MIOCENE PALEOGEOGRAPHIC RECONSTRUCTION IN THE SANGATTA AREA, EAST KALIMANTAN BASED ON CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY AND BENTHONIC FORAMINIFERAL ANALYSIS

REKONSTRUKSI PALEOGEOGRAFI KALA MIOSEN DI AREA SANGATTA, KALIMANTAN TIMUR BERDASARKAN BIOSTRATIGRAFI NANOFOSIL DAN ANALISIS FORAMINIFERA BENTONIK

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ABSTRACT: The Kutai Basin is a significant hydrocarbon potential basin with up to 15 km thickness of Tertiary sediments. It is dominated by a complex deltaic system to a marine shelf environment. Thus, it is crucial to understand the facies distribution in the area. This study was carried out to assess, correlate, and reconstruct the paleoceanographic evolution of the basin using lithological and microfossil data obtained from five exploration wells. The lithostratigraphic analysis was used to identify lithological units of each well, while the calcareous nannofossils biostratigraphy was applied to estimate the age and benthic foraminifera was analysed for paleoenvironmental interpretation. The findings reveal that the study region consisted of claystone, siltstone, shale, coal, and sandstone of the Gelingseh and Kelandasan Formation. The age of these lithological units is assigned from the Middle to Late Miocene epoch (NN6-NN11), based on the presence of some nannofossil index fossils such as *Catinaster coalitus*, *Discoaster hamatus*, *Discoaster quinqueramus*, *Discoaster calcaris*, and *Coronocyclus nitescens*. Benthic foraminifera assemblages are primarily composed of arenaceous species such as *Trochamina* spp. and *Haplophragmoides* spp., indicating a transitional environment, though some species such as *Elphidium* spp. and several planktonic foraminifera species appeared, which reflect marine influence on the research area. Based on the biofacies analysis; mudflats, tidal flats, delta front, prodelta-marine shelf, and fluvial plain were formed during the Middle to Late Miocene in the studied area.

Keywords: Calcareous nannofossil, benthic foraminifera, biostratigraphy, paleogeography, Kutai Basin

***ABSTRAK**: Cekungan Kutai merupakan cekungan potensial hidrokarbon yang signifikan dengan ketebalan sedimen Tersier mencapai 15 km. Hal ini didominasi oleh sistem delta yang kompleks hingga lingkungan landas laut. Oleh karena itu, penting untuk memahami sebaran fasies di wilayah tersebut. Studi ini dilakukan untuk mengkaji, mengkorelasikan, dan merekonstruksi evolusi paleoceanografi cekungan tersebut menggunakan data litologi dan mikrofosil yang diperoleh dari lima sumur eksplorasi. Analisis litostratigrafi digunakan untuk mengidentifikasi unit litologi setiap sumur, sedangkan biostratigrafi nannofosil gampingan digunakan untuk memperkirakan umur dan foraminifera bentik dianalisis untuk interpretasi lingkungan purba. Hasil penelitian menunjukkan bahwa daerah penelitian terdiri dari batulempung, batulanau, serpih, batubara, dan batupasir Formasi Gelingseh dan Kelandasan. Umur satuan litologi ini* *diperkirakan berumur Miosen Tengah hingga Akhir (NN6-NN11), berdasarkan keberadaan beberapa fosil indeks nannofosil seperti Catinaster coalitus, Discoaster hamatus, dan Discoaster quinqueramus, Discoaster calcaris, dan Coronocyclus nitescens. Kumpulan foraminifera bentik terutama terdiri dari spesies arenaceous seperti Trochamina spp. dan Haplophragmoides spp., menunjukkan lingkungan transisi, meskipun beberapa spesies seperti Elphidium spp. dan beberapa spesies foraminifera planktik muncul, menunjukkan adanya pengaruh laut di wilayah penelitian. Berdasarkan analisis biofasies terbentuk: mudflat, tidal flat, delta front, prodelta-marine shelf, dan fluvial plain pada umur Miosen Tengah hingga Miosen Akhir di daerah penelitian.*

Kata Kunci: *Nanofosil gampingan, foraminifera bentonik, biostratigrafi, paleogeografi, Cekungan Kutai*

INTRODUCTION

The Kutai Basin is a Tertiary basin that extends from the central highlands of Kalimantan to the eastern coast of the island and spreads into the Makassar Strait. It is the largest basin in Indonesia, characterized by 60,000 square kilometres of sediment cover and up to 15 kilometres of sediment thickness (Rose and Hartono, 1978). The basin is also known as one of the largest Tertiary basins in Indonesia and it has produced substantial hydrocarbon potential (Alam et al., 1999). The hydrocarbon accumulations have been identified in the sedimentary deposit, becoming progressively younger as they move eastward. These sediments include sandstone units deposited in delta-front and delta-margin depositional environments (Nuay et al., 1985).

