ENVIRONMENTAL CHANGES DURING THE LATE MIOCENE TO PLEISTOCENE USING SMALL FORAMINIFERA AND PALYNOMORPHS IN THE KUTAI BASIN, EAST KALIMANTAN

PERUBAHAN LINGKUNGAN UMUR MIOSEN AKHIR HINGGA PLISTOSEN MENGGUNAKAN FORAMINIFERA KECIL DAN PALINOMORF PADA CEKUNGAN KUTAI, KALIMANTAN TIMUR

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ABSTRACT: The Kutai Basin is one of the large basins in East Kalimantan which was formed during the Tertiary Period. The sedimentation process in this basin is strongly influenced by sea level changes. This study conducts quantitative analysis using the abundance of small foraminifera and palynomorphs in well “FN O-1” located in the northern part of offshore Kutai Basin. It applies the Planktonic-Benthic Ratio to determine the range of the bathymetric-related environments in the entire depth interval. The aims of this study are to interpret the sequence stratigraphy in the Kutai Basin using small foraminifera and palynomorphs associated with sea level changes. Three sequence stratigraphy phases are identified; TST (Transgressive System Tract), HST (Highstand System Tract), and FSST (Falling Stage System Tract), from the Late Miocene to Pleistocene in an inner to outer neritic environment. The results of the P/B ratio calculation show that wells with a depth of 1,230 feet to 12,180 feet are predominantly located in the inner neritic zone with a ratio percentage less than 20%. The highest abundance of small benthic foraminifera reaching 534 individuals was found at a depth of 1,650 feet within the TST phase. The most abundant planktonic foraminifera (452 individuals) was observed at a depth of 1,350 feet during the TST-HST transition. The FSST revealed the most abundance of mangrove palynomorphs with 100 fossil grains at 11,640 feet and 56 back-mangrove palynomorphs fossils were identified within the TST at 2,340 feet. This study concludes that the abundance of small foraminifera and palynomorphs suggests both marine and terrestrial influences on the basin.

Keywords: Sequence stratigraphy, small foraminifera, palynomorph, Late Miocene, Pleistocene, Kutai Basin

ABSTRAK*: Cekungan Kutai merupakan salah satu cekungan besar di Kalimantan Timur yang terbentuk pada Zaman Tersier. Proses sedimentasi di cekungan ini sangat dipengaruhi oleh perubahan muka air laut. Penelitian ini menggunakan metode analisis kuantitatif kelimpahan foraminifera kecil dan palynomorf di sumur "FN O-1" yang terletak di lepas pantai bagian utara Cekungan Kutai. Studi ini menggunakan Rasio Planktonik-Bentonik untuk menentukan kisaran lingkungan yang berhubungan dengan batimetri di seluruh interval kedalaman. Tujuan dari penelitian ini adalah untuk menginterpretasikan sikuen stratigrafi di Cekungan Kutai dengan menggunakan foraminifera kecil dan palinomorf yang terkait dengan perubahan permukaan air laut. Tiga fase sikuen stratigrafi yang diidentifikasi yaitu TST (Transgressive System Tract), HST*

(Highstand System Tract), dan FSST (Falling Stage System Tract) dari Miosen Akhir hingga Plistosen dengan lingkungan neritik dalam hingga neritik luar. Hasil perhitungan rasio P/B menunjukkan bahwa sumur dengan kedalaman 1.230 kaki sampai dengan 12.180 kaki dominan berada pada zona neritik dalam dengan persentase rasio kurang dari 20%. Kelimpahan foraminifera bentonik kecil paling banyak mencapai 534 individu ditemukan pada kedalaman 1.650 kaki pada fase TST. Kelimpahan foraminifera planktonik tertinggi (452 individu) berada pada kedalaman 1.350 kaki pada fase transisi TST-HST. Pada fase FSST didapatkan kelimpahan palinomorf mangrove sejumlah 100 unit individu pada kedalaman 11.640 kaki dan 56 unit individu palinomorf back-mangrove yang ditemukan pada kedalaman 2.340 kaki pada fase TST. Studi ini menyimpulkan bahwa kelimpahan foraminifera kecil dan palynomorf dipengaruhi oleh perubahan laut dan darat di cekungan tersebut.

Kata Kunci: *Sikuen stratigrafi, foraminifera kecil, palinomorf, Miosen Akhir, Plistosen, Cekungan Kutai*

INTRODUCTION

The Kutai Basin is one of the hydrocarbon basins in Indonesia. A basin thickness of up to six km has been removed because of weathering and erotion during Neogene (Hall & Nichols, 2002). The factors that influence these hydrocarbons are the depositional environment and geological processes. Hydrocarbon production in the basin is divided into two plays; deltaic play (Middle to Late Miocene) and the deep-water play (Late Miocene to Pliocene). The availability of hydrocarbons in this basin occurs due to a complete tectonic process from the Late Paleocene to the present. The formation of the basin began with rifting in the Paleocene until the highland formed at the edge of the basin in the Oligocene. The reverse structure that occurred during the Miocene - Pliocene made the sedimentation process faster in this basin. Therefore, since the Pliocene until now the Kutai basin has continued to subsidence and sedimentation processes towards the east offshore (Darman & Sidi, 2000).

In the Late Paleocene to Early Oligocene, the basin subsided due to rifting of the bedrock forming a half graben. This was then continued with the sagging mechanism in the Oligocene (Darman & Sidi, 2000) and uplift at the edge of the basin in the Late Oligocene. In the Late Miocene to Early Pliocene, a structural inverse occurred due to the convergent interaction of Banggai-Sula and continued to the Meratus mountains (Biantoro et al., 1992). Until now, the Kutai Basin is still experiencing a process of subsidence and delta sedimentation towards the offshore to the east (Darman & Sidi, 2000).

Exploration of hydrocarbon potential in the Kutai Basin remains ongoing, driven by the possibility of even larger reserves. One of the most widely conducted studies is regarding stratigraphy to determine environmental influences and the characteristics of each rock layer in this basin.

Environmental changes that occur in the Kutai Basin are strongly influenced by sea-level fluctuations. Paleoclimatic take control of sediment deposition especially in the Middle Miocene of Lower Kutai Basin (Jamaluddin et al., 2023). This phenomenon results in a multi-stage stratigraphic record in the Kutai Basin. Microfossils enable a detailed reconstruction of these changes in sequence stratigraphy. The presence of microfossils, including marine-indicative foraminifera and palynomorphs of plant origin reflecting terrestrial to transitional settings, significantly contributes to understanding the depositional environment. The differential abundance of these microfossils constitutes a key tool for determining the basin's stratigraphy.

