POLLEN RECORD OF EARLY/ MIDDLE MIOCENE BOUNDARY IN THE SOUTH SUMATRA BASIN

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First Registered on 12 June 2009; Received after Corection on 8 August 2009
Publication Approval on : 24 November 2009

ABSTRACT

Early to Middle Miocene sediment obtained from three wells drilled in South Sumatera area has been evaluated for its micropaleontological content including foraminifera, calcareous nannoplankton and palynomorph. The boundary of Early/ Middle Miocene is clearly represented by zone N8/ N9 boundary based on foraminiferal analysis and zone NN4/ NN5 boundary on the basis of calcareous nannoplankton analysis. The rich assemblage of foraminifera and calcareous nannoplankton indicates the occurrence of marine sediment within the well sections. In addition, environmental markers of benthonic foraminifera suggest the occurrence of inner to middle neritic along the studied sections.

Palynological analysis however, proves the high occurrence of pollen and spore along the marine successions situated in Early/ Middle Miocene boundary which is the first time to yield a good quality of palynological record.

The Early/ Middle Miocene boundary is marked by low sea level in global sea level curve as indicated by significant decrease of foraminifera and calcareous nannoplankton. In addition, palynological record reflects climatic changes over N8/ N9 sediment marking Early/ Middle Miocene boundary with the declines of pollen assemblage suggesting seasonal/ dry climate condition. N8 sediment shows high abundance and diversity of palynomorphs including those of wet climate markers. Palynological assemblage drops gradually approaching foram zone N9/ N8 boundary, whilst seasonal climate indicators increase. On the other hand, palynological record recovers its assemblage over N9 sediment.

*Key words**:** pollen record, early/ middle miocene, south Sumatra basin.*

I. BACKGROUND RESEARCH

Palynological analysis of the South Sumatera samples was mostly focused on Early Miocene to Oligocene sediment which includes Talang Akar Formation (Lelono, 2004a dan b). Most palynological samples derived from this sediment which is the target of exploration due to its high hydrocarbon potentiality within the South Sumatera Basin. The Early Miocene to Oligocene sediment may be classified as the synrift deposit because they were deposited during rifting phase which presumably occurred in Oligo-Miocene age (Lemigas, 2001). This sediment was generally formed in the non-marine to transition (deltaic) environment (De Coster and Adiwidjaja, 1973). Therefore, this type of sediment contains rich palynomorph which was suitable for palynological investigation (Hasjim et al., 1993, Morley, 1995 and Lelono, 2003). For the above reasons, palynological study was frequently performed on the Early Miocene to Oligocene sediment.

Generally, the stratigraphy of the South Sumatera Basin is initiated by transgression and ended up with regression (Lemigas, 2006). The transgression occurred during Oligocene up to Middle Miocene including Lahat Formation (fluviatile-lacustrine), Talang Akar Formation (transition), Baturaja Formation (shal-

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low marine) and Gumai Formation (deep marine). On the contrary, regression appearing during Middle Miocene to Pliocene resulted in the formation of the following successions: Air Benakat Formation (shallow marine), Muara Enim Formation (transition) and Kasai Formation (fluviatile-terrestrial). The regional stratigraphy of the South Sumatra Basin is shown in Figure 1.

The studied sediment may include Gumai Formation and Air Benakat Formation with an age ranging from Early to Middle Miocene. The Gumai Formation was deposited during the time of maximum transgression in a deep marine condition at Early Miocene (Hartanto et al., 1991). This formation consists of *Globigerina* bearing clay and marly shale with minor intercalation of claystone and sandstone. In the shelf environment, the deposition of Gumai Formation might continue up to Middle Miocene. In the eastern part of the Jambi Sub-basin, this formation less develops which is represented by sandy lithology overlying the Talang Akar Formation locally (Sundari, 1996). On the other hand, the younger sediment of Air Benakat Formation was deposited during Middle Miocene when a regressive cycle started (Hartanto et al., 1991). It is generally characterised by a marine clay with abundant glauconite and micro-forams, claystone and an increasing number of sandstone layers toward the top formation. The Air Benakat Formation is interpreted to be formed in deep marine, which gradually changed to shallow marine.

This study provides the opportunity to reveal palynological succession within the marine Early/ Middle Miocene sediment which is previously lack of information. It is also useful to interpret the vegetational condition throughout this age. This succession allows the understanding of climatic changes especially those that mark Early/ Middle Miocene boundary. Therefore, this paper is published to provide biostratigraphic information which allows explorationists to possess better understanding of the stratigraphy of the South Sumatra Basin.