Regionally, the Kutai Basin is primarily characterized by extensive delta systems. It is formed through substantial sediment deposition from the Middle Miocene to the Pliocene periods, progressively prograding from west to east, and continues to accumulate until today (Galloway, 1975). Moss and Chambers (1999) have noted that the deltaic system of the basin has been filled with sediments originating from the interior of Kalimantan. After the tectonic inversion occurred at the end of the early Miocene, deltaic sediments prograded from the Samarinda anticlinorium into the Makassar Strait, and finally formed the Mahakam delta. The depocenter shifted towards the Samarinda area and the deltaic formations extended into offshore Kutai Basin during the Middle Miocene (Marshall et al., 2015). Several sedimentary rocks were formed during this time, including Pamaluan, Pulubalang, Balikpapan, and Kampung baru Formation and deposited until the Pleistocene (Satyana et al., 1999).

Neogene biostratigraphic study in the Kutai Basin is a crucial aspect for geological research in the region. Neogene biostratigraphic study in the Kutai Basin plays a pivotal role in unravelling the geological history, environmental changes, and hydrocarbon potential of this region. Several researchers (Morley et al., 2006; Hardy and Wrenn, 2009; Salahuddin and Lambiase, 2013; Marshall et al., 2015; Renema et al., 2015; Senduk et al., 2021) have examined the ages and paleoenvironment of the basin, but a comprehensive update of the paleontological record is still needed.

This research will study foraminifera and calcareous nannofossil for biostratigraphic correlation and paleoenvironmental analysis based on the data collected in the studied area. The outcome of this research will provide stratigraphic correlation and paleogeographic map using microfossils as the primary indicators.

Geological Setting

Geological structure of the Kutai Basin is dominated by a series of densely packed N-NE and S-SW trending folds, along parallel and coastline. The geological features are known as the Mahakam Samarinda Anticlinorium Fold Belt. In this fold belt system, irregular anticlines are separated by a large syncline and filled with Miocene siliciclastics sediment (Ott, 1987; McClay et al., 2000).

Stratigraphic evolution of the Kutai Basin (Figure 1) begins with Paleogene transgressive deposits and marked by various tectonic events like rifting, post-rift sagging, and basin subsidence. This section includes the Boh bed, Kelam Halo bed, Atan bed, Marah Formation, and Pamaluan Formation (Satyana et al., 1999).

The age of Maruat Formation and Pulau Balang Formation ranges from Early to Middle Miocene. These formations exhibit different lithological characteristics due to lateral facies change. Maruat Formation is primarily composed of carbonate rock, while Pulau Balang Formation comprises interbedded sandstone and limestone. The study states that Balikpapan Group encompasses thick

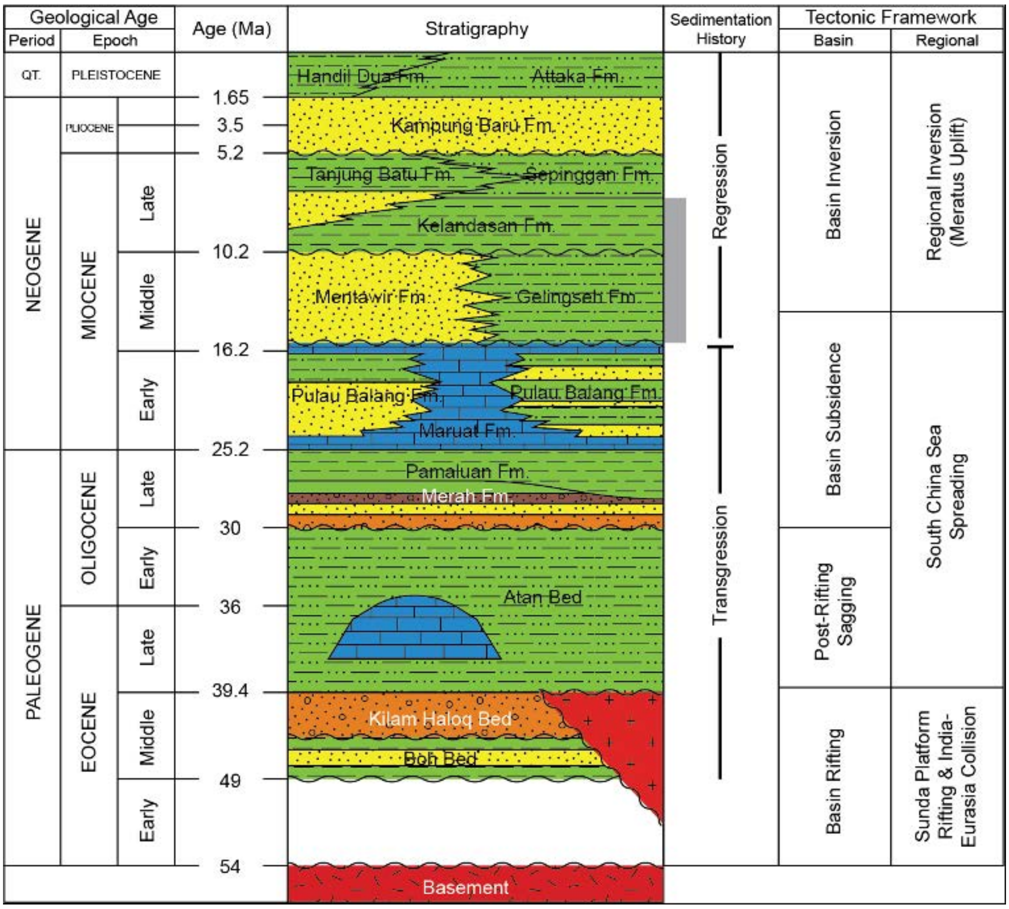

Figure 1. Regional stratigraphic column of the Kutai Basin, East Kalimantan (modified from Satyana et al., 1999). The studied formations are highlighted in grey.

massive sandstone of Mentawir Formation, claystone of Gelingseh Formation, and shale of the Kelandasan Formation from the Middle Miocene to Late Miocene. It is also mentioned that Kampung Baru Formation was deposited unconformably above the Balikpapan group, composed of siltstone, shale, and sandstone and rich in coal.

