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THE STUDY OF CONSTRUCTION MATERIALS SOURCES FROM OLD BUILDING: A CASE STUDY ON MUARAJAMBI TEMPLE, JAMBI PROVINCE, INDONESIA

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ABSTRACT: Muarajambi temple area contains old buildings, which are made of various types of materials. The problem is whether the building materials come from around Muarajambi temple area. This study aims to determine the position of Muarajambi temple area on the regional geological map to determine the types and sources of material for Muarajambi temple. The method used in this study describes the restricted layout using geological maps, petrographic analysis of temple building samples, and XRF and XRD analysis of pottery and rock sediment samples. The results showed that the temple area was in the Muara Enim, Kasai, and alluvial rock formations. The results of the petrographic analysis showed that the samples contained in Kembarbatu Temple: were claystone, Kedaton Temple: quartz arenite, and Gumpung Temple: tuffaceous sandstone, which characterizes the characteristics of the Muaraenim and Kasai rock formations. The results of XRF analysis of 3 samples of artifacts (pottery vessels) from Gedong and Astano temples showed high levels of quartz, namely Silica 24.21% and aluminum 10.52. Likewise, the results of the XRD analysis of the pottery vessels from Kedaton Temple and Astano Temple contained high quartz (SiO2 86.2%) and tellurite (SiO6 67.2%). This has similarities with two sediment samples (T-366 and T-367) taken from the banks of the Batanghari River containing high quarts (SiO2 70.6%) and tellurite (SiFe2O4 43.9%). Based on the results of the Petrography, XRF, and XRD analysis indicated that the materials from the temple buildings and artifacts were made from in-situ materials.

Keywords: Material, Mineral, sample, Temple, Muarajambi

1. INTRODUCTION

The temple building is an old building that is a cultural heritage and historical monument of a nation [1]. The building serves as a place of worship for Hindus and Buddhists [2]. Inside the temple building, placing deity statues as objects of worship. Religious leaders bring ceremonial equipment, such as pottery vessels filled with water and offerings. [3]. This equipment is considered sacred because when the religious ceremony takes place, the equipment is deemed to be directly related to the gods [4]. Religious ceremonies are performed in the courtyard of the temple.

Temple buildings were built from brick, stone, wood, and mud [5]. These elements are essential in the construction of buildings as brick is used for building because of its low cost, wide availability, durability, easy handling [7], waterproof [8], ease of building construction, and can withstand earthquakes [9]. Stone is used for buildings because it is solid and durable [10]. Wood serves as a support and roof construction [11]. Mud is used as wall plaster [12] and coolant for buildings [10]. The grouping of temple buildings is based on the type of material, namely *suddha, misra*, and *samkirna*. *Suddha* is a sacred building built using only 1 type of material, such as stone or brick. *Misra* is a temple building made of 2 types of material: tuff and brick, brick and lime. *Samkirna* is a temple building made of more than two materials: stone, brick, wood, bamboo, and others [3]. In general, the temple material in Central Java is andesite stone. In contrast, the temples in East Java are made from bricks (claystone) [13], such as Jabung Temple, which is made of high-quality bricks with relief decorations on the walls of the body of the temple [14] Bahal Monastery in North Sumatra is made of bricks, Lesungbatu temple in Musi Rawas is made of bricks and tuff, and Muara Takus temple is made of brick and sandstone.

The temple buildings in South Sumatra are found in the watershed [15]. The existence of those temples is indicated due to the previous trading contact with India. The trading activity stimulates Hinduist-Buddhist influence to develop in South Sumatra, particularly near the river bank [16]. One of the temples in the Batanghari watershed is Muarajambi temple, which is in a linear position to the Batanghari River. The temples have an area of 3,981 acres with a boundary with the channels or tributaries of the Batanghari River [17]. Muarajambi temple area contains old buildings dating from the 10th century AD. These buildings are still standing strong. This is presumably because the buildings were built from materials that were not easily destroyed or damaged. Several temple buildings have been conserved, such as Gumpung 1 Temple, Gumpung 2 Temple, Kembarbatu Temple, Astano Temple, Kedaton Temple, Gedong 1 Temple, and Gedong 2 Temple. Fragments of pottery vessels were found, indicating that the equipment used was used for religious ceremonies.