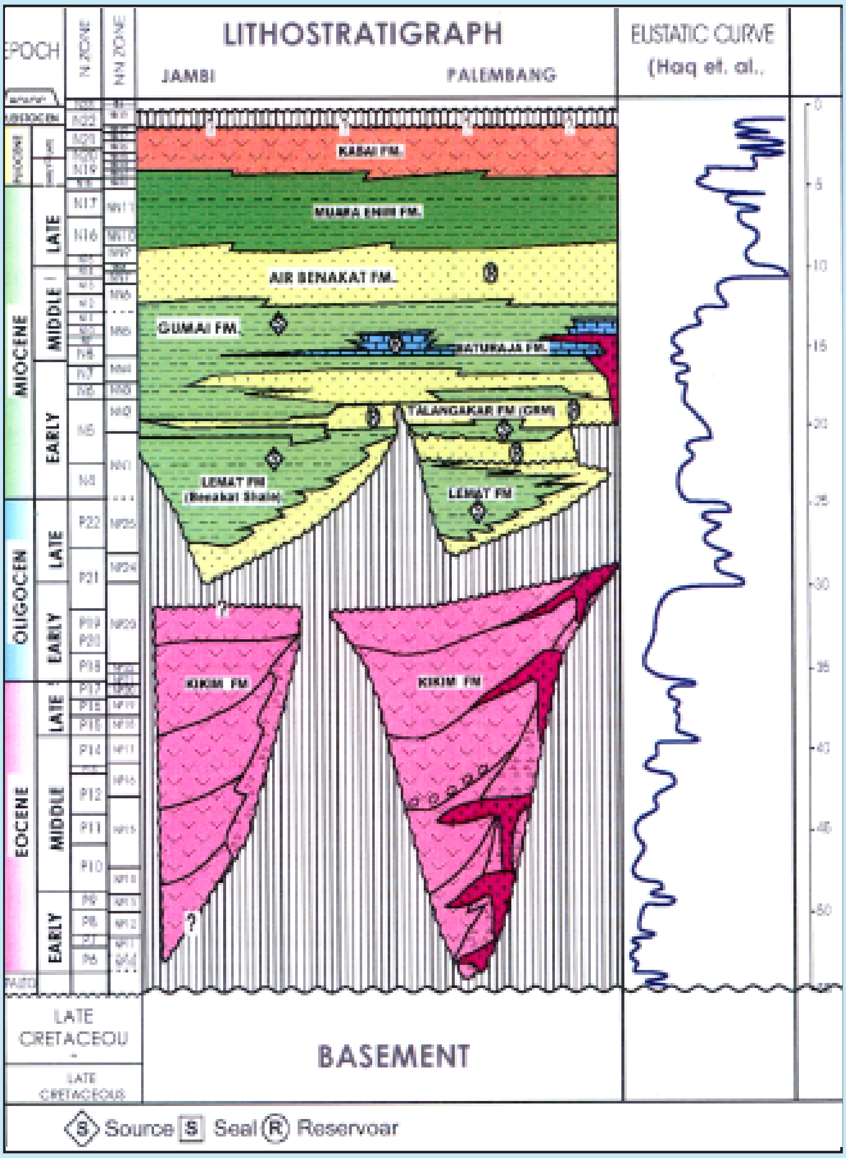

Figure 1
Regional stratigraphy of the South Sumatera Basin
(Sundoro et al., 2006, with minor modification)

II. MATERIALS AND METHODS

The material used in this study is cutting samples which were collected from exploration wells drilled on the on-shore area. Having this fact, data produced during this study is considered to be confidential. Regarding data confidentiality, well names are therefore hidden and alternated by using alphabetical codes. Three wells are selected to cover Early/ Middle Miocene sediment including E, B and L. In addition, only relevant information is exhibited in this paper due to space limitation. In this case, the biostratigraphic diagrams only show selected taxa which determine interpretation.

Basically, this study combines palynological analysis with nannoplankton and foraminiferal analyses in order to get reliable interpretation. Nannoplankton and foraminifera are used to control the age of the sections. In addition, nannoplankton and foraminiferal assemblages can be an indication of sea level changes especially those of benthonic foraminifera. For these purposes, each well is analysed using three different disciplines including palynology, micropaleontology (foraminifera) and nannoplankton. Samples were split into three parts where possible. First part was used for palynology whilst second part for micropaleontology. On the other hand, the third part was for nannoplankton. For palynology, it is demanded 250 palynomorphs for applying quantitative analysis. The abundance and diversity of palynomorph in each sample are useful to understand the palaeoclimate and palaeoenvironment. The first or last occurrence of the age-restricted palynomorphs is used to identify the age of the studied sediment. The abundance and diversity of palynomorph are plotted in percentage on pollen diagram, which usually fluctuates from one sample to another, reflecting vegetational and climatic changes. In addition, nannoplankton and foraminiferal analyses are also conducted based on quantitative method. The nanos and forams zonations are reconstructed on the basis of the first or last appearance of index taxa. These taxa are also used to determine the age of the studied sections. The occurrence of environmental marker of benthonic foraminifera allows stratigraphers interpreting paleoenvironment during sedimentation of the studied samples which leads to the identification of sea level changes. The benthonic foraminiferal assemblage combined with planktonic foraminiferal and nannoplankton assemblages supports the identification of sea level fall within Early/ Middle Miocene boundary.

