Palynological analysis to infer environmental dynamics of Muarajambi Temple compound

F M H Sihombing1, S Sirait2, A Purnomo3, D Sulistiowati3 and T L Indra1

1Geoscience Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia
2Minning Engineering Study Program, Faculty of Engineering, Institut Teknologi dan Sains Bandung (ITSB), Bekasi 17530, Indonesia
3Archeology Study Program, Faculty of Humanities (FIB), Universitas Indonesia, Depok 16424, Indonesia

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

Abstract. Muarajambi Temple Compound situated in the side of a river in Jambi Province, Indonesia. Due to its vicinity to the river, the compound has experienced various geological event associated to the river sedimentation, such as river flood and alluvial sedimentation. We have collected two soil sample from beneath an excavated human-made structure in the sideway of a river. The first sample was collected right in bottom of the structure, while the second sample was collected around 20cm beneath the structure. Taking sample right beneath the structure is ideal for the analyses because this would avoid contamination after the temple construction. The pollen and spore content from these samples were analysed to understand its variation. From the analyses, we found that the first younger sample has larger AP (arboreal pollen) percentage but smaller NAP (non-arboreal pollen) compared to the second sample. This indicate that the vegetation is less dense in the first sample. This study might indicate the environmental changes due to human activities, particularly human activities around the temple compound which led to the construction of the temple compound itself.

Keywords: Pollen, spore, Muarajambi, palynomorph

1. Introduction
Muarajambi Temple Compound is a Buddhist Temple Compound in Jambi Province Indonesia, located right beside the Batanghari River, about 40 km from Jambi City. It was nominated as UNESCO World Heritage and covers area of 2062 hectares with 82 ruins of ancient brick buildings [1]. The archeological studies are frequently carried out in this area. However, the geological study is uncommon, particularly the palynological studies.

Palynology is the science of palynomorphs, a general term for all entities found in palynological samples [2]. In the geological study, the object of palynological studies mostly are palynomorphs from pollen, fern spore, fungal spore, and dinoflagellates. In geological study, palynology was commonly used to determine the relative age of rock strata [3] or the paleoenvironment [4-6]. In archeological study, palynology was commonly used in archaeological sites to infer its environmental condition prior or at the time of its construction [7] and the use of specific type of plants in the past [8-10].
The purpose of this study is to test the application of palynological analysis to infer the environmental dynamics of area around of the Muarajambi temple compound. It is expected that this initial study could be the starting point for a more detailed study.

2. Methodology
Two soil samples were collected beneath the brick structure in the Muarajambi Temple Compound. samples taken from Excavation Pit U17-B12, west wall (figure 1). The geographical coordinate of the excavation pit is 01° 28’ 39.4” S and 103° 38’ 33.5” E. The first soil sample (labeled as S2) were collected right beneath the brick structure, around 46 cm from the top surface. The second soil sample (labeled as S1) second collected 10 cm beneath the sample S2. Each sample weighted around 200 mg each. The sample S2 assumed to represent soil horizon right before the construction of temple, while the sample S1 represent relatively older horizon prior to the construction of the temple.After samples were collected, both were prepared for palynological studies Institut Teknologi Bandung (ITB) Palynological Laboratory. After prepared, the sample was analysed to determine its palynomorph content using Olympus CX23 microscope. From the determination process we were able to interpret the genus of species of the plant types where the palynomorph is derived. Using this dataset, the percentage of AP (arboreal pollen) and NAP (non-arboreal pollen) was calculated. In addition to that, the similarity index between these two samples was calculated using Sorensen Similarity Index [11]. The diversity index for each sample was calculated using Shannon Diversity Index [12, 13].

2.1. AP and NAP percentage
After every palynomorph was determined in each sample, the percentage of AP and NAP pollen was calculated compared to the number of all pollen and spore that are collected. Since AP derived from wooden plants, AP percentage will reflect the relative abundance of wooden plants in the area. Meanwhile, larger NAP percentage will reflect the relative abundance of grass and bush plants because NAP was produced by these types of plants.