2. RESEARCH SIGNIFICANCE

This study proves that around Muarajambi temples area, the material is abundant and is used by the community for temple materials and ritual facilities. This is evidenced by the results of petrographic, XRF, and XRD analyses of building samples and pottery containers containing minerals that characterize the characteristics of the constituent rocks of the local rock formations.

2.1 Research Location Analysis

The method used here was conducting a survey. Making a geological map is based on references from the Geological Research and Development Center of Indonesia's Shapefile Data, such as the ArcGIS software application, the BIG data of the geological map.

2.2 Petrographic Analysis

The Petrographic analysis is a branch of petrology as the study of rocks, especially rock contents and texture relations [18]. This analysis aims to discover the name of each rock sample taken at the research location based on the rock's texture, structure, and mineral content. The data was collected by conducting a field survey, and then the samples were sent to the laboratory to determine the mineral content. Petrographic analysis was carried out on five rock samples, 1 sample each from Kembarbatu, Gumpung, Kutomahligai Temples, and two from Kedaton Temple. A combination of petrographic and geochemical data of rocks can reveal the area where the rock originated [19]. The classification of sedimentary rocks was performed based on the classification by Pettijohn [20] and Fisher [21].

2.3 XRF and XRD Analysis

XRF, namely X-Ray Fluorescence, is a method that aims to determine mineral elements in the form of major elements and trace elements such as silica (Si), oxides (O), aluminum (Al), etc. XRF analysis was carried out on three artifacts (pottery vessels) samples, namely 1 sample from Gedong Temple and two samples from the Astano temple courtyard. Meanwhile, XRD/X-Ray Diffraction is a quick mineral/material characterization method, including phase formation, as well as quantitative analysis of its crystal structure so that it can determine the type of mineral/material contained. These methods use a material phase in the form of powders or solids, which an X-Ray beam will later shoot. XRD analysis was carried out on 1 sample pottery vessel from the Kedaton and Astano temples. In addition, XRD analysis was carried out on two rock sediment samples from rock outcrops on the banks of the Batanghari River.

3. RESULT AND DISCUSSION

3.1 Muara Jambi Temple Stratigraphy Area

The research location was in the South Sumatra basin, specifically in the Jambi sub-basin. The stratigraphy of the South Sumatra basin consisted of the following formations: Kikim, Telisa, Lahat, Talang Akar, Gumai, Baturaja and the equivalent, Air Benakat, Muara Enim, Kasai, and the equivalent, and the alluvial sediment on the upper surface [22]. Muara Enim rock formation was deposited at the Late Miocene to Pliocene in the second regression cycle with a shallow marine deposition environment up to continental sands, delta, and claystone. A relatively thick coal layer in this Muara Enim rock formation and the absence of glauconitic sandstone distinguish the first (Air Benakat formation) and the second regression cycle. The precipitation is initiated in a coastal plain's swamp area, and then it continues to the delta plain area with a local shale sequence development and thick sandstone. In this formation, there is iron-oxide in the form of concretions and silicified wood. Meanwhile, the coal available in this formation is generally in the form of lignite. The thickness in this formation is categorized as thin in the northern part, and the maximum is in the southern region, with a thickness of 750 m [23]. The Kasai rock formation is deposited from the Pliocene to the Pleistocene. This formation results from the erosion of lifting the Bukit Barisan and Tigapuluh mountains.

