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Sedimentation Dynamics of the Lower Part of Sentolo Formation at Niten Stream Traverse, Girimulyo, West Progo

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***Abstract*- Previous geologists showed that Sentolo Formation was interfingering with Jonggrangan Formation and both of them laid unconformably on Old Andesite Formation. The aim of this study is a deeper understanding of the sedimentation dynamics of Sentolo Formation in order to know its stratigraphic relationship to Old Andesite Formation. Petrographic analysis was used to describe the microfacies. Paleontological analysis was used to know the age and sedimentation environment. Stratigraphic measurement of Sentolo Formation in the section of Niten Stream traverse showed that Sentolo Formation was sedimented on the basin environment (SMF3/FZ1; SMF2/FZ1), deep shelf margin (SMF3/FZ3) to foreslope (SMF4/FZ4). The paleontological data indicate that these sedimentary rocks was depositing during Early Miocene until the beginning of Middle Miocene (N6 – N9). Sedimentary rock succession is generally dominated by layered limestone with tuff sandstones that develop well in the lower – middle layer. It indicates that the dynamic of basin sedimentation which formed during that period was influenced by volcanic activity that gradually weakened and caused the basin relatively quiet, producing thick limestone.**

***Keywords*- sedimentation dynamics; Sentolo Formation; limestone; microfacies**

I. INTRODUCTION

Local and foreign geologists had conducted some researches in West Progo Hills [1]–[4]. They reported that the stratigraphical state of Kulon Progo stratigraphy was revised from time to time. It assumed that there were two important cycles of volcanic activity in Java Island [1]. The first cycle commenced on Early Miocene, when basaltic and andesitic volcanoes were formed. This volcanic activity caused the formation of a sequence of rocks consisting of breccia, conglomerates, and sandstones. Sediment production and transport controlled by explosive volcanic activity increase both the sediment supplied to the basin and the energy of depositional event [5]. It is characterized by the grain size trend of gravel detritus. The second cycle started on Late Neogene until recent consisting of andesitic rock producing sequences of similar volcanic rocks. This first (Early Miocene) volcanic rock sequence was called Old Andesite Formation while the second (Late Neogene - Quaternary) was named Young Andesite Formation. It used this terminology of Old Andesite Formation for andesitic volcanism rock unit that was formed from Late Paleogene until Early Miocene [1]. Old Andesite Formation were unconformably overlain by Jonggrangan Formation and unconformably overlain Sentolo Formation.

It is explained that Jonggrangan Formation was formed on Miocene which is unconformable on top of Old Andesite Formation and interfingering with Sentolo Formation that was formed on Early Miocene until Pliocene [2]. It had also discussed in detail about biostratigraphy in South part of Central Java and West Progo. Sentolo Formation is divided into three members; namely Kanyaranyar, Genung, and Tanjunggunung Members [4]. The research location is in Girimulyo District, West Progo, Yogyakarta (Fig. 1).

Fig. 1 Research location in West Progo, Yogyakarta

II. Material and Methods

This research uses both primary and secondary data. Secondary data includes geological data collection in selected locations, especially on sedimentologic and stratigraphic data. Primary data consist of collected stratigraphic measurements, which is presented in lithostratigraphic column including lithological characteristics and the development of rock facies sequence [6]. Laboratory analysis was conducted to augment the field data, including carbonate and non-carbonate rocks petrographical and paleontological analysis [7].

Petrographic testing of several rock samples on this track has used to increase the accuracy of the analysis and interpretation of sedimentological aspects, especially on microfacies of the limestone. The classification of limestone type is based on Dunham Limestone Classification [8]. That classification of limestone also explained prelimininary facies based on visual inspection and sedimentological and mineralogical analyses [9]. Microfacies analysis can be examined by mineralogical component, macrofossil, and microfossil assemblage, and texture of the samples observed inthin section [10].

