Gmail

ANGKASA

99+

Mail

Tulis

Kotak Masuk 173

Chat

Berbintang

Ditunda

Spaces

Terkirim

Draf 10

Meet

Selengkapnya

Label

ha

[sustinere.jes] Editor Decision

Eksternal Kotak Masuk ×

Dr Heri Kuswanto kuswanto.its@gmail.com lewat elasticemail.net
kepada saya

Inggris Indonesia Terjemahkan pesan

Al Hussein Flowers Rizqi (Author):

We have reached a decision regarding your submission to Sustinere: Journal of Environment and Sustainability, "Correl
using Markov Chain Analysis in Sambipitu Formation at Ngalang River, Gunung Kidul, Yogyakarta, Indonesia".

Our decision is: Revisions Required

Dr Heri Kuswanto
Institut Teknologi Sepuluh Nopember
kuswanto.its@gmail.com

Sustinere: Journal of Environment and Sustainability | Journal's Website: https://sustinerejes.com | Contact Editor: sust
sustinere.jes@gmail.com

Campus Publisher, Jl. Pandawa, Pucangan, Kartasura, Sukoharjo, Central Java, 57168, Indonesia, http://su

UNSUBSCRIBE

Gmail

ANGKASA

99+

Mail

Chat

Spaces

Meet

Tulis

Kotak Masuk 173

Berbintang

Ditunda

Terkirim

Draf 10

Selengkapnya

Label

ha

Revision of journal

Al Hussein Flowers Rizqi <alhussein@sttnas.ac.id>
kepada kuswanto.its

Good afternoon, Dr. Heri Kuswanto
by this following massage, i send my revision due to my account is error to upload the revision in journal system

thank you

--

Best regards,

AL HUSSEIN FLOWERS RIZQI
Department of Geological Engineering
STTNAS Yogyakarta
Jl. Babarsari Caturtunggal, Depok, Sleman, Yogyakarta
E: alhusseinrizqi@gmail.com
alhussein.rizqi@yahoo.com
alhussein@sttnas.ac.id
P: +6281230596561

Satu lampiran • Dipindai dengan Gmail

124-Article Text-1.

Gmail

Telusuri dalam email

99+
Mail
Chat
Spaces
Meet

Tulis

Kotak Masuk 173
Berbintang
Ditunda
Terkirim
Draf 10
Selengkapnya

Label

ha

3 Lampiran • Dipindai dengan Gmail

B-124-Article Tex..

B-SUSTINERE RE...

A-reviewer A 124...

Al Hussein Flowers Rizqi <alhussein@sttnas.ac.id>
kepada Dr

okay thank you, i will revise as soon as possible

--
Best regards,

AL HUSSEIN FLOWERS RIZQI
Department of Geological Engineering
STTNAS Yogyakarta
Jl. Babarsari Caturtunggal, Depok, Sleman, Yogyakarta
E: alhusseinrizqi@gmail.com
alhussein.rizqi@yahoo.com
alhussein@sttnas.ac.id
P: +6281230596561

Balas Teruskan

RESEARCH PAPER

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

Abstract. The Research area is located at Ngalang river, Gedangsari sub-district, Gunung Kidul Regency, Special Region of Yogyakarta.The research area is included in Southern Mountain Zone, composed by lithology of Sambipitu Calcareous Sandstone. The depositional process phase in the Sambipitu Formation has a unique pattern and relevance to previous lithology that was interesting to reviewed the stratigraphic position and its lithological repetition pattern using the statistical method (Markov Chain). This research purpose is to analyze of the sedimentation pattern and prediction of facies presence in the Sambipitu Formation, and it expected to be able to assist in predicting and interpreting the relevance of subsequent lithology appearances in each unit of lithology cycle. The research method is included measured stratigraphy, determination of rock age and depositional environment based on fossil identification, also using probability matrix in Markov Chain analysis. The results of the Markov chain analysis, lithology of rock in the Upper Sambipitu Formation has a non-random transition pattern with the results of statistical calculation showed that the calculation value is greater than the Chi-square table value (333.9 > 34.38) that the Ho component is rejected. The prediction of facies presence on next 0,2 meters are (CT-1 Classical Turbidite) to (CT-1 Classical Turbidite), (CT-2 Classical Turbidite) to (CT-2 Classical Turbidite), (PS - Pebbly Sandstone) to (PS - Pebbly Sandstone). On other hand, the prediction of facies presence (Bouma,1962) on next 0,2 meters were (Tb) Lower Interval with Paralel Lamination - (Tb) Lower Interval with Paralel Lamination (Td) Upper Interval With Paralel Lamination - (Td) Upper Interval With Paralel Lamination (Te) Pellitic Interval - (Te) Pellitic Interval.

Keywords: Stratigraphy, Markov Chain, Repetition Pattern, Facies, Sambipitu

1. Introduction

The applied statistics in geological science has not been recognized yet could solve any problem included in pattern of lithology and facies cycle. The previous research Jun (2019) has studied in seismic oceanography special in estimation of speed and temperature with seismic data. The geostatistics also could be applied in determination of depositional environment. Apriani (2016) used markov chain analysis to estimate the developed lithology and depositional environment in West Sumatra.

The Sambipitu Formation is included in Southern Mountain Zone which has been done by many researchers. Bothe (1929), Surono et al (1992), Van Bemmelen (1949), and Pandita (2008) also Rizqi (2019) reviewed about stratigraphy in surrounding research area. Research area is located in Southern Mountain Zone, specific at Ngalang River, Gedangsari Sub district, Gunung Kidul Regency, Indonesia. However, the geostatistics research that related to depositional environment specific at quantitative analysis had never been done in this area.

This research used a quantitative descriptive method with markov chain analysis. The sedimentation pattern could be interpreted from the result of the repetition of lithology especially in Sambipitu Formation at Ngalang River. This repetition of lithology could determine the lithofacies that represent the depositional environment of sedimentation process. The presence of Sambipitu Formation has an important aspect for stratigraphy analysis due to those position of stratigraphy in Southern Mountain that located in between volcanism period and post volcanism period (Surono et al, 1992).

The purpose of this research is to identification of lithofacies and facies model also determined the correlation of markov analysis and depostional environment. Sambipitu Formation has product of rock lithology from silisiclastics and carbonate rocks. Sequence of lithology and facies from Sambipitu Formation was being interest to be analysis in this research using markov chain method. By using markov chain analysis, the prediction of lithology or sedimentation process was determined by probability or quantitatively number that should be test in Chi Square Analysis.

Commented [R1]: Explain in more detail

Commented [R2]: Elaborate why did you use this method

Commented [R3]: Why?

Commented [R4]: Typo?

Commented [R5]: Typo?

Commented [R6]: Why interesting to be studied? And why did you implement markove chain for the analysis o

2. Literature Review

Geological conditions define tectonic activities, basin settings, and sequence of rocks or stratigraphic (Suprapto et al, 2017), Current morphological and rock conditions around river can describe river's past condition such as rocks formed it 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).

A Markov chain is a model of the random motion of an object in a discrete set of possible location (Walrand et al, 2000). The value of X factor at *t* (time) process was named by *state* Hillier et al (1995). If those system move from *state i* in interval time to *state j*, the system could be determined a transition transisi from *i* to *j*. The possibility of transition in a step of *state i* heading to *state j* could be determined in a formula:

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

Commented [R7]: Put it in introduction and add some review of the literatures

Commented [R8]: Put it in the methodology

3. Methodology

The research method used in this research was done in three steps such as fieldwork step, data analysis step and reporting step (Figure 1). The primary data was obtained from stratigraphic data. Stratigraphic data was taken by stratigraphy measuring section along 55,90 meters of thickness in Ngalang River (Figure 2), specific located on upper part of Sambipitu Formation. Preliminary study was a previous step that collected previous data and make a topographic map. The fieldwork was conducted to identify the characteristic of lithological description such as colour, sedimentary structure, texture, rock composition, fossils content

On analysis step, the fossil analysis was conducted to identify planktonic and benthonic to obtain the age and depositional environment in research area. The markov chain analysis was done in stratigraphy of Sambipitu Formation comprised of observation transition matrix, probability of observation and transition matrix. Then analysis of Markov chain, matrix of possibility frequent transition, and the calculation of chi square were done.

Megascopic rock name classification used is Pettijohn (1975). The classification used in facies determination is Bouma (1962) and Walker (1970). The Zone of Blow is used in determination of age and the depositional environment was classified by Phleger (1960) and Tipsword, Setzer, and Smith (1966).

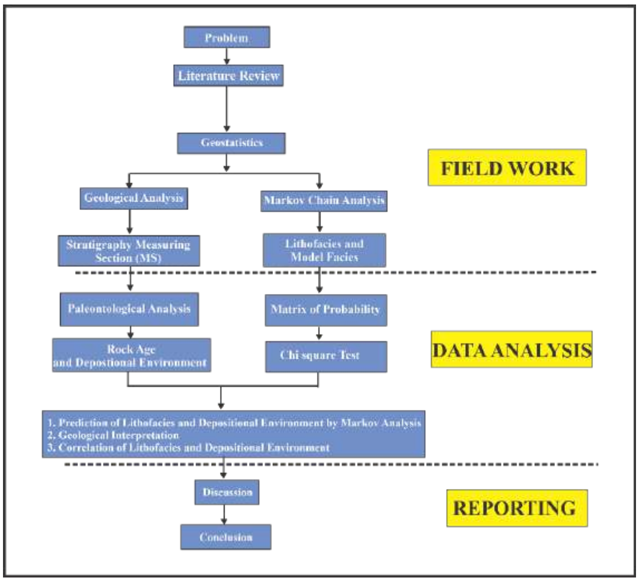

Figure 1. The methodology flow chart

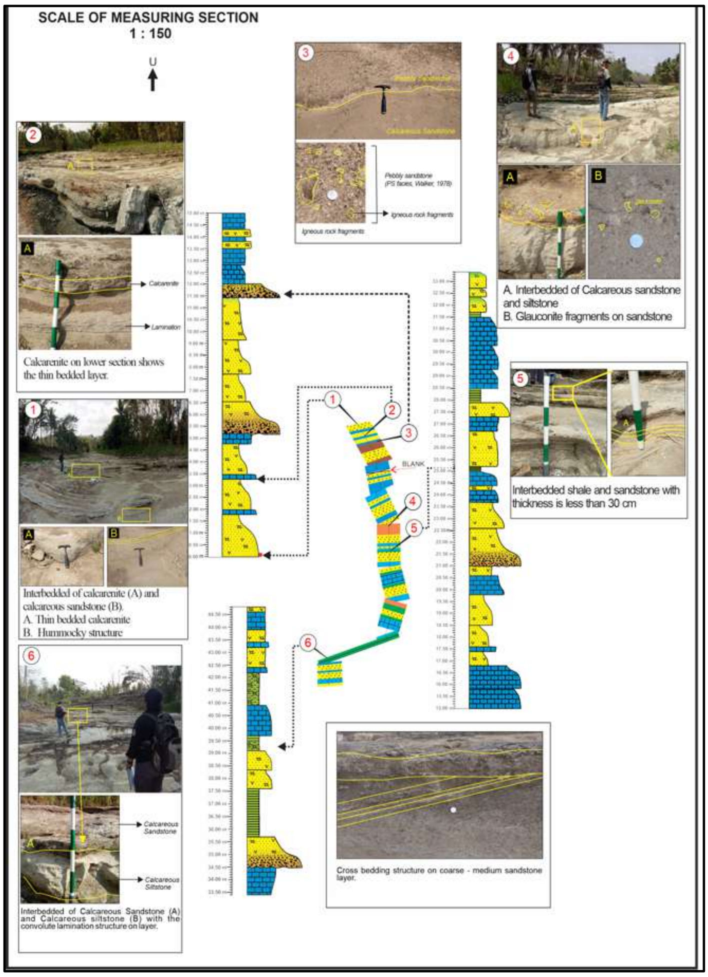

Figure 2. Track map of measuring section at Ngalang river

4. Result and Discussion

The measuring section at Ngalang River has five observation points such as point of 1,2,3,4,5, and 6 which represented the different rock. Based on result data of measuring stratigraphy section, the thickness of rock is about 55.90 meters. It consists of Calcareous Sandstone, Calcarenite (Sandy Limestone), Polymics Breccia, Pebbly Sandstone, Shale, and Calcareous Siltstone. By foraminifera fossils identification, the age of rocks in this section is N 12 to N 14 (Middle Miocene) (Blow, 1969), it included in Upper Sambipitu Formation and it were deposited at depth of 20 m to 500 meters (Inner Neritic to Upper Bathyal) (Phleger, 1960) (Figure. 3).