METHODS

The data for this study was derived from cuttings samples and side wall core samples obtained from five wells: DN1 (1,520 m), DN2 (1,280 m), DN3 (1,510 m), DN4 (1,505 m), and DN5 (1,510 m), located from North Sangatta, East Kalimantan (Figure 2). Lithological data of each well were recorded through manual descriptions conducted at two meters intervals. The smear slide technique was employed for the calcareous nannofossil preparation process (Bown and Young, 1998), which involved the following steps: sample extraction of the rock sliced it thinly and spread it evenly on a covered glass. The sample smoothed over the cover slip a toothpick, and added a few drops of water in the cover slip. A prepared sample was then dried using a hotplate, and placed the cover slip to the objective glass and let it dry in a UV. Finally, the prepared samples were checked under a polarizing microscope at 1500x magnification and quantitative analysis was undertaken using cascade methods (Styzen, 1997).

For benthic foraminifera analysis, sample preparations were conducted using oxidation technique by adding hydrogen peroxide (De Vernal et al., 2010). The following steps outline the process: start by organizing the cutting sample for analysis. Then, the samples were soaked in a beaker filled with hydrogen peroxide for 24 hours. After the soaking period, the samples were rinsed with water and returned to the beaker. The beaker was placed with the sample on an ultrasonic device and run for 15 minutes to ensure thorough cleaning. Following the ultrasonic treatment, the samples were rinsed rigorously with water once more, using a 0.63 µm sieve to ensure precise separation and later dried out in an oven for 24 hours. Afterwards, we inspected the prepared sample under a stereo microscope to identify and analyse the foraminifera assemblages.

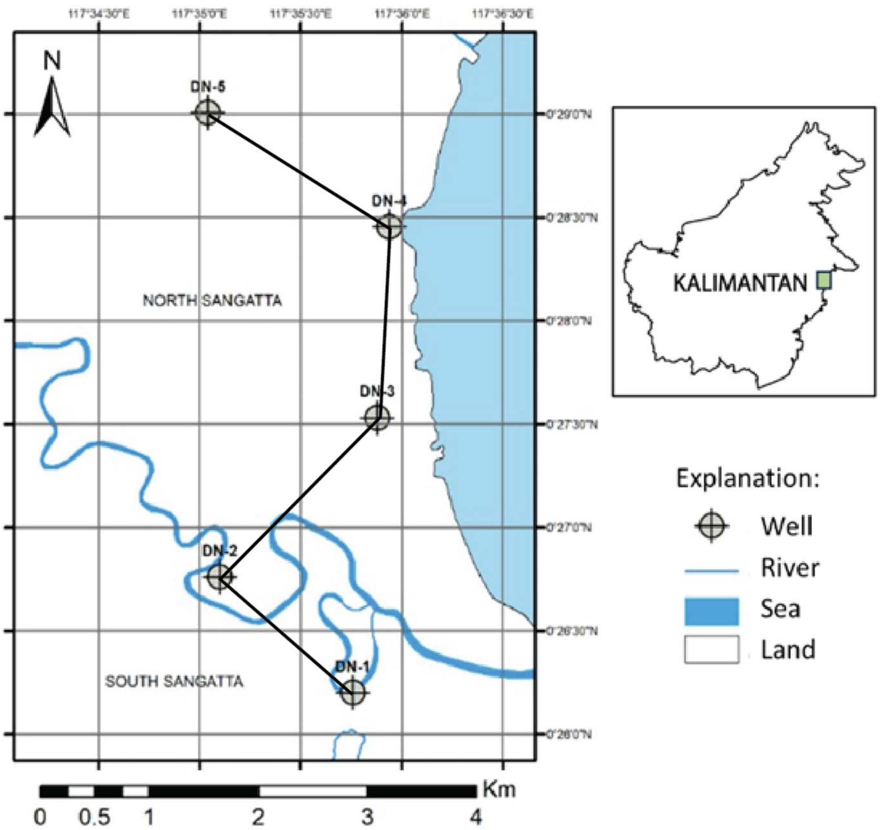

Figure 2. Location of five studied wells in Sangatta Area, East Kalimantan.

Biostratigraphic analysis is conducted to determine age using the interval zone, where the First Occurrence (FO) and Last Occurrence (LO) of calcareous nannofossil index species on the distribution chart are employed to define biozones and geological age. Facies analysis involves examining the distribution and assemblage of benthic foraminifera. The calcareous nannofossil zonation follows Martini (1971) and Anthonisen et al., (2012), while paleoenvironmental indicators from benthic foraminifera are based on Kadar et al., (1996) and Lambert (2003).