Paleontological analysis was used to determine the age and sedimentation environment of the rocks, in order to determine the stratigraphic position. The microfacies are interpreted based on the results of petrographic analysis, combination and paleontological criteria [11], while belt facies are based on rock composition, processes and depositional environments [12]. It is estimated the depositional environment based on planktonic / benthonic ratios. Detailed paleontological and petrographic analysis were combined with all field data and synthesized together to explain the sedimentation environment and dynamics of the research area [13].

III. Results and Discussion

A. Stratigraphy of Niten Section

Stratigraphic sequence of Niten section are included in the Old Andesite Formation and Sentolo Formation [3]. Old Andesite Formation composes of volcanic breccia, lava, lapilli breccia, tuff lapilli, and volcanic sandstone. Sentolo Formation is unconformable laid on Old Andesite Formation, consisting of limestone, sandstone, and well–bedding tuffaceous marl [3]. The dynamic interplay of tectonics, eustasy, climate, in situ carbonate production, an variations in silisiclastic sediment supply influenced the succession of sedimentary rocks [14]. Based on the results of observations and measurements at Niten traverse, Sentolo Formation laid conformably on Old Andesite Formation (Table 1) and generally consists of bedded limestone and tuff sandstone. The sedimentary rock which were dominated by carbonate rocks with intercalation of argillaceous facies is associated with rapid sea level rise [15].

The age of Sentolo Formation is Early Miocene – early Middle Miocene (N6 – N9), based on the identification of *Globoquadrina dehiscens* (Chapman, Parr & Collins), *Globoquadrina praedehiscens* Blow & Banner, *Globoquadrina altispira* (Cushman & Jarvis), *Globigerinoides immaturus* Le Roy, *Globigerinoides trilobus* (Reuss), *Globigerinopides diminutus* Bolli, *Globigerinopides subquadratus* Bronnimman, *Globigerinoides obliquus* Bolli, *Globigerinoides sacculiferus* (Brady), *Globigerina praebulloides* Blow, *Globigerina venezuelana* Hedberg, *Globigerina tripartite* Koch, *Catapsydrax dissimilis* (Cushman & Bermudez), *Globorotalia mayeri* Cushman & Ellisor, *Globorotalia obessa* Bolli, *Globorotalia peripheroronda* Blow & Banner, *Orbulina suturalis* Bronnimann, *Praeorbulina sicana* De Stefani, *Praeorbulina transitoria* Blow. Based on benthonic foraminifera, rock of the research area was deposited on Middle Neritic depositional environment (Table 2). The existence of *Uvigerina sp* shows that its depositional environment was outer shelf to bathyal [16].

Petrographic testing was done to 18 rock samples. The beginning of Sentolo Formation in Niten track is the appearance of bedded limestone, yellowish white in color, medium-sand sized, with the thickness of 45 - 55 cm (Sample code NT 01) which named Wackestone base on Dunham classification [8] (Fig. 2). Among interbedded limestones there are tuff sandstone (lithic tuff) inserts (Sample code NT 02), bright gray, compact, hard, medium sand sized, with quite a lot of hornblende.

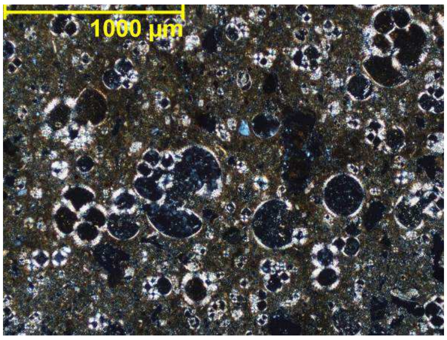

Fig. 2 Wackestones (Sample code NT 01) medium fragmental bioclastica, poor sorting, open fabric and supported mud, grain size (average) 0.30 mm

The development upward, shows that the bottom part of this section consisting of limestone develops into a limestone indicating a thin layer (Sample code NT 06), a layer thickness of 10-20 cm and at the top reaching 130 cm. This rock is Wackestone [8] (Fig. 3).