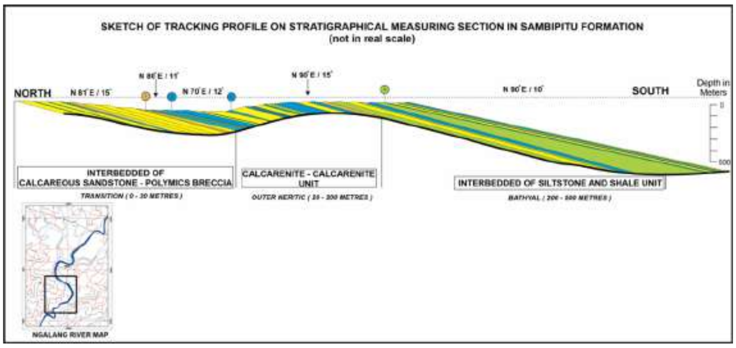

Figure 3. The Profile of Tracking map of measuring section at Ngalang river

4.1 Markov Chain Analysis (Lithological Pattern)

The Markov analysis was done at 44,90 thickness of the measuring section. The measuring section profile was arranged at interval of 0.2 meters (20 cm) from bottom to top layers (Figure 4). The transition of observation matrix and the probability of transition and observation matrix showing the probability value of each rocks. By both of matrix, the Markov chain could be made which show the cycle of rock repetitions that related to each other.

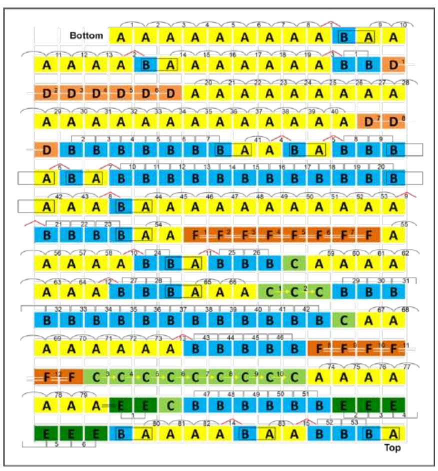

Figure 4. The sortation of repetition rock lithology with markov chain analysis

Commented [R9]: why

Commented [R10]: why

The probability matrix of frequency and transition. Frequency of possibility values were distributed to each possibility at Matrix of Random Transition that obtained the pattern of lithology cycle that has been tested by Chi Square. By reviewed chi square test, the hypotheses of random or no random rock cycle would be determined. The thickness of 11 meters from measuring section was used in comparison to the presence of next rocks by the calculation.

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

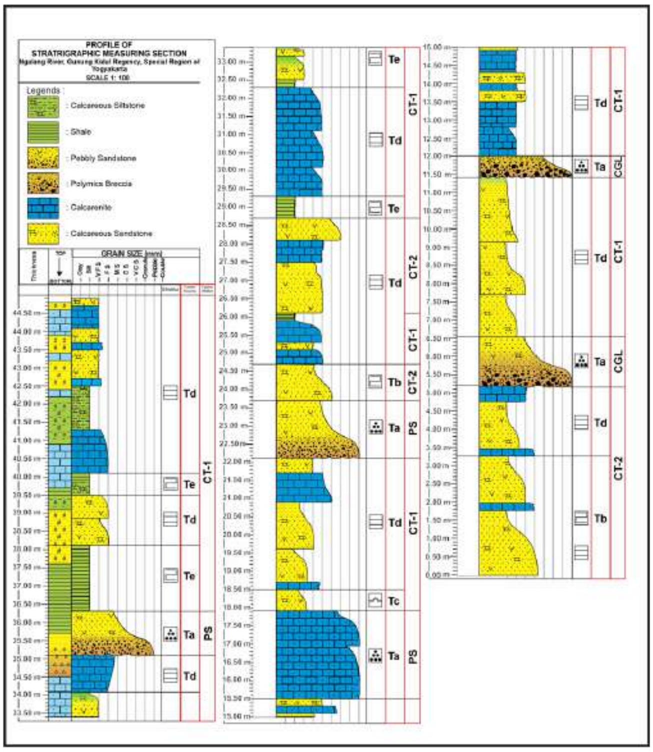

Figure 5. The sortation of repetition rock lithology with markov chain analysis

Commented [R11]: What do you want to say?

Based on Bouma Facies Model (1962), the repetition pattern of facies consisted of Interval with Parallel Lamination turned to (Td) Upper Interval with Parallel Lamination (Tb) and Interval with Graded Bedding (Ta) upward. At middle part of section, the facies consist 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 is consisted of Classical Turbidite (CT-2) and Clasts supported Conglomerate (CGL). At middle part, the rock facies consisted of Pebbly Sandstone (PS) and Classical Turbidite (CT-1). At upper part, the facies model was classified by Classical Turbidite (CT-1), Pebbly Sandstone (PS), and Classical Turbidite (CT- model was classified by Classical Turbidite (CT-1), Pebbly Sandstone (PS), and Classical Turbidite (CT-1).

4.2 Matrix of Probability Percentage

Based on percentage value of probability in research area, the possibility of lithology presence at interval of 0.2 meters, the lithology pattern that would be presence with value in range 66.6 % 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 result of prediction percentage of lithology presence at next 0.2 meters on depth of 11 meters (Figure 6). Based on markov chain, the cycles of sedimentation process were be determined in Table 1.

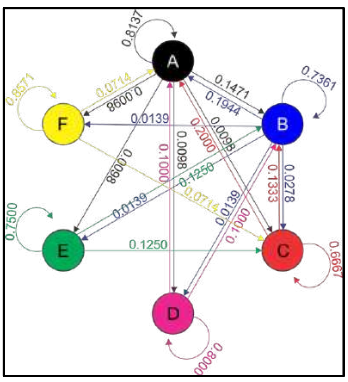

Figure 6. Markov Chain of Rock Lithology of Sedimentation Pattern at Ngalang River

Table 1. Cycle of markov chain

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*)
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 (*Polimic 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*)

4.3 Geological Interpretation

Commented [R12]: Please make an analysis from table 1 and figure 5

Geological Interpretation of depositional environment in research area was determined based on sedimentary structures, traces fossil, benthonic foraminifera, and also facies analysis model. Sedimentray structures that could be determined to depositional environment in research area such as Hummocky Cross Stratification (HCS). Paleocurrent Analysis of HCS was obtained the general trend of Northwest – Southeast (NW-SE). It means that the source of sedimentation come from northwest part of research area due to the dip of sedimentary layer is south direction.

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

Identified of Benthonic foraminifera fossils were in three parts of section. The bottom and the middle part of section was identified at inner (shelf) neritic (depth of 0- 20 meters) and the top part of 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 obtained the values of observation and expectation probability, the values were compared to table of chi square (Table 3) for determined the hypotheses acceptation and rejectation (HI) (Table 4).

Table 3. Chi square calculation

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

Based on the cross plot of value in table above, the calculation value of chi square distribution was **2409,86 > 16,92 = (HI > HO)** with the consequences that:

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

HI was accepted means that the significance of facies presence depend 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 Sambipitu Formation. The discussions were :

Commented [R13]: ... will be present

Commented [R14]: Make it into paragraph

1. Based on comparison data of lithology facies and (Bouma facies, 1962 and Walker facies, 1978), there were some equalities of probability lithology data and facies. It was proven by all the lithology probability appropriated with facies probability on thickness of 44.90 meter, however the total percentage of those probability were not suitable. whereas the interval of markov chain analysis was done at each 20 cm either in lithology or facies. It caused by the division or determination of Sambipitu Formation was not done at each single sedimentary layer (Table 5).

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 %		
Polimic Breccia - Polimic Breccia	80,00%	Ta-Ta	86.11 %	CGL – CGL	80 %
Pebble Sandstone - Pebble Sandstone	85,71%			PS – PS	88.46

2. Based on the comparison data of lithology and facies (Bouma, 1962 and Walker, 1978) after chi square test related to each other and showed the same probability. There were some of different lithology with the result before the chi square has been done. After the chi square was done, there is no presence of polymic breccia. It was possible that by the sediments supply stopped to deposit before arrive at research area due to the sediments flow weaker and the fine materials were formed at last depositional process (Table 6).

Commented [R15]: Write in paragraph

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%		

3. Based on interpretation of cross section.,the research area is located near to source area. The value of percentage of Pebble Sandstone is about 50%. Based on cross section the lithology of coarse grain size is decreased. This event is related to the classification of turbidity deposits (Kuenen, 1950) that on the last phase of depositional process, by the transportation distance and sediments mass, the coarse deposit is less at far distance of source area.

4. Based on comparison data and correlation of depositional environment, research area is included in paleobathimetry of *Inner (Shelf) Neritik – Upper (Slope) Bathyal* and according to lithofacies analysis can be interpreted as Upper Fan to Lower Fan. In this case, there was no relationship on benthonic fossil analysis and facies analysis data especially at Upper area. The bentonic fossil analysis is Upper (slope) Bathyal which could not relate to facies analysis of lower fan (Walker, 1978).