RESULTS

Lithological Units

The five wells contain various lithological units of claystone, siltstone, shale, coal, and sandstone of Gelingseh and Kelandasan Formation as described below (from the deepest to the shallowest):

1. DN1: consists of intercalated shale and coal, interbedding of shale and coal with sandstone intercalations, and interbedding of shale and coal with siltstone intercalations.
2. DN2: consists of interbedding of siltstone, coal, and sandstone; and interbedding of siltstone and coal with sandstone intercalations.
3. DN3: consists of shale with coal intercalations, interbedding of shale and coal with sandstone intercalations, and interbedding of siltstone and coal with clay intercalations.
4. DN4: consists of shale, interbedding of shale and coal with sandstone intercalations, and interbedding of shale and coal.
5. DN5 contains interbedding of shale with coal and claystone; Interbedding of shale with coal and claystone, with sandstone intercalations; and interbedding of shale with coal, with claystone intercalations.

Calcareous Nannofossil Biostratigraphy

Biostratigraphic analysis was performed by examining the nannofossil distribution of well samples. The results show that the five wells' dates span from the Middle Miocene to Late Miocene (NN6-NN11). An unconformity was also discovered at the NN8 zone in wells DN1, DN2, DN3, and DN5 (Table 1). Biostratigraphic zonation in the studied area is shown in table 1.

1. DN1: 12 species of five genera discovered in borehole DN1. The species discovered in this well

are Miocene in age. Various index fossils present in the core site, including *Catinaster coalitus*, *Discoaster hamatus*, and *Discoaster quinqueramus*. The DN1 well dates from the Middle Miocene to the Late Miocene, within the NN7-NN11 zone.

2. DN2: 18 species of eight genera were discovered in borehole DN2. The species discovered in this well are Miocene in age. Various index fossils and ages of core site DN2 are found similar to DN1
3. DN3: 19 species of eight genera were discovered. Index fossils and age are still similar with DN1 and DN2 core sites with *Catinaster coalitus*, *Discoaster hamatus*, and *Discoaster quinqueramus* occured. DN3 spans from the Middle Miocene to the Late Miocene age.
4. DN4: 17 species of ten genera were found in the DN4 well. Several genera and species were discovered in this well that were not found in other wells, including *Coccolithus* and *Cribocentrum*. These are the genera discovered after the Miocene. According to the investigation, the species is a reworked fossil. *Coronocyclus nitescens*, *Discoaster calcaris*, *Sphenolithus abies*, and *Geminilithela jafari* were also discovered. Well date spans from the Middle Miocene within NN6 - NN7 zone.
5. DN5: A total of 17 species of ten genera were discovered in the DN4 well. Several genera of *Coccolithus* and *Cribocentrum* still existed in the DN5 well. These fossils are assumed as reworked fossils. *Coronocyclus nitescens*, *Discoaster calcaris*, *Sphenolithus abies*, and *Geminilithela jafari* were also discovered. The Well age ranges from the Middle Miocene within NN6 - NN7 zone.

Benthic Foraminifera Biofacies and Paleoenvironmental Analysis

Selected foraminiferal paleoenvironmental indicators for the Miocene of Kutai Basin by Kadar et al., (1996) were used to classify the paleoenvironments and bathymetry. Most of the benthic genera consist of arenaceous species which indicates either a deep marine setting or a terrestrial setting, while the calcareous species indicate a marine influence on the area. For a practice of biofacies and paleoenvironmental analysis, most species were grouped into their bigger genera for example *Trochamina squamata* and *Trochamina inflata* were grouped into the same *Trochamina group*. In the case of *Quinqueloculina* genera, these species will be grouped into the miliolids group. *Trochamina* group as well as *Haplophragmoides* group noticeably dominate the assemblage indicating a brackish environment, other genera such as *Ammonia*, *Milliamina*, and *Ammonium* were found in a smaller quantity. Some calcareous and planktonic species were also found in the least quantity indicating either a marine influence on the area or tide activities. Other species that were non-substantial for the interpretation of either the paleoenvironment or biofacies were ignored.

According to Parker (1952), the presence of tiny arenaceous species such as *Milliammina* cf. *quadriloba*, *Trochammina* sp., *Haplopragmoides compressa*, *Haplopragmoides canariensis*, *Haplo-pragmoides* sp., and *Ammobaculites* sp. characterize the deltaic facies. Furthermore, Kadar et al., (1996) also suggested that *Trochamina* spp., *Haplophragmoides*, *Milliamina fusca*, and *Ammobaculites foliaceus* species represent a brackish environment, though species like *Haplophragmoides* spp., *Milliamina fusca*, and *Trochamina* spp. also represent a marginal marine environment alongside with *Ammonia beccarii*, *Elphidium* spp., *Nonionella* spp., and the presence of ostracods. These arenaceous or agglutinated foraminifera are commonly found in low salinity, brackish water habitats near a river mouth or a delta. Therefore, the microfaunas found and the lithology variety confirm that the paleoenvironment of the research area was controlled by a deltaic environment.