III. BIOSTRATIGRAPHIC EVIDENCE OF EARLY/ MIDDLE MIOCENE

Haq et al. (1988) indicates that the Early/ Middle Miocene boundary is marked by low sea level. Land was widely exposed, whilst sea significantly reduced during this age (Figure 2). This condition implies to

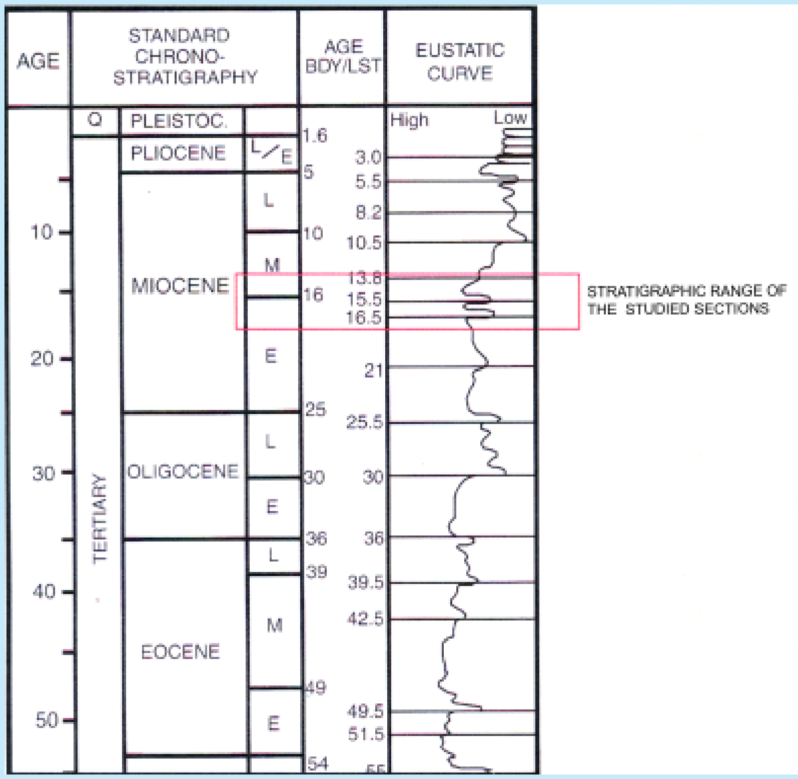

Figure 2
Geological time framework and global eustatic curve (Haq et al., 1988). In the third main column, BDY represents age in Ma of Epoch boundaries, whilst LST shows age in Ma of the main periods of low sea level according to the eustatic curve

the diversity and abundance of flora and fauna. In term of marine micro-fauna, the period of sea level high priors to Early/ Middle Miocene boundary (foraminifera zone N8) is characterised by high diversity and abundance of marine micro-fossils which suddenly significantly decreased approaching this boundary (Figure 3). Low abundance and diversity of marine micro-fossils occurring in the Early/ Middle Miocene boundary related to the period of low sea level. Less marine influence within the depositional environment during this period caused less development of marine microfossils. This phenomenon can be widely seen in the South Sumatera area. Mean while, palynological record indicates high abundance of mangrove pollen in the period of high sea level. This pollen drops dramatically within Early/ Middle Miocene boundary following sea level fall (Figure 4). Subsequently, this pollen gradually increases when sea level gradually rises. In addition, palynological record throughout Early/ Middle Miocene boundary provides an evidence for climatic change which will be discussed in next chapter.

IV. EARLY/ MIDDLE MIOCENE BOUNDARY BASED ON THE INDEX FOSSILS OF FORAMINIFERA AND NANNOPLANKTON

Referring to the foraminiferal zone, the Early/ Middle Miocene boundary fits with zone N8/ N9 boundary which is marked by the first occurrence of planktonic foraminifera of *Orbulina universa* or the last occurrence of planktonic foraminifera of *Globigerinoides bisphaericus* (Blow, 1969 with modification by Baumann, 1974). In the studied area, the occurrence of *Orbulina universa* is irregular and even unobserved in some sections. This might relate to rare planktonic foraminiferal appearance within zone N9 which was caused by unfavorable environment resulting in the occurrence of low sea level (Figure 3). In this case, low sea level is represented by shallow marine setting as suggested by moderate occurrence of shallow water markers of benthonic foraminifera such as *Ammonia umbonata*, *A. beccarii*, *Asterorotalia yabei* and *Pseudorotalia* sp. The occurrence of shallow marine condition results in poor development of planktonic foraminifera as shown in Figure 3. On the other hand, the appearance of *Globigerinoides bisphaericus* can be regularly traced up to the top of zone N8 due to suitable condition of marine environment. Planktonic and benthonic foraminifers provide moderate to high abundance and diversity indicating stronger marine influence than that of zone N9 (Figure 3).