2.2. Fern spores and fungal spore occurrence
Both fern and fungal lived in relatively more humid environment compared to woody plants. Therefore, the occurrence of fern spores and fungal spores could indicate the humidity when the soil accumulated.

![Figure 1](image_url)

Figure 1. (Left) Excavation pit U17-B12. Photographed toward west, with hammer for scale. (Right) Sampling location for sample S1 and S2 is marked in the inset picture. Hammer and measurement tape for scale.
In this study the total of fern spores and fungal spores are calculated and compared between each sample to infer the humidity variation between two samples.

2.3. Sorensen similarity index
The similarity between to samples was analysed using Sorensen Similarity Index. The Sorensen Similarity Index (SS) area calculated using equation 1 [11]:

$$SS = \frac{2a}{2a + b + c}$$

where ‘a’ represents number of species that common in both samples, ‘b’ represents number of species only found in the first sample, and ‘c’ represents number of species that only found in the second sample.

2.4. Shannon diversity index
The Shannon Diversity Index was calculated to measure the diversity for each sample. The index (H) was calculated using the equation 2 [12]:

$$H = - \sum_{i=1}^{n} p_i \ln p_i$$

where $p_i$ refers to proportion of individuals belong to the species $i$ and $n$ refers to total number of species in the sample. This index was based on the common question in communication theory where workers need to predict the next letter in a message or other form of communication media [4]. The lower indices value indicates more diversity while higher indices values indicates less diversity.

3. Results and discussion
The result of palynomorph analysis is shown in table 1. From this table we can see that there are thirty-five taxa identified from two samples. The palynomorph abundance is relatively low. This condition possibly because of the small amount of soil samples collected for each sample collected. The S1 was signified by the occurrence of *Pinuspollenites* sp. While the S2 signified by the occurrence of plants from genus *Gramineae* and *Cyperaceae*.

From the calculation of AP and NAP (table 2), it can be seen that from S1 that represents the older horizon to the S2 that represent the younger horizon, the percentage of AP is decreasing while the NAP is increasing. The decreased AP indicates decreasing number of wooden plants between the S1 horizon and S2. This can be associated to land clearing that might needed to develop community around the temple. In addition, there are increasing NAP percentage, that support the land clearing assumption, but also support the possibility of agricultural work around the study area.

As seen in the table 2, the occurrence of fern spores and fungal spore is drastically increased. Despite the total count only increasing by one, the percentage of spore compared to other samples increased from 35% to 44%. We assume these increases was associated with increasing humidity in the area due to climate change by the time the of the temple construction.

The result of Sorensen Similarity Index is 56%. According to Krebs [14] this number represent relatively high similarity between the two samples. This shows that despite the difference, the two samples hold similarity. This similarity was expected from two samples that taken from the same location with minor difference to the environment.

For each sample, the Shannon Diversity Index shows medium diversity. Interestingly, the index is decreasing from S1 to S2. Therefore, we interpret that the type of plants is decreasing from the S1 to S2, although the type of plants for both samples are still considered at medium diversity.
Table 1. List of palynomorph found in collected samples.

