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39 Dian Sustinere

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RESEARCH PAPER

# Correlation of Lithofacies and Depositional Environment using Markov Chain Analysis in Sambipitu Formation at Ngalang River, Gunung Kidul, Yogyakarta, Indonesia

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**Abstract.** The Research area is located at Ngalang river, Gedangsari sub-district, Gunung Kidul Regency, Special Region of Yogyakarta. The research area is part of Southern Mountain area which is composed of lithology of Sambipitu Calcareous Sandstone. . The depositional process phase in the Sambipitu Formation has a unique pattern and its relevance to previous lithology, so the stratigraphic position and lithological repetition pattern were reviewed using the statistical method (Markov Chain). The aim of this research is to use geostatistics to examine the sedimentation trend in order to predict the existence of rock facies in Sambipitu Formation. In each unit of lithology cycle, geostatistics is expected to assist in predicting and interpreting the significance of subsequent lithology appearances. The research method used were measured stratigraphy, determination of rock age and depositional environment based on fossil identification. In addition, this research used probability matrix in Markov Chain analysis. The results of the Markov chain analysis showed thatlithology of rock in the Upper Sambipitu Formation had a non-random transition pattern. The results of statistical calculation showed that the calculation value was greater than the Chi-square table value (333.9 > 34.38) that the Ho component was rejected. Lithofacies and depositional environment are correlated to several geological aspects such as distribution of rock facies, source of rock, paleobtahymetri, trace fossils and sedimentation process.

**Keywords:** Stratigraphy, Markov Chain, Correlation, Facies, Sambipitu

## 1. Introduction

Geological conditions define tectonic activities, basin settings, and sequence of rocks or stratigraphic (Suprapto et al, 2017). The applied statistics in geological science or condition has not been recognized yet could solve any problem related to geological condition especially for pattern of lithology and facies cycle. In order to characterize surface and subsurface variability and related instability, geostatistical approaches have been used extensively (Michael et al, 2010). For example, a

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study by Jun (2019) used special seismic oceanography to estimate speed and temperature using seismic data. The geostatistics also could be applied in determining depositional environment. Furthermore, the siginificance of vertical facies in Australia could be determined with Markov chain analysis as well (He et al, 2019). Apriani (2016) used Markov chain analysis to estimate the developed lithology and depositional environment in West Sumatra.

The Sambipitu Formation is part of in Southern Mountain Zone (Van Bemmelen, 1949), which has been studied by many researchers. The presence of Sambipitu Formation has an important aspect for stratigraphy analysis due to the stratigraphic position of Sambipitu that is located in between volcanism period and post volcanism period (Surono et al, 1992). Bothe (1929) and Pandita (2008) reviewed about geological aspect specifically in stratigraphy. The research area of this study is located in the Southern Mountain Zone, specifically at the Ngalang River, Gedangsari Sub district, Gunung Kidul Regency, Indonesia. The geological data were collected by observing the outcrop along the Ngalang river. The upper part of rock distribution in the Ngalang river is dominated by calcareous rock composition with several trace fossils (Flowers, 2019). Pramunita and Pandita (2020) reported that the trace fossils consisted of several ichnofacies that were successfully identified as Scoyenia, Skolithos, Cruziana, dan Zoophycos. There have been several geological qualitative studies conducted in the Ngalang river. However, the geostatistics researches that are related to depositional environment specifically in quantitative analysis (Markov chain) have never been done.

This research used a quantitative descriptive method with Markov chain analysis. Markov chain analysis combines the geological data (qualitative data) and statistics data (quantitative data). The purpose of this research is to identify lithofacies and facies model and also to determine the correlation of Markov analysis and depositional environment. The rock lithology of the Sambipitu Formation is made up of clastic and carbonate rocks. The Markov chain method was used to analyze a sequence of lithology and facies from Sambipitu Formation in this study. The sedimentation pattern could be interpreted from the result of the repetition of lithology especially in the Sambipitu Formation at the Ngalang River. The repetition of lithology could determine the lithofacies that represent the depositional environment of sedimentation process. By using Markov chain analysis, the prediction of lithology or sedimentation process was determined by probability or quantitative number that must be tested in Chi Square Analysis. The Markov chain analysis also implicates the recent sedimentary rocks product such as alluvial sediment or tsunami sediment are deposited.

## 2. Literature Review

Current morphological and rock conditions around a river can describe past condition of the river, such as rocks formed or lithology, geological structure, current erosion and sedimentation process (Zamroni, 2020). Sedimentation process requires some flow current such as turbidity current in a basin as transportation media (Selley, 1985). The Markov chain analysis can be used to assess the role of determinism ("memory") in a series of physical events (Lumsden, 1971). The value of X factor at $t$ (time) process was named by *state* Hillier et al (1995). If this system moves from *state* $i$ in interval time to *state* $j$, the system can be determined as a transition from $i$ to $j$. The possibility of transition in a step of *state* $i$ heading to *state* $j$ could be determined in a formula:

$$P_{ij} = P\{X_{t_k} = j | X_{t_{k-1}} = i\}$$

## 3. Methodology

Research in this study was divided into three steps. The first step was fieldwork, followed by data analysis and report preparations respectively (Figure 1). ). Primary data which was used for analysis was obtained from stratigraphic data. The stratigraphic data was collected from the Ngalang river, using a stratigraphy section measurement with a thickness of 55.9 meters. The data was gathered fromobservation point 1 to 6 that were located on the upper part of Sambipitu Formation (Figure 2). Every observation point represented different rock types or lithology variation. However, before the primary data was obtained, a pre-eliminary analysis was conducted to collect secondary data and to produce a topography map. The fieldwork was conducted to identify the characteristic of lithological properties such as colour, sedimentary structure, texture, rock composition, and fossils content.