5. There were some factors of distribution facies which could not related to benthonic fossil analysis :
   a. Sedimentary process
      Sedimentary process was effected in distribution and facies change due to progradation facies. Novian (2011), the mixing of silisiclastic materials and carbonate materials were deposited in site., punctuated, and source mixing. The facies repetition in transitional zone showed that there were some shallowing event cycles upward (*middle shelf – inner shelf*

b. Supply of Sediments

The sedimentary materials effected in form of facies thickness and kinds of sedimentary materials. The supply of sediments in research area can be interpreted from Nglanggeran Formation deposit. The rock product of Nglanggeran Formation is the result of sedimentation which is deposited on land and in underwater (sea). It placed a big part of southern part of Nglanggeran Mountain with the direction pattern of east – west. (Febbyanto, 2012).

c. Climate

The warm climate effected to carbonates development. The benthonic fossils developed at top part of stratigraphic measuring section which there were some fossils in Bathyal paleobathymetric. The warm climate makes a good condition of carbonate development. The presence of carbonate cement has become an indication of shallow marine less than 200 meters (Donovan, 2017).

d. Tectonic events

The tectonism is a factor of facies change which is locally caused by vertical movements and dip of fault block. The fault in research area, specific in upper part of Sambipitu Formation is controlled by sinistral fault (Putra and Pandita, 2014).

e. The eustacy (sea level) changes

The eustacy (sea level) changes caused the sea level depth that the sedimentary depositional were deposited in different product. The Sambipitu Formation was deposited in intra arc basin and it was in proximal facies area is shallow marine 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 depositional of Nglanggeran Formation which a part of Volcanic body was under seawater. The facies change in Sambipitu was affected by volcanism activity in lower and upper part of Sambipitu Formation was affected by eustasy (sea level) changes.

f. Volcanism activity

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

6. Trace fossils presence at Ngalang River would support the interpretation of paleobathymetry or depositional environment. Based on interpretation of depositional environment by trace fossil identification (Seilacher, 2007), the depositional environment at bottom, middle, and top of Upper Sambipitu Formation at Ngalang River were in Table 7.

The sedimentation processed from continental shelf (0-20 meters) to neritic (20-100 meters). At the top part of Sambipitu Formation, the sedimentation processed 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).

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

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

5. Conclusion

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

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

3. The presence of lithology depend on next lithology, which rock lithology was not random. It showed that *chi square* test with value of $\mathcal{X}^2 calculation$ (574,40) > $\mathcal{X}^2 table$ (37,65)
4. The prediction of lithology on 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 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 prediction of facies (Bouma,1962) depend on previous facies which the facies was not random. It was showed by *chi square* test with the value of $\mathcal{X}^2 calculation$ (605,65) > $\mathcal{X}^2 table$ (26,30)
7. The prediction of facies presence (Bouma,1962) on 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 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 facies (Walker,1978) depend on previous facies which the sortation of facies is not random. It was showed by *chi square* test with value of $\mathcal{X}^2 calculation$ (2409,86) > $\mathcal{X}^2 tabel$ (16,92)
10. The prediction of facies presence (Walker,1978) on 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)

Acknowledgement

This research is dedicated to Institut Teknologi Nasional Yogyakarta which has funded and supported.

References

Apriani, A., 2016, *Markov Chains* Method to Analysis of Facies Repetition in Kiliran Sub Basin Kiliran Jao, West Sumatra, *Journal of Angkasa*, Volume VII, Nomor 1.

Ashari and Pandita (2008), The transition of depositional environment between Antara i Nglanggran Formation and Sambipitu Formation, Kali Ngalang, Dusun Karanganyar, Ngalang area, Gedang Sari Village, Gunung Kidul Regency, Special Region of Yogyakarta

Bouma., 1962, Bouma Sequence, The Geological Society of London. Dunham, 1962, Clasification of Carbonate Rock According Depositional Texture, AAPG.

Bogie ,I.,and Mackenzie, K.M., 1998, The Application of A Volcanic Facies Model to An Andesitic Stratovolcano Hosted Geothermal System at Wayang Windu, Java, Indonesia*, Proceedings 20th*, NZ Geothermal Workshop.

Donovan, S. K. (2017). Trace fossils and tropical karst. *Geological Magazine*, *154*(1), 166-168. doi:10.1017/S0016756815000965

Febbyanto, H. (2012). Geology and Study of GEOLOGI DAN STUDI FORMASI Nglanggeran Formation in Patuk Area, Patuk sub district, Gunung Kidul Regency, Special Region of Yogyakarta (Doctoral dissertation, UPN" Veteran" Yogyakarta).

Flowers rizqi, al hussein. (2019). Analisis Siklus Perulangan Litologi pada Stratigrafi Formasi Sambipitu di Sungai Ngalang, Kecamatan Gedangsari, Kabupaten Gunung Kidul,DIY. *ReTII*,359-375.Retrievedfrom //journal.itny.ac.id/ index.php/ReTII/ article/view/1191

Hillier, F.S. dan Lieberman, 1995, *Introduction to Operations Research,* Sixth Edition, Mc. Graw Hill Inc., Singapore.

Jun, H., Cho, Y., & Noh, J. (2019). Trans-dimensional Markov chain Monte Carlo inversion of sound speed and temperature: Application to Yellow Sea multichannel seismic data. *Journal of Marine Systems*, *197*, 103

Kuenen, P. H. H., Migliorini, C. I., 1950, Turbidity Current as a Cause of Graded Bedding, *The Journal of Geology v58,* hal. 91-12*,*175.111.89.45.

Moch Indra Novian, S. T. (2011). Stratigraphy and Sedimentation Of Transition Zone Of Sambipitu – Oyo Formation at Widoro River, Ngalang River and Kedungdowo River, Nglipar Sub District, Gunung Kidul Regency, Special Region Of Yogyakarta (Doctoral Dissertation, Universitas Gadjah Mada).

Pandita, H., 2008, Depositional environment of Sambipitu Formation Based on Trace Fossil in Nglipar Area, *JTM*, Institut Teknologi Bandung, Vol. XV, No. 2 hal 85-94. ISSN 0854-8528

Prayoga, O. A., & Hartono, H. G. (2017). Correlation of Lithofacies and Ichnofacies as Parameter of Ancient Volcano Identification in depositional of Sambipitu Formation, Daerah Ngalang, Yogyakarta. *ReTII*. Retrieved from// journal.itny.ac.id /index.php /ReTII/article/view/266

Putra, D. C., & Pandita, H. (2015). Identification of Kali Ngalang fault in Karanganyar village, Ngalang, Gedang Sari Sub district, Gunung Kidul Regency, Special Regency of Yogyakarta. *ReTII*.

Seilacher, Adolf (2007). Trace Fossil Analysis. Berlin: Springer-Verlag

Selley, R. C., 1985, *Ancient Sedimentary Environments*, 3rd edition, Cornell University Press, New York. p. 317

Surono., Toha, B., Sudarno, I., Wiryosujono, S., 1992, Stratigraphy of *Southern Mountain, Central Java,* P3G-Ditjen GSM Dept. Pertamben, Bandung.

Tipsword, H.L., Setzer, F.M dan Smith, F.L Jr, 1966. Interpretation of Depositional Environment in Gulf Coast Petroleum Exploration from Paleocology and Related Stratigraphy, Transaction G.C, Assoc. Geol. Soc., 119-130.

Van Bemmelen R.W,. 1949, *The Geology of Indonesia*. The Goge, Martinus.

Walker, R.G., 1978, Facies Models, Geological Association of Canada, Toronto.
Walker, R.G. and James, N.P., 1992, *Facies Model,* Second Edition, Geological Association of Canada, Ontario, 454p
Walrand, J., & Varaiya, P. P. (2000). *High-performance communication networks*. Morgan Kaufmann. https://doi.org/10.1016/B978-0-08-050803-0.50014-9

EDITORIAL OFFICE
Sustinere: Journal of Environment and Sustainability
Centre for Science and Technology
Institut Agama Islam Negeri (IAIN) Surakarta
Website: https://sustinerejes.com
Email: sustinere.jes@gmail.com; sustinere.jes@iain-surakarta.ac.id

Sustinere

SUSTINERE - REVIEW FORM 1

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

Date of review :

A. Evaluation objects:

	Yes	No	See Comment
1. Is the paper content original?	☐	☐	☑
2. Does the paper title represent its content?	☑	☐	☐
3. Does the abstract reflect the paper content?	☑	☐	☐
4. Do the keywords indicate the scope of the research?	☑	☐	☐
5. Is the research methodology or the approach of the problem solving clearly described?	☑	☐	☐
6. Do the data presentation and interpretation valid and reasonable?	☑	☐	☐
7. Do the use of tables and figures help to clarify the explanation?	☑	☐	☐
8. Have the discussion and/or analysis been relevant with the results of the study?	☑	☐	☐
9. Are the references used relevant?	☑	☐	☐

	Very good	Good	Fair	Poor
10. Contribution to science	☐	☑	☐	☐
11. Originality	☐	☐	☑	☐
12. Systematic	☐	☐	☑	☐
13. Language	☐	☐	☑	☐
14. Writing accuracy	☐	☐	☑	☐

EDITORIAL OFFICE
Sustinere: Journal of Environment and Sustainability
Centre for Science and Technology
Institut Agama Islam Negeri (IAIN) Surakarta
Website: https://sustinerejes.com
Email: sustinere.jes@gmail.com; sustinere.jes@iain-surakarta.ac.id

B. Reviewer's decision

The paper:

i. could be published directly ☐

ii. could be published with minor revision ☐

iii. could be published with major revision ☑

iv. please return to us for reevaluation after revision ☐

v. is not worth to publish based on the above reasons ☐

C. Comment about the paper (Use additional sheet, if necessary).

Reviewer comment about the paper for author

All comments are provided in the paper with track and changes.

D. Note for the editors

Reviewer note for the journal editor, if any.

RESEARCH PAPER

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

Abstract. The Research area is located at Ngalang river, Gedangsari sub-district, Gunung Kidul Regency, Special Region of Yogyakarta.The research area is included in Southern Mountain Zone, composed by lithology of Sambipitu Calcareous Sandstone. The depositional process phase in the Sambipitu Formation has a unique pattern and relevance to previous lithology that was interesting to reviewed the stratigraphic position and its lithological repetition pattern using the statistical method (Markov Chain). This research purpose is to analyze of the sedimentation pattern and prediction of facies presence in the Sambipitu Formation, and it expected to be able to assist in predicting and interpreting the relevance of subsequent lithology appearances in each unit of lithology cycle. The research method is included measured stratigraphy, determination of rock age and depositional environment based on fossil identification, also using probability matrix in Markov Chain analysis. The results of the Markov chain analysis, lithology of rock in the Upper Sambipitu Formation has a non-random transition pattern with the results of statistical calculation showed that the calculation value is greater than the Chi-square table value (333.9 > 34.38) that the Ho component is rejected. The prediction of facies presence on next 0,2 meters are (CT-1 Classical Turbidite) to (CT-1 Classical Turbidite), (CT-2 Classical Turbidite) to (CT-2 Classical Turbidite), (PS - Pebbly Sandstone) to (PS - Pebbly Sandstone). On other hand, the prediction of facies presence (Bouma,1962) on next 0,2 meters were (Tb) Lower Interval with Paralel Lamination - (Tb) Lower Interval with Paralel Lamination (Td) Upper Interval With Paralel Lamination - (Td) Upper Interval With Paralel Lamination (Te) Pellitic Interval - (Te) Pellitic Interval.

Commented [u1]: 1. How is the explanation of the Correlation of Lithofacies and Depositional Environment? This is just the result of the Markov chain analysis.
2. What is the conclusion of your research?

Keywords: Stratigraphy, Markov Chain, Repetition Pattern, Facies, Sambipitu

1. Introduction

The applied statistics in geological science has not been recognized yet could solve any problem included in pattern of lithology and facies cycle. The previous research Jun (2019) has studied in seismic oceanography special in estimation of speed and temperature with seismic data. The geostatistics also could be applied in determination of depositional environment. Apriani (2016) used markov chain analysis to estimate the developed lithology and depositional environment in West Sumatra.

Commented [u2]: Describing the research problem and providing evidence to support why the topic (**Lithofacies and Depositional Environment)** is important to study. Reference (minimum 3) required from international and / national journals.