Based on calcareous nannoplankton analysis, the Early/ Middle Miocene boundary is situated within nanno zone NN4/ NN5 boundary which is defined by the last occurrence of *Helicosphaera ampliaperta* (Martini, 1971). The appearance of this calcareous nannoplankton can be observed regularly throughout the studied wells (Figure 4).

After all, the Early/ Middle Miocene boundary can be identified based on the occurrence of index fossil of both planktonic foraminifera and calcareous nannoplankton. The use of last occurrence of these microfossils for identifying Early/ Middle Miocene boundary is highly confident especially for cutting sample as it prevents from caving problem.

V. CLIMATIC CHANGE OF EARLY/ MIDDLE MIOCENE BOUNDARY

The paleoclimate during Early/ Middle Miocene boundary (foram zone N8/ N9 boundary or nanno zone NN4/ NN5 boundary) is mainly interpreted based on the occurrence of the climate indicator of the selected palynomorphs. The wet climate indicator is represented by *Blumeodendron* sp., *Cephalomappa* sp., *Durio* type, *Sapotaceoidaepollenites* spp., *Lycopodium cernuum* and *Selaginella plana*. On the other hand, the seasonal/ dry climate indicator includes *Echitriporites schoutenoides*, *Malvacipollis diversus*, *Monoporites annulatus*, *Campnosperma* sp. and *Magnastriatites howardi*.

The wet climate indicator shows moderate abundance and diversity during foram zone of N8 or nanno zone of NN4 (Early Miocene) as shown by *Blumeodendron* sp., *Cephalomappa* sp., *Durio* type and *Sapotaceoidaepollenites* spp. (Figures 5 and 6). This condition may indicate the occurrence of wet climate during zone N8 or zone NN4. In fact, vegetation was well developed during this zone as proved by moderate abundances of mangrove pollen *Zonocostites ramonae*, back-mangrove pollen of *Florschuetzia levipoli* and *F. trilobata* and rattan pollen of *Dicolpopollis malesianus* and *Dicolpopollis* spp. and high abundance of fresh water pollen *Calophyllum* type (Lemigas, 2008). Referring to relative sea level curve (Haq et al., 1988), this wet condition relates to high sea level which result in