During the second step, fossil analysis was conducted to identify planktonic and benthonic foraminifera. The analysis was carried out to determine the age and depositional environment in the research area. The determination of age was done by observing the abundance of foraminifera in small grain size rocks samples., The determination of the age as well as the depositional environment would support the rock distribution and rock facies. Meanwhile, the stratigraphy of Sambipitu Formation was analysed using Markov Chain model which consist of observation of transition matrix and probability and transition matrixes. A Markov chain is a model of the random motion of an object in a discrete set of possible location (Walrand et al, 2000). In addition to the Markov chain analysis, matrix of possibility frequent transition and chi square analysis were also conducted. Megascopic rock name classification used was Pettijohn (1975). The classification used in facies determination was Bouma (1962) and Walker (1970). The Zone of Blow (1969) was used in determining the age and the depositional environment according to Phleger (1951) and Tipsword, Setzer, and Smith (1966).

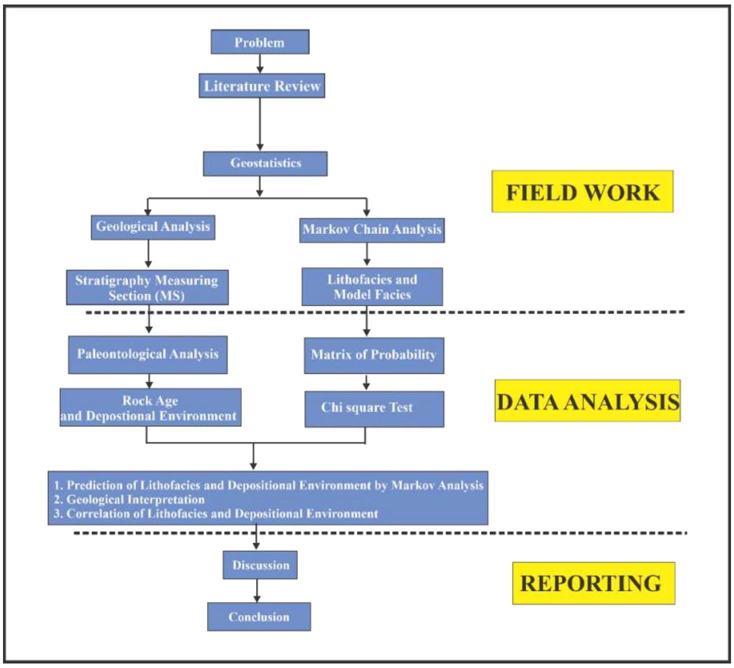


**Figure 1.** The methodology flow chart

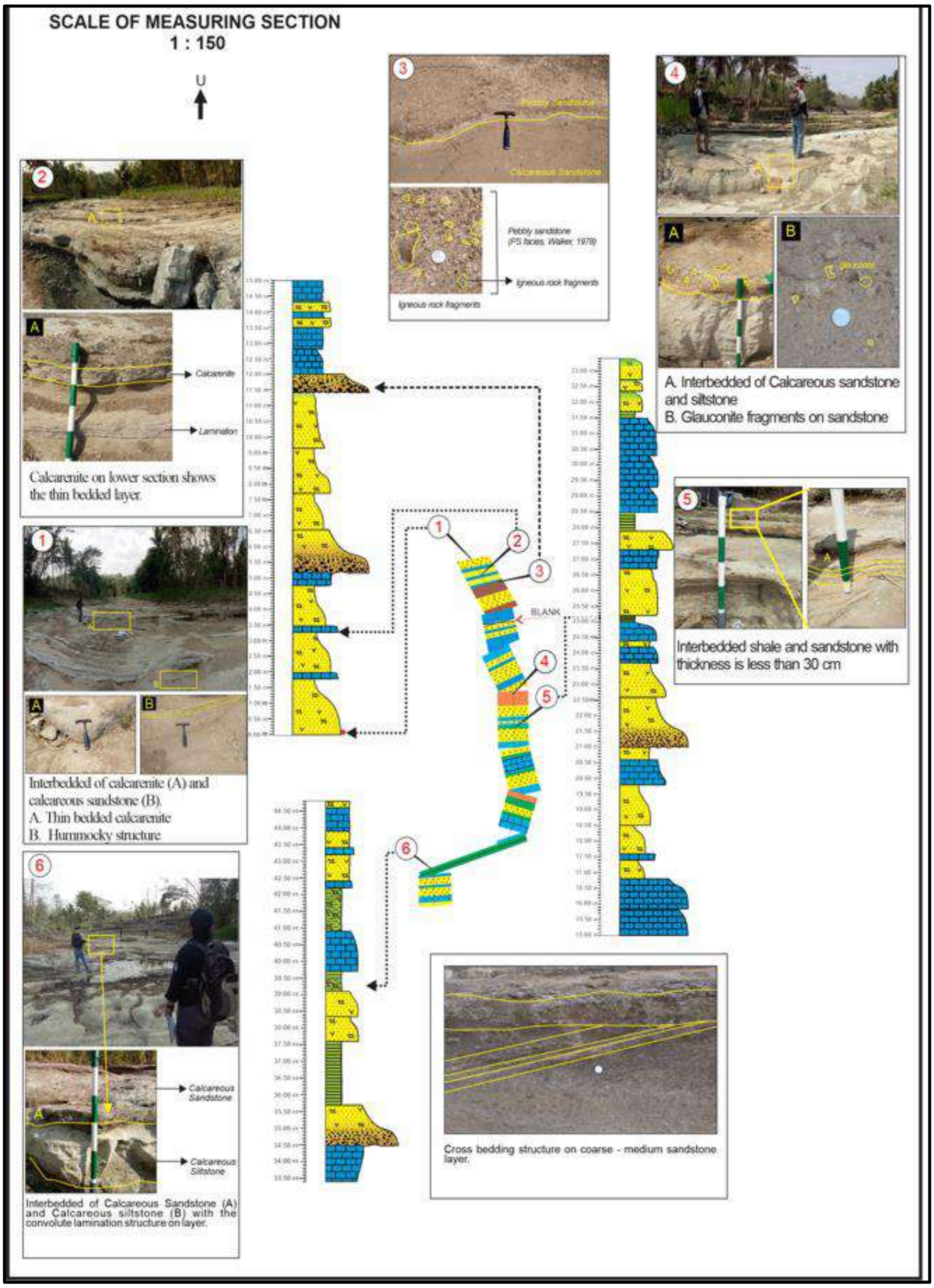


**Figure 2.** Track map of measuring section at Ngalang river

## 4. Result and Discussion

The measuring section at the Ngalang River consisted of six observation points, which are point 1,2,3,4,5, and 6 which represented different type of rock. Based on the result of stratigraphy section measurement, the thickness of rock was about 55.90 meters. The rocks consisted of Calcareous Sandstone Calcarenite (Sandy Limestone), Polymics Breccia, Pebbly Sandstone, Shale, and Calcareous Siltstone. The age of the rocks was determined using foraminifera fossils identification. The age obtained was N

12 to N 14 (Middle Miocene) (Blow, 1969)). The rocks were deposited at the Upper part of the Sambipitu Formation and were deposited at the depth of 20 m to 500 meters (Inner Neritic to Upper Bathyal) (Phleger, 1951) (Figure. 3).