The Sambipitu Formation is included in Southern Mountain Zone which has been done by many researchers. Bothe (1929), Surono et al (1992), Van Bemmelen (1949), and Pandita (2008) also Rizqi (2019) reviewed about stratigraphy in surrounding research area. Research area is located in Southern Mountain Zone, specific at Ngalang River, Gedangsari Sub district, Gunung Kidul Regency, Indonesia. However, the geostatistics research that related to depositional environment specific at quantitative analysis had never been done in this area.

This research used a quantitative descriptive method with markov chain analysis. The sedimentation pattern could be interpreted from the result of the repetition of lithology especially in Sambipitu Formation at Ngalang River. This repetition of lithology could determine the lithofacies that represent the depositional environment of sedimentation process. The presence of Sambipitu Formation has an important aspect for stratigraphy analysis due to those position of stratigraphy in Southern Mountain that located in between volcanism period and post volcanism period (Surono et al, 1992). The purpose of this research is to identification of lithofacies and facies model also determined the correlation of markov analysis and depostional environment. Sambipitu Formation has product of rock lithology from silisiclastics and carbonate rocks. Sequence of lithology and facies from Sambipitu Formation was being interest to be analysis in this research using markov chain method. By using markov chain analysis, the prediction of lithology or sedimentation process was determined by probability or quantitatively number that should be test in Chi Square Analysis.

Commented [u3]: Describe the results of their research, giving rise to the importance of geostatistical research that is related to the depositional environment. In this paragraph, the research gap is not clear. Research gaps can be in the form of results, methods, etc. Reference support from the latest international / national journals (maximum of the last 5 years) is needed.

2. Literature Review

Commented [u4]: Reference literature review is still quite superficial. Citation and bibliography must be in sync. For example, Suprapto and Zamroni are not listed in the literature.

Geological conditions define tectonic activities, basin settings, and sequence of rocks or stratigraphic (Suprapto et al, 2017), Current morphological and rock conditions around river can describe river's past condition such as rocks formed it 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).

A Markov chain is a model of the random motion of an object in a discrete set of possible location (Walrand et al, 2000). The value of X factor at *t* (time) process was named by *state* Hillier et al (1995). If those system move from *state i* in interval time to *state j*, the system could be determined a transition transisi 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

The research method used in this research was done in three steps such as fieldwork step, data analysis step and reporting step (Figure 1). The primary data was obtained from stratigraphic data. Stratigraphic data was taken by stratigraphy measuring section along 55,90 meters of thickness in Ngalang River (Figure 2), specific located on upper part of Sambipitu Formation. Preliminary study was a previous step that collected previous data and make a topographic map. The fieldwork was conducted to identify the characteristic of lithological description such as colour, sedimentary structure, texture, rock composition, fossils content

Commented [u5]: Explain point of 1,2,3,4,5, and 6 where are they? Are there specific distances between points? Or is it determined by differences in rock types?

On analysis step, the fossil analysis was conducted to identify planktonic and benthonic to obtain the age and depositional environment in research area. The markov chain analysis was done in stratigraphy of Sambipitu Formation comprised of observation transition matrix, probability of observation and transition matrix. Then analysis of Markov chain, matrix of possibility frequent transition, and the calculation of chi square were done.

Commented [u6]: What methods are used for planktonic and benthonic identification? Include the references.

Megascopic rock name classification used is Pettijohn (1975). The classification used in facies determination is Bouma (1962) and Walker (1970). The Zone of Blow is used in determination of age and the depositional environment was classified by Phleger (1960) and Tipsword, Setzer, and Smith (1966).

Commented [u7]: Many citations are not supported by bibliography

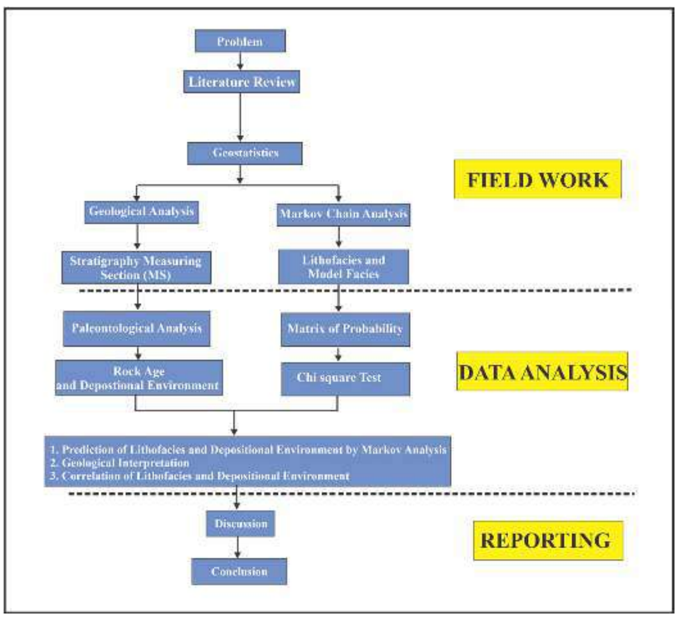

Figure 1. The methodology flow chart

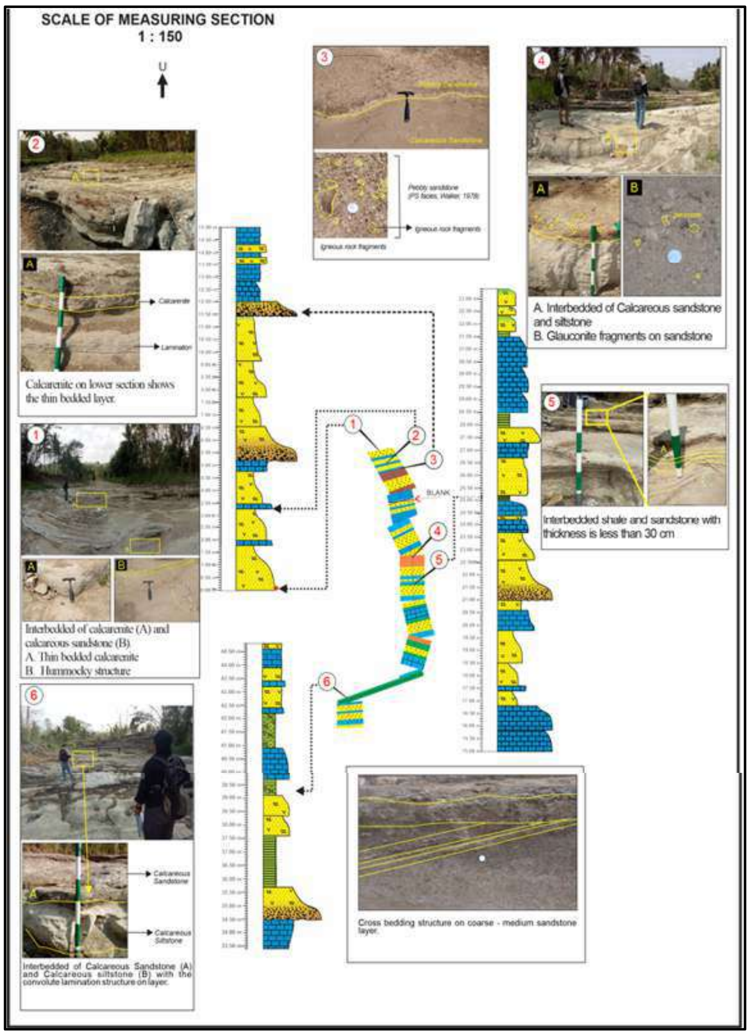

Figure 2. Track map of measuring section at Ngalang river

4. Result and Discussion

The measuring section at Ngalang River has five observation points such as point of 1,2,3,4,5, and 6 which represented the different rock. Based on result data of measuring stratigraphy section, the thickness of rock is about 55.90 meters. It consists of Calcareous Sandstone, Calcarenite (Sandy Limestone), Polymics Breccia, Pebbly Sandstone, Shale, and Calcareous Siltstone. By foraminifera fossils identification, the age of rocks in this section is N 12 to N 14 (Middle Miocene) (Blow, 1969), it included in Upper Sambipitu Formation and it were deposited at depth of 20 m to 500 meters (Inner Neritic to Upper Bathyal) (Phleger, 1960) (Figure. 3).

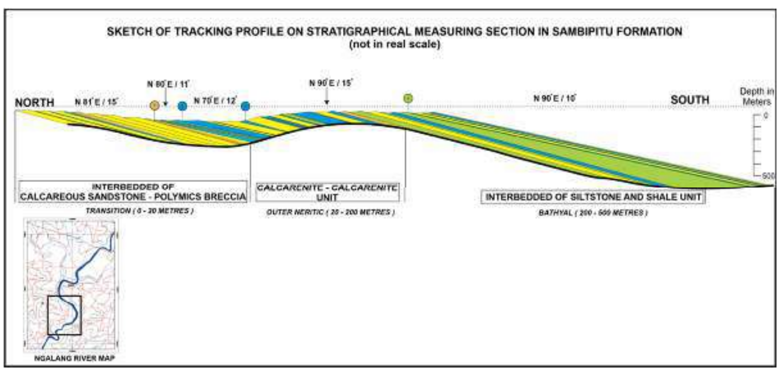

Figure 3. The Profile of Tracking map of measuring section at Ngalang river

4.1 Markov Chain Analysis (Lithological Pattern)

The Markov analysis was done at 44,90 thickness of the measuring section. The measuring section profile was arranged at interval of 0.2 meters (20 cm) from bottom to top layers (Figure 4). The transition of observation matrix and the probability of transition and observation matrix showing the probability value of each rocks. By both of matrix, the Markov chain could be made which show the cycle of rock repetitions that related to each other.

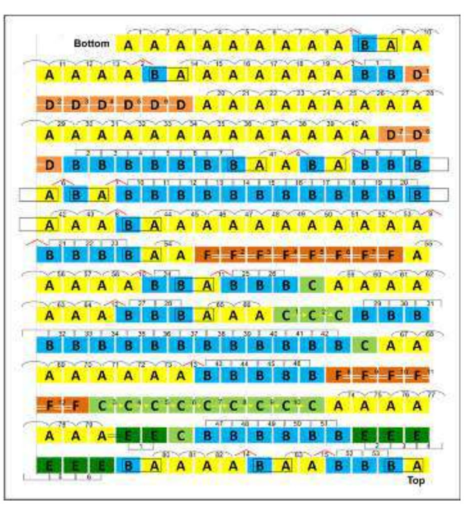

Figure 4. The sortation of repetition rock lithology with markov chain analysis

The probability matrix of frequency and transition. Frequency of possibility values were distributed to each possibility at Matrix of Random Transition that obtained the pattern of lithology cycle that has been tested by Chi Square. By reviewed chi square test, the hypotheses of random or no random rock cycle would be determined. The thickness of 11 meters from measuring section was used in comparison to the presence of next rocks by the calculation.