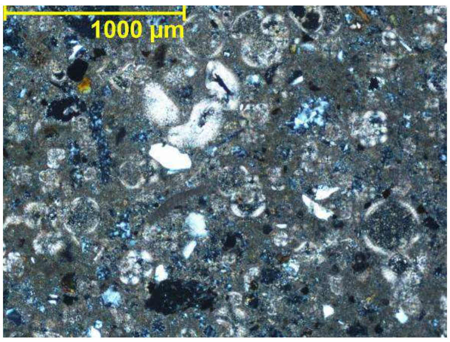

Fig. 3 Wackestone (Sample code NT 06) fine fragmental bioclastica, poor sorting, open fabric and supported mud, grain size (average) 0.20 mm

The tuff sandstones are well developed showing the repetition with limestone (Sample code 07). Tuff sandstones (vitric tuff) are dark gray, medium coarse sized sand, grain supported texture, 1 to 10 cm thickness. The thickness of this sandstone is thinner than the limestone section with the thickness of 10-20 cm (Fig. 4).

TABLE I
STRATIGRAPHIC COLUMN OF SENTOLO FORMATION ON NITEN STREAM TRAVERSE

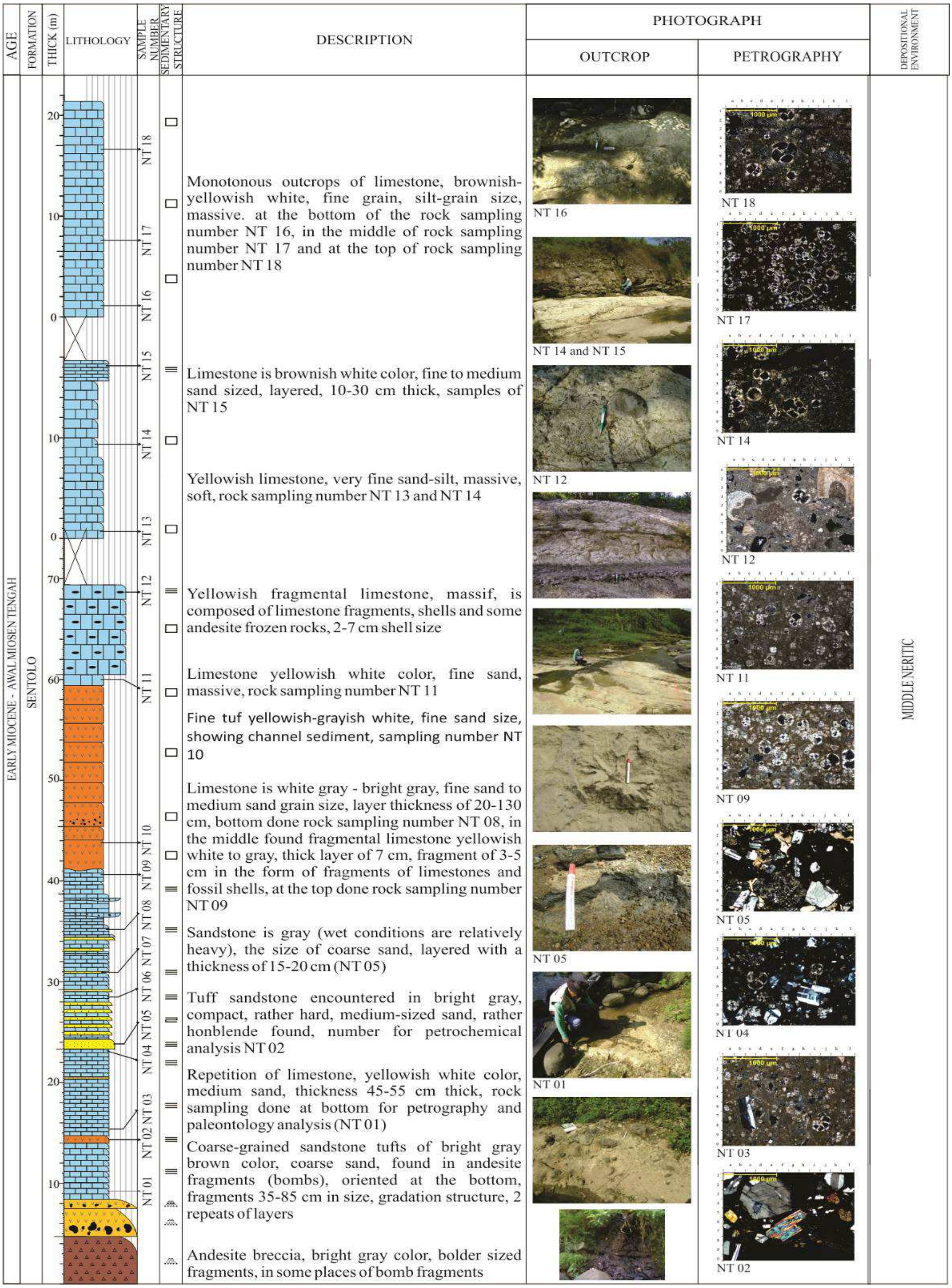

TABLE II

DETERMINATION OF THE DEPOSITION ENVIRONMENT BASED ON BENTHONIC FORAMINIFERA

SAMPLE	SPECIES	ZONE BATHYMETRI (METER)				
		Intertidal	Inner Neritic (0-30)	Middle Neritic (30-80)	Outer Neritic (80-200)	Upper Bathyal (200-500)
NT 18	- *Amphisteegina lessonii* D'Orbigny - *Cibicides sp. Aff. C. floridanus* Cushman					
NT 17	- *Amphisteegina lessonii* D'Orbigny - *Nodosaria sp*					
NT 16	- *Anomalina Colligera* (Champman & Parr) - *Nodosaria sp*					
NT 15	- *Amphisteegina lessonii* D'Orbigny - *Nodosaria sp*					
NT 14	- *Anomalina Colligera* (Champman & Parr)					
NT 13	- *Anomalina Colligera* (Champman & Parr)					
NT 12	- *Neocorbina sp.cf. N. terquemi* (Rzehak)					