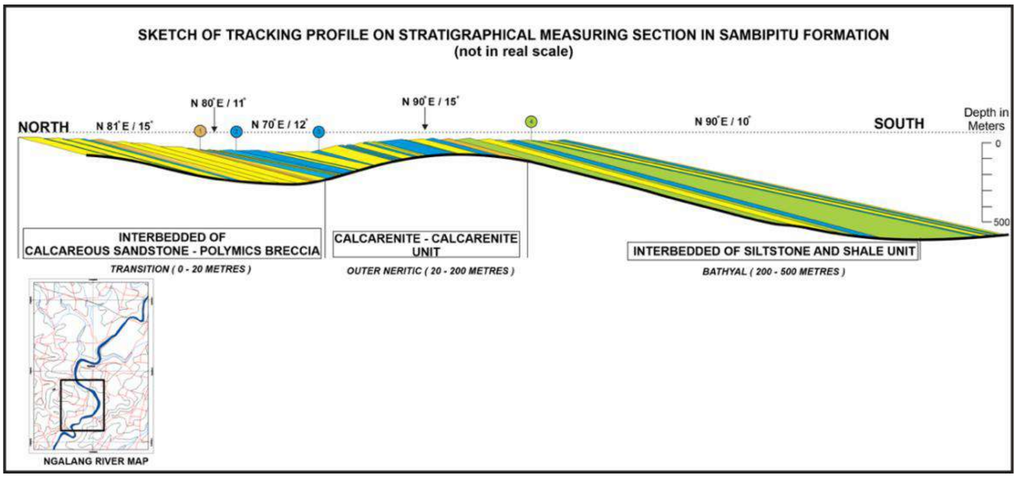


**Figure 3**. The profile of tracking map of measuring section at Ngalang river

## 4.1 Markov Chain Analysis (Lithological Pattern)

The Markov analysis was carried out at 44,90 meter thickness meter of the measuring section along the Ngalang river in fieldwork observation. The measuring section profile was arranged at interval of 0.2 meters (20 cm) from bottom to top layers of rock distribution (Figure 4). The transition of observation matrix and the probability of transition and observation matrix showed the probability value of each rock. Data obtained from the two matrixes were then used in Markov Chain analysis to show the cycle of rock repetitions that are related to each other.

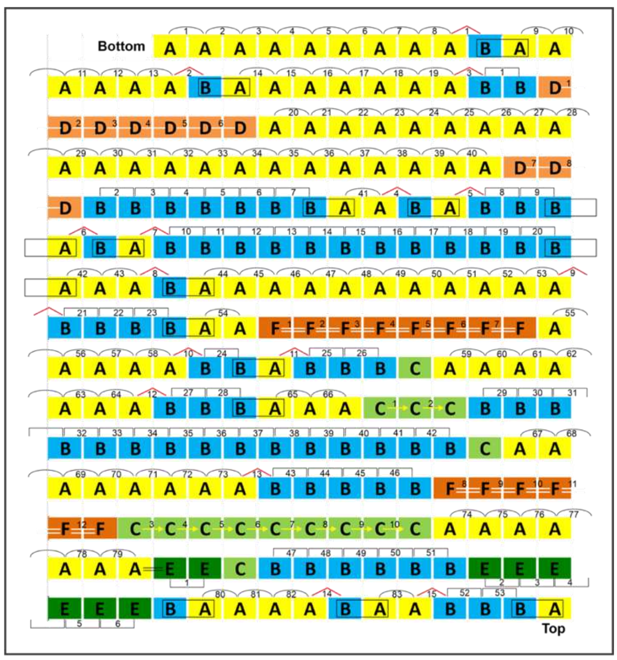


**Figure 4.** The sortation of repetition rock lithology with markov chain analysis

At Matrix of Random Transition, the probability matrix of frequency and transition included the frequency of possibility values is allocated to each possibility. It obtained the pattern of lithology cycle that was tested using Chi Square. By reviewing the chi square result, the hypotheses of random or no random rock cycle was determined. The thickness of 11 meters from the measuring section was used to compare to the presence of the next rocks by the calculation.

The Markov chain facies also was analyzed using Bouma Facies Model (1962) and Walker Facies Model (1978) based on the texture of grain size, sedimentary structures, geometric, and rock relationship. The sedimentation process was carried out by turbidity current, which created the submarine fan on submarine slopes, according to the understanding of lithology period at the Upper Sambipitu Formation. The result of facies was classified with interval of 0.2 meters (20 cm) that was arranged from bottom to top layer based on Bouma Facies Model (1962) and Walker Facies Model (1978) (Figure. 5).