Besides the microfossil, Large Benthic Foraminifera is also most often used to analyse stratigraphic markers in shallow marine environments in Southeast Asia. According to Renema (2015), foraminiferal research in the Kutai Basin is focused on the middle Miocene and older sections that are usually used for oil and gas exploration. Therefore, there is still limited data describing this site about benthic and small planktonic foraminifera. The Miocene macrofossils, especially molluscs and corals, were identified in the northeastern part of the Kutai Basin by the Naturalis Biodiversity Centre (Renema et al., 2015).

In addition to foraminifera, other studies were conducted as complementary data to determine whether hydrocarbons in the Kutai Basin are palynomorphs. Biozonation intervals conducted by 2 wells in the Kutai Basin have an average age of Middle Miocene-Late Miocene. This age determination is based on palynofacies including the abundance of phytoclasts, amorphous organic matter, and palynomorphs. The abundance of those three affects the characteristics of the environment (Anggritya & Kurniadi, 2017). Analysis using palynomorphs will help to determine the environment during sea level changes especially sea transgression due to the increase of palynomorphs (Senduk et al., 2021).

This study aims to interpret the sequence stratigraphy of the Kutai Basin, East Kalimantan, by analysing the abundance of small foraminifera and palynomorphs. The abundance of these microfossils is related to past seawater fluctuations within the basin.

Geological Setting

The tectonic processes of Eastern Kalimantan are influenced by several plate interactions including the Indo-Australian, the Pacific, and the Eurasian Plates, in southeast Asia (Biantoro et al., 1992). The formation of Kalimantan Island is strongly influenced by three of the world's major tectonic plates including the Eurasian Plate moving relative to the south, the Pacific Plate moving towards the west, and the Indo-Australian Plate moving relatively north (Hamilton, 1979). These three plates approach each other so that a convergent process occurs which results in the formation of a subduction zone.

The study area shown in Figure 1 is the East Kalimantan region with general geological associations, namely the Kutai Basin. This basin formed during the Tertiary Period due to extensional stress in the southern part of the Eurasian Plate (Allen & Chambers, 1998).

The formation of the Kutai basin is divided into four main stages (Nugrahanto et al., 2021b):

1. In the Middle Eocene rifting occurred which resulted in a succession of terrestrial deposits below the lower Kutai to marine deposits above the Kutai basin (Bachtiar, 2018). Source distribution of sediment occurs in shallow marine areas from the north and southwest of the basin (Darman, 2023). This rifting then formed a deeper part of the Kutai Basin called the North Makassar Basin (Nur'Aini et al., 2005).
2. Sagging occurred during the Late Eocene to Oligocene (Hall, 2013).
3. In the Early Miocene, uplift, and erosion occurred so that progradation deposits were wider towards the basin (Advokaat et al., 2018). The Borneo landmass was one of the high sources of erosion deposits that filled the Basin resulting progradation of the Proto-Mahakam Delta (Novak et al., 2013 in Renema et al., 2015).
4. During the Pliocene, a convergence occurred which resulted in the highlands of western Sulawesi being exposed (Fraser et al., 2003). This part of the plateau then experienced erosion and sediment was transported toward the North Makassar Basin to this day (Puspita et al., 2005).

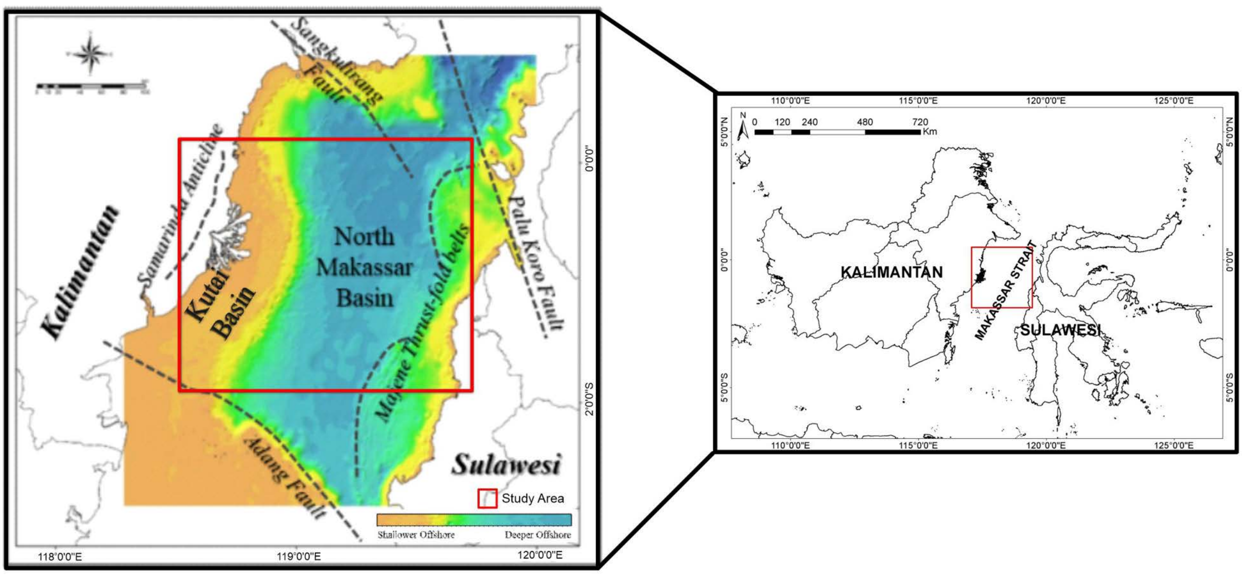

Figure 1. Study area (Modified from Nugrahanto et al., 2021a)

METHODS

The data source in this study is from the Centre of Data and Information Technology (Pusdatin) of the Ministry of Energy and Mineral Resources (KESDM), the Republic of Indonesia with the name of the Well "FN O-1". This study is to calculate the number of foraminifera and palynomorph individuals at each depth conducted in September 2003. The method employed in this study is the Foraminifera Planktonic-Benthic Ratio (P/B Ratio). This method is used for analysing environments (bathymetric-range zone) by calculating the abundance of planktonic and benthic foraminifera in the entire depth interval, especially in the Mesozoic and Cenozoic (Gibson, 1989). The number of foraminifera that are abundant and widely distributed geographically makes these microfossils as an object for environmental analysis and marine ecosystems (Jurnaliah & Winantris, 2015). This method is generally used to identify foraminifera in deep water. However, the presence and distribution of foraminifera are also influenced by the presence of current and wave patterns, making it possible for them to occur in shallow water (Gustiantini et al., 2005). The depth of the sample is also a factor that can determine the high or low percentage values including upwelling which determines biogenic productivity (Van Marle, 1989). The environmental classification of this method is shown in Table 1 which refers to the size of the percentage value calculated.