NT 11	- *Brizalina acutula* (Bandy) - *Anomalina colligera* (Champman & Parr)					
NT 09	- *Buccela tenerrima* (Bandy) - *Siphonina pulchra* Cushman					
NT 08	- *Anomalina Colligera* (Champman & Parr) - *Nodosaria sp*					
NT 06	- *Amphisteegina lessonii* D'Orbigny - *Nodosaria sp*					
NT 04	- *Anomalina Colligera* (Champman & Parr) - *Nodosaria sp*					
NT 03	- *Anomalina Colligera* (Champman & Parr) - *Nodosaria sp*					
NT 01	- *Anomalina colligera* (Champman & Parr) - *Eponides Umbonatus* Reuss					

Fig. 4 Tuf sandstone, gray, dominant compositions of glass, andesite-basal fragments, generally have been altered, as well as unidentified rocks due to the strong oxidation

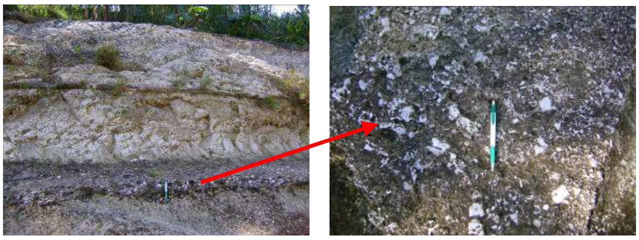

Fig.5 Fragmental limestone, 7 cm thick layer thickness, 3 to 5 cm fragment of limestone and fossil shels

Granules show 0.3 - 1 mm in size, angular-subrounded, composed mainly by igneous weather rock fragments, slightly plagioclase, hornblend, fossils of the genus of globigerinid. The ground mass consist of weathered volcanic glass. Porosities in the form of intergrain and fracture. The rock name is vitric tuff.

On top of the interbedded limestone there is fragmental limestone, yellowish white color, 7 cm thick layer thickness, 3 to 5 cm fragments of limestone and fossil shells (Fig. 5).