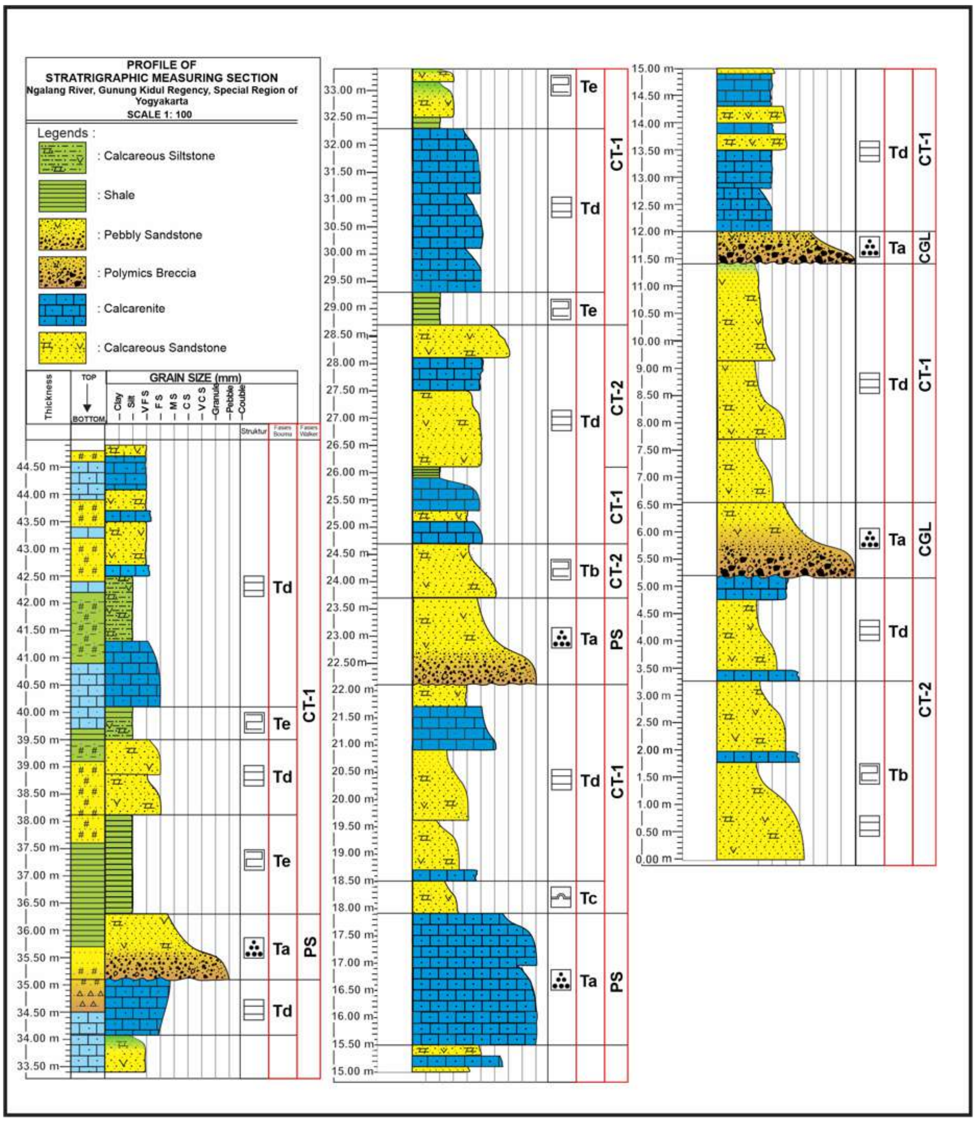

**Figure 5.** The sortation of repetition rock lithology with markov chain analysis

Based on Bouma Facies Model (1962), the repetition pattern of facies consists of Interval with Parallel Lamination turned to (Td) Upper Interval with Parallel Lamination (Tb) and Interval with Graded Bedding (Ta) upward. At the middle part of the section, the facies consists of Interval with Current Ripple Lamination and Convolute Lamination (Tc) - Upper Interval With Parallel Lamination (Td) - Interval with Graded Bedding (Ta) – Lower Interval With Parallel Lamination (Tb) – Upper Interval With Parallel Lamination (Td) – Pellitic Interval (Te) – Upper Interval With Parallel Lamination (Td) – Pellitic Interval (Te). At top part, the facies consist of facies Upper Interval with Parallel Lamination (Td) - Interval with Graded Bedding (Ta) – Pellitic Interval (Te) - Upper Interval with Parallel Lamination (Td) – Pellitic Interval (Te) – Upper Interval with Parallel Lamination (Td).

Based on Bouma Facies Model (1962), the repetition pattern of facies at lower part of Upper Sambipitu Formation consists of Classical Turbidite (CT-2) and Clasts supported Conglomerate (CGL). At the middle part, the rock facies consists of Pebbly Sandstone (PS) and Classical Turbidite (CT-1). At the upper part, the facies model was classified with Classical Turbidite (CT-1), Pebbly Sandstone (PS), and Classical Turbidite (CT- model was classified with Classical Turbidite (CT-1), Pebbly Sandstone (PS), and Classical Turbidite (CT-1).

### 4.2 Percentage of Probability Matrix

Based on the likelihood of lithology presence at intervals of 0.2 meters in the study field, The percentage of lithology trend was around 66.6% up to 85,71%. The predictions of lithology were Calcareous Sandstone (A) to Calcareous Sandstone (A) (81,37%), Calcarenite (B) to Calcarenite (B) (73.61%), Shale (C) to shale (C) (66.67%), Polymics Breccia (D) to Polymics Breccia (D) (80.00%), Calcareous Siltstone (E) to Calcareous Siltstone (E) (75.00%), Pebble Sandstone (F) to Pebble Sandstone (F) (85.71%). These are the percentages of lithology presence predicted for the next 0.2 meters at a depth of 11 meters (Figure 6). Based on markov chain, the cycles of sedimentation process are presented in Table 1.

