peak does not change by air dried and ethylene glycol treatment. The kaolinite has 1:1 layer, white colored, fine particle size, has a soft plastic-like texture, and non-expand characteristics (Murray, 2007; Yang & Yang, 2024). Kaolinite can be formed from the hydrolysis reaction from the albite during the weathering process in acid condition (Manning, 2022; Velde & Meunier, 2008).

The second clay mineral that detected is montmorillonite ($(Ca,Na)_{0.3}Al_2(Si,Al)_4O_{10}(OH)_2xH_2O$)).

Montmorillonite is a clay mineral that included in smectite group. It characterized by peak 2θ 17A in air dried, but shifting to the 14A in ethylene glycol treatment (Fig. 3). This also indicates that montmorillonite is a 2:1 interlayer clay mineral that has expanding or swelling capability in wet condition and shrink upon drying process. Montmorillonite also has higher plasticity than kaolinite. The montmorillonite can be formed as the result of the weathering process of the sedimentary rocks in high rainfall level, however the leaching process is low, hence silica, calcium, aluminum, and other cation do not lose during the weathering process (Murray, 2006; Uddin, 2018; Utami, 2018).

The third mineral that detected is illite $(K,H_{30})Al_2(Si_3Al)O_{10}(OH)_2xH_2O$. Illite is a 2:1 in which the interlayer cation is potassium clay mineral. It detected in XRD analysis by its 10A peak in both air dried and ethylene glycol treatment. Illite is a phyllosilicates that has a strong interlocking iconic bond structure which holding the separate layers together and prevent waters molecule from filling the interlayer position, hence illite does not has swelling characteristic. The illite may be formed from the alteration of the feldspar mineral in tropical environment during the earlier steps of water – rock interaction by meteoric process. This type of clay mineral generally formed in alkaline condition and high concentration of aluminum and potassium which reflected by its chemical formula. Illite mineral also commonly found along with kaolinite and smectite, including montmorillonite (Bétard, Caner, Gunnell, & Bourgeon, 2009; Danish et al., 2022; Murray, 2006).