At the center of the Niten traverse, rocks develop as smooth tuffs, yellowish white, fine massive sand, with rock geometry showing channel deposits and the overall thickness reaches 18 meters (Sample code NT 10b, Fig.6). Petrographic observation shows matrix supported texture. The rock shows 0.15 - 2 mm in size, angular-subrounded, composed primarily of igneous fragments in weathered conditions, little plagioclase, hornblend and fossil of globigerinid genus. The ground mass was observed in the form of weathered volcanic glass. Porosity develops in the form of intergrain and fracture. The name of this rock is Vitric Tuff.

Spread over mentiond rocks, lays fragmental limestone (Sample code NT 12), yellowish white in color, massive, fragments of limestones and some igneous andesite rocks, shell fossils with the size of 2 - 7 cm. Petrographic observation shows matrix supported texture. The grains are generally 0.15 - 2.2 mm in size, composed of carbonate clastica rock (intraclast), large benthos foraminifera (lepidocyclina, paleonumulites), small benthos (biserial), planktonic foraminifera, globigerinid genus, red algae, igneous rock fragments and plagioclase. Some micrite show neomorphism to be microspars. The visible porosity is the type of moldic, vug, intragrain. There are dissolution of particles and matrix. Some of the pores are filled by calcite cementations and replacement by silica. The rock's name is Packstone [8] (Fig. 7).

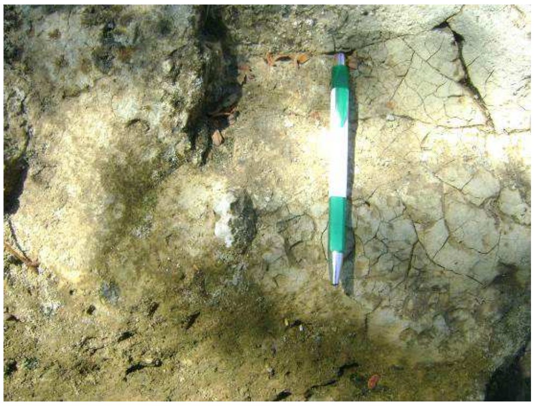

Fig. 6 Fine tuff outcrop, the ground mass was observed in the form of weathered volcanic glass

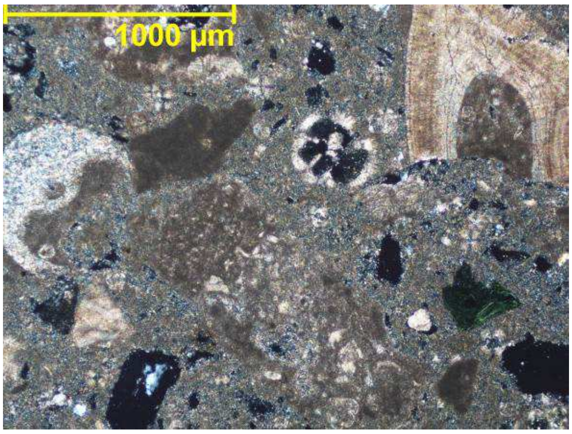

Fig. 7 Packstone with lithoclastic (Sample code NT 12) coarse fragmental clastica, poor sorting, close fabric, grain size (average) 1.20 mm,

At the top of measured section there is yellowish white limestone (Sample code NT 15), silt-fine sand sized, massive, soft, upward sides of the center of the limestone exhibit a coarse to medium sand size, and a fine layer structure of 10 - 30 cm thickness (Fig. 8).

Petrographic observation shows matrix supported texture. Granules are generally 0.15 - 0.45 mm in size, composed primarily of planktonic foraminifera, the globigerinid genus, a bit of plagioclase and opaque minerals. Some micrite shows neomorphism to be microspar. The visible porosity is the type of intragrain, moldic, vug and fracture. There is dissolution of particles and matrix. Some of the pores, especially intragrain and moldic, are filled by zeolite, cementite calcite and replacement by silica. The rock name is Wackestone [8] (Fig. 9).