The calculation formula for this method is:

$$\text{Ratio P/B} = \left(\frac{P}{P+B}\right) \times 100\% \quad (1)$$

Explanation:
P : The abundance of planktonic foraminifera for each well-depth
B: The abundance of benthic foraminifera for each well-depth

The environmental classification in Table 1 is further divided by Berggren, 1998 in Jurnaliah et al., 2016 into two main parts, namely neritic (inner, middle, and outer neritic) and oceanic (bathyal to hadal).

The abundance of palynomorphs was analyzed using quantitative methods. The number of mangrove and back-mangrove palynomorphs was counted at each 60 feet depth interval. The increasing number of back mangrove palynomorphs can be a consideration for sea level rise.

The study focuses on sequence stratigraphy, specifically the Transgressive System Tract (TST), Highstand System Tract (HST), and Falling Stage System Tract (FSST) (Figure 2). Each type of phase has different characteristics and is related to sea level. The abundance of microfossils and palynomorphs is

Table 1. Environmental classification of the P/B ratio (Grimsdale & Morkhoven, 1955)

Value P/B	Bathymetry Zone
< 20%	Inner Neritic
20% – 60%	Middle Neritic
40% - 70%	Outer Neritic
>70%	Upper Bathyal
>90%	Lower Bathyal

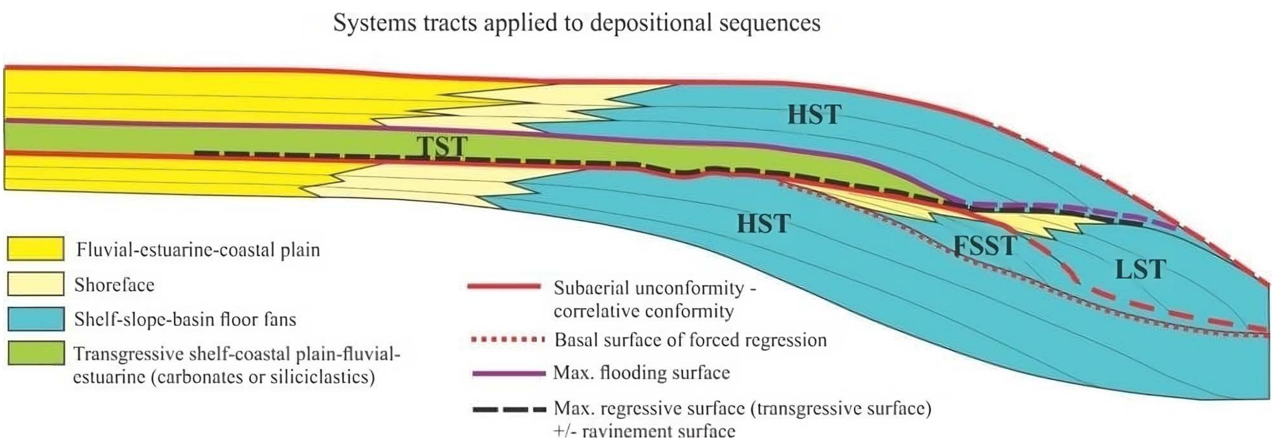

Figure 2. A scheme of Transgressive System Tract (TST), Highstand System Tract (HST), and Falling Stage System Tract (FSST) ; Van Wagoner et al.(1988)

an important object for identifying sequence stratigraphy relationships in each phase.

The TST phase is related to sea levels that have risen so that the sea becomes deeper. This phase is characterized by a decrease in the number of benthic foraminifera, and an increase in the number of planktonic foraminifera which results in high P/B ratio percentage values (Olson & Leckie, 2003). The number of palynomorphs in this phase tends to decrease (Morley, 1996).

The HST phase is related to the highest sea level and at this stage sea water will gradually fall. This phase is characterized by a decrease in the number of benthic foraminifera, and an increase in the number of planktonic foraminifera which results in high P/B ratio percentage values (Olson & Leckie, 2003). The number of palynomorphs in this phase tends to decrease (Morley, 1996).

The FSST phase is related to the process of lowering sea levels so that the environment becomes siltation. This phase is marked by an increase in the number of benthic foraminifera, and a decrease in the number of planktonic foraminifera so that the value of the P/B ratio is small (Olson & Leckie, 2003). The number of palynomorphs tends to increase from the underlying sedimentary layer (Morley, 1996).

RESULTS

Sequence Stratigraphy

The depth range studied was 1,230 feet – 12,180 feet, in the Late Miocene - Pleistocene. The phases of change in the sequence stratigraphy include HST which relates to the highest sea level before it decreases, TST reflects rising sea levels, and FSST indicates a gradual fall in sea level.

The TST phase has the highest frequency of events in the Late Miocene – Pleistocene. There are 19 layers with a large difference in depth intervals in the TST phase generally occurs in the near-surface (shallow) area. The HST phase occurred in the Late Pliocene – Pleistocene and occurred 5 times. This phase generally occurs at low depths with relatively fast occurrence intervals. The FSST phase occurred in the Late Miocene – Late Pliocene which occurred 12 times. This phase occurs at the deepest depth from the well identification point up to 2,420 feet and occurs alternately with the TST phase (**Figure 3**).

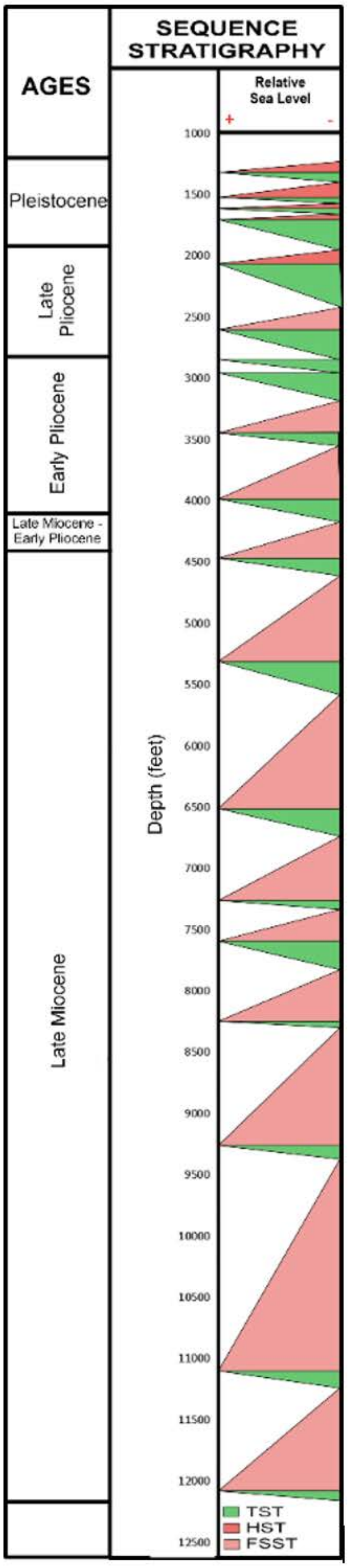

Figure 3. System tracts changes in the Kutai Basin, East Kalimantan

P/B Ratio

The P/B ratio value at each well depth with a depth interval of 60 feet refers to the number of benthic and planktonic foraminifera. The percentage