The Kasai rock formation has contact with the Muara Enim rock formation, which is marked by the lithology of tuffaceous sandstones. This formation is deposited in the third regression cycle characterized by the occurrence of volcanic products. The Kasai rock formation comprises continental sandstones, claystone, and pyroclastic materials (pumice tuff, tuffaceous sandstone, and tuffaceous claystone). This formation finalized the oceanic tide cycle. The lower part consists of tuffaceous sandstone with variations of tuffaceous claystone and loose sandstone layers. The upper part consists of a layer of tuffs and pumice that contains the remnant of plants and wood in a cross-

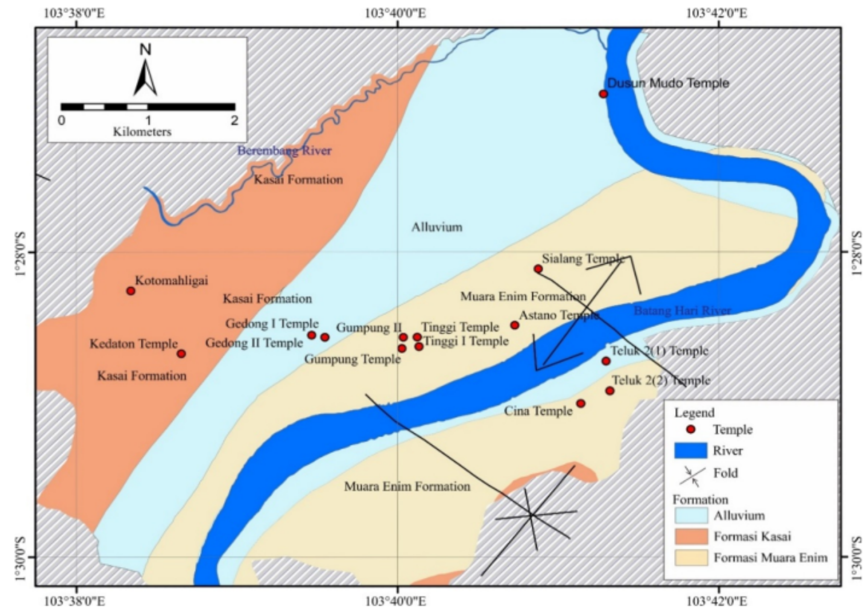

Fig. 1 The Distribution of Muarajambi Temples (red dot) lining up above the stratigraphy of Muara Enim Formation, Kasai Formation, and Alluvial

bedding structure. There is also a lens-shaped lignite in sandstones containing tuffs. The deposition environment of this formation is fluvial, with a thickness of >200 m. Alluvial sediment is a material deposit from a rock disintegration available in an area, usually in either a lowland area or a river. The alluvial sediment generally consists of blocks, pebbles or gravels, and sands up to mud. [22].

Muarajambi temples area is in the line-up position above the stratigraphy of Muara ations. Muara Enim rock formation is marked green on the map. The stratigraphy of this formation contains iron-oxide in the form of concretions and silicified wood. On the western side, alluvial sediment contains blocks, pebbles, sand, and mud.

The westernmost part of the temple area is located on the stratigraphy of the Kasai rock formation, which contains continental sandstones, claystone, and pyroclastic materials (pumice tuff, tuffaceous sandstones, and tuffaceous claystone) (Fig. 1)

3.2 Material for Temple Building

Five samples were taken from Muarajambi temple area. The samples were taken from the temple courtyard, 1 sample each from Kembarbatu, Gumpung, Kutomahligai temples, and two samples from Kedaton temple. Those samples were then analyzed using a petrographic analysis by cutting the stone to know the mineral content. After cutting the sample, the rock sample was identified using a microscope at 40x magnification.

Rock samples were taken from the eastern courtyard of Kembarbatu temple, 200 meters away, at coordinate 48 M 0352147 9836597. Kembarbatu Temple. The rock composition comprises 11% quartz, 2% lithic, 8% Iron-Oxide, 3% porosity, and 76% clay cement. In fig. 2, the rock name can be known as clay stone.