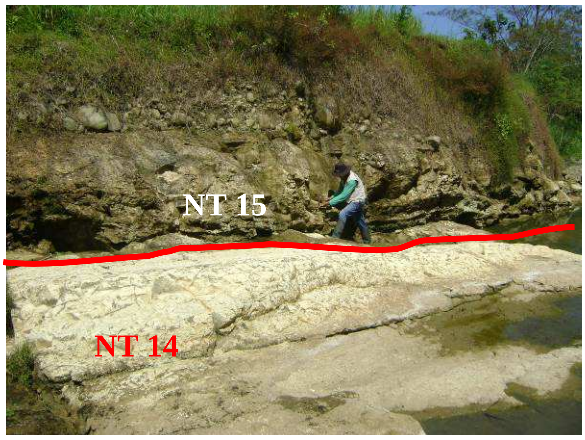

Figure 8. Massive limestone that develops upwardly into a thin-bedded limestone.

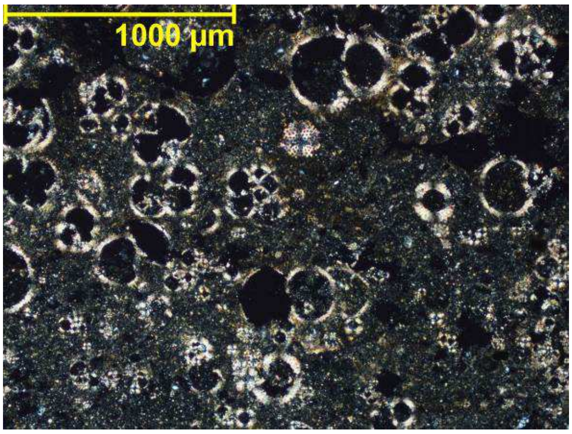

Fig. 9 Wackestone (Sample code NT 15) fine fragmental bioclastica, poor sorting, open fabric and supported mud, grain size (average) 0.15 mm

B. Sedimentary Environment

The observation of the Niten traverse, shows wackestone at the bottom, yellowish-white, foraminiferal rocks, matrix supported texture, fine-grained sand, many fossils of planktonic foraminifera, slightly benthonic foraminifera, well segregated beds foraminifera, characterized the basin environment (SMF3/FZ1; SMF2/FZ1) (Table 3). Further development of wackestone, bright gray-gray, matrix-grain supported texture, fine carbonate grain size, many planktonic foraminifera fossils, slightly benthonic foraminifera, layered laminated and structures, characterize the deep shelf margin (SMF3/FZ3). This environment grew to the center of Niten's track, and finally back to the basin (SMF2 / FZ1 and SMF3 / FZ1). Further developing show fragmental limestones (Packstone), characterizing the fore slope environment (SMF4 / FZ4). At the top of the re-growing Foraminiferal Wackestone, yellowish-white-gray, silt-fine sand sized rock, many planktonic foraminifers' fossils, slightly coronal foraminifera, well segregated beds, characterized the basin environments (SMF3/FZ1; SMF2/FZ1).

C. Sedimentation Dynamics

The dynamics of sedimentation on the Niten river track began with the Old Andesite Formation as the bedrock of the Sentolo Formation deposition. Rocks of andesite breccia, open fabric, in some places fragments of volcano bombs are still relatively intact.

This facies represents the active phase of volcanism occurring in the Late Oligocene Epoch which ended with the presence of coarse tuff sandstones affected by the volcanic activity, indicated by bomb and block fragments encountered at the bottom of the tuff sandstone. The fragment sizes are 35-85 cm, the structure of the bomb is relatively intact, characterizing the bomb fragment immediately transported after the deposition of the tuffaceous sandstone, thus indicating the corresponding relationship of the two rocks.