| Palynomorph            | Number of occurrence | Family          | AP/NAP |
|------------------------|----------------------|-----------------|--------|
|                        | Sample S1 | Sample S2 |                        |        |
| **POLLEN**             |            |            |                        |        |
| Pinuspollenites sp.    | 4          | 0          | Pinusaceae              | AP     |
| Amaryllis belladona    | 2          | 0          | Amaryllidaceae          | AP     |
| Elephantopus mollis    | 5          | 0          | Asteraceae              | AP     |
| Dalbergia retusa       | 1          | 0          | Fabaceae                | AP     |
| Cordia spinescens      | 5          | 7          | Boraginaceae            | AP     |
| Bambusa arudinacea     | 2          | 0          | Poaceae                 | NAP    |
| Cyclista aequinoctalis | 1          | 1          | Bignoniaceae            | AP     |
| Guetarda foliacea      | 1          | 2          | Rubiaceae               | AP     |
| Pelogyne purpureo      | 0          | 1          | Fabaceae                | AP     |
| Oryza latifolia        | 0          | 2          | Graminieae              | NAP    |
| Paspillidium decumbens | 0          | 1          | Graminieae              | NAP    |
| Hoffmania woodsonii    | 2          | 0          | Rubiaceae               | AP     |
| Casearia aculeata      | 0          | 1          | Salicaceae              | AP     |
| Sida rhombifolia       | 4          | 3          | Malvaceae               | AP     |
| Cyperus densicaepitosus| 0          | 1          | Cyperaceae              | NAP    |
| **FERN SPORE**         |            |            |                        |        |
| Selaginella haematodes | 1          | 0          | Selaginelaceae          |        |
| Selaginella exalata    | 5          | 4          | Selaginelaceae          |        |
| Selaginella horizontalis| 1        | 3         | Selaginelaceae          |        |
| Hymenophyllum breviform| 1          | 0          | Hymenophyllaceae        |        |
| Trichomanes sphenoides | 1          | 0          | Hymenophyllaceae        |        |
| Thelyptetr poitena     | 1          | 0          | Polypodiaceae           |        |
| Polypodium pectinatum  | 0          | 4          | Polypodiaceae           |        |
| Vitaria lineata        | 1          | 0          | Polypodiaceae           |        |
| Salvinia radula (?)    | 1          | 0          | Polypodiaceae           |        |
| Blechnum occidentale   | 1          | 0          | Polypodiaceae           |        |
| Dictyoxyphium panamense| 1          | 4          | Polypodiaceae           |        |
| Vitaria graminifolia   | 0          | 0          | Polypodiaceae           |        |
| Adiantum frustuosum    | 0          | 1          | Polypodiaceae           |        |
| Cyclopolis semicordata | 1          | 0          | Polypodiaceae           |        |
| **FUNGAL SPORE**       |            |            |                        |        |
| Pluricellaesponetes bivalve| 0  | 10         |                        |        |
| Involutisporonites     | 0          | 2          |                        |        |
| Pluricellaesporites    | 1          | 0          |                        |        |
| Inapertisporites       | 1          | 10         |                        |        |
| Fusiformisporites      | 2          | 0          |                        |        |
| Exesisporites          | 2          | 0          |                        |        |
Table 2. AP pollen, NAP pollen, and spore occurrence in collected samples.

| Sample code         | S1  | S2  |
|---------------------|-----|-----|
| AP (total)          | 25  | 16  |
| NAP (total)         | 2   | 4   |
| Spore (total)       | 15  | 16  |
| AP (divided by total pollen) | 0.92593 | 0.8 |
| NAP (divided by total pollen) | 0.07407 | 0.2 |
| Spore (divided by total palynomorph) | 0.35714 | 0.44444 |

From the analysis we interpret that the variation of palynomorph content is possibly affected by the human activities in the area. The decreasing AP, increasing NAP, and slightly decreasing Shannon Diversity Index possibly associated with the land clearing and agricultural activities that tend to replace trees to bushes and grasses, and reduced diversity within area.

The result of this study is far from complete. There are limitations that limit the impact of this studies. The age difference between to samples is not known yet. Therefore, the result is only able to tell the difference between younger and older horizon. It is important to define the geological and cultural horizon properly. In addition, because the study area is very close to the river prone to flooding, we still cannot make sure whether the palynomorph observed in the collected samples derived entirely for the vicinity of study area or have been mixed with other palynomorph transported by the flood. If the second possibility that actually occurred, hence the result of this study might represent a wider area to uphill than we predicted.

4. Conclusion
This study finds that the brick construction where two soil have been sampled has variation in its pollen and spore contents. From older to younger horizon, the AP percentage is decreasing while the NAP percentage increasing that possibly indicate land clearing and vegetational change. The spore percentage is increasing possibly due to increasing humidity. The Sorensen Similarity Index shows that two samples still have high vegetation similarity while the Shannon Diversity Index indicates that the diversity is slightly decreased from the older to younger sample. However, due to the small amount of area samples, the result of this study is far from complete.

Despite the result is still incomplete, this initial study demonstrates that palynological studies from the soil samples beneath the brick structures could be useful to provide additional insight of the environmental dynamics in the study area. A follow-up study with more samples can be carried out to better understood the environmental dynamics of the study area.

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