Paleoecology and Paleoclimate of Tanjung Formation Deposition, Based on Palynological Data From Siung Malopot, Central Borneo

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Abstract. The northern part of Barito basin is exposed around Siung Malopot area (Central Kalimantan), showing the late cretaceous basement of andesite lavas and granite intrusion. The basement is unconformably overlaid by the rocks of Tanjung formation at middle to late Eocene age. Compressive phase during Miocene and Plio-Pleistocene folded and uplifted all existing rocks, made the rocks become relatively north-south structurally oriented. The exposed Tanjung formation consists of sandstone, mudstone, siltstone with intercalation of coals and thin layers of limestone. These lithologies may represent the upper parts of Tanjung formation. Palynology quantitative study is an approach to identify the palaeoclimate and palaeoecology of a certain sedimentation system. Analyses from 18 samples taken from lithologies of Tanjung formation show the presence of palinomorph fossils associated in Proxapertites operculatus zonation indicating the P18-P20 age intervals, or late eocene age. The ratio of spore and non-spore percentage, as well as the comparison between arboreal pollen (AP) and non-arboreal pollen (NAP) show the significant change of environment from time to time during the deposition of the Tanjung formation, also indicating the climate humidity that became more stable to the younger ages. From 52 observed taxa in the samples, the ratio of marine versus non-marine taxon indicates the influence of sea-water influx in the sedimentation system, explaining the possible presence of thin limestone intercalations at the upper parts of Tanjung formation.

Palynology quantitative study on Tanjung Formation indicates the sedimentation of this formation was in backmangrove environment that tends to become more influenced by marine conditions.

1. Introduction

Borneo island has a complex geological history, as can be clearly seen from the diversity of basement lithology as a result of tectonic events at Pre-Tertiary age. The island is composed of varied amalgamation basement that preserved in cratonic area, then metamorphed and folded during the pre-tertiary uplift [1]. Potential energy resources, such as coal, are also found abundantly in the Borneo island, as in the Tanjung formation in the Barito basin. Tanjung formation along with basement rock are exposed in the research area which is in the northern part of Barito basin, Siung Malopot area, North Barito regency, Central Kalimantan. The coordinates of research area is mN 9821000 - 9828500 mE mN and 302 500 - 308 500 mE (UTM zone 50 S), within 277 km to the northeast from Palangkaraya. Surface geological mapping study was conducted to renew the regional geological map that was done by [2].
Stratigraphy of research area was divided into four unofficial lithology unit, from older to younger are andesit unit (equivalent to Pitap formation), granodiorite unit (equivalent to cretaceous granite group), sandstone-mudstone unit (equivalent to Tanjung formation), and alluvial deposit unit (Figure 1). Geological structure in research area such as fold, thrust fault, and shear fault were developed after the deposition of sandstone-mudstone unit at eocene age. The compression regime is expected to begin at early miocene and reached the peak at plio-pleistocene, along with the tectonic activity in the Barito basin which was associated with Meratus uplift.

Based on the previous research interpretation, Tanjung formation was deposited in the transitional environment with many land plants as the main source of coal formation, which these plants can leave as residual organic material in sedimentary rocks. According to this interpretation, the authors were interested in conducting a palaeoecology and paleoclimate study based on palynological data. Palynology is the study of palynomorph fossils, including pollen, spores, dinoflagellate, acritarch, chitinozoa, and scolecodont, as well as organic materials and kerogen that is found in the sedimentary rocks and sediments [3]. The purpose of this analysis was to determine the depositional environment condition and determine the environmental change during the deposition of Tanjung formation that exposed in the research area.

2. Data Acquisition and Analysis Method

Rock samples required for palynological analysis were fine grained sedimentary rocks (such as clay, silt, shale, silty sand) which has dark color as an obvious indication of organic material in sedimentary rocks. These rock samples were taken at certain points while conducting stratigraphy measuring section (Figure 2), as many as 18 sample from top to bottom of the sedimentary rock outcrop layers. Stratigraphy measuring section was done by measuring the actual thickness of Tanjung formation outcrops that well exposed at the edge of Hasnur road. The samples were then prepared in the Palynological Laboratory in Institute of Technology Bandung to separate the palynomorph fossils with other elements of sedimentary rocks.