In fig. 3, rock samples were taken from 150 meters south of Kedaton temple at coordinate 48 M 0349139 9836619. The rock sample contains a *monokristalin* (90%). *lithic* (2%) and silica sediment (8%). The rock name is *quartz arenite* [20]

Rock samples were taken from 150 meters south of Kedaton temple at coordinate 48 M 0349139 9836619. The rock sample is cream/white and pearly and contains 100% colorless calcite. In fig.4, the sample is classified as carbonate rock and known as Calcite Sandstone (Cal)[24]

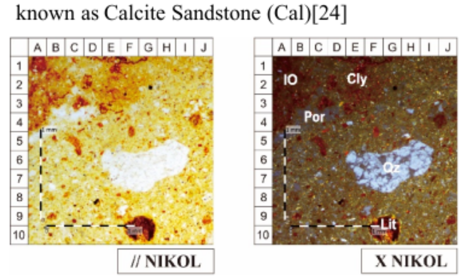

Fig. 2 Clay stone sample from Kembarbatu Temple

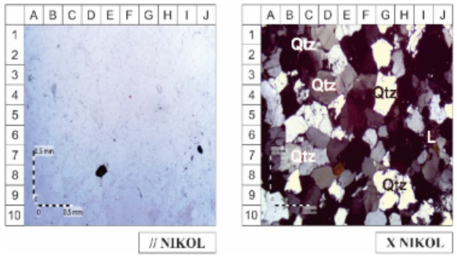

Fig. 3 Quartz Arenite sample from Kedaton Temple

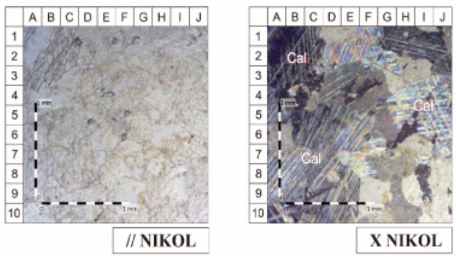

Fig. 4 Calcite Sandstone sample from Kedaton Temple

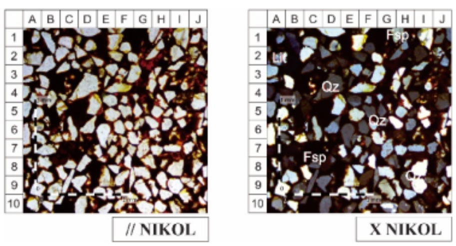

Fig. 5 Tuffaceous Sandstone sample from Gumpung Temple

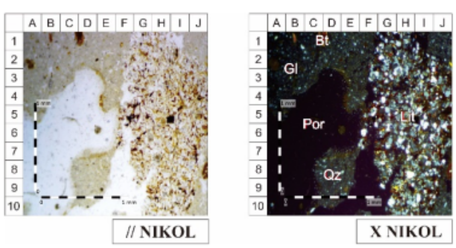

Fig. 6 Andesite stone sample from Kutomahligai Temple

In fig. 5, the rock samples were taken from the reconstruction room of the Gumpung temple fence (GT) at coordinate 48 M 0351746 9836749. The sample is cloudy white, and brownish cream. The rock sample contains 6% quartz (Qtz), having 1% brown biotite, and 42% colorless lithics. The primary mass is 25% grayish cream, dark gray glass (PPL), and 26% porosity. Through the pyroclastic rock classification, the rock name is known as *Tuffaceous Sandstone/Vitric Tuff* [21].

Rock samples were taken 200 meters from the east side of Kutomahlihai temple at coordinate 48 M 0348611 98373699. In fig. 6, The rock sample shows cloudy white with greenish and brownish gray spots, having a primary mineral content in the form having a primary mineral content in the form of 38 % colorless quartz, 45 % colorless (cloudy) plagioclase, and 12 % colorless alkali feldspars. Based on the classification of extrusive igneous rock, the rock name is known as Andesite [25].

Based on the results of the petrographic analysis of 3 samples from the Muarajambi temple area, rock characteristics were identical to materials from the Muara Enim rock formation, such as claystone from Kembar Batu Temple and quartz arenite from Gedong 1 Temple. Meanwhile, the characteristics of the Kasai rock Formation were shown by tuffaceous sandstone samples from Gumpung Temple. So, these components were made in situ in Muarajambi temple area. Muarajambi temple area generally uses claystone as the material for the temple building and floor. It is because claystone is suitable for buildings established on a wetland as it is waterproof, heat absorbent, and durable [10].