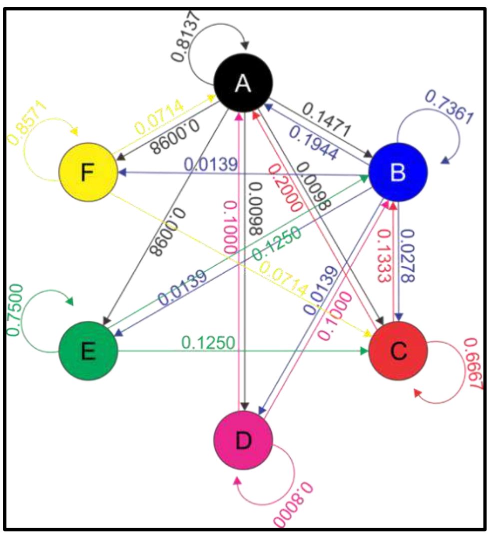

**Figure 6**. Markov Chain of Rock Lithology of Sedimentation Pattern at Ngalang River

| Cycle | Legend (Rock Formation) |
|---|---|
| Cycle 1 | A (*Calcareous Sandstone*) – B (*Calcarenite*) – C (*Shale*) – A (*Calcareous Sandstone*) |
| Cycle 2 | A (*Calcareous Sandstone*) – B (*Calcarenite*) – D (*Polimic Breccia*) - A (*Calcareous Sandstone*) |

**Table 1**. Cycle of markov chain

| | |
|---|---|
| Cycle 3 | A (*Calcareous Sandstone*) – B (*Calcarenite*) – F (*Pebble Sandstone*) – C (*Shale*) - A (*Calcareous Sandstone*) |
| Cycle 4 | A (*Calcareous Sandstone*) – B (*Calcarenite*) – E (*Calcareous Siltstone*) – C (*Shale*) - A (*Calcareous Sandstone*) |
| Cycle 5 | A (*Calcareous Sandstone*) – C (*Shale*) – B (*Calcarenite*) - D (*Polymic Breccia*) - A (*Calcareous Sandstone*) |
| Cycle 6 | A (*Calcareous Sandstone*) - D (*Polimic Breccia*) – B (*Calcarenite*) – E (*Calcareous Siltstone*) – C (*Shale*) - A (*Calcareous Sandstone*) |
| Cycle 7 | A (*Calcareous Sandstone*) - D (*Polimic Breccia*) – B (*Calcarenite*) – F (*Pebble Sandstone*) – C (*Shale*) - A (*Calcareous Sandstone*) |
| Cycle 8 | A (*Calcareous Sandstone*) - E (*Calcareous Siltstone*) – C (*Shale*) – B (*Calcarenite*) - D (*Polimic Breccia*) - A (*Calcareous Sandstone*) |
| Cycle 9 | A (*Calcareous Sandstone*) - E (*Calcareous Siltstone*) - B (*Calcarenite*) – F (*Pebble Sandstone*) – C (*Shale*) - A (*Calcareous Sandstone*) |

**C**alcareous sandstone was predicted as the type of rock that has the highest distribution percentage, which occurs at the start or end of the Markov chain cycle. The thickness of rock distribution is also dominated by calcareous sandstone. Some variations of rock distribution shows the product of sedimentation process.

### 4.3 Geological Interpretation

Geological Interpretation of depositional environment in research area was determined based on the sedimentary structures, traces fossil, benthonic foraminifera, and also facies analysis model. Hummocky Cross Stratification (HCS), for example, is a sedimentary structure that can be linked to the depositional climate (HCS). Paleocurrent Analysis of HCS was obtained from the general trend of Northwest – Southeast (NW-SE). It means that the source of sedimentation comes from northwest part of the research area because the dip of sedimentary layer is in the south direction.

Several trace fossils were found in the research area such as *Chondrites* (Zoophycos), *Rhizocorallium* (Cruziana Facies), and *Thalasinoides* (Skolithos) (Collinson and Thompson, 1982). By identifying the fossils trace, the depositional environments were able to be determined. The bottom part of the section was deposited in continental shelf (tidal). The middle part of the section was deposited in Neritic (Sub lithoral) and the top part of section was deposited in Upper Bathyal.

Benthonic foraminifera fossils were discovered in three parts of measuring section. The bottom and the middle part of the section were identified at inner (shelf) neritic (depth of 0- 20 meters) and the top part of the section was identified at upper slope bathyal (depth of 200 – 500 meters) (Table 2).

**Table 2.** Comparison and correlation of depositional environment

| COMPARISON AND CORRELATION OF ENVIRONMENT DEPOSITIONAL DATA BEFORE CHI SQUARE TEST | | | |
|---|---|---|---|
| **DEPOSITIONAL ENVIRONMENT BASED ON BENTHONIC FORAMINIFERA** | | **DEPOSITIONAL ENVIRONMENT BASED ON FACIES** | |
| TOP | *Upper (Slope) Bathyal* (depth of 200 - 500 meters) | TOP | *Lower Fan* |
| MIDDLE | *Middle (shelf) Neritic* (depth of 20 - 100 meters) | MIDDLE | *Mid fan* |
| BOTTOM | *Inner (Shelf) Neritic* (depth of 0 - 20 meters) | BOTTOM | *Upper - Mid Fan* |

| COMPARISON AND CORRELATION OF ENVIRONMENT DEPOSITIONAL DATA AFTER CHI SQUARE TEST | |
|---|---|
| **DEPOSITIONAL ENVIRONMENT BASED ON BENTHONIC FORAMINIFERA** | **DEPOSITIONAL ENVIRONMENT BASED ON FACIES** |
| *Upper (Slope) Bathyal* (depth of 200 - 500 meters) | *Lower Fan* |