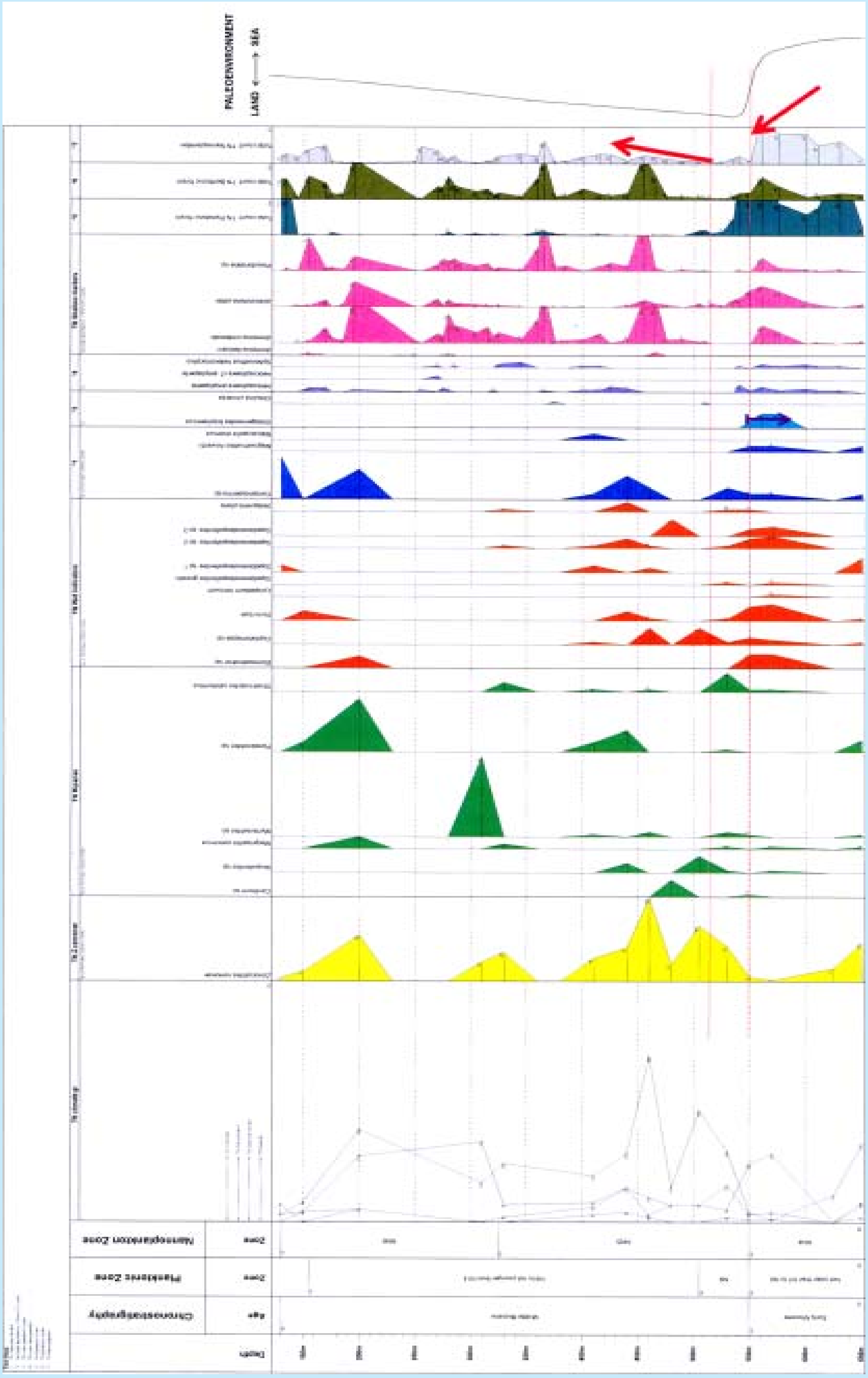

Figure 3

Vertical distribution of Palynomorph, foraminifera and nannoplankton in well E which shows significant decline of marine micro-fossil (foraminifera and nannoplankton) in Early/ Middle Miocene boundary. The last occurrences of planktonic foraminifera *Globigerinoides bisphaericus* and calcareous nannoplankton *Helicosphaera ampliaperta* in depth of 550m indicate this boundary