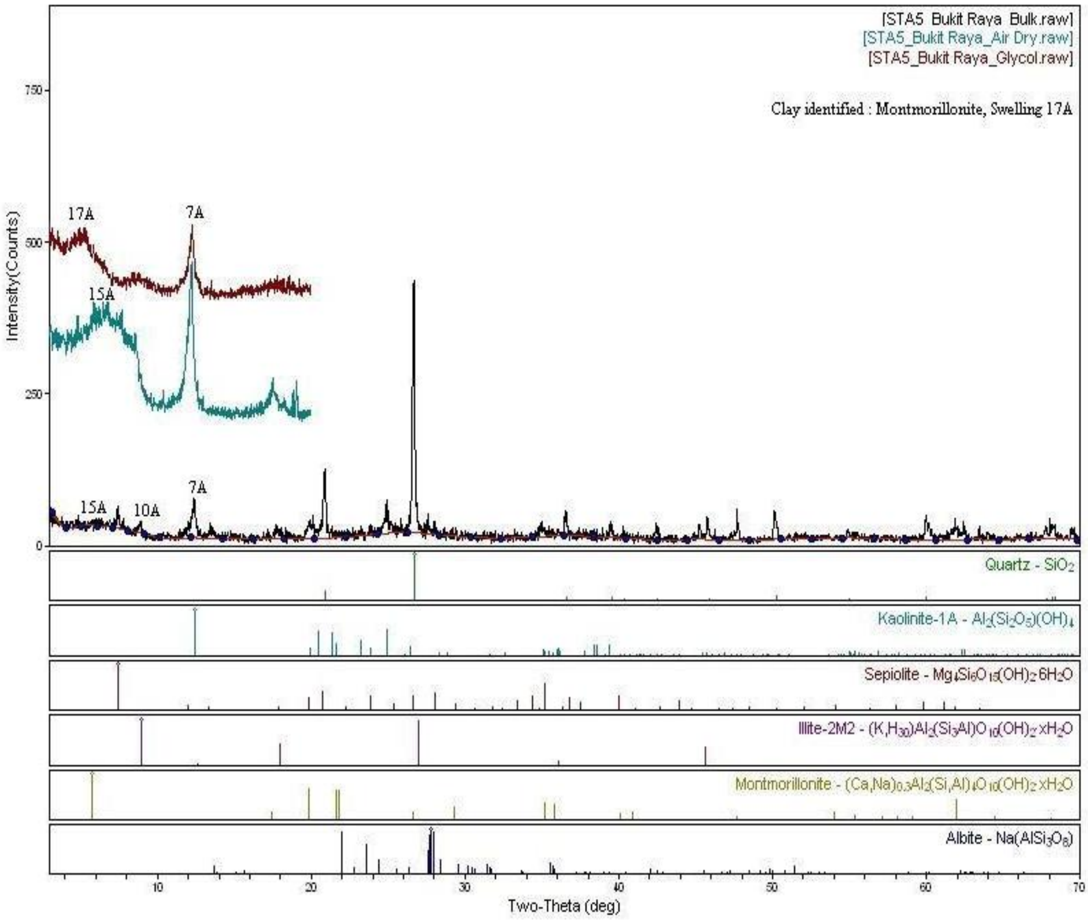


Fig. 3. The result of the XRD analysis in the one of sample displaying montmorillonite (17A) clay mineral.

The SEM analysis is carried out in four samples, displaying the morphology characteristic of the clay minerals in the research area. The non-clay minerals also detected in the sample as quartz, which is the dominant minerals found in the samples (Fig.4.). Quartz characterized by its prismatic shape. The clay minerals that detected by SEM are montmorillonite and kaolinite. The smectite minerals is characterized by the platy morphology stacked to each other and forming a honey comb texture (Fig.4.) The kaolinite is identified by its pseudo-hexagonal plates and stacks shape (Fig.4.) (Christidis, 2010; Islam et al., 2022; Kogel, 2009; Murray, 2006; Uddin, 2018).

Geochemistry analysis using *X-Ray Fluorescence* (XRF) is done in four samples (Table 2). According to its geochemistry composition, the silica ($SiO_2$) content in the samples of the research area ranging from 45.8% to 55.50%. The high content of the silica indicates that the samples in mainly compose by silicate minerals, including quartz and clay minerals which also detected in the XRD analysis. According to the SNI No.1145-1984 (Nur et al., 2020) the maximum iron ($Fe_2O_3$) content for the pottery including bricks is 0.8 wt.%.