## 4.4 Calculation of Chi Square Test

After obtaining the values of observation and expectation probability, the values were compared to the chi square table (Table 3) to determine the hypotheses acceptation and rejectation (HI) (Table 4).

| Class | OBSERVATION DATA (OJ) | EXPECTATION DATA (EJ) | (OJ-EJ)''/EJ |
|---|---|---|---|
| CT-1 - CT-1 | 136 | 90.24 | 23.20 |

Table 3. Chi square calculation

| | | | |
|---|---|---|---|
| CT-1 - CT-2 | 1 | 28.20 | 26.24 |
| CT-1 - PS | 3 | 16.92 | 11.45 |
| CT-1 - CGL | 1 | 7.05 | 5.19 |
| CT-2 - CT-1 | 2 | 13.20 | 9.50 |
| CT-2 - CT-2 | 41 | 4.40 | 304.45 |
| CT-2 - PS | 0 | 0.44 | 0.44 |
| CT-2 - CGL | 1 | 21.12 | 19.17 |
| PS - CT-1 | 2 | 7.80 | 4.31 |
| PS - CT-2 | 1 | 2.60 | 0.98 |
| PS - PS | 23 | 0.26 | 1988.88 |
| PS - CGL | 0 | 12.48 | 12.48 |
| CGL - CT-1 | 2 | 3.00 | 0.33 |
| CGL - CT-2 | 0 | 1.00 | 1.00 |
| CGL - PS | 0 | 0.10 | 0.10 |
| CGL - CGL | 8 | 4.80 | 2.13 |
| | | TOTAL | **2409.86** |

Degree of freedom (u) =

V= {total of facies - 1}$^2$

= {4-1}$^2$

= {3}$^2$

= 9

This research was taken a value of alpha (A) 5% with accuration rate of 5% = 0,05, so that the critical value such as $X^2$ = 0,05, 9 = **16,92**

Table 4. Plotting of chi-square distribution

| V (degree of freedom) | A=0,30 | A=0,20 | A=0,10 | A=0,05 | A=0,02 | A=0,01 | A=0,001 |
|---|---|---|---|---|---|---|---|
| 1 | 1,07 | 1,64 | 2,71 | 3,84 | 5,41 | 6,64 | 10,83 |
| 2 | 2,41 | 3,22 | 4,60 | 5,99 | 7,82 | 9,21 | 13,82 |
| 3 | 3,66 | 4,64 | 6,25 | 7,82 | 9,84 | 11,34 | 16,27 |
| 4 | 4,88 | 5,99 | 7,78 | 9,49 | 11,67 | 13,28 | 18,46 |
| 5 | 6,06 | 7,29 | 9,24 | 11,07 | 13,39 | 15,09 | 20,52 |
| 6 | 7,23 | 8,56 | 10,64 | 12,59 | 15,03 | 16,81 | 22,46 |
| 7 | 8,38 | 9,80 | 12,02 | 14,07 | 16,62 | 18,48 | 24,32 |
| 8 | 9,52 | 11,03 | 13,36 | 15,51 | 18,17 | 20,09 | 26,12 |
| 9 | 10,66 | 12,24 | 14,68 | **16,92** | 19,68 | 21,67 | 27,88 |
| 10 | 11,78 | 13,44 | 15,99 | 18,31 | 21,16 | 23,21 | 29,59 |
| 11 | 12,90 | 14,63 | 17,28 | 19,68 | 22,62 | 24,72 | 31,26 |
| 12 | 14,01 | 15,81 | 18,55 | 21,03 | 24,05 | 26,2 | 32,91 |
| 13 | 15,12 | 16,98 | 19,81 | 22,36 | 25,47 | 27,69 | 34,53 |
| 14 | 16,22 | 18,15 | 21,06 | 23,68 | 26,87 | 29,14 | 36,12 |
| 15 | 17,32 | 19,31 | 22,31 | 25,00 | 28,26 | 30,58 | 37,70 |

**The continued Table 4**

| V (degree of freedom) | A=0,30 | A=0,20 | A=0,10 | A=0,05 | A=0,02 | A=0,01 | A=0,001 |
|---|---|---|---|---|---|---|---|
| 16 | 18,42 | 20,46 | 23,54 | 26,30 | 29,63 | 32,00 | 39,25 |
| 17 | 19,51 | 21,62 | 24,77 | 27,59 | 31,00 | 33,41 | 40,79 |
| 18 | 20,60 | 22,76 | 25,99 | 28,87 | 32,35 | 34,80 | 42,31 |
| 19 | 21,69 | 23,90 | 27,20 | 30,14 | 33,69 | 36,19 | 43,82 |
| 20 | 22,78 | 25,04 | 28,41 | 31,41 | 35,02 | 37,57 | 45,32 |
| 21 | 23,86 | 26,17 | 29,62 | 32,67 | 36,34 | 38,93 | 46,80 |
| 22 | 24,94 | 27,30 | 30,81 | 33,92 | 37,66 | 40,29 | 48,27 |
| 23 | 26,02 | 28,43 | 32,01 | 35,17 | 38,97 | 41,64 | 49,73 |
| 24 | 27,10 | 29,55 | 33,20 | 36,42 | 40,27 | 42,98 | 51,18 |
| 25 | 28,17 | 30,68 | 3,38 | 37,65 | 41,57 | 44,31 | 52,62 |
| 26 | 29,25 | 31,80 | 35,56 | 38,88 | 42,86 | 45,64 | 54,05 |
| 27 | 30,32 | 32,91 | 36,74 | 40,11 | 44,14 | 46,96 | 55,48 |
| 28 | 31,39 | 34,03 | 37,92 | 41,34 | 45,42 | 48,28 | 56,89 |
| 29 | 32,46 | 34,14 | 39,09 | 42,56 | 46,69 | 49,59 | 58,30 |
| 30 | 33,53 | 36,25 | 40,26 | 43,77 | 47,96 | 50,89 | 59,70 |

The calculation value of chi square distribution was 2409,86 > 16,92 = (HI > HO) based on the cross plot of values in Table 4, with the following consequences:

- HO = HO means that the data is derived from random transition population, the sortation of facies does not depend on previous facies.
- HI = HI means that the data is derived from random transition population, the sortation of facies depends on previous facies.