Ages	Depth (feet)	Σ Foram P	Σ Foram B	P/B Ratio (%)	Bathy metry Zone
Pleistocene	1230	50	48	51	M-ON
	1290	93	91	51	
	1350	452	452	50	
	1410	238	238	50	
	1470	0	48	0	IN
	1530	0	91	0	
	1590	0	137	0	
	1650	0	534	0	
	1710	0	165	0	
	1770	0	19	0	
	1830	0	42	0	
	1890	0	32	0	
Late Pliocene	1950	0	56	0	IN
	2010	0	35	0	
	2070	0	60	0	
	2130	0	23	0	
	2190	19	19	50	M-ON
	2250	0	0	0	IN
	2310	0	2	0	
	2370	0	5	0	
	2430	0	1	0	
	2490	0	22	0	
	2550	0	31	0	
	2610	0	22	0	
	2670	0	7	0	
	2730	0	20	0	
	2790	0	10	0	
Early Pliocene	2850	0	15	0	IN
	2910	0	29	0	
	2970	0	5	0	
	3030	0	15	0	
	3090	16	17	48	M-ON
	3150	0	9	0	IN
	3210	0	0	0	
	3270	0	12	0	
	3330	0	3	0	
	3390	0	0	0	
	3450	0	0	0	
	3510	0	0	0	
	3570	0	1	0	
	3630	0	0	0	
	3690	0	0	0	
	3780	0	14	0	
	3810	0	3	0	
	3870	0	11	0	
	3930	0	2	0	
	3990	0	16	0	
	4050	3	3	50	M_ON
	4110	0	9	0	IN
	4170	0	7	0	
Late Miocene - Early Pliocene	4230	0	6	0	IN
	4290	0	0	0	
	4350	0	6	0	
	4410	0	30	0	
	4470	0	5	0	
Late Miocene	4530	0	4	0	IN
	4590	0	1	0	
	4650	0	3	0	
	4710	0	15	0	
	4770	0	3	0	
	4830	0	11	0	
	4890	0	3	0	

Ages	Depth (feet)	Σ Foram P	Σ Foram B	P/B Ratio (%)	Bathy metry Zone
Late Miocene	4950	0	1	0	IN
	5010	0	5	0	
	5070	0	0	0	
	5130	0	2	0	
	5190	0	3	0	
	5250	0	0	0	
	5310	0	0	0	
	5370	0	6	0	
	5430	0	9	0	
	5490	0	4	0	
	5550	14	8	64	
	5610	0	1	0	
	5670	0	13	0	
	5730	0	30	0	
	5790	0	34	0	
	5850	6	5	55	M-ON
	5910	0	5	0	IN
	5970	0	6	0	
	6030	0	16	0	
	6090	0	3	0	
	6150	214	420	34	MN
	6210	210	408	34	
	6270	0	21	0	Inner Neritic
	6330	0	91	0	
	6390	0	3	0	
	6450	0	15	0	
	6510	0	50	0	
	6570	0	20	0	
	6630	0	30	0	
	6690	0	15	0	
	6750	0	14	0	
	6810	0	95	0	
	6870	0	3	0	
	6930	0	40	0	
	6990	0	8	0	
	7050	0	2	0	
	7110	0	10	0	
	7170	0	14	0	
	7230	0	43	0	
	7290	0	32	0	
	7350	0	92	0	
	7410	0	64	0	
	7470	0	60	0	
	7530	0	37	0	
	7590	0	38	0	
	7650	0	123	0	
	7710	0	38	0	
	7770	0	83	0	
	7830	0	6	0	
	7890	0	15	0	
	7950	0	69	0	
	8010	0	30	0	
	8070	0	32	0	
	8130	0	178	0	
	8190	0	21	0	
	8250	0	75	0	
	8310	0	53	0	
	8370	0	33	0	
	8430	0	43	0	
	8490	0	23	0	
	8550	0	8	0	
	8610	0	18	0	

Ages	Depth (feet)	Σ Foram P	Σ Foram B	P/B Ratio (%)	Bathy metry Zone
Late Miocene	8670	0	4	0	
	8730	0	2	0	
	8790	0	6	0	
	8850	0	0	0	
	8910	0	1	0	
	8970	0	0	0	
	9030	0	0	0	
	9090	0	6	0	
	9150	0	0	0	
	9210	0	30	0	
	9270	0	16	0	
	9330	0	41	0	
	9390	0	23	0	
	9450	0	4	0	
	9510	0	32	0	
	9570	0	9	0	
	9630	0	2	0	
	9690	0	15	0	
	9750	0	0	0	
	9810	0	5	0	
	9870	0	5	0	
	9930	0	4	0	
	9990	0	7	0	
	10050	0	0	0	
	10110	0	3	0	
	10170	0	0	0	
	10230	0	0	0	
	10290	0	5	0	
	10350	0	3	0	
	10410	0	4	0	
	10470	0	0	0	
	10530	0	6	0	
	10590	0	0	0	
	10650	0	10	0	
	10710	0	0	0	
	10770	0	0	0	
	10830	0	0	0	
	10890	0	37	0	
	10950	0	0	0	
	11010	0	6	0	
	11070	0	11	0	
	11130	0	158	0	
	11190	0	11	0	
	11250	0	7	0	
	11310	0	0	0	
	11370	0	1	0	
	11430	22	27	45	M-ON
	11490	1	1	50	
	11550	0	5	0	IN
	11610	0	4	0	
	11670	0	8	0	
	11730	0	0	0	
	11790	0	9	0	
	11850	0	8	0	
	11910	0	0	0	
	11970	0	0	0	
	12030	163	182	47	M-ON
	12090	100	115	47	
	12150	0	6	0	IN
	12180	0	5	0	

P = Planktonic Foram
B = Benthic Foram
IN = Inner Neritic
MN = Middle Neritic
ON= Outer neritic

Figure 4. Total number of foraminifera related with value P/B Ratio

of the calculation results is then classified based on Grimsdale & Morkhoven (1955). In the research well, the bathymetric zone is generally in the inner neritic zone with a percentage value of less than 20% (**Figure 4**). Planktonic foraminifera greatly influence the ratio calculation so that the presence of these foraminifera at each depth can affect changes in the bathymetric zone.