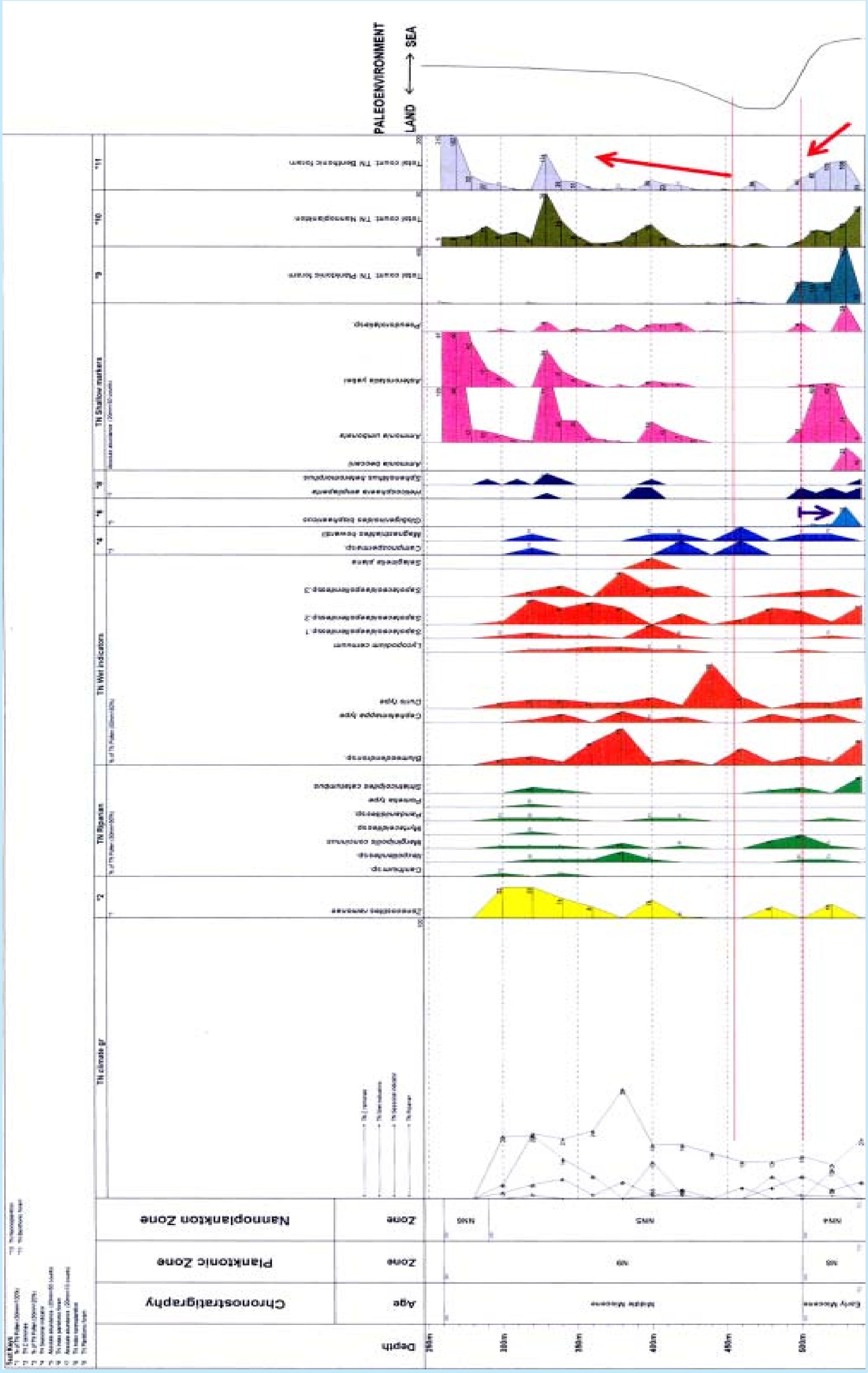

Figure 4
Summary of micro-flora and fauna distribution of well B which demonstrates dramatic decrease of foraminifera and nannoplankton within the boundary of Early/ Middle Miocene. The last occurrences of planktonic foraminifera *Globigerinoides bisphaericus* and calcareous nannoplankton *Helicosphaera ampliaperta* coincide in sample 500m marking this boundary

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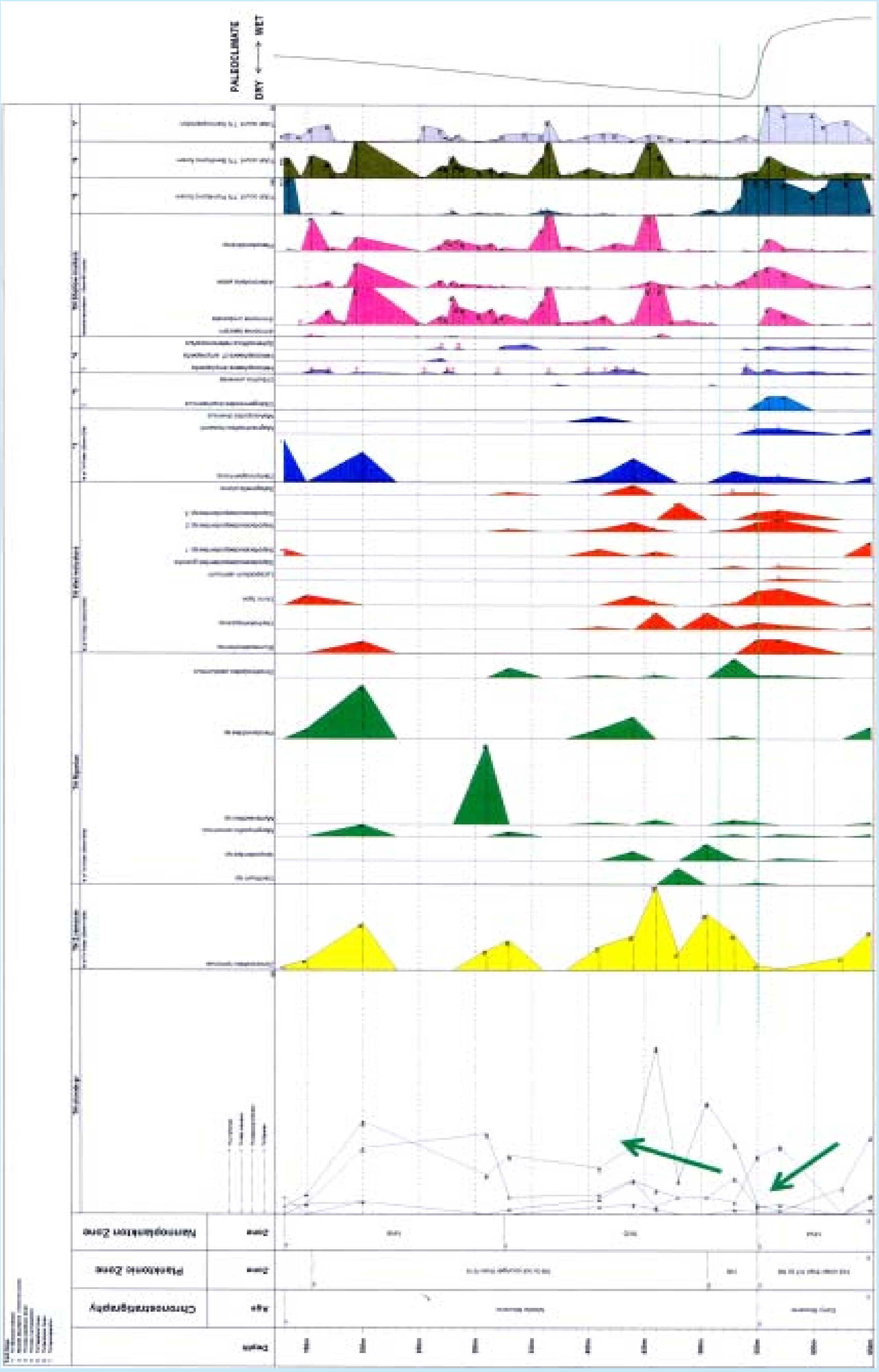