HI was accepted which means that the significance of facies present depends on previous facies. The sortation of facies was not random and has some patterns.

### 4.5 Discussion

There were some discussions in research area related to the stratigraphy of the Sambipitu Formation. The discussions will be presented:

There were some equality of probability lithology data and facies based on comparison data of lithology facies and depositional environment (Bouma facies, 1962 and Walker facies, 1978). Both lithology probabilities were appropriated with facies probabilities on a thickness of 44.90 meters, but the total percentage of those probabilities was not suitable, despite the interval of Markov chain analysis being performed every 20 cm in lithology or facies.

**Table 5.** The comparison and correlation of facies probability data before chi square test

| COMPARISON AND CORRELATION OF PROBABILITY FACIES DATA BEFORE CHI SQUARE TEST ON SAMBIPITU FORMATION STRATIGRAPHY WITH PERCENTAGE OF > 50 % | | | | | |
|---|---|---|---|---|---|
| **LITHOLOGY** | | **BOUMA FACIES** | | **WALKER FACIES** | |
| *Calcareous Sandstone - Calcareous Sandstone* | 81,37% | Tb-Tb | 90.48 % | CT2 - CT2 | 93.18 % |
| *Calcarenite – Calcarenite* | 73,61% | Tc-Tc | 66.67 % | | |
| *Shale – Shale* | 66,67% | Td-Td | 94.16 % | CT1 - CT1 | 96.45 % |
| *Calcareous Siltstone - Calcareous Siltstone* | 75,00% | Te-Te | 83.33 % | | |
| *Polymic Breccia - Polymic Breccia* | 80,00% | Ta-Ta | 86.11 % | CGL – CGL | 80 % |
| *Pebble Sandstone - Pebble Sandstone* | 85,71% | | | PS – PS | 88.46 |

Based on the lithology and facies comparison data (Bouma, 1962 and Walker, 1978), the chi square test applied to their probability facies data and revealed the same likelihood. Before the chi square test, there were a few different lithologies with their physical rock characteristics. There was no polymic breccia after the chi square was completed. It is likely that the sediment supply stopped depositing before arriving at the study area because the sediment flow was lower, resulting in the formation of fine materials at the end of the depositional phase (Table 6).

**Table 6**. The comparison and correlation of facies probability data before chi square test

| COMPARISON AND CORRELATION OF PROBABILITY FACIES DATA AFTER CHI SQUARE TEST ON SAMBIPITU FORMATION STRATIGRAPHY WITH PERCENTAGE OF > 50 % | | | | | |
|---|---|---|---|---|---|
| **LITHOLOGY** | | **BOUMA FACIES** | | **WALKER FACIES** | |
| *Calcareous Sandstone - Calcareous Sandstone* | 83,33% | Tb-Tb | 100% | CT2 - CT2 | 100 % |
| *Calcarenite – Calcarenite* | 83,33% | | | | |
| *Calcareous Siltstone - Calcareous Siltstone* | 85,71% | Td-Td | 90% | CT1 - CT1 | 92.22 % |
| | | Te-Te | 95.35% | | |
| *Pebble Sandstone - Pebble Sandstone* | 50 % | Ta-Ta | 50% | PS – PS | 50 % |
| Pebble Sandstone – Calcareous Siltstone | 50 % | Ta-Te | 50% | | |

Based on the interpretation of cross section, the research area is located near to the source area. The percentage value of Pebble Sandstone was about 50%. Based on the cross section, the lithology of coarse grain size decreased. This occurance is related to the classification of turbidity deposits (Kuenen, 1950) which states that in final step of depositional process, the coarse deposit location is close to the source area

The rocks in Sambipitu Formation were deposited at paleobathimetry of Inner (shelf) Neritic – Upper (slope) Bathyal based on the correlation of depositional environment. According to lithofacies review, the paleobathymetry can be translated as Upper Fan to Lower Fan (Walker, 1978). In this case, there was no relationship on benthonic fossil analysis and facies analysis data especially at the Upper area. The bentonic fossil analysis is Upper (slope) Bathyal which could not relate to facies analysis of lower fan (Walker, 1978).

Factors of facies distribution that cannot be linked to benthonic fossil studies :

a. Sedimentary process

Sedimentary process was effected in distribution and facies change due to progradation facies. Novian (2011) discovered that silisiclastic sediments and carbonate materials were mixed on site, punctuated, and mixed at the source. The facies repetition in transitional zone showed that there were some shallowing event cycles upward (*middle shelf – inner shelf).*

b. Supply of Sediments

The facies thickness and types of sedimentary materials affects the sedimentary processes. The Nglanggeran Formation deposit can be used to predict the availability of sediments in the research area. The rock product of Nglanggeran Formation is the result of sedimentation which is deposited on land and in underwater (sea). It positions a large portion of southern part of Nglanggeran Mountain in an east – west direction (Febbyanto, 2012). Semilir Formation rocks are older than Nglanggeran Formation rocks at N4-N5 (Early Miocene) and may support the sedimentation phase in the research area (Rizqi, 2019).

c. Climate

The warm climate affects carbonates development. The benthonic fossils develop at the top part of stratigraphic measuring section where some fossils in Bathyal paleobathymetric are found. The warm climate makes a good condition of carbonate development. The presence of carbonate cement has become an indication of shallow marine with a depth of less than 200 meters (Donovan, 2017).

d. Tectonic events

The tectonism is a facies shift element change that is locally triggered by vertical movements and dip of a fault block. The fault in research area, specifically located in upper part of Sambipitu Formation, is controlled by sinistral fault (Putra and Pandita, 2014).