Claystone used for temple buildings indicates that it is light and non-waterproof, so it is suitable for buildings established on a wetland [26]. Besides, some temples use two materials, such as clay stone with tuff and clay stone with sandstone. At Gumpung Temple, the brick structure is paired with tuff on the fence around the temple.

Likewise, the Kedaton temple's staircase is made from claystone and sandstone (Fig.7). Calcite sandstone from the Kedaton temple is a *makara* (staircase decoration). It is indicated that this makara was brought by an outsider as a gift for the temple.

This is proven on the surface of the written makara [1] ll *pamur sitanira mpu* ku [2] *suma* ll 0 \\ (…), which is interpreted as a gift from Empu Kusuma [27]. Empu is the title of a Hindu priest, while Muarajambi temple has a Buddhist background. So, it is estimated that the makaras were gifts from Hindu priests outside the Muarajambi temple area (Fig.8).

The function of andesite samples near Kembarbatu Temple is unknown and is thought to have come from outside the Muarajambi temple area. It is indicated that this sample is a statue fragment because, in Muarajambi Museum, there are also statues made of andesite stone. Sandstones and tuffs are used as statue material, as the Dualapara statue from Gedong temple is made from sandstone, and the Prajnaparamitha statue from Gumpung temple is made from tuff.

Fig. 7 The door gate of Kedaton Temple made of claystone and quartz arenite

Fig. 8 Inscription in Makara, Kedaton temple: [1] ll pamur sitanira mpu ku [2] suma ll 0 \\ (…)

3.3 Material Sources of Muarajambi Temples

The material source analysis is known by carrying out an interpretation of the relationship between the placement of the sample and the rock formation at a regional scale.

Therefore, it can indicate the material source of the temple building if it is from the inside or near the site location or the material taken from outside the location/region.

One pottery sample was taken from the courtyard of Gedong temple, 35 meters on the temple's south side, at coordinate 48 M 0350809 9836799.

Two pottery samples were taken from the main temple yard of Astano temple, at coordinate 48 M 0353030 9836929 (table 1).

The results of this XRF analysis showed the content of non-metallic elements which did not react with X-rays. They showed high Al (Aluminum) and Fe (Iron) contents. This is a material characteristic of the Muara Enim rock formation.

Table 1. XRF result sample from Gedong, Astano

	Gedong	Astano	Astano
Si	22,3	24.2	19,8
Al	10,97	10,52	10,18
Fe	5,68	3,24	6,36
Ka	1.50	1,55	1,87
Mg	1,34	1,53	1,35
S	1,24		
LE	55,3	56,68	57,70

XRD analysis was carried out on pottery vessel samples from Kedaton Temple and Astano Temple. The pottery vessel sample was taken from the Kedaton Temple courtyard at coordinate 48 M 0349138 9836619. The pottery vessel sample from Astano Temple was taken from the main temple courtyard at coordinate 48 M 0353030 and 9836929. The results of the XRD analysis of the pottery vessel terracotta material from the two temples, namely Kedaton and Astano. They show several peaks of elements which can then be interpreted into specific types of minerals. There were indications of 2 minerals from Kedaton temple sample contained in the form of SiO2 (Quartz) 86.2 % and O3SrTe (Tellurite) 13.8 % (Fig.9). The mineral from Astano temple sample in the form SiO2 (Quartz) 32.8 % and Si2O6 (leucite) 67.2 % (Fig.10). Both samples contain quite a lot of quartz which is 86.2 % and 32.8 %. These minerals can be used as an aspect of the approach to the material for making terracotta. Quartz and Tellurite are the minerals found in the Muarajambi temple area, which is composed of the Muara Enim rock formation, which is the supplier of these two minerals.