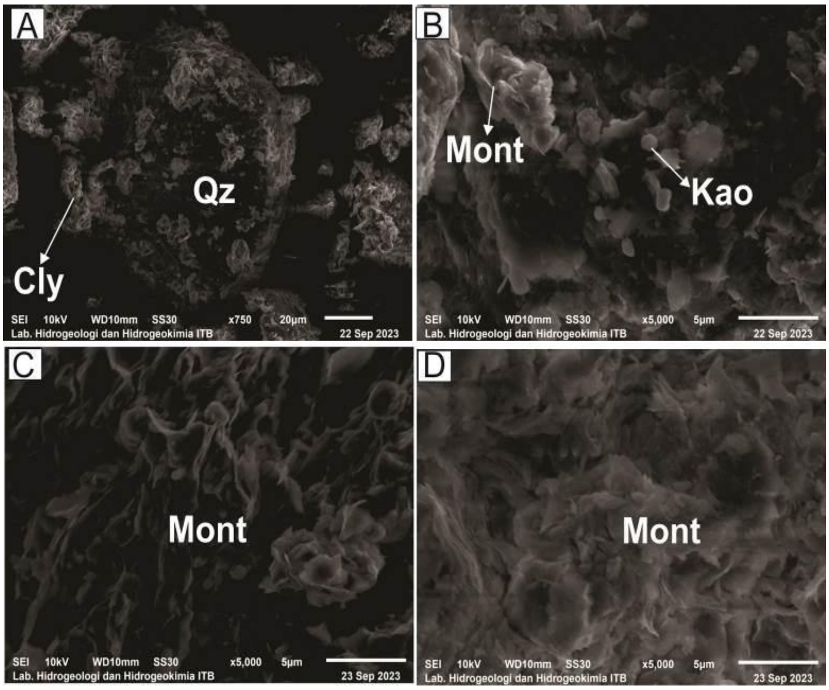


Fig. 4. The result of the SEM analysis in the research area, which are Quartz (Qz), Clay (Cly), Montmorillonite (Mont), and Kaolinite (Kao).

However, in samples that analyzed the value of the iron oxide are surpassing the upper limit value, accounted for 2.02% to 5.96%. The CaO component of samples, varying from 0.117 to 0.221 wt.%, which still in the allowed value for the pottery materials which set to maximum 1 wt%. Another SNI No.1145-1984 requirements for a good brick material is minimum value of the $K_2O$ plus $Na_2O$ is 6% and maximum 15%. However, due to the limitation of the equipment the $Na_2O$ in the samples is not able to be detected. The $TiO_2$ composition is not consider to the quality of the bricks material according to the SNI No.1145-1984 (Nur et al., 2020; T. Winarno et al., 2018). The high aluminum oxide content in the samples is interpreted to be due to the clay minerals found in the research area, especially kaolinite and montmorillonite (Bergaya, 2008; Uddin, 2018).

**Table 2.** The geochemical composition of the samples in Bukit Raya by XRF analysis

| Component | STA 2 (wt.%) | STA 1 (wt.%) | STA 5 (wt.%) | STA 1B (wt.%) |
|---|---|---|---|---|
| $Al_2O_3$ | 16.9 | 16.8 | 16.7 | 14.7 |
| $SiO_2$ | 50.2 | 49.8 | 45.8 | 55.5 |
| $K_2O$ | 1.14 | 1.04 | 1.51 | 0.923 |
| CaO | n/a | 0.117 | 0.286 | 0.221 |
| $Fe_2O_3$ | 5.96 | 4.7 | 3.02 | 2.02 |
| $TiO_2$ | 1 | 0.803 | 0.7411 | 0.71 |

Analysis on the minerals in the research area shows that the material used for bricks in the research area is still dominated by quartz, with the total of the clay minerals varies from 10 – 28%. The abundance of clay minerals in the materials affect their plasticity characteristics. A higher percentage of clay content in the material will result increased plasticity (Diko-Makia & Ligege, 2020). On the contrary, a high abundance of quartz in the material will result in decreased plasticity (Gonggo & Edyanti, 2013). Moreover, the montmorillonite in the samples has swelling characteristics in wet condition, and shrink upon drying process, which may cause cracking in the products. Hence, the utilization of the clay in Bukit Raya may not be suitable for other pottery products such as ceramic or porcelain since the clay minerals is low and the plasticity is low too.

## CONCLUSION

The materials used for bricks are primarily composed of quartz, which accounts for over 50% in STA 5 and STA 6, and more than 80% in STA 1B and STA 2. The clay minerals present in these materials range from 10% to 28% and predominantly consist of kaolinite, illite, and montmorillonite, with additional minerals such as sepiolite and scolecite identified in smaller amounts. These mineral compositions contribute to the low plasticity of the material. The presence of montmorillonite, known for its swelling characteristics, can also affect the quality of the final product which might be cracking while drying.

According to the National Standard of Indonesia for the geochemical composition of pottery materials, the clay materials in the research area contain higher levels of $Fe_2O_3$ than the standard permits for pottery. However, the concentrations of other geochemical components, such as $SiO_2$ and CaO, fall within the acceptable range of the standard.

The detailed analysis such as quality assessment of the material and the bricks in the research area is recommended to determine the quality of the products compare to the National Standard of Indonesia.

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