The method used in this research was quantitative analysis method, based on calculation of every observed palynomorph, with the following stages:

2.1 Determination Stage
Palynomorph determination was done by palynomorph observation through binocular microscope with 400 times and 1000 times magnification. The goal of this stage was classifying every palynomorph up to the level of family, genus, or species based on its physical properties (such as aperture, size, shape, and ornamentation). Each individual of determined palynomorph was counted and recorded accurately in number.

2.2 Palynomorph Classification Stage
At this stage, the determined palynomorph data taken during the determination stage was classified based on its environment vegetation according to [4]
Figure 1. Geological map of research area
Figure 2. Stratigraphy measuring section column, based on the field observation at the outcrop on Jalan Hasnur (left) and the photo of *Proxapertites operculatus*, index fossil of eocene age (right)

2.3 Data Presentation
The palynological data is presented as palynological diagram. The calculation formulas for palynological diagram are as below:

2.3.1 Palynomorph Proportion Percentage
The percentage of each type of palynomorph can be obtained by comparing the amount of a group of palynomorph with the total number of palynomorphs in each sample (pollen, spores, fungi,
dinoflagellate and foraminifera tests lining). The proportion of a palynomorph group in this diagram illustrates the proportion of plants found in research area during the deposition of sandstone–mudstone unit. Here is the formula of a palynomorph proportion percentage:

\[
\% \text{ taxa} = \frac{\sum \text{峡 taxa}}{\sum \text{all palynomorph}} \times 100 \%
\]

### 2.3.2 Spore / Pollen Percentage

This percentage would give an idea about palaeoclimate according to the humidity level at the past time. The number of spores percentage represents the rate of humidity in palaeoclimate, which leads to interpretation whether the palaeoecology was in dry or wet climate at the certain time. The percentage of spores is a result of comparison of a number of Pteridophyta spores by the total number of all palynomorph (excluding foraminifera tests lining and dinoflagellate), where the formula can be presented as follows:

\[
\% \text{ spore} = \frac{\sum \text{spore}}{\sum (\text{spore} + \text{pollen})} \times 100 \%
\]

### 2.3.3 Arboreal Pollen (AP) / Non-Arboreal Pollen (NAP) Percentage

Arboreal pollen is pollen which was derived from woody plants as part of a forest that is identical with closed environment. Non-Arboreal pollen is pollen of graminiae, herbaceae, and plants that live in an open environment (such as savannas and steppes). The percentage of AP / NAP illustrates the forest environment boundary movement as a reflection of environmental change. Here is the formula to determine the percentage of AP / NAP:

\[
\% \text{ NAP} = \frac{\sum \text{NAP}}{\sum (\text{AP} + \text{NAP})} \times 100 \%
\]

\[
\% \text{ AP} = \frac{\sum \text{AP}}{\sum (\text{AP} + \text{NAP})} \times 100 \%
\]

### 2.3.4 Marine / Non Marine Taxa Percentage

This percentage can be used to determine the movement of the shoreline to estimate the influence of marine environment during sedimentation, which can be formulated as follows:

\[
\% \text{ Marine Taxa} = \frac{\sum \text{Marine Taxa}}{\sum (\text{Marine Taxa} + \text{Non-Marine Taxa})} \times 100 \%
\]

\[
\% \text{ Non-Marine Taxa} = \frac{\sum \text{Non-Marine Taxa}}{\sum (\text{Marine Taxa} + \text{Non-Marine Taxa})} \times 100 \%
\]

### 3. Age and Depositional Environment Analysis of Tanjung Formation

Based on the analysis of palynological diagram (Figure 3), the age of deposition sandstone-mudstone unit is late eocene. It is according to the presence of index fossils like Proxapertites Operculatus, and the presence of other fossils such as Proxapertites cursus, Proxapertites sp., Meyeripollis naharkotensis, Cicatricosisporites eocenicus, Cicatricosisporites dorogensis, and Palmaepollenites kutchensis that indicate that the sandstone-mudstone unit are in Proxapertites operculatus zone which is in P18-P20 age or late eocene [5]