Abundance of Small Foraminifera

In general, the foraminiferal analysis is carried out at a depth interval of 60 feet. The step is by only distinguishing and calculating the number of small benthic foraminifera and planktonic foraminifera. The abundance of foraminifera is distributed at each depth of the sampling depth. The highest abundance of small benthic foraminifera (534 individuals) was at a depth of 1,650 feet in the TST dominated by small rotallids (73 individuals) and miliolids (89 individuals). Meanwhile, the abundance of planktonic foraminifera was found very rarely in every sediment layer studied. The highest abundance of planktonic foraminifera was observed in 452 individuals at a depth of 1,350 feet during the transition from TST to HST (Figures 4 & 5).

Abundance of Palynomorphs Mangrove and Back-mangrove

Identification of palynomorphs abundance was carried out at a depth interval of 60 feet. The sample identification process is differentiated based on its environment, namely mangrove and back-mangrove. The abundance of palynomorphs is distributed at each sampling depth. The most abundant of mangrove palynomorphs was at a depth of 11,640 feet with 100 fossil grains in the FSST phase. Different from palynomorphic mangroves, the abundance of palynomorphic back-mangroves is found at almost every point of the depth interval but with fewer fossil grains. The number of back-mangrove palynomorphs was 56 fossil grains at a depth of 2,340 feet during the TST (Figures 6 & 7).

DISCUSSIONS

The depositional environment in the study is shallow marine with inner neritic to outer neritic bathymetry (Figure 8). The inner neritic zone (0-20 m) is characterized by a P/B ratio of less than 20% so this area is dominated by benthic foraminifera. This zone is included in the shallow marine so that it indicates a decrease in sea level. This process is related to the FSST and HST. For example, at a depth of 4,050 feet to 3,090 feet, there is a bathymetry change from middle neritic to inner neritic. At this depth, the system tract changes from TST to FSST.

Environmental changes that occur significantly are at a depth of 5,550 feet with a P/B ratio of 64% which belongs to the outer neritic environment (100 – 200 m). The process of changing the bathymetric zone to outer neritic occurs when the sea level rises so that the environment which was originally a shallow marine will become deeper due to sea flooding. Environmental changes at this depth are also part of the TST which occurs at a depth of 5,580 feet – 5,310 feet.

The abundance of planktonic foraminifera in this study is almost the same as that of benthic foraminifera. This is indicated by the value of the P/B ratio which tends to be in the range of 45%-55% thus indicating a middle neritic environment (20-100 m).

The abundance of small foraminifera and palynomorphs differed markedly at some depth. The environment is one of the factors that make this difference. Foraminifera, which live in marine, will be very abundant in a sediment layer when sea water floods the sediment deposition environment. Unlike the case with palynomorphs, especially mangroves and back-mangroves that are found in transitional environments. The abundance of small foraminifera is different from palynomorphs at a depth of 1,770 feet – 1,710 feet. At this depth, mangrove and back-mangrove palynomorphs increased (Figure 9-1). The system tracts that occurred were HST and TST during the Pleistocene. In Figure 9-2 with a depth of 2,080 feet – 5,580 feet, shows little or no abundance of foraminifera at a certain depth. This is different with palynomorphs which are very abundant at every depth. The system tracts that occur in this depth range are TST and FSST. This occurred in the upper Late Miocene – Late Pliocene. In Figure 9-3, the depth of 5,580 feet – 6,510 feet shows a few abundance of small foraminifera but there is a significant increase at a depth of 6,150 feet – 6,210 feet. In general, the depth range of zone 3 is in the TST and FSST. The significant increase of small foraminifera in the depth range above is in the FSST. This is related to a decrease in sea level which is characterized by an increase of benthic foraminifera compared to planktonic foraminifera. This occurred in the upper Late Miocene. In Figure 9-4. with a depth of 6,510 feet – 8,429 feet shows the abundance of foraminifera and palynomorphs which almost shows the same trend at each depth. This occurs in the middle part of the TST and FSST system tract of the Late Miocene. In Figure 9-5, at a depth of 8,429 feet