After the sedimentation of coarse tuff sandstone, the environment became calm, volcanism began to weaken, therefore at Early Miocene evolved foraminiferal wackestone rocks deposited in Basin position (SMF3/FZ1; SMF2/FZ1). On the sidelines of the formation of this limestone the depositional environment was still influenced by volcanic activity as indicated by 110 cm thick tuffs sandstone amounting to 15 - 20 layers which show the increasing fluctuation of sediment supply. Upward at the bottom of the Niten track shows the siliciclastic sediment fluctuations and carbonate sediment acceleration, as shown by thick limestone layer of 10-20 cm thickness and tuff sandstone of 1 to 10 cm. The consequence of this relatively rapid sedimentation leads to the increasingly shallow deposition environment. The appearance of fine-grained siliciclastic indicates a change in the environment from shallower water region to deeper water region [17]. The pattern of facies of sediment mixed carbonate - siliciclastic system shows that there is a change in depositional environment of inner ramps and outer ramp to basin [18]. It is shown that limestone was deposited in a deep shelf margin environment (SMF3 / FZ3). There was a transgression process which is shown by fining upward texture of siliciclastic grains, which means the environment back to basin environment (SMF2 / FZ1, SMF3 / FZ1).

The volcanism was active again and produced fine tuff facies, which deposited in the channel environment. The energy of tuff deposition process was quite strong, which is indicated by the fragment of limestone and andesite rock on several layers of tuff. The deposition of tuff was long enough as shown by the overall thickness of 18 meters. The volcanic activity indicates the last part of Niten section and cause the depositional environment to be shallow. The degradation of the sedimentary environment will certainly cause different facies, such as in the middle of the path of Niten measurement begins to show the appearance of yellowish white to fragmental limestone, thick layer of 7 cm, fragment size of 3 to 5 cm. The limestone consisting of foraminiferal packstone, characteriezes the fore slope environment (SMF4/FZ4).

TABLE III.
RESULTS OF MICROFACIES ANALYSIS

SAMPLE CODE	NT 01	NT 02	NT 03	NT 04	NT 05	NT 06	NT 07	NT 08	NT 09	NT 10	NT 11	NT 12	NT 13	NT 14	NT 15	NT 16	NT 17	NT 18	INFORMATION
DISCRIPTION																			
Texture	bf	cf	bf	cf-bf	cf	bf	bf	bf	bf	bf	bf	cf	bf	bf	bf	bf	bf	bf	
Fabric	o	c	o	o	c	o	o	c	c	o	o	c	o	o	o	o	c	o	bioclastic carbonaceous
Grain size	0.3	0.3	0.3	0.15	0.3	0.2	0.1	0.2	0.2	0.05	0.2	1.2	0.15	<0.10	0.15	0.15	0.25	0.15	clastics fragmental
Grain shape	sa-sr	a-sr	sa-sr	a-sr	a-sr	sa-sr	a-sr	sa-r	sa-r	sa	sa-sr	a-sr	sr	sr	sr	sr	sa-sr	sa-sr	non clastic
% Butiran Karbonat																			crystalline
Bioclast	30	0	34	0	0	22	0	54	57	0	29	22	21	14	22	26	49	15	
Intraclast/Extraclast	1	0	2	0	0	2	0	0	0	0	0	38	0	1	1	0	1	0	
Pelet/peloid	1	0	1	0	0	0.5	0	2	1	0	1	0	0.5	0	1	0.5	0	0	close
Terigeneous grain																			open
Quartz	0		0	0	0	0	0	0	0.5	1	0.5	0	0	0	0.5	0.5	0	0	
Feldspar	0	12	2	18	14	4	2	1	1	6	0	0.5	0	0	0	1	0	0	
Rock fragmen	0	45	3	9	51	3	16	1	0.5	7	0	0.5	0	0.5	0.5	2	0	0	angular
Other grains	0	6.5	1	16	17	2	6	1	0.5	15	0	2	0.5	0	1	1	0	0	subangular
Matric																			subrounded
Mud / Micrite	47	0	48	0	0	55	0	27	30	7	60	24	66	77	60	45	34	70	rounded
Clay minerals	5	2	0	43	4	0	6	0	0	60	0	0	0	0	0	10	0	10	
Vulcanic glass	0	28	0	10	5	0	66	0	0	0	0	0	0	0	0	0	0	0	
Cement																			Packstone
Orthosparite	2	0	2	0	3	1	0	5	2	0	3	2	2	1	1	1	1	0	Wackestone
Iron oxide	0	1.5	1	2	2	3	2	0.5	0.5	3	0.5	1	1	1	1	2	1	0.5	Lithic Tuf
Authigenic clay	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	Tufaceous Greywacke
Other cement	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Lithic Arenit
Neoformism																			Vitric Tuf
Microsparite	3	0	2	0	0	2	0	4	4	0	2	6	4	3	3	4	2	0	Calcareous Claystone
Porosity																			
Between particle	10	3	3	1	1	5	1	4	2.5	0.5	1.5	3	4	2	8	6	10	4	
Vug	0.5	1	0.5	1	1	0.5	1	0.5	0.5	0.5	0.5	1	0.5	0	1	1	2	0.5	Standard microfacies (Flugel,1982)
Other secondary	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	Facies zone (Wilson, 1975)
	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	
Rock name	W	LT	W	TG	LA	W	VT	P	P	CC	W	P	W	W	W	W	P	W	
SMF / FZ	3 / 1	-	3 / 3	-	-	3 / 3	-	2 / 1	2 / 1	-	3 / 1	4 / 4	3 / 1	3 / 1	3 / 1	3 / 1	2 / 1	3 / 1	