Figure 5
Paleoclimate interpretation of well E based on the occurrence of climate indicators of Palynomorph combined with foraminiferal and nannoplankton assemblages

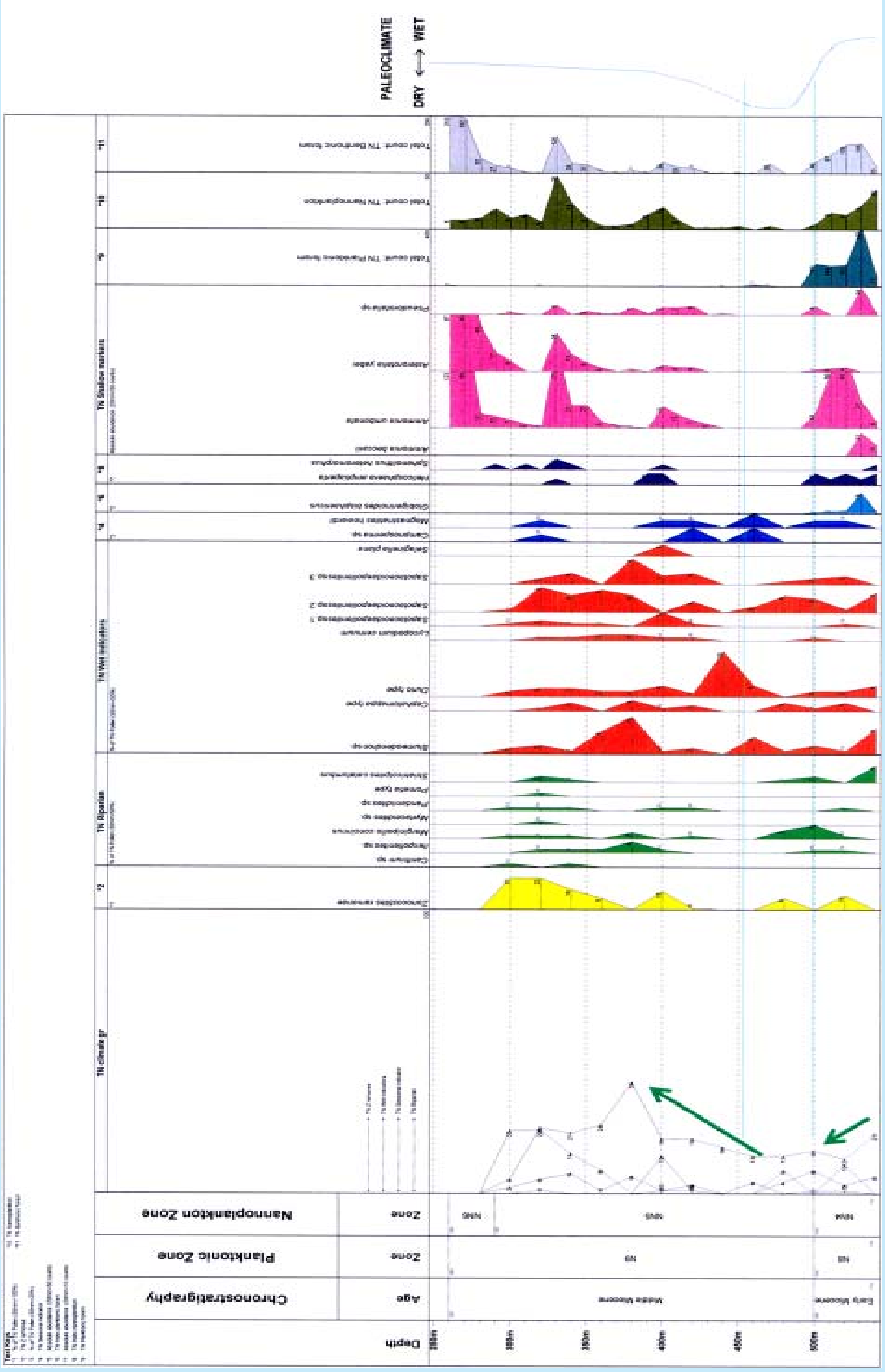

Figure 6
Climatic changes along well B section as indicated by climatic indicators of palynomorph supported by foraminiferal and nannoplankton assemblages