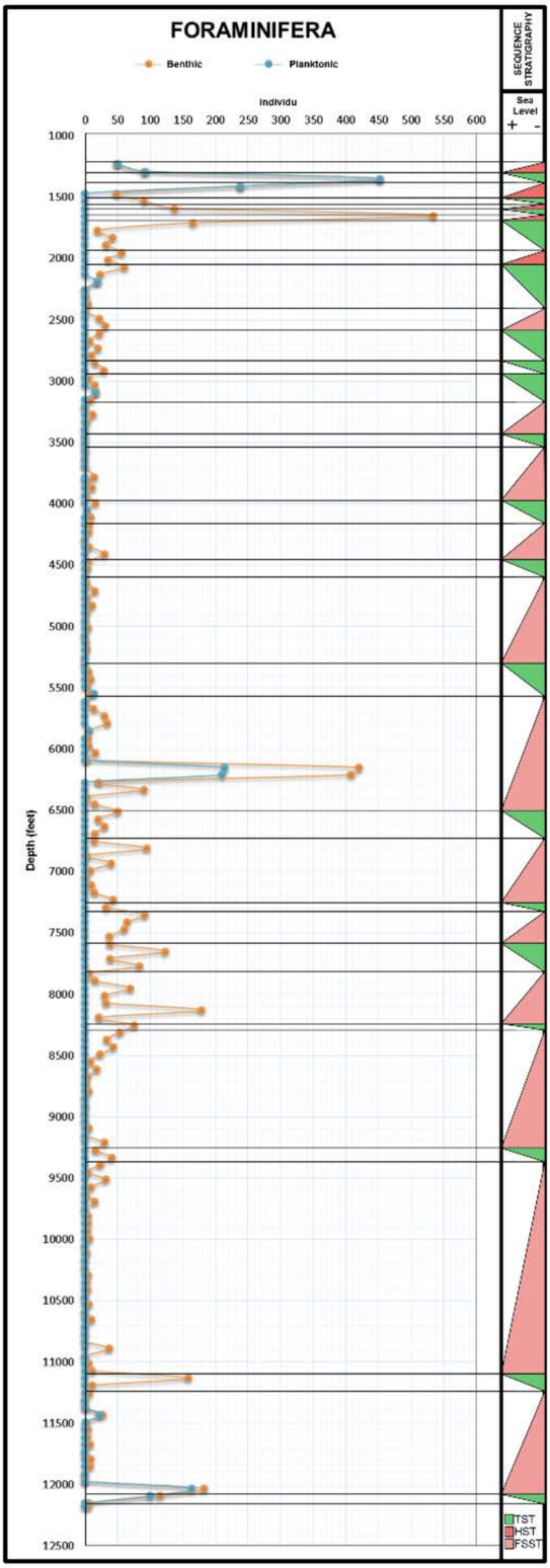

Figure 5. Abundance of small foraminifera in the Kutai Basin, East Kalimantan

Depth		Environment	
Feet	Meter	Backmangrove	Mangrove
1230	374.9	5	13
1260	384.0	6	10
1320	402.3	7	18
1380	420.6	6	50
1440	438.9	8	15
1500	457.2	2	87
1560	475.5	2	88
1620	493.8	8	55
1680	512.1	4	36
1740	530.4	8	34
1800	548.6	4	66
1860	566.9	5	50
1920	585.2	10	26
1990	606.6	4	19
2040	621.8	1	73
2100	640.1	2	68
2160	658.4	10	33
2220	676.7	20	48
2280	694.9	40	45
2340	713.2	56	61
2400	731.5	5	23
2460	749.8	10	15
2520	768.1	5	11
2580	786.4	1	3
2640	804.7	13	23
2700	823.0	25	39
2760	841.2	7	45
2770	844.3	9	26
2880	877.8	11	39
2940	896.1	14	30
3000	914.4	7	15
3060	932.7	13	25
3120	951.0	6	11
3180	969.3	9	19
3240	987.6	6	13
3300	1005.8	5	12
3360	1024.1	7	12
3420	1042.4	8	11
3480	1060.7	1	5
3540	1079.0	5	24
3600	1097.3	2	10
3660	1115.6	13	24
3720	1133.9	2	27
3780	1152.1	3	17
3840	1170.4	6	48
3900	1188.7	7	22
3960	1207.0	2	71
4020	1225.3	6	28
4080	1243.6	6	28
4140	1261.9	2	28
4200	1280.2	6	14
4260	1298.4	4	13
4320	1316.7	3	14
4380	1335.0	16	23
4440	1353.3	8	18
4500	1371.6	11	24
4560	1389.9	8	26
4620	1408.2	7	31
4680	1426.5	9	16
4740	1444.8	12	17
4800	1463.0	5	10
4860	1481.3	5	11
4920	1499.6	5	10
4980	1517.9	9	15
5040	1536.2	8	15
5100	1554.5	10	34
5160	1572.8	11	23
5220	1591.1	14	41
5280	1609.3	8	22
5340	1627.6	13	42
5400	1645.9	20	46
5460	1664.2	17	33
5520	1682.5	15	24
5580	1700.8	2	6
5640	1719.1	4	14
5700	1737.4	4	6
5760	1755.6	5	26
5820	1773.9	7	22
5880	1792.2	5	12
5940	1810.5	5	15
6000	1828.8	9	16
6060	1847.1	12	16
6120	1865.4	12	17
6180	1883.7	3	7
6240	1902.0	6	10
6300	1920.2	5	14
6360	1938.5	1	3
6420	1956.8	0	1
6480	1975.1	4	42
6540	1993.4	13	13
6600	2011.7	7	49
6660	2030.0	4	50
6720	2048.3	7	12
6780	2066.5	1	8

Depth		Environment	
Feet	Meter	Backmangrove	Mangrove
6840	2084.8	4	8
6900	2103.1	2	8
6960	2121.4	6	12
7020	2139.7	6	9
7080	2158.0	1	1
7140	2176.3	0	2
7200	2194.6	3	6
7260	2212.8	5	52
7320	2231.1	12	24
7380	2249.4	9	16
7440	2267.7	10	12
7500	2286.0	6	9
7560	2304.3	1	2
7620	2322.6	11	11
7680	2340.9	3	12
7740	2359.2	4	18
7800	2377.4	7	12
7860	2395.7	2	11
7920	2414.0	3	4
7980	2432.3	1	4
8040	2450.6	2	7
8100	2468.9	6	8
8160	2487.2	1	1
8220	2505.5	5	7
8280	2523.7	9	9
8340	2542.0	4	8
8400	2560.3	4	4
8460	2578.6	10	10
8520	2596.9	0	3
8580	2615.2	3	3
8640	2633.5	0	0
8700	2651.8	5	0
8760	2670.0	2	0
8820	2688.3	0	0
8880	2706.6	2	2
8940	2724.9	0	7
9000	2743.2	2	2
9060	2761.5	0	0
9120	2779.8	0	0
9180	2798.1	0	0
9240	2816.4	0	0
9300	2834.6	0	0
9360	2852.9	10	15
9420	2871.2	0	0
9480	2889.5	3	0
9540	2907.8	0	0
9600	2926.1	0	0
9660	2944.4	0	3
9720	2962.7	0	0
9840	2999.2	0	0
9900	3017.5	3	3
9960	3035.8	0	9
10020	3054.1	12	25
10080	3072.4	0	8
10140	3090.7	8	33
10200	3109.0	0	0
10260	3127.2	4	4
10320	3145.5	3	6
10380	3163.8	5	5
10440	3182.1	0	0
10500	3200.4	0	30
10560	3218.7	7	7
10620	3237.0	13	40
10680	3255.3	0	23
10740	3273.6	13	27
10800	3291.8	0	25
10860	3310.1	0	0
10920	3328.4	5	11
10980	3346.7	5	16
11040	3365.0	3	22
11100	3383.3	7	24
11160	3401.6	10	31
11220	3419.9	3	12
11280	3438.1	5	12
11340	3456.4	9	18
11400	3474.7	0	10
11460	3493.0	0	3
11520	3511.3	0	0
11580	3529.6	0	0
11640	3547.9	0	100
11700	3566.2	0	28
11760	3584.4	0	8
11820	3602.7	0	40
11880	3621.0	0	0
11940	3639.3	0	0
12000	3657.6	0	16
12060	3675.9	3	10
12120	3694.2	3	9
12150	3703.3	0	0
12180	3712.5	8	0

Figure 6. Number of individual palynomorphs at each depth

– 12,149 feet, the abundance of foraminifera is inversely proportional to the abundance of palynomorphs. In this zone, the abundance of foraminifera tends to be small and does not show any trend of increasing or decreasing. Meanwhile, palynomorphs show significant fluctuations in increasing and decreasing trends at each depth. This occurs in the lower Late Miocene TST and FSST.