Two rock sediment samples were taken from rock outcrops on the banks of the Batanghari River for XRD analysis, namely samples T-366 and T-367 (at coordinate 48 M 0351977 9837568). Furthermore, this is shown by the XRD results that the mineral content of sedimentary rock T-366: SiO_2 213.8 %, SiFe2O4 43,9%, TeO3Sr 29,2% (Fig.11) and sedimentary rock T-367: SiO_2 70,6%, Si Fe_2 O_4 29,4 % (Fig.12). When compared, the XRD analysis of artifact samples, namely the pottery vessel from Kedaton, Astano temples, and sedimentary rocks T-366, T-367.

They showed a similarity in the high content of silica minerals, such as the sample of artifact from Kedaton (86.2%), Astano (32.8%), and the sample of sediment from T-366 (213.8%), T-367 (70,6%). Tellurite mineral was found in the Kedaton sample (13.8%), Astano sample (67.2%), T-366 sample (43,9 % and 29,2%), and T-367 sample (29,4%). This indicates that the primary material for pottery vessels was obtained from material in situ.

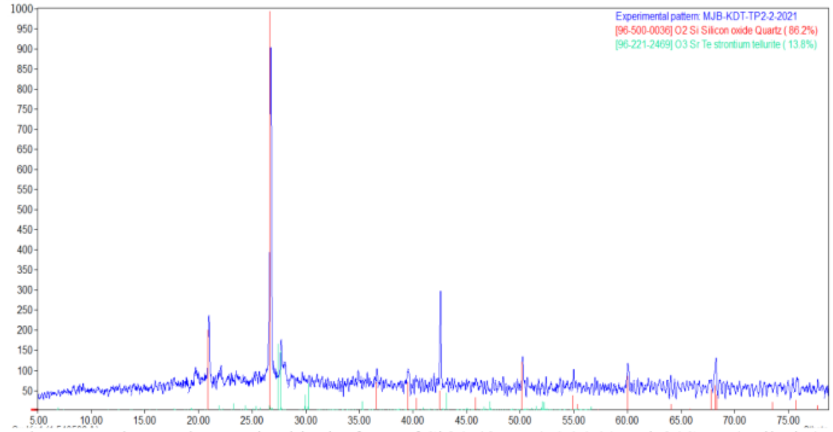

Fig. 9 Kedaton temple sample contained in the form of SiO2 (Quartz) 86.3 % and O3SrTe (Tellurite) 13.8%

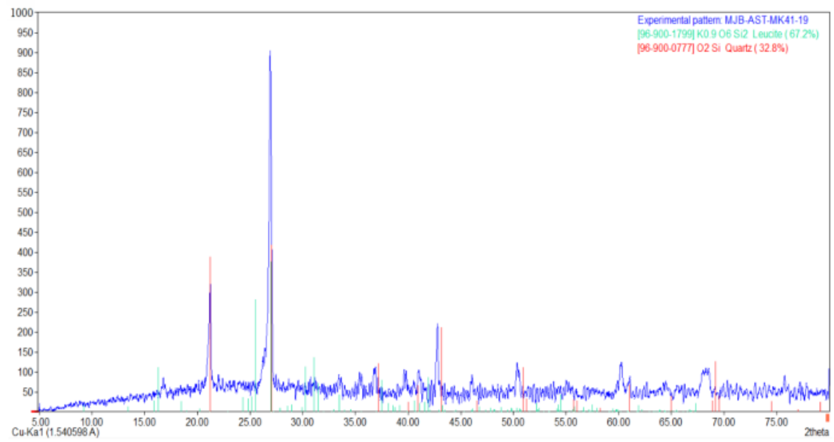

Fig.10 Astano temple sample contained in the form SiO2 (Quartz) 32.8 % and Si2O6 (leucite) 67.2 %