Several groups of biofacies were grouped referring to Lambert (2003) (Tabel 2). Tidal plain biofacies of mud flats (Biofacies I) were represented by the *Trochamina* group, *Ammotium salsum*, *Milliamina fusca*, and *Arenoparrella* spp. In comparison, tidal flat facies (Biofacies II) were reflected by the *Trochamina* group, *Ammobaculites* sp., and *Haplophrag-moides* sp. The delta front facies (Biofacies III) were represented by the occurrence of the *Elphidium* group and Miliolid species. The facies of the prodelta slope-marine shelf facies (Biofacies IV) were represented by a more diverse microfauna including several arenaceous species, calcareous species, and planktonic species. Finally, the barren portion from the interval represents a fluvial control in the fluvial plain facies (Biofacies V). Each biofacies was also represented by the lithological characteristics (Table 2). Most of the wells were composed of the same biofacies (tidal plain, tidal flat, and delta front biofacies) a major change in the biofacies can be seen in the DN4 well. The DN4 well comprises delta front and marine shelf

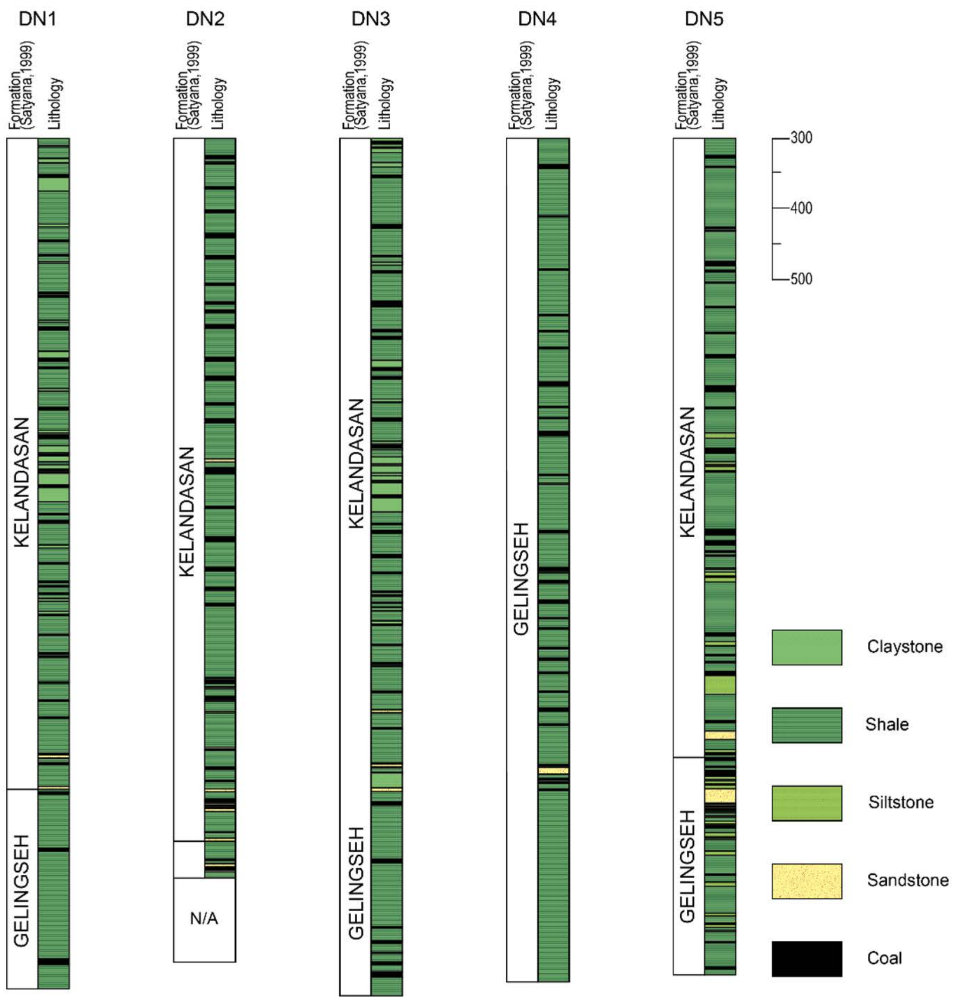

Figure 3. Lithological columns of five wells used for this

Table 1. Distribution of calcareous nannofossil datum in the five studied wells.

Nannofossil datum	Biozone (Martini,1971)	Depth positition (m)				
		DN-1	DN-2	DN-3	DN-4	DN-5
FO *Discoaster quinqueramus*	NN10/NN11	532/572	322/330	536/550		536/568
Bottom Paracme *Reticulofenestra pseudoumbilicus*	NN10	632/652	530/540	550/568		
LO *Discoaster hamatus*	NN9/NN10	1002/1032	976/982	962/1006		962/1006
LO *Catinaster coalitus*	NN9		1008/1016	1148/1176		
FO *Discoaster hamatus*	NN9/NN8	1032/1092	1258/1278			
FO *Catinaster coalitus*	NN8/NN7		1278/1290	1176/1210		1176/1210
LO *Coronocyclus nitescens*	NN7				488.5/516	

indicating the area of DN4 was more influenced by marine processes. The fluvial plain biofacies were complexly spread through all the wells, one was easily spotted on the DN2 well on the NN8 zone.