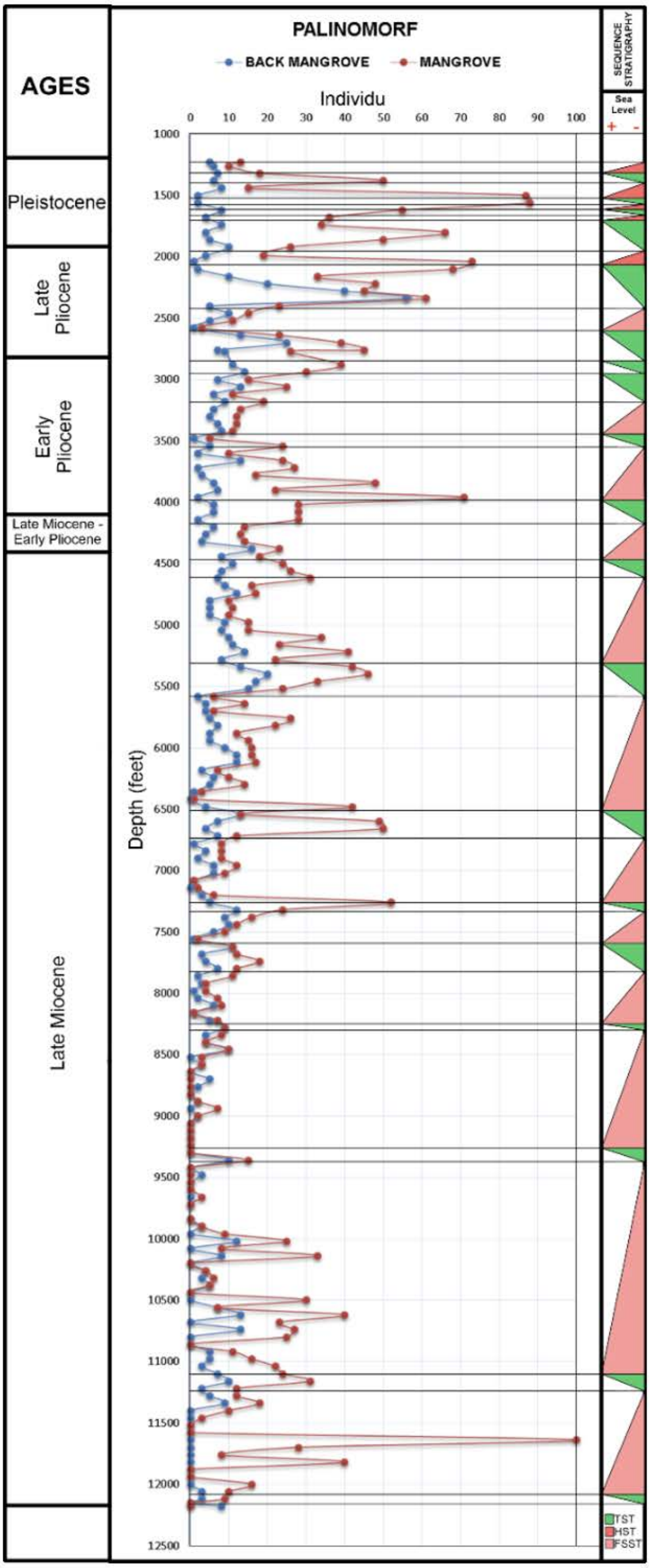

Figure 7. Abundance of palynomorphs mangrove and back-mangrove in the Kutai Basin, East Kalimantan