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

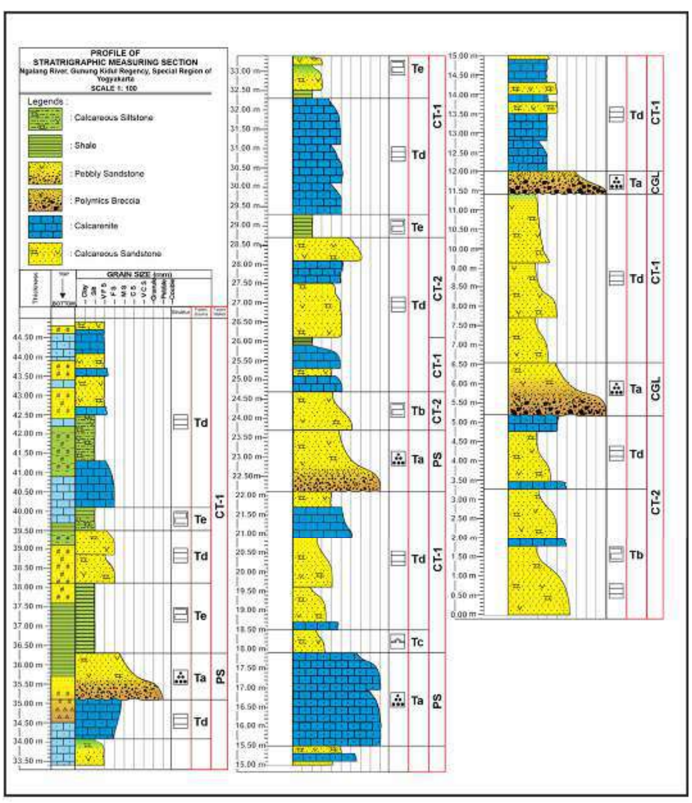

Figure 5. The sortation of repetition rock lithology with markov chain analysis

Based on Bouma Facies Model (1962), the repetition pattern of facies consisted of Interval with Parallel Lamination turned to (Td) Upper Interval with Parallel Lamination (Tb) and Interval with Graded Bedding (Ta) upward. At middle part of section, the facies consist 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 is consisted of Classical Turbidite (CT-2) and Clasts supported Conglomerate (CGL). At middle part, the rock facies consisted of Pebbly Sandstone (PS) and Classical Turbidite (CT-1). At upper part, the facies model was classified by Classical Turbidite (CT-1), Pebbly Sandstone (PS), and Classical Turbidite (CT- model was classified by Classical Turbidite (CT-1), Pebbly Sandstone (PS), and Classical Turbidite (CT-1).

4.2 Matrix of Probability Percentage

Based on percentage value of probability in research area, the possibility of lithology presence at interval of 0.2 meters, the lithology pattern that would be presence with value in range 66.6 % 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 result of prediction percentage of lithology presence at next 0.2 meters on depth of 11 meters (Figure 6). Based on markov chain, the cycles of sedimentation process were be determined in Table 1.

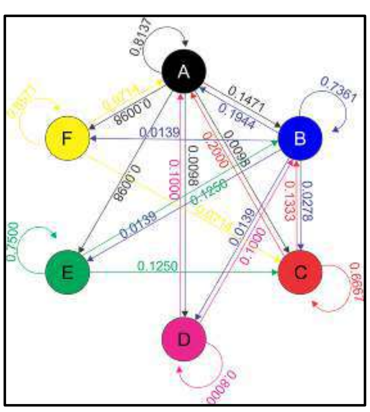

Figure 6. Markov Chain of Rock Lithology of Sedimentation Pattern at Ngalang River

Table 1. Cycle of markov chain

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*)
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 (*Polimic 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*)

4.3 Geological Interpretation

Geological Interpretation of depositional environment in research area was determined based on sedimentary structures, traces fossil, benthonic foraminifera, and also facies analysis model. Sedimentray structures that could be determined to depositional environment in research area such as Hummocky Cross Stratification (HCS). Paleocurrent Analysis of HCS was obtained the general trend of Northwest – Southeast (NW-SE). It means that the source of sedimentation come from northwest part of research area due to the dip of sedimentary layer is south direction.

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

Identified of Benthonic foraminifera fossils were in three parts of section. The bottom and the middle part of section was identified at inner (shelf) neritic (depth of 0- 20 meters) and the top part of 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 obtained the values of observation and expectation probability, the values were compared to table of chi square (Table 3) for determined the hypotheses acceptation and rejectation (HI) (Table 4).

Table 3. Chi square calculation

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

Based on the cross plot of value in table above, the calculation value of chi square distribution was **2409,86 > 16,92 = (HI > HO)** with the consequences that:

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

HI was accepted means that the significance of facies presence depend 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 Sambipitu Formation. The discussions were :

1. Based on comparison data of lithology facies and (Bouma facies, 1962 and Walker facies, 1978), there were some equalities of probability lithology data and facies. It was proven by all the lithology probability appropriated with facies probability on thickness of 44.90 meter, however the total percentage of those probability were not suitable. whereas the interval of markov chain analysis was done at each 20 cm either in lithology or facies. It caused by the division or determination of Sambipitu Formation was not done at each single sedimentary layer (Table 5).

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 %		
Polimic Breccia - Polimic Breccia	80,00%	Ta-Ta	86.11 %	CGL – CGL	80 %
Pebble Sandstone - Pebble Sandstone	85,71%			PS – PS	88.46

2. Based on the comparison data of lithology and facies (Bouma, 1962 and Walker, 1978) after chi square test related to each other and showed the same probability. There were some of different lithology with the result before the chi square has been done. After the chi square was done, there is no presence of polymic breccia. It was possible that by the sediments supply stopped to deposit before arrive at research area due to the sediments flow weaker and the fine materials were formed at last depositional process (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%		

3. Based on interpretation of cross section.,the research area is located near to source area. The value of percentage of Pebble Sandstone is about 50%. Based on cross section the lithology of coarse grain size is decreased. This event is related to the classification of turbidity deposits (Kuenen, 1950) that on the last phase of depositional process, by the transportation distance and sediments mass, the coarse deposit is less at far distance of source area.

4. Based on comparison data and correlation of depositional environment, research area is included in paleobathimetry of *Inner (Shelf) Neritik – Upper (Slope) Bathyal* and according to lithofacies analysis can be interpreted as Upper Fan to Lower Fan. In this case, there was no relationship on benthonic fossil analysis and facies analysis data especially at Upper area. The bentonic fossil analysis is Upper (slope) Bathyal which could not relate to facies analysis of lower fan (Walker, 1978).

5. There were some factors of distribution facies which could not related to benthonic fossil analysis :
   a. Sedimentary process
      Sedimentary process was effected in distribution and facies change due to progradation facies. Novian (2011), the mixing of silisiclastic materials and carbonate materials were deposited in site., punctuated, and source mixing. The facies repetition in transitional zone showed that there were some shallowing event cycles upward (*middle shelf – inner shelf*

b. Supply of Sediments

The sedimentary materials effected in form of facies thickness and kinds of sedimentary materials. The supply of sediments in research area can be interpreted from Nglanggeran Formation deposit. The rock product of Nglanggeran Formation is the result of sedimentation which is deposited on land and in underwater (sea). It placed a big part of southern part of Nglanggeran Mountain with the direction pattern of east – west. (Febbyanto, 2012).

c. Climate

The warm climate effected to carbonates development. The benthonic fossils developed at top part of stratigraphic measuring section which there were some fossils in Bathyal paleobathymetric. The warm climate makes a good condition of carbonate development. The presence of carbonate cement has become an indication of shallow marine less than 200 meters (Donovan, 2017).

d. Tectonic events

The tectonism is a factor of facies change which is locally caused by vertical movements and dip of fault block. The fault in research area, specific in upper part of Sambipitu Formation is controlled by sinistral fault (Putra and Pandita, 2014).

e. The eustacy (sea level) changes

The eustacy (sea level) changes caused the sea level depth that the sedimentary depositional were deposited in different product. The Sambipitu Formation was deposited in intra arc basin and it was in proximal facies area is shallow marine 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 depositional of Nglanggeran Formation which a part of Volcanic body was under seawater. The facies change in Sambipitu was affected by volcanism activity in lower and upper part of Sambipitu Formation was affected by eustasy (sea level) changes.

f. Volcanism activity

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

6. Trace fossils presence at Ngalang River would support the interpretation of paleobathymetry or depositional environment. Based on interpretation of depositional environment by trace fossil identification (Seilacher, 2007), the depositional environment at bottom, middle, and top of Upper Sambipitu Formation at Ngalang River were in Table 7.

The sedimentation processed from continental shelf (0-20 meters) to neritic (20-100 meters). At the top part of Sambipitu Formation, the sedimentation processed 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).

Commented [u8]: Either compare your results with the findings from other studies or use the studies to support a claim.

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

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

5. Conclusion

Commented [u9]: Suggest future experiments

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

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

3. The presence of lithology depend on next lithology, which rock lithology was not random. It showed that *chi square* test with value of $\mathcal{X}^2 calculation$ (574,40) $>$ $\mathcal{X}^2 table$ (37,65)
4. The prediction of lithology on 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 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 prediction of facies (Bouma,1962) depend on previous facies which the facies was not random. It was showed by *chi square* test with the value of $\mathcal{X}^2 calculation$ (605,65) $>$ $\mathcal{X}^2 table$ (26,30)
7. The prediction of facies presence (Bouma,1962) on 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 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 facies (Walker,1978) depend on previous facies which the sortation of facies is not random. It was showed by *chi square* test with value of $\mathcal{X}^2 calculation$ (2409,86) $>$ $\mathcal{X}^2 tabel$ (16,92)
10. The prediction of facies presence (Walker,1978) on 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)

Acknowledgement

This research is dedicated to Institut Teknologi Nasional Yogyakarta which has funded and supported.

References

Apriani, A., 2016, *Markov Chains* Method to Analysis of Facies Repetition in Kiliran Sub Basin Kiliran Jao, West Sumatra, *Journal of Angkasa*, Volume VII, Nomor 1.

Ashari and Pandita (2008), The transition of depositional environment between Antara i Nglanggran Formation and Sambipitu Formation, Kali Ngalang, Dusun Karanganyar, Ngalang area, Gedang Sari Village, Gunung Kidul Regency, Special Region of Yogyakarta

Bouma., 1962, Bouma Sequence, The Geological Society of London. Dunham, 1962, Clasification of Carbonate Rock According Depositional Texture, AAPG.

Bogie ,I.,and Mackenzie, K.M., 1998, The Application of A Volcanic Facies Model to An Andesitic Stratovolcano Hosted Geothermal System at Wayang Windu, Java, Indonesia*, Proceedings 20th*, NZ Geothermal Workshop.

Donovan, S. K. (2017). Trace fossils and tropical karst. *Geological Magazine*, *154*(1), 166-168. doi:10.1017/S0016756815000965

Febbyanto, H. (2012). Geology and Study of GEOLOGI DAN STUDI FORMASI Nglanggeran Formation in Patuk Area, Patuk sub district, Gunung Kidul Regency, Special Region of Yogyakarta (Doctoral dissertation, UPN" Veteran" Yogyakarta).

Flowers rizqi, al hussein. (2019). Analisis Siklus Perulangan Litologi pada Stratigrafi Formasi Sambipitu di Sungai Ngalang, Kecamatan Gedangsari, Kabupaten Gunung Kidul,DIY. *ReTII*,359-375.Retrievedfrom //journal.itny.ac.id/ index.php/ReTII/ article/view/1191

Hillier, F.S. dan Lieberman, 1995, *Introduction to Operations Research,* Sixth Edition, Mc. Graw Hill Inc., Singapore.