e. The eustacy (sea level) changes

The eustasy (sea level changes) caused the sea level depth to change, resulting in different sedimentary depositional products. The rocks of Sambipitu Formation were deposited in intra arc basin with a shallow marine facies in the proximal facies region (Ongki et al, 2017). It was supported by the presence of andesitic lava on lower part of Sambipitu Formation. The source of Sambipitu rock Formation is derived from the deposition of Nglanggeran Formation which is a part of Volcanic body located under seawater. Volcanism influenced the rocks facies shift in Sambipitu and eustasy affected the upper part of Sambipitu Formation (due to the sea level change).

f. Volcanism activity

Volcanism activity is caused locally by material volcanic of the Nglanggeran Formation. The presence of volcanoes and islands were the environmental factor that directly affected the depth of seawater. At the research area, the volcanic products were deposited in northern area that was included in proximal facies according to Bogie et al (1998).

Trace fossils presence at Ngalang River could support the interpretation of paleobathymetry or the depositional environment. Based on interpretation of the depositional environment by trace fossil identification (Seilacher, 2007), the depositional environment at bottom, middle, and top of Upper Sambipitu Formation at Ngalang River is presented in Table 7. The sedimentation process occurred from continental shelf (0-20 meters) to neritic (20-100 meters). At the top part of Sambipitu Formation, the sedimentation process occurred at Upper Bathyal (200 – 500 meters). It showed that the depositional environment developed from shallow marine to deeper marine related to facies model (Bouma, 1962) and (Walker, 1978) from upper fan to lower fan (deepening upward). Purbantoro et al (2020) who studied for detailed stratigraphy in Sambipitu revealed that Sambipitu Formation deposited at Outer Neritic (20 – 100 meters) to Upper Bathyal (200-500 meters). In addition, Aprilita et al (2020) showed the depositional system of Sambipitu Formation in open circulation shallow marine based on microfacies analysis.

**Table 7**. The depositional environment of Upper Sambipitu Formation based on trace fossil

| Trace Fossil | Ichnofacies | Environment |
|---|---|---|
| Top<br> | (Chondrites)<br>(Zoophycoos)<br>(Seilacher, 2007) | *Upper bathyal*<br>(depth of 200-500 meters) |
| Middle<br> | (Rhizocorallium)<br>(Cruziana)<br>(Seilacher, 2007) | Neritic<br>(*Sublitoral*)<br>(depth of 0-20 meters) |
| Bottom<br> | Thalasinoides<br>(Skolithos)<br>(Seilacher, 2007) | C*ontinental shelf*<br>(Tidal)<br>(Beach shore line) |

## 5. Conclusion

The conclusion based on the analysis of stratigraphic measuring section in Ngalang River at Upper Sambipitu Formation are :

1. The *Markov Chain* could be used to evaluate lithology and facies using observed and measured probability transition matrix which predicted the presence of next lithology and facies.
2. There were 9 rock cycles,,in which with the highest possibility of repetition of A (Calcareous Sandstone) – B (Calcarenite) – E (Calcareous Siltstone) – C (Shale) - A (Calcareous Sandstone) is 48,60 %

3. The presence of lithology depends on the previous lithology, in which the sortation of the lithology is not random (in a pattern). This can be seen from the result of *chi square* test with value of $\mathcal{X}^2 calculation$ (574,40 ) $>$ $\mathcal{X}^2 table$ (37,65)
4. The lithology predictionof the next 0.2 meters were
    a. Calcareous sandstone to Calcareous sandstone
    b. Calcarenite to Calcarenite
    c. Pebble Sandstone to Pebble Sandstone
    d. Calcareous siltstone to calcareous siltstone
5. The sortation of stratigraphic measuring section (Bouma facies,1962) on the upper part of Sambipitu Formation with the biggest possibility is Ta (Interval With Graded Bedding) or and Tc (Interval With Current Ripple Lamination and Convolute Lamination) or and Td (Upper Interval With Parallel Lamination) or and Ta (Interval With Graded Bedding) about 40 %
6. The rock facies prediction (Bouma,1962) is based on the previous facies which the rock facies was not random (in a rock pattern). This can be seen from the*chi square* test with value of $\mathcal{X}^2 calculation$ (605,65 ) $>$ $\mathcal{X}^2 table$ (26,30)
7. The prediction of facies that will be found (Bouma,1962) of the next 0,2 meters were
    a. (Tb) Lower Interval with Parallel Lamination to (Tb) Lower Interval with Parallel Lamination
    b. (Td) Upper Interval with Parallel Lamination to (Td) Upper Interval with Parallel Lamination
    c. (Te) Pellitic Interval to (Te) Pellitic Interval
8. The facies sortation (Walker,1978) on the upper part of Sambipitu Formation showed that the biggest possibility of repetition pattern is (CT-1 *Classical Turbidite*) to (PS *Pebbly Sandstone*) to (CT-2 *Classical Turbidite*) to (CGL *Clast Supported Conglomerate*) to (CT-1 *Classical Turbidite*) about 28,25 %
9. The presence of rock facies (Walker,1978) depend on the previous facies which the sortation of facies is not random. This can be seen from the *chi square* test result with value of $\mathcal{X}^2 calculation$ (2409,86 ) $>$ $\mathcal{X}^2 tabel$ (16,92)
10. The prediction of facies presence (Walker,1978) of the next 0,2 meters were
    a. (CT-1 Classical Turbidite) to (CT-1 Classical Turbidite)
    b. (CT-2 Classical Turbidite) to (CT-2 Classical Turbidite)
    c. (PS Pebbly Sandstone) to (PS Pebbly Sandstone)

The next or future research could be done on rock contact formation in between Sambipitu and Oyo Formation by using Markov chain analysis. Sedimentary structure analysis is required to make a comprehensive interpretation of geological data.

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