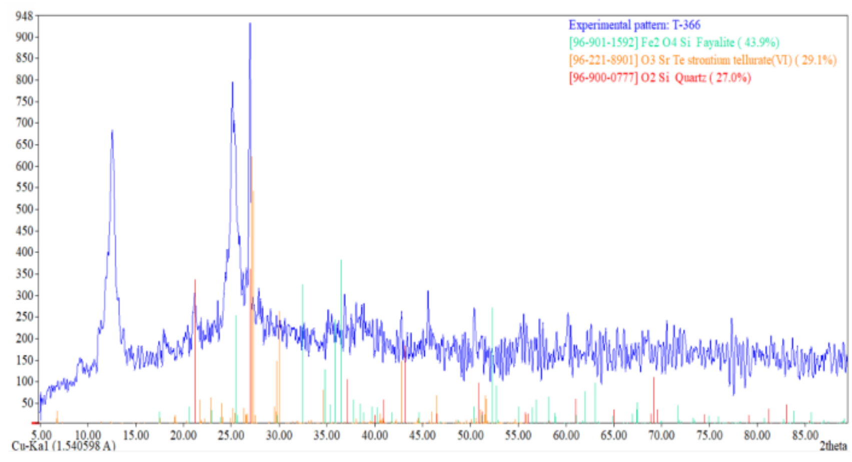

Fig. 11 The mineral content of sedimentary rock T-366: SiO_2 27 %, SiFe2O4 43,9%, TeO3Sr 29,1%

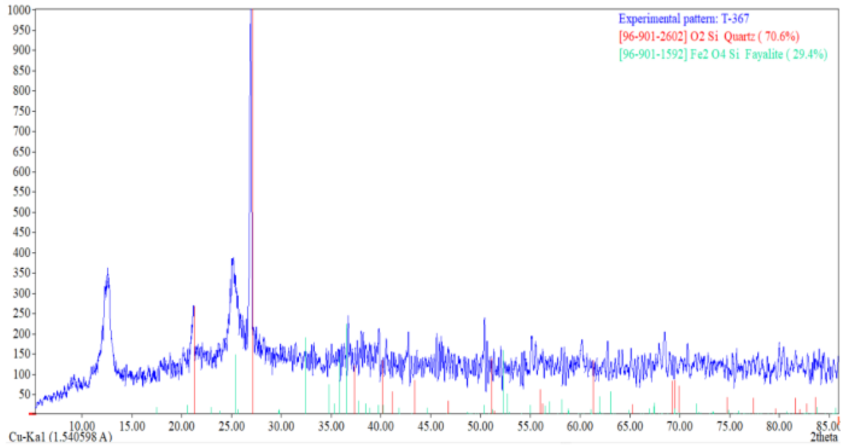

Fig. 12 The mineral content of sedimentary rock T-367: SiO_2 70,6 % and Si Fe_2 O_4 29,4 %

4. CONCLUSION

Muarajambi temple area contains old buildings in the Muara Enim, Kasai, and alluvial alluvial rock formations. The results of the petrographic analysis showed material claystone (Kembarbatu temple), quartz arenite (Kedaton Temple), and tuffaceous sandstone (Gumpung temple). These samples characterize the constituent rocks of the Muara Enim and Kasai rock formations.

Based on the XRF analysis result, the artifact samples (pottery vessels) consisted of 1 sample from Gedong Temple and two samples from Astano Temple containing aluminum (10.97%) and 6.36% iron, which characterizes the Muara Enim rock formation. Likewise, the XRD analysis results of artifact samples (pottery vessels) from Kedaton and Astano temples showed high quart content such as quartz (SIO2): 86.2% and 32.8%, and tellurite minerals: 6.5% and 67.2%. Quartz and tellurite are pottery-forming materials.

This has similarities with sedimentary rock samples taken from the banks of the Batanghari River, such as samples T-366 and T-367. The material samples contained high quartz content of 27% and 70.6%. They have Tellurite minerals like SiFe2O4: 43.9% and 29.4%.

The minerals contained in the rock samples and artifacts (pottery vessels) characterize the characteristics of the Muara Enim rock formations. It is indicated that the temple buildings and pottery vessels were made from in situ materials.

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