Jun, H., Cho, Y., & Noh, J. (2019). Trans-dimensional Markov chain Monte Carlo inversion of sound speed and temperature: Application to Yellow Sea multichannel seismic data. *Journal of Marine Systems*, *197*, 103

Kuenen, P. H. H., Migliorini, C. I., 1950, Turbidity Current as a Cause of Graded Bedding, *The Journal of Geology v58,* hal. 91-12*,*175.111.89.45.

Moch Indra Novian, S. T. (2011). Stratigraphy and Sedimentation Of Transition Zone Of Sambipitu – Oyo Formation at Widoro River, Ngalang River and Kedungdowo River, Nglipar Sub District, Gunung Kidul Regency, Special Region Of Yogyakarta (Doctoral Dissertation, Universitas Gadjah Mada).

Pandita, H., 2008, Depositional environment of Sambipitu Formation Based on Trace Fossil in Nglipar Area, *JTM*, Institut Teknologi Bandung, Vol. XV, No. 2 hal 85-94. ISSN 0854-8528

Prayoga, O. A., & Hartono, H. G. (2017). Correlation of Lithofacies and Ichnofacies as Parameter of Ancient Volcano Identification in depositional of Sambipitu Formation, Daerah Ngalang, Yogyakarta. *ReTII*. Retrieved from// journal.itny.ac.id /index.php /ReTII/article/view/266

Putra, D. C., & Pandita, H. (2015). Identification of Kali Ngalang fault in Karanganyar village, Ngalang, Gedang Sari Sub district, Gunung Kidul Regency, Special Regency of Yogyakarta. *ReTII*.

Seilacher, Adolf (2007). Trace Fossil Analysis. Berlin: Springer-Verlag

Selley, R. C., 1985, *Ancient Sedimentary Environments*, 3rd edition, Cornell University Press, New York. p. 317

Surono., Toha, B., Sudarno, I., Wiryosujono, S., 1992, Stratigraphy of *Southern Mountain, Central Java,* P3G-Ditjen GSM Dept. Pertamben, Bandung.

Tipsword, H.L., Setzer, F.M dan Smith, F.L Jr, 1966. Interpretation of Depositional Environment in Gulf Coast Petroleum Exploration from Paleocology and Related Stratigraphy, Transaction G.C, Assoc. Geol. Soc., 119-130.

Van Bemmelen R.W,. 1949, *The Geology of Indonesia*. The Goge, Martinus.

Walker, R.G., 1978, Facies Models, Geological Association of Canada, Toronto.

Walker, R.G. and James, N.P., 1992, *Facies Model,* Second Edition*,* Geological Association of Canada, Ontario, 454p

Walrand, J., & Varaiya, P. P. (2000). *High-performance communication networks*. Morgan Kaufmann. https://doi.org/10.1016/B978-0-08-050803-0.50014-9

Gmail

in:sent

99+

Mail

Chat

Spaces

Meet

Tulis

Kotak Masuk 173

Berbintang

Ditunda

Terkirim

Draf 10

Selengkapnya

Label

ha

revision journal (final)

Al Hussein Flowers Rizqi <alhussein@sttnas.ac.id>

kepada Septin

by this message, i will give the revision
with the title of

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

--
Best regards,

AL HUSSEIN FLOWERS RIZQI
Department of Geological Engineering
STTNAS Yogyakarta
Jl. Babarsari Caturtunggal, Depok, Sleman, Yogyakarta
E: alhusseinrizqi@gmail.com
alhussein.rizqi@yahoo.com
alhussein@sttnas.ac.id
P: +6281230596561

Satu lampiran • Dipindai dengan Gmail

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

124-Article Text-1

Gmail

in:sent

99+
Mail
Chat
Spaces
Meet

Tulis
Kotak Masuk 173
Berbintang
Ditunda
Terkirim
Draf 10
Selengkapnya

Label
ha

Copyedit paper

Eksternal Kotak Masuk ×

Septin Astuti <septinastuti@gmail.com>
kepada saya

Dear Bapak Al Hussein,

Saya Septin dari jurnal Sustinere. Kami sudah melakukan copyedit atas paper bapak. Namun, kami perlu komunikasi in
Whatsapp yang bisa kami hubungi supaya proses bisa lebih cepat. Atau bapak kontak ke nomor whatsapp saya +4475
Terima kasih.

Salam
Septin

Virus-free. www.avast.com

Al Hussein Flowers Rizqi <alhussein@sttnas.ac.id>
kepada Septin

081230596561 ini wa saya terimakasih sebelumnya

--
Best regards,

AL HUSSEIN FLOWERS RIZQI
Department of Geological Engineering
STTNAS Yogyakarta
Jl. Babarsari Caturtunggal, Depok, Sleman, Yogyakarta
E: alhusseinrizqi@gmail.com

RESEARCH PAPER

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

Al Hussein Flowers Rizqi[1,1], Hendri Tri Purnomo[2]

[1]*Departemet of Geological Engineering at Institut Teknologi Nasional Yogyakarta 1, Indonesia*

[2] *Departemet of Geological Engineering at Institut Teknologi Nasional Yogyakarta 2, Indonesia*

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 using probability matrix in Markov Chain analysis. The results of the Markov chain analysis, lithology of rock in the Upper Sambipitu Formation has a non-random transition pattern. The results of statistical calculation showed that the calculation value is greater than the Chi-square table value (333.9 > 34.38) that the Ho component is rejected. Lithofacies and depositional environment are correlated to several geological aspects such as distribution rock facies, source 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

[1]Corresponding author. E-mail: correspondingauthor@email.com

DOI: xxxxx.xxxxx.xxxx

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 study by Jun (2019) that use special seismic oceanography to estimate speed and temperature using seismic data. The geostatistics also could be applied in determination of depositional environment. Furthermore, the siginificance of vertical facies in Australia could be determined by Markov chain analysis (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 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 Sambipitu position of stratigraphy of Southern Mountain that 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 Southern Mountain Zone, specific at Ngalang River, Gedangsari Sub district, Gunung Kidul Regency, Indonesia. The upper part of rock distribution in Ngalang river is dominated by calcareous rock composition with several trace fossils (Flowers, 2019). Pramunita and Pandita (2020) reported that the trace fossils identified consisted of several ichnofacies that were successfully identified as Scoyenia, Skolithos, Cruziana, dan Zoophycos. There have been several geological qualitative studies conducted in 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 combined the geological data (qualitative data) and statistics data (quantitative data). The purpose of this research is to identification of lithofacies and facies model also determined 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 Sambipitu Formation at Ngalang River. This 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 quantitatively number that must be tested in Chi Square Analysis. The Markov chain analysis also implicate the recent sedimentary rocks product such as alluvial sediment or tsunami sediment deposited.

2. Literature Review

Current morphological and rock conditions around river can describe river's past condition 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 method of 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 could be determined 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

The research method used in this research was done in three steps which are fieldwork step, data analysis step and reporting step (Figure 1). The primary data was obtained from stratigraphic data. In Ngalang river, stratigraphic data was collected using a stratigraphy section measurement with a thickness of 55.9 meters. Specifically, at point of observation 1 to 6 that located on upper part of Sambipitu Formation (Figure 2). Each point of observation represented the differences rock types or variation of lithology. Before the primary data was collected, 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, fossils content.

On analysis step, the fossil analysis was conducted to identify planktonic and benthonic foraminifera to determine the age and depositional environment in research area. In determining age, the rock sample has been prepared in small grain size to observed the abundance of foraminifera. The determination of age and depositional environment would support the rock distribution and rock facies. A Markov chain is a model of the random motion of an object in a discrete set of possible location (Walrand et al, 2000). The Markov chain analysis was done in stratigraphy of Sambipitu Formation comprised of observation transition matrix, probability of observation and transition matrix. The next steps are analysis of Markov chain, matrix of possibility frequent transition, and the calculation of chi square were done. Megascopic rock name classification used is Pettijohn (1975). The classification used in facies determination is Bouma (1962) and Walker (1970). The Zone of Blow (1969) is used in determination of age and the depositional environment according to Phleger (1951) and Tipsword, Setzer, and Smith (1966).