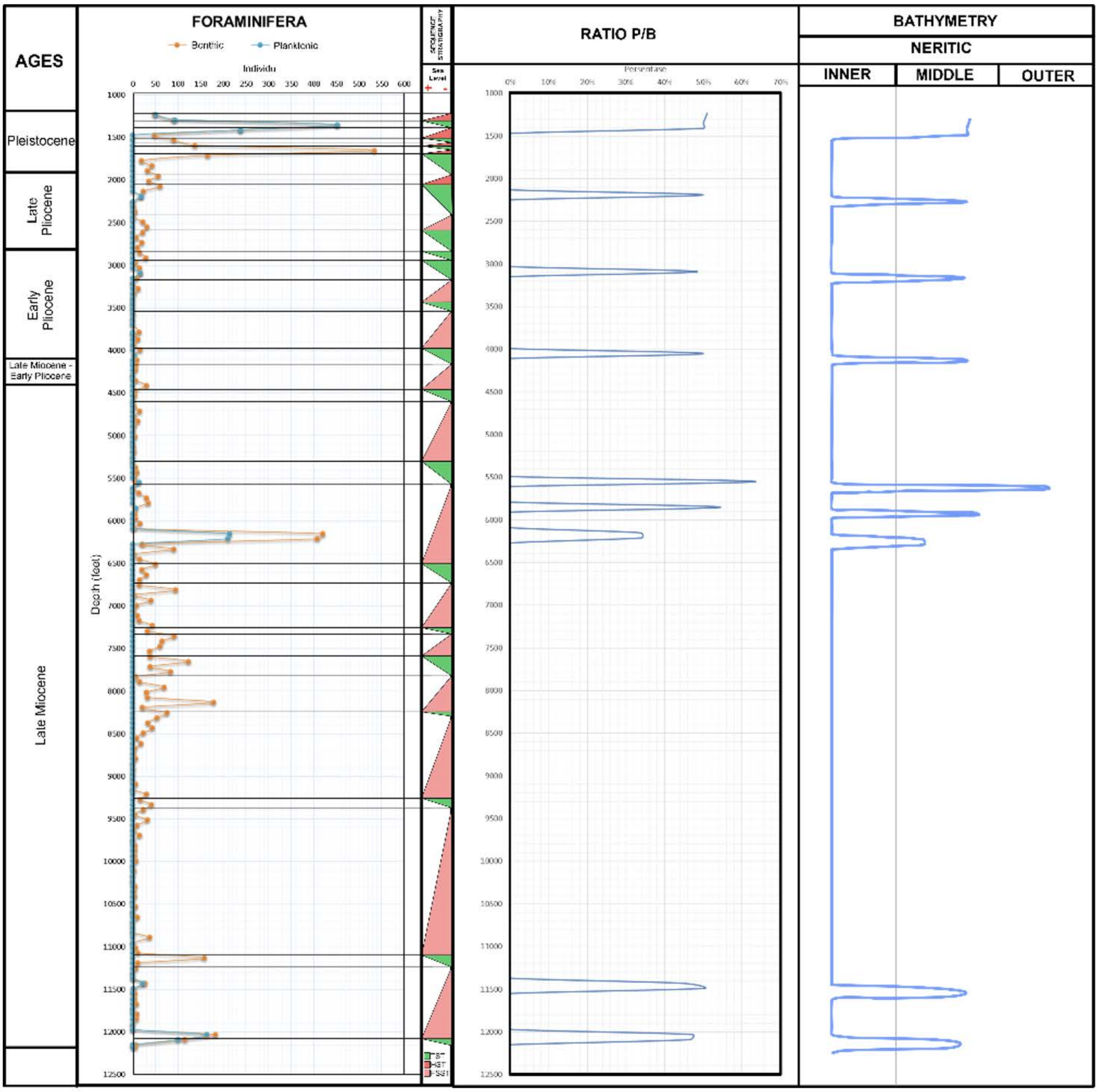

Figure 8. The relationship between foraminiferal abundance and sequence stratigraphy is associated with the bathymetric environment based on the P/B Ratio in the Kutai Basin, East Kalimantan

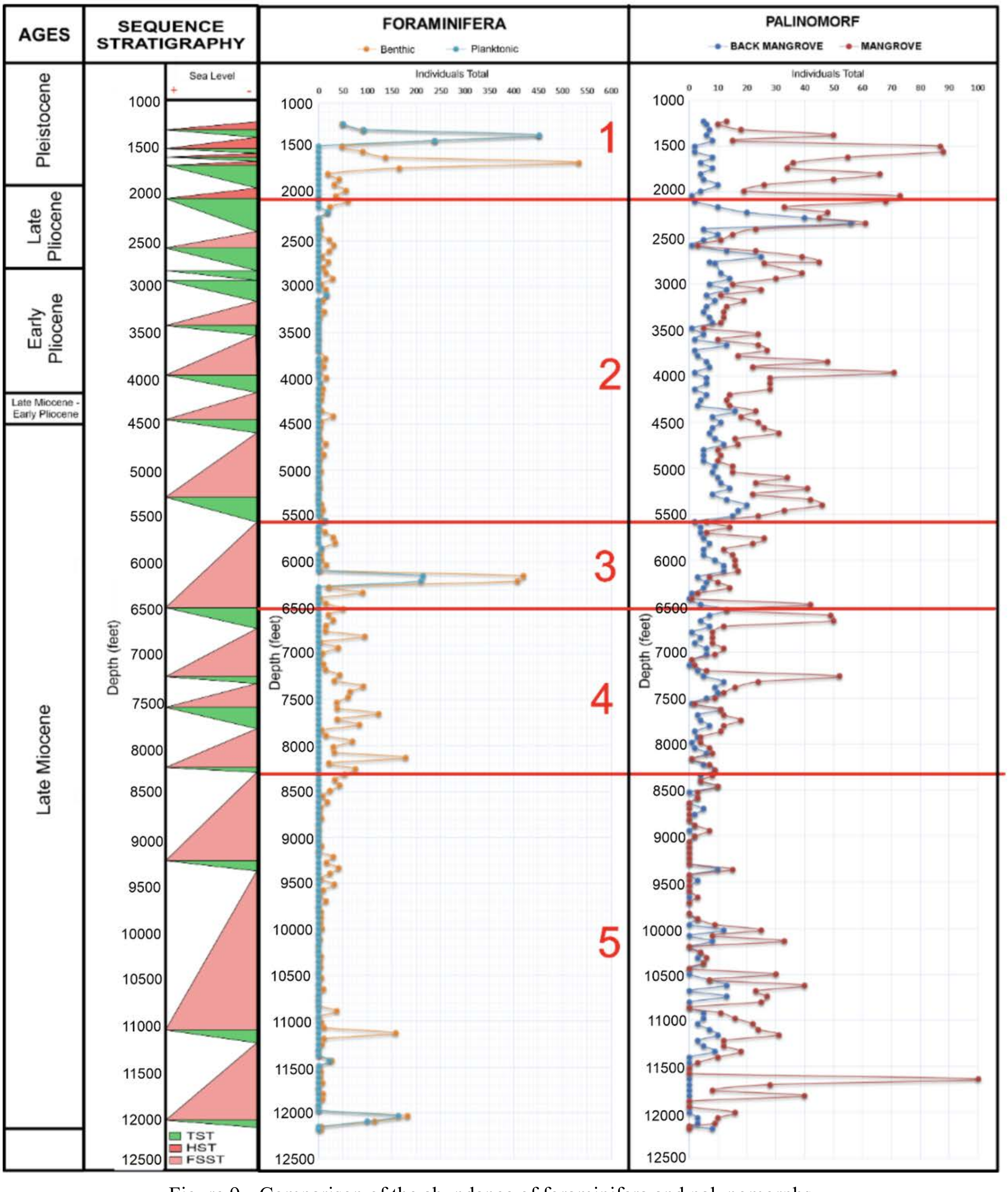

Figure 9. Comparison of the abundance of foraminifera and palynomorphs

CONCLUSSIONS

In the study area, three phases of sequence stratigraphy change occurred, including HST (Highstand System Tract), TST (Transgressive System Tract), and FSST (Falling Stage System Tract) during the Late Miocene - Pleistocene with a depth of 1,230 feet – 12,180 feet. The most abundant small benthic foraminifera was found at a depth of 1,650 feet with 534 individuals in the TST. Meanwhile, the most abundant of planktonic foraminifera found, namely 452 individuals, was found at a depth of 1,350 feet during the transition from TST to HST. The most abundant of mangrove palynomorphs was at a depth of 11,640 feet with 100 fossil grains in the FSST. Meanwhile, the back-mangrove palynomorphs were 56 fossil grains at a depth of 2,340 feet during the TST.

The P/B ratio value at all well-depth intervals conducted in this study is generally in the inner neritic zone with a value of less than 20%. Some specific depths in the middle-outer neritic zone are due to planktonic foraminifera, which is one of the important aspects of the calculation. For example in the depth of 5,550 feet with a P/B ratio of 64% which belongs to the outer neritic environment (100 – 200 m).

Several depths in this well did not contain foraminifera and palynomorphs including 9,750 feet, 10,170 – 10,230 feet, and 11,910 – 11,970 feet in the Late Miocene. The absence of foraminifera fossils, mangrove palynomorphs, and back-mangroves indicates that this depth belongs to the terrestrial (land) environment. Another factor is the sediment type and the organic decomposition process, especially in palynomorphs.

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