DISCUSSIONS

Biostratigraphic Correlation

Biostratigraphic correlation was carried out on the results of the biostratigraphic analysis of the five wells (Figure 4). The NN6 zone is only found in well DN4 based on the LO of *C. nitescens* and is absent in wells DN1, DN2, DN3, and DN5. This is assumed as a result of the local structural that affects the area around well DN4, causing the NN6 to be "uplifted" to the surface. Zone NN7 can be detected in all five wells, while in DN4, Zone NN7 is covered in relatively shallow depth and is believed to be caused by the local geological structures.

NN8 – NN9 zone can be observed in wells DN1 – DN3. In this zone, a continuous unconformity is detected in DN1, DN2, DN3 and DN5 based on the concurrent depth of FO of *D. hamatus*, FO of *C. coalitus*, and LO of *D. hamatus*. The unconformity can be linked to the basinal tectonic activity, during the late Miocene when the basin was undergoing an inversion/uplift. This activity also affected the rate of sediments deposited, as mentioned by Satyana et al., (1999) that the sedimentation during the NN8 underwent a transition from transgressional to regression. The unconformity might be formed by the sifting of this sedimentary process transition.

The NN10 zone in the DN1, DN2, DN3, and DN5 is marked by the LO of *D. hamatus* at the base and the FO of *D. quinqueramus* at the top. However, in the DN3 well, the top of NN10 is marked by the FO of *D. berggrenii*. Zone NN11 is found in wells DN1, DN2, DN3 and DN5 based on the correlation FO of *D. quinqueramus* at the base of this zone. Both NN10 and NN11 were not found in well DN4 as mentioned before. Since the distance between all of the wells is relatively close to one another, diachronism of the datum could be eliminated.

Biofacies Correlation

Based on the biostratigraphic correlation, The biofacies distribution from the NN6-NN1 along the five wells varied with several environmental settings. Intermittent changes of prodelta and delta facies are observed only in DN4 during NN6. The facies shifted to tidal plain and mudflat during NN7, as observed in DN1, DN2, DN3, and DN5. However, in DN4, these tidal plain and mudflat facies are interfingering with delta front facies. Fluvial plain facies are observed only in DN2 based on the barren of benthic foraminifera, and these facies are overlying the NN8 unconformity.

During NN9-NN10, tidal plain and tidal flat facies, as observed in DN1 and DN3, are interfingering with tidal plain and mudflat facies, which are distributed in DN3 and DN5, while in DN4, we assumed that the area had been uplifted by the late Miocene basinal tectonic activity as mentioned before.

Table 2. Biofacies division based on lithological and benthic foraminifera characteristics in the study area.

	Biofacies				
	I	**II**	**III**	**IV**	**V**
Lithology	Shale & Coal	Sandstone, Shale, Siltstone, and coal	Sandstone, Shale, Siltstone, and coal	Shale & Coal	Sandstone, Shale, Siltstone, and coal
Benthic Foram	*Trochamina* spp., *Miliamina fusca*, *Ammonia* spp.	Arenaceous species: *Trochamina* spp., *Haplo-phragmites* spp.	Arenaceous species with several calcareous species: *Elphidium* spp., *Quinque-loculina* spp.	Several brackish species: *Trochamina* spp., with several shelf benthic species and calcareous planktonic species	Barren
Paleo-environment	Brackish to marginal marine	Brackish to marginal marine	Brackish & dominant marginal marine	Brackish to marine shelf environment	Land
Facies	Mudflat near the tidal portion of the delta	Tidal flats in the inner delta	Delta Front	Prodelta	Fluvial Plain
	Tidal Plain				

During the upper NN10, delta front facies are distributed in DN1 and DN2, interfingering with tidal plain and mudflat facies in DN3 and DN5. The NN11 is marked by the distribution of tidal plain and mudflat in DN1 and DN5, and laterally shifted to tidal plain and tidal flat in DN3.

Paleogeography

To reconstruct the paleogeographic evolution through the Middle-Late Miocene, a facies map was reconstructed in every age interval based on the calcareous nannofossil zone (Figure 5). The contour line of the ratio of arenaceous benthic foraminifera and calcareous benthic foraminifera indicates a landwards or marine-ward facies. The direction of sedimentation was reflected by the distribution of biofacies, showing northeast orientation.

Moss and Chambers (1998) described from the Middle Miocene to the recent (comparable from NN5 to present) were marked by the post-inversion deltaic progradation tract, which is suitable with the result of this study as a succession of deltaic sediments discovered. Then the model from Lambert (2003) was used for the analog model of the biofacies map (Figure 5). During The NN6, delta front facies were recognized on the North-East side of the area based on the foraminifera assemblages on DN4, while DN1, DN2, DN3 and DN5, foraminifera were barren. During NN7, tidal flats facies are distributed from the South to the West of the area, which dominated the area alongside a prodelta facies from the North to the East of the area. The facies on DN4 specifically were recognized by several foraminifera shelf species and calcareous planktonic species, showing transgression during this time.