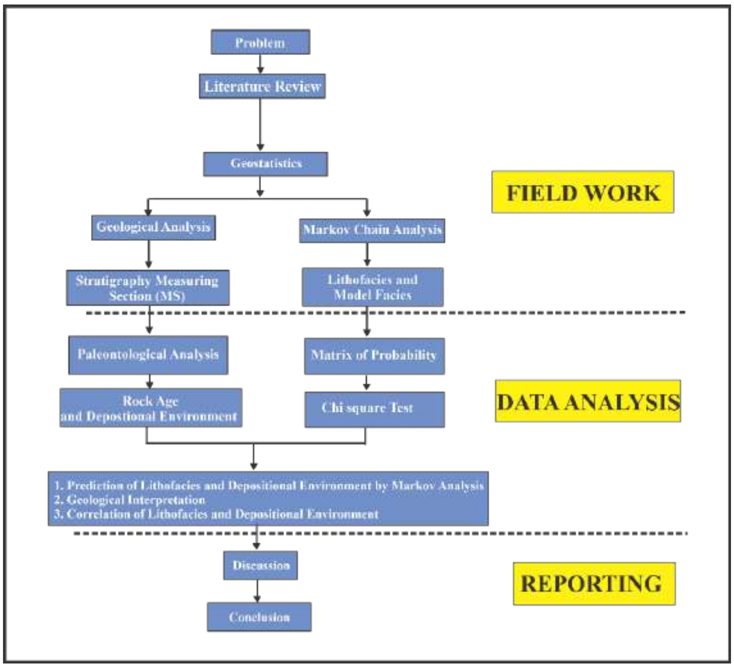

Figure 1. The methodology flow chart

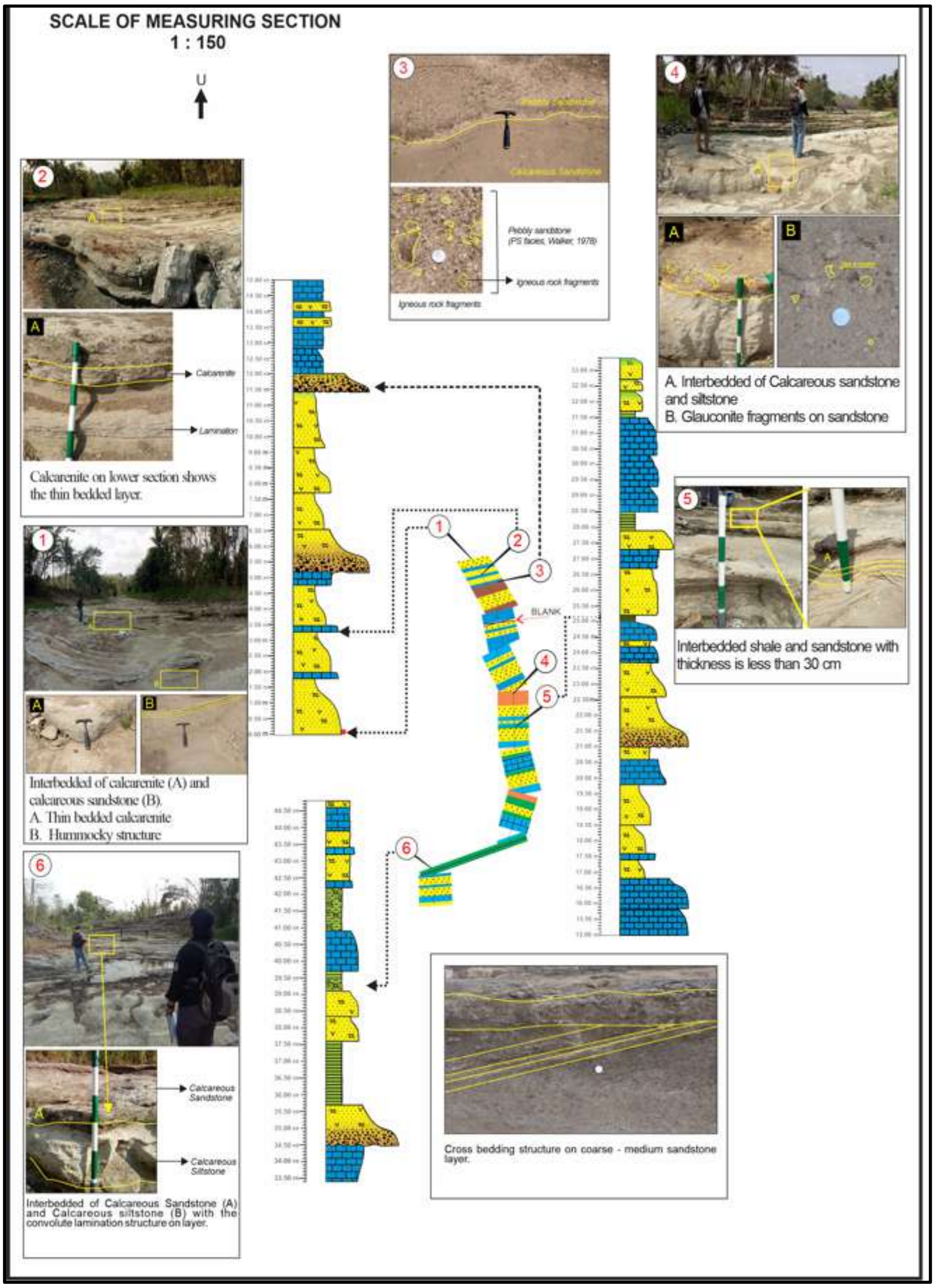

Figure 2. Track map of measuring section at Ngalang river

4. Result and Discussion

The measuring section at Ngalang River consisted of five observation points such as point of 1,2,3,4,5, and 6 which represented the different rock. Based on result data of stratigraphy section measurement, the thickness of rock is about 55.90 meters. It consists 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 part of Upper Sambipitu Formation and it were deposited at depth of 20 m to 500 meters (Inner Neritic to Upper Bathyal) (Phleger, 1951) (Figure. 3).

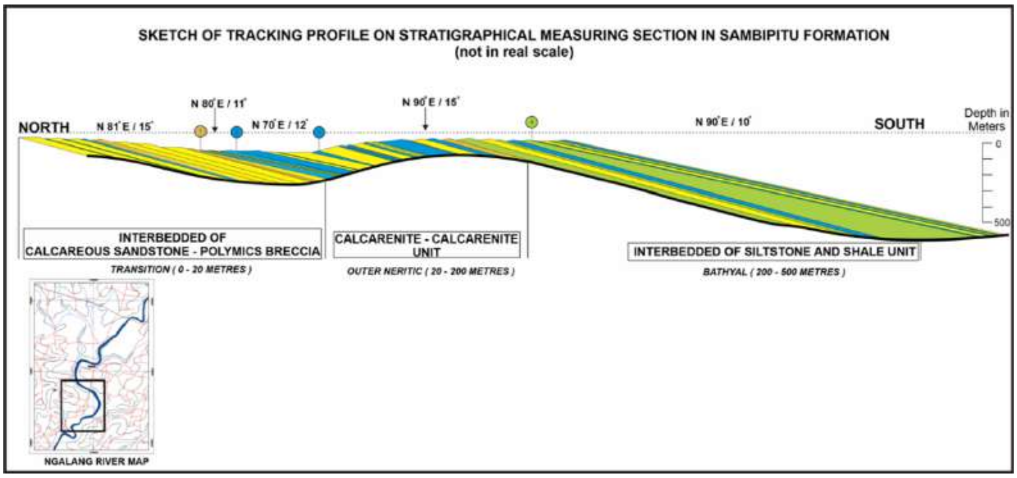

Figure 3. The profile of tracking map of measuring section at Ngalang river

4.1 Markov Chain Analysis (Lithological Pattern)

The Markov analysis was done at 44,90 thickness of the measuring section along the Ngalang river in field work 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 shows the probability value of each rocks. 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.

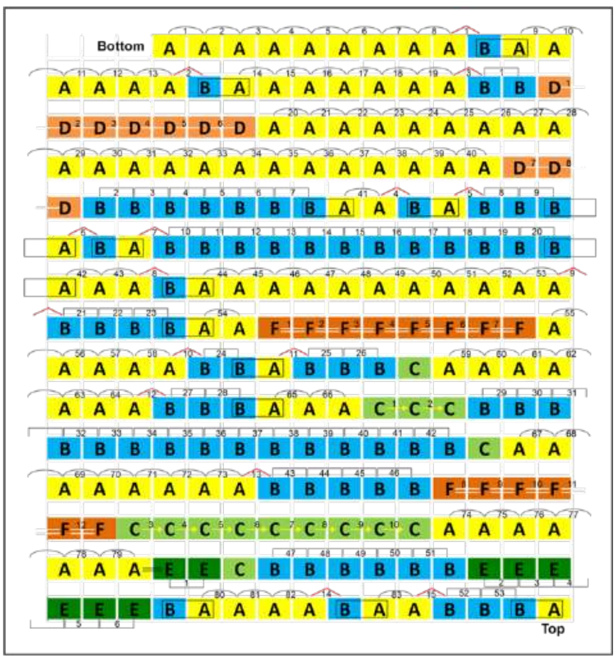

Figure 4. The sortation of repetition rock lithology with markov chain analysis

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

The Markov chain facies also was done using Bouma Facies Model (1962) and Walker Facies Model (1978) based on 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 Upper Sambipitu Formation. The result of facies classified by 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).

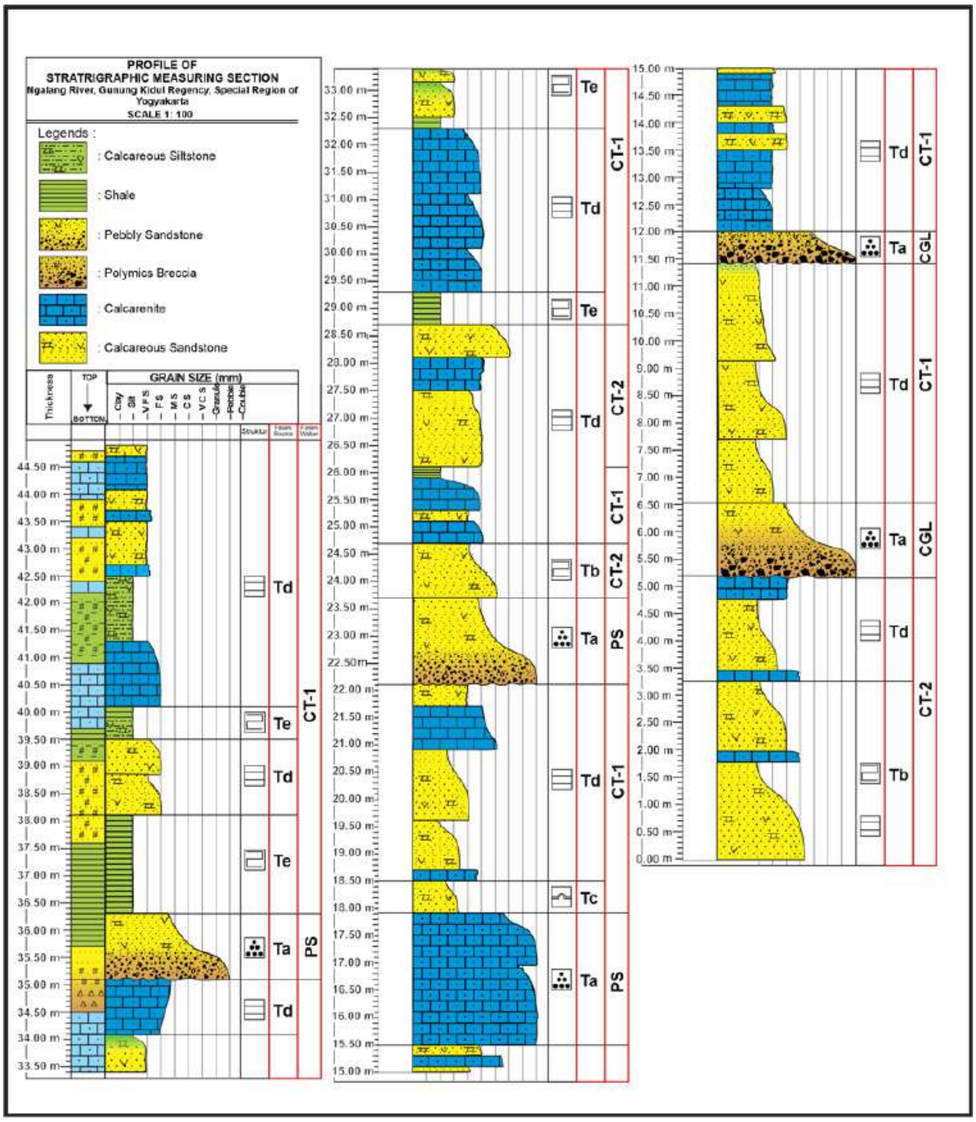

Figure 5. The sortation of repetition rock lithology with markov chain analysis

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 Matrix of Probability Percentage

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 were be presented in Table 1.

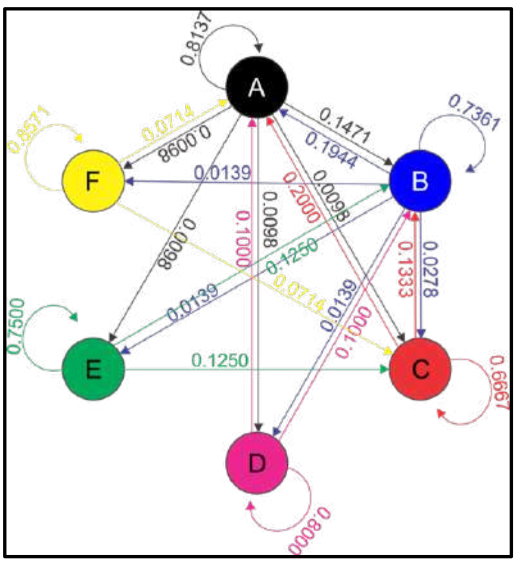

Figure 6. Markov Chain of Rock Lithology of Sedimentation Pattern at Ngalang River

Table 1. Cycle of markov chain

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*)
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*)

Calcareous 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 showed the product of sedimentation process.

4.3 Geological Interpretation

Geological Interpretation of depositional environment in research area was determined based on 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 the general trend of Northwest – Southeast

(NW-SE). It means that the source of sedimentation come from northwest part of research area due to the dip of sedimentary layer is south direction.