In general, vegetation environment of sandstone-mudstone unit was backmangrove, proven by the abundance of Acrosticum auerum with average number in each sample reaching 48.59% (Figure 3). According to [4], this vegetation environment associated with depositional environment at the lower delta plain (Figure 4)
Palaeoecology and palaeoclimate condition at the deposition of sandstone-mudstone unit time was generally interpreted as the closed environment with high humid climate, evidenced by the average assemblage of AP (Arboreal Pollen) is 71.66% and the average assemblage of spores reached 68.82% in each sample. Nevertheless, there was the influence of the sea water flux, characterized by the presence of little amount of marine taxa percentage, with the average assemblage up to 2.46% per sample.
Figure 3. Palynological Diagram, including Spore-Pollen percentage chart, AP/NAP percentage chart and Marine / Non Marine Taxa percentage chart.
4. Palaeoecology and Palaeoclimate Analysis

To simplify the palaeoecology and palaeoclimate analysis explanation based on the spore-pollen percentage chart, AP/NAP percentage chart and Marine / Non Marine Taxa percentage chart in palynological diagram (Figure 3), the graph was divided into three time deposition intervals from the older to the younger.

At the interval A, based on the AP/NAP chart and Spore/Polen chart, the fluctuation of palaeoecological changes during that period can be obviously seen. However, the opposite trend is shown by the palaeoecological and palaeoclimate conjunction: the closed environment associated with the low humidity environment (dry climates) and vice versa. The number of palinomorphs *Acrosticum aureum* was found very abundant at this interval, reached the highest number over all intervals at 79.09%. This kind of palinomorph indicates the vegetation environment of backmangrove [4]. There was a little effect of the sea water influx at the interval A, evidenced by the average percentage of Marine-Non Marine only at 1.5%.

Unlike the interval A, the graphic trend between the AP/NAP chart and Spore/Polen chart shows a relatively trend, they both show the slightly decreased trend from the older to the younger age at the same percentage level. The result of this comparison indicates the gradual environmental change from the closed environment into more open environment and also the gradual change from the dry climate into wetter climate at the same time. *Acrosticum aureum* is still found abundantly at the interval B with an average percentage of 51.82%, showing the same vegetation environment as interval A, backmangrove. There was an increase of marine taxa palinomorph number at this interval, where the average percentage of marine taxa increased up to 2.92% and foraminifera test lining taxa reached the peak of its development in this interval (7.02%). It is estimated that the marine influence towards to depositional environments is greater than at interval A.

The AP/NAP chart and Spore/Polen chart at interval C remained relatively constant, shows stable palaeoecological and palaeoclimaltical change during that interval. There was a tendency of environmental changes into more open environment and more dry climate, compared to the two previous intervals. Depositional environment at this interval was still in backmangrove environment based on the highly abundance of *Acrosticum aureum*, but the number was steadily decreasing. The average percentage of marine taxa in this interval reached 2.94%, slightly increased compared to the previous interval. Interval C obtained the highest marine influence compared to the two previous intervals.

Based on the percentage of *Acrostichum aureum* and the percentage of marine taxa, there was a tendency of environmental changes from terrestrial environment to transitional environment from the older to the younger strata, but this condition could change fluctuatively at the certain time, as it have happened to the interval A. This tendency can explain the insertion of thin limestone in sandstone-mudstone unit. We interpret this environmental changes as a result of the sea level rising.
5. Conclusion
Sandstone-mudstone unit synchronized by the authors as Tanjung formation that was deposited at late eocene age (P18-P20). Vegetation environment of this unit in general was backmangrove that associated with lower delta plain depositional environment. This analysis also shows the palaeoecological condition of research areas was largely covered with forest as a closed environment with high humidity (wet climate). The environmental changes from the older to the younger deposition of sandstone-mudstone unit was relatively stable, although fluctuation is happened at certain interval, but it also shows a tendency to be more open and dry environment.

The percentage of *Acrosticum aureum* was inversely proportional to the percentage of marine taxa, which indicates a change of the terrestrial environment into the transitional environment, from older to younger interval. This may explain the insertion of thin limestone that are present in upper Tanjung formation in research area.

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