Texture
bf = bioclastic carbonaceous
cf = clastics fragmental
Grain shape
a = angular
sa = subangular
sr = subrounded
r = rounded

Rock name
P = Packstone
W = Wackestone
LT = Lithic Tuf
TG = Tufaceous Greywacke
LA = Lithic Arenit
VT = Vitric Tuf
CC = Calcareous Claystone

Fabric
c = close
o = open
Mikrofacies
SMF = Standard microfacies (Flugel,1982)
FZ = Facies zone (Wilson, 1975)

After the volcanism activity ceased, gradually the deposition environment became deep, and the siliciclastic or carbonic material previously located above sea level was ended and deposited into the hollow as fragments of the wackestone. These carbonate rocks characterize the environment of basin (SMF3/FZ1 and SMF2/FZ1). The sedimentation of the carbonate rock of Sentolo Formation continued until the Middle Miocene (N9).

D. Discussion

So far, previous researchers have always stated that Sentolo Formation overlays unconformable above the Old

Andesite Formation. However, the reality of stratigraphic measurements in Niten river track shows the conformity relationship. Thus, at the time of the first tectonic phase of Early Oligocene – Late Oligocene, the paleogeography in West Progo basin shows the existence of high land area in the form of land and low land and sea. Active tectonics was followed by active volcanism that produced Gadjah, Ijo and Menoreh volcanos producing volcanic eruption in the high altitude. The products of volcanic activity were sedimented in the areas near the source of the eruption and sedimented as deposits in the lowlands far from eruption center.

In the second tectonic phase of the Early Miocene exhibited the decrease of West Progo area, thus causing the lowland areas became the sea and continued the process of sedimentation. In the highlands the erosion process occurred. The decline continued and the area of the highs became the sea where Jonggrangan Formation was deposited and at the same time the low area that became neritic environment clastic limestone was deposited with source maybe come from Jonggrangan Formation or derived from other reef systems. Thus the stratigraphy in the West Progo shows that Jonggrangan Formation unconformable with the Old Andesite Formation and Sentolo Formations conformably laid upon Old Andesite Formation. It is obvious that with such a sedimentation pattern there will be no direct contact between Jonggrangan Formation and Sentolo Formation which has always been said to be interfingered.

IV. Conclusions

The Sentolo formation in Niten traverse is generally composed by the limestone, Early Miocene - early Middle Miocene (N6 - N9), overlying above the Old Andesite Formation. At the bottom, wackestone was deposited in basin environments (SMF3/FZ1; SMF2/FZ1) and deep shelf margin (SMF3/FZ3) and in the middle, packestone was sedimented in the Foreslope environment (SMF4/FZ4) the top it was re-deposited wackestone in the environment of basin (SMF3/FZ1; SMF2/FZ1). Sentolo formation at the bottom was affected by volcanic activity and its peak occurred in the middle with lithic tuff precipitation, and more the influence of volcanism was smaller along with the increasing development of wackestone.

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