Several trace fossils were found in research area such as *Chondrites* (Zoophycos), *Rhizocorallium* (Cruziana Facies), and *Thalasinoides* (Skolithos) (Collinson and Thompson, 1982). By identifying of the fossils trace, the depositional environments were 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 table of chi square (Table 3) to determine the hypotheses acceptation and rejectation (HI) (Table 4).

Table 3. Chi square calculation

Class	OBSERVATION DATA (OJ)	EXPECTATION DATA (EJ)	(OJ-EJ)''/EJ
CT-1 - CT-1	136	90.24	23.20
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 Sambipitu Formation. The discussions will be presented:

There were some equalities 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 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 is no polymic breccia after the chi square has been completed. It's 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 interpretation of cross section, the research area is located near to source area. The value of percentage of Pebble Sandstone is about 50%. Based on cross section the lithology of coarse grain size is decreased. This oocurance 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 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 Upper area. The bentonic fossil analysis is Upper (slope) Bathyal which could not relate to facies analysis of lower fan (Walker, 1978).

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

c. Climate

The warm climate affects to carbonates development. The benthonic fossils developed at the top part of stratigraphic measuring section where there some fossils in Bathyal paleobathymetric found. The warm climate makes a good condition of carbonate development. The presence of carbonate cement has become an indication of shallow marine with 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 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 factor of environment changes that directly affected to the depth of seawater. At research area, the volcanic products were deposited in northern area that included in proximal facies according to Bogie et al (1998).

Trace fossils presence at Ngalang River could support the interpretation of paleobathymetry or depositional environment. Based on interpretation of depositional environment by trace fossil identification (Seilacher, 2007), the depositional environment at bottom, middle, and top of Upper Sambipitu Formation at Ngalang River 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 area 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 	(Chondrites) (Zoophycoos) (Seilacher, 2007)	*Upper bathyal* (depth of 200-500 meters)
Middle 	(Rhizocorallium) (Cruziana) (Seilacher, 2007)	Neritic (*Sublitoral*) (depth of 0-20 meters)
Bottom 	Thalasinoides (Skolithos) (Seilacher, 2007)	C*ontinental shelf* (Tidal) (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* can 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 of rock repetition possibility with the presence of biggest possibility is A (Calcareous Sandstone) – B (Calcarenite) – E (Calcareous Siltstone) – C (Shale) - A (Calcareous Sandstone) about of 48,60 %

3. The presence of lithology is dependent on presence of the next lithology, and the sorting of rock lithology was not done at random (in a pattern). It showed that *chi square* test with value of $\mathcal{X}^2 calculation$ (574,40) $>$ $\mathcal{X}^2 table$ (37,65)
4. The prediction of lithology for the next rock lithology of 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 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). It was showed by *chi square* test with the value of $\mathcal{X}^2 calculation$ (605,65) $>$ $\mathcal{X}^2 table$ (26,30)
7. The prediction of facies presence (Bouma,1962) on 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 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 previous facies which the sortation of facies is not random. It was showed by *chi square* test with value of $\mathcal{X}^2 calculation$ (2409,86) $>$ $\mathcal{X}^2 tabel$ (16,92)
10. The prediction of facies presence (Walker,1978) on 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.

Acknowledgement

This research is highly dedicated to Institut Teknologi Nasional Yogyakarta which has funded and supported. We would like to thank some anonymous reviewers whose comments improved the early version of this manuscript's quality.

References

AL HUSSEIN FLOWERS, R. I. Z. Q. I. (2019). IDENTIFIKASI STRUKTUR GEOLOGI DAN IMPLIKASINYA TERHADAP PENYEBARAN BATUAN FORMASI ANDESIT TUA–SENTOLO DI SUNGAI NITEN, GIRIPURWO, KULON PROGO. *Angkasa: Jurnal Ilmiah Bidang Teknologi*, *11*(2), 152-163.

Apriani, A., 2016, *Markov Chains* Method to Analysis of Facies Repetition in Kiliran Sub Basin Kiliran Jao, West Sumatra, *Journal of Angkasa*, Volume VII, Nomor 1.

Aprilita, L., Pandita, H., & Nuraini, S. (2020). ANALISIS FASIES PADA KONTAK ANTARA FORMASI SAMBIPITU DAN FORMASI OYO DI LINTASAN KALI NGALANG, GUNUNG KIDUL. *Geoda*, *1*(2), 43-52.

Ashari and Pandita (2008), The transition of depositional environment between Antara i Nglanggran Formation and Sambipitu Formation, Kali Ngalang, Dusun Karanganyar, Ngalang area, Gedang Sari Village, Gunung Kidul Regency, Special Region of Yogyakarta

Blow, W. H. (1969). Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In *Proceedings of the First International Conference Planktonic Microfossils 1967* (Vol. 1, pp. 199-242). EJ Brill.

Bouma., 1962, Bouma Sequence, The Geological Society of London. Dunham, 1962, Clasification of Carbonate Rock According Depositional Texture, AAPG.

Bogie ,I.,and Mackenzie, K.M., 1998, The Application of A Volcanic Facies Model to An Andesitic Stratovolcano Hosted Geothermal System at Wayang Windu, Java, Indonesia*, Proceedings 20th*, NZ Geothermal Workshop.

Bothe, A. C. D. (1929). The Geology of the Hills Near Djiwo and Southern Range. In *4th PacificScience Congress, Bandung*.

Donovan, S. K. (2017). Trace fossils and tropical karst. *Geological Magazine*, *154*(1), 166-168. doi:10.1017/S0016756815000965

Febbyanto, H. (2012). Geology and Study of GEOLOGI DAN STUDI FORMASI Nglanggeran Formation in Patuk Area, Patuk sub district, Gunung Kidul Regency, Special Region of Yogyakarta (Doctoral dissertation, UPN" Veteran" Yogyakarta).

Flowers rizqi, al hussein. (2019). Analisis Siklus Perulangan Litologi pada Stratigrafi Formasi Sambipitu di Sungai Ngalang, Kecamatan Gedangsari, Kabupaten Gunung Kidul,DIY. *ReTII*,359-375.Retrievedfrom //journal.itny.ac.id/ index.php/ReTII/ article/view/1191

He, J., La Croix, A. D., Wang, J., Ding, W., & Underschultz, J. R. (2019). Using neural networks and the Markov Chain approach for facies analysis and prediction from well logs in the Precipice Sandstone and Evergreen Formation, Surat Basin, Australia. *Marine and Petroleum Geology*, *101*, 410-427.

Hillier, F.S. dan Lieberman, 1995, *Introduction to Operations Research,* Sixth Edition, Mc. Graw Hill Inc., Singapore.

Jun, H., Cho, Y., & Noh, J. (2019). Trans-dimensional Markov chain Monte Carlo inversion of sound speed and temperature: Application to Yellow Sea multichannel seismic data. *Journal of Marine Systems*, *197*, 103

Kuenen, P. H. H., Migliorini, C. I., 1950, Turbidity Current as a Cause of Graded Bedding, *The Journal of Geology v58,* hal. 91-12,175.111.89.45.

Lumsden, D. N. (1971). Markov chain analysis of carbonate rocks: applications, limitations, and implications as exemplified by the Pennsylvanian system in southern Nevada. *Geological Society of America Bulletin*, *82*(2), 447-462.

Michael, H. A., Li, H., Boucher, A., Sun, T., Caers, J., & Gorelick, S. M. (2010). Combining geologic-process models and geostatistics for conditional simulation of 3-D subsurface heterogeneity. *Water Resources Research*, *46*(5).

Moch Indra Novian, S. T. (2011). Stratigraphy and Sedimentation Of Transition Zone Of Sambipitu – Oyo Formation at Widoro River, Ngalang River and Kedungdowo River, Nglipar Sub District, Gunung Kidul Regency, Special Region Of Yogyakarta (Doctoral Dissertation, Universitas Gadjah Mada).

Pandita, H., 2008, Depositional environment of Sambipitu Formation Based on Trace Fossil in Nglipar Area, *JTM*, Institut Teknologi Bandung, Vol. XV, No. 2 hal 85-94. ISSN 0854-8528.

Pettijohn, F. J. (1975). *Sedimentary rocks* (Vol. 3). New York: Harper & Row.

Phleger, F. B. (1951). *Ecology of foraminifera, northwest Gulf of Mexico* (Vol. 46). Geological Society of America.

Pramunita, S. W., & Pandita, H. (2020). ANALISIS KEPADATAN FOSIL JEJAK SEBAGAI PARAMETER TINGKAT KANDUNGAN OKSIGEN DAN PERUBAHAN LINGKUNGAN PENGENDAPAN DI KALI NGALANG, GEDANGSARI, GUNUNG KIDUL, DIY. *Geoda*, *1*(2), 1-18.

Prayoga, O. A., & Hartono, H. G. (2017). Correlation of Lithofacies and Ichnofacies as Parameter of Ancient Volcano Identification in depositional of Sambipitu Formation, Daerah Ngalang, Yogyakarta. *ReTII*. Retrieved from// journal.itny.ac.id /index.php /ReTII/article/view/266

Purbantoro, R., & Nuraini, S. (2020). KONFIGURASI STRATIGRAFI BATAS FORMASI SAMBIPITU DAN OYO DI JALAN NGALANG–GADING, KECAMATAN GEDANGSARI–PLAYEN, GUNUNGKIDUL. *Geoda*, *1*(2), 81-94.

Putra, D. C., & Pandita, H. (2015). Identification of Kali Ngalang fault in Karanganyar village, Ngalang, Gedang Sari Sub district, Gunung Kidul Regency, Special Regency of Yogyakarta. *ReTII*.

Seilacher, Adolf (2007). Trace Fossil Analysis. Berlin: Springer-Verlag

Selley, R. C., 1985, *Ancient Sedimentary Environments*, 3rd edition, Cornell University Press, New York. p. 317

Suprapto, N., Zamroni, A., & Yudianto, E. A. (2017). One Decade of the "LUSI" Mud Volcano: Physical, Chemical, and Geological Dimensions. *CHEMISTRY*, *26*(4), 615-629.

Surono., Toha, B., Sudarno, I., Wiryosujono, S., 1992, Stratigraphy of *Southern Mountain, Central Java,* P3G-Ditjen GSM Dept. Pertamben, Bandung.

Tipsword, H.L., Setzer, F.M dan Smith, F.L Jr, 1966. Interpretation of Depositional Environment in Gulf Coast Petroleum Exploration from Paleocology and Related Stratigraphy, Transaction G.C, Assoc. Geol. Soc., 119-130.

Van Bemmelen R.W,. 1949, *The Geology of Indonesia*. The Goge, Martinus.

Walker, R.G., 1978, Facies Models, Geological Association of Canada, Toronto.

Walker, R.G. and James, N.P., 1992, *Facies Model,* Second Edition*,* Geological Association of Canada, Ontario, 454p

Walrand, J., & Varaiya, P. P. (2000). *High-performance communication networks*. Morgan Kaufmann. https://doi.org/10.1016/B978-0-08-050803-0.50014-9

Zamroni, A., Putra, B. P., & Prasetya, H. N. E. (2020). Anthropogenic influences on morphological changes in the Progo River, Daerah Istimewa Yogyakarta Province, Indonesia. *Sustinere: Journal of Environment and Sustainability*, *4*(3), 205-223.