During the NN8, considering a relatively thick bed of sand and barren foraminifera assemblage, it is proposed that DN2 during that time was controlled by the fluvial plain facies. With less marine influence in the area during this interval, we assume that the sedimentation of the area changed to a regression state that formed an unconformity. The end of the proto-South China sea subduction and Luconia continental block collision during the Middle

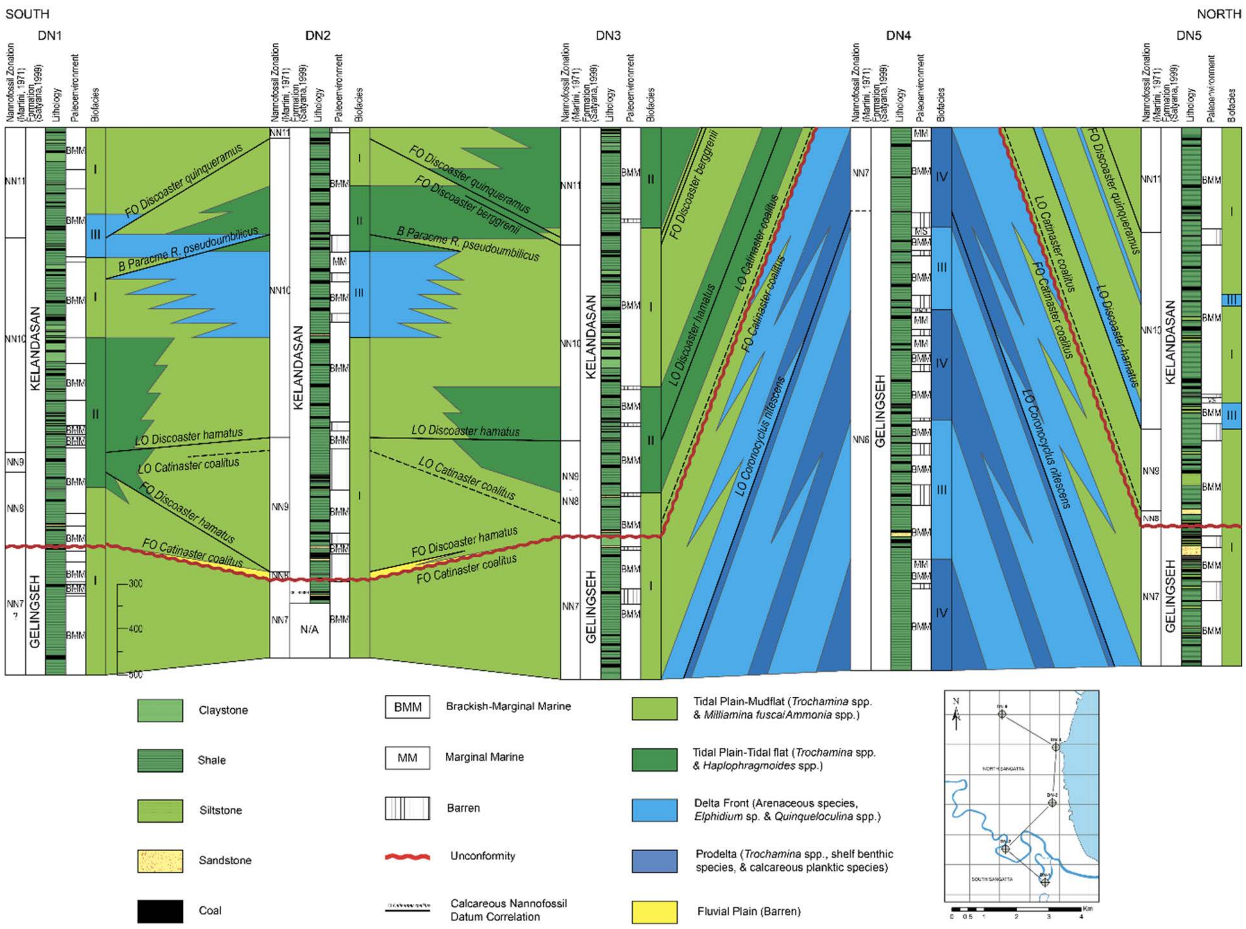

Figure 4. Age (calcareous nannofossil datum correlation line) and paleoenvironmental correlation (colored area) of five studied well based on calcareous nannofossil biostratigraphy and benthic foraminifera from South (left) to North (Right). Legends of the symbols and abbreviations are shown on the bottom of the figure alongside the map of the study areas and the wells.

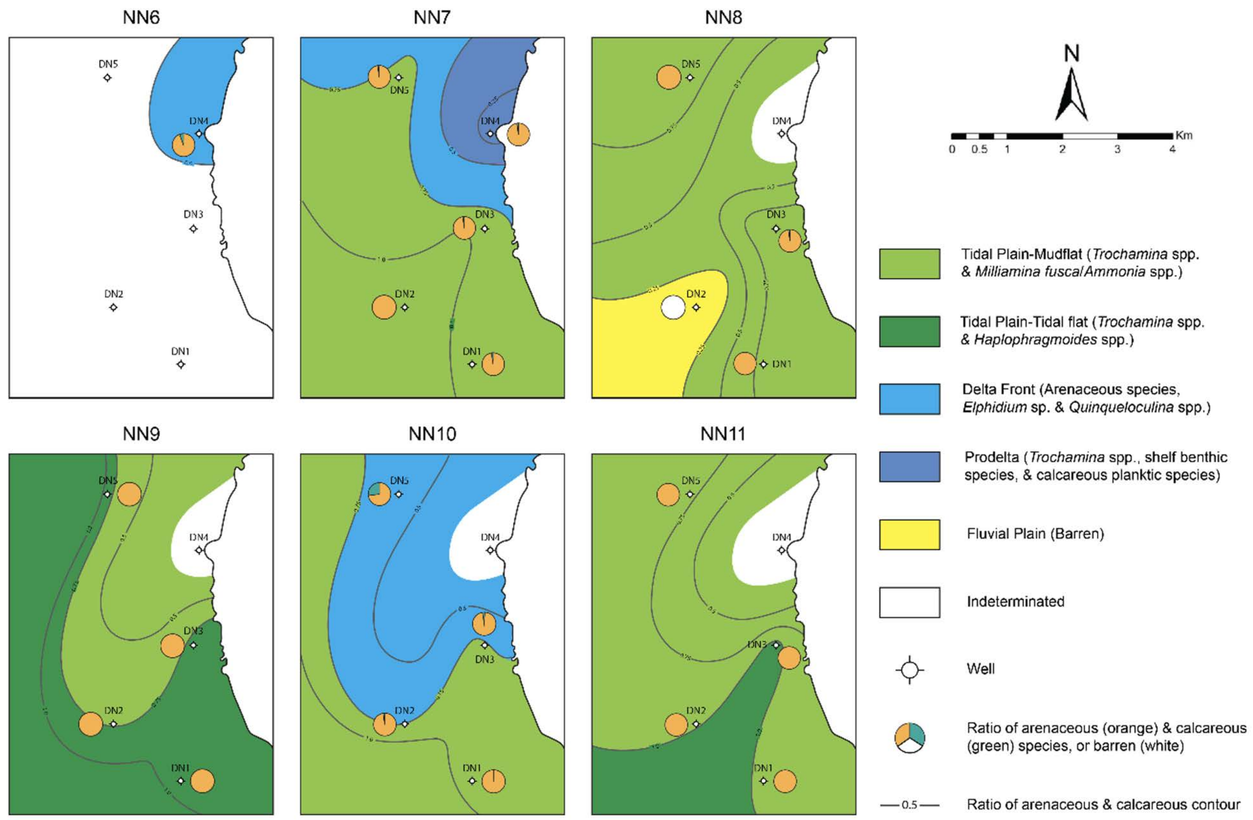

Figure 5. Paleogeographic evolution of the study area illustrated on maps from NN6-NN11 of Middle to Late Miocene based on the distribution of benthic foraminifera ratios and lithological units (Table 2).

Miocene in the South East Asia (Moss and Chambers, 1999) could be controls on this unconformity. The NN8 unconformity found in this study is confidently similar process with this regional unconformity in the Kutai Basin (Bachtiar, et al., 2013).

The mudflat facies were distributed from the Southwest to the Northwest during the NN9. The transition between tidal flats facies to mudflats facies indicates a transgression during this time. The presence of several calcareous, arenaceous and several planktonic species on DN5 also indicates prodelta slope facies. During NN11 the delta front facies were not recognized, while both the mudflats and tidal flats facies were present indicating a regression.

With the data analysed above, the evolution of the basin is shown, having a complex history of sedimentation. High cyclicity of transgression and regression were also recorded by the microfossils. The result also has a positive correlation to the tectonic and sedimentation evolution of the basin. However, more data on a regional scale would also need to be incorporated for a comprehensive and confident conclusion.

CONCLUSSIONS

The research area focuses on Gelingseh Formation and Kelandasan Formation which consist of shales, clay, siltstone, sandstone and coals. Several key index fossils such as *Discoaster hamatus, Discoaster quinqueramus, Catinaster coalitus, Reticulofenestra pseudoumbilicus,* and *Coronocyclus nitescens* found in this area. Nannofossil biostratigraphy concludes that the studied area ranges from the Middle to Late Miocene (NN6-NN11 zone) with an unconformity at the NN8 zone.

Based on biofacies analysis using benthic foraminifera, the studied area throughout the Middle to Late Miocene is characterized by deltaic environment. Benthic foraminifera assemblages of *Miliamina fusca* and *Trochamina sp* dominated the research area. It can be concluded that the facies change from landward to the marine ward along the Southwest-Northeast direction of the study area is tidal flat to delta front facies. Furthermore, several similar lithologies exhibit different microfaunal diversities. This indicates that relying solely on lithofacies is insufficient; additional biofacies analysis is essential for accurately interpreting facies distribution.

Complex changes of the facies in the area are consequence of the transgression-regression processes and regional tectonic activity during the Middle to Late Miocene. This study demonstrates the critical need for further micropaleontological research on deltaic settings, as such work is essential for interpreting the facies complex within deltaic systems. Biostratigraphic reconstruction and biofacies changes in this area show basin evolution at the regional scale occurred during short intervals within NN6-NN11 of the nannoplankton zone and it influenced the sedimentation process. The implications of biostratigraphic and biofacies analyses demonstrate that minor biofacies changes can result in several small but correlatable unconformities. We suggest further research that encompasses a large basin area and integrates regional data.

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