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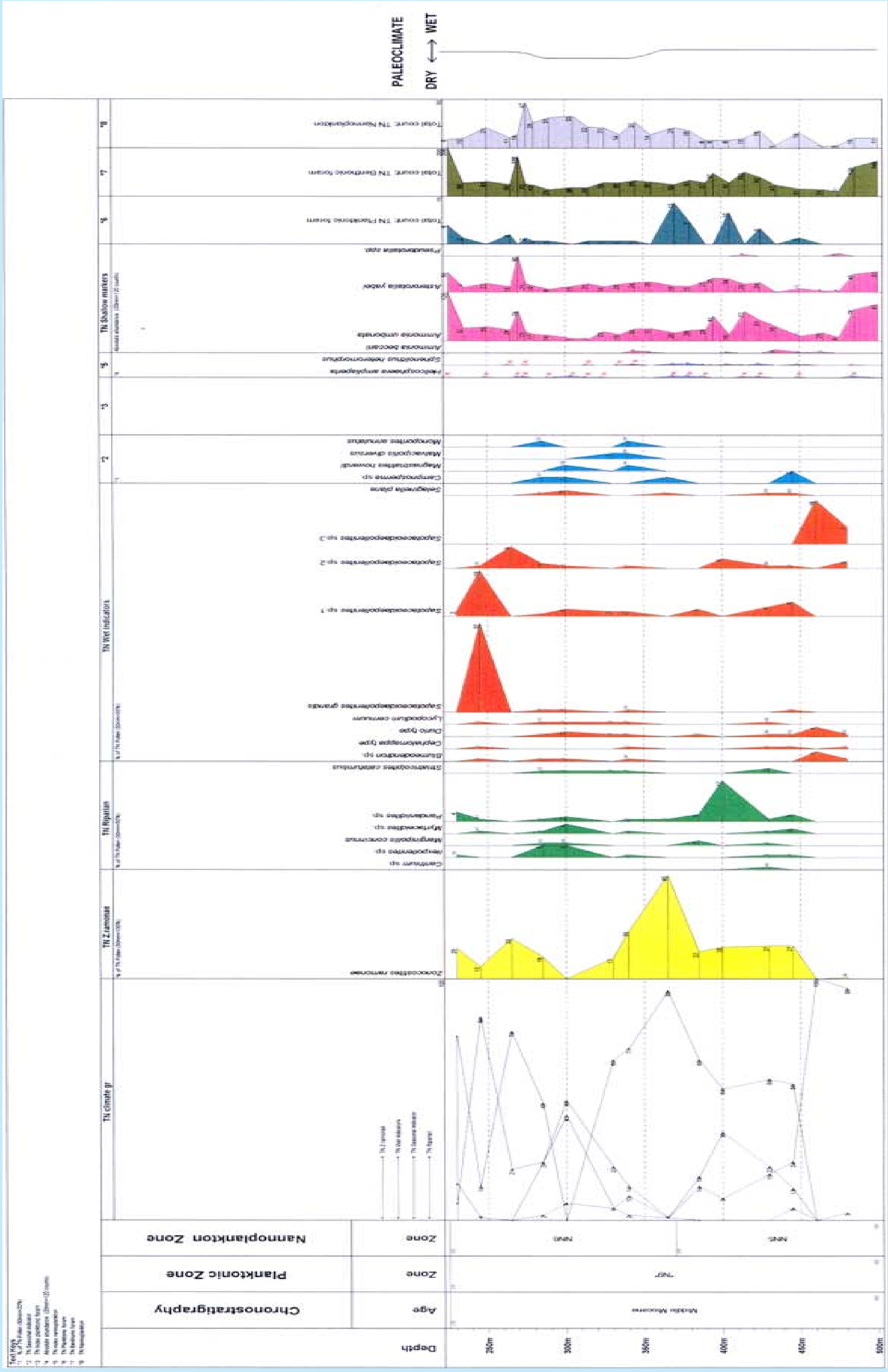

Figure 7
Moderate occurrence of mangrove pollen *Zonocostites ramonae* and moderate occurrence of foraminifera and nannoplankton indicate rising sea level during wetter climate in NN5-NN6 (Middle Miocene) sediment of well L

drown on the wider areas. Subsequently, it triggers the expansion of brackish vegetation as proved by moderate abundance of mangrove and back-mangrove elements (Figures 5 and 6). Moreover, wet climate condition causes well development of angiosperm as shown by moderate abundance of rattan and fresh water palynomorphs.

The wet climate indicators drop significantly within the boundary of zone N8/ N9 or zone NN4/ NN5. Those indicators are alternated by the increase of seasonal climate indicators such as *Monoporites annulatus*, *Campnosperma* sp. and *Magnastriatites howardi* (Figure 5). This condition clearly indicates the appearance of seasonal/ dry climate within zone N8/ N9 boundary (Early/ Middle Miocene boundary). The seasonal/ dry climate relates to low sea level which results in the emergence of the depositional area. This means that the shoreline moves basin ward reducing the number of brackish vegetation as reflected by the significant decline of brackish palynomorphs such as *Zonocostites ramonae* (mangrove pollen), *Spinizonocolpites echinatus*, *Florschuetzia trilobata* forms, *F. levipoli*, *Discoidites novaguenensis* and *D. pilosus* (back-mangrove pollen). The effect of low sea level is also seen in the foraminiferal and calcareous nannoplankton assemblages which exhibit significant decrease within Early/ Middle Miocene boundary (Figure 6). The sediment was mostly deposited in the shallow marine environment as shown by high abundance of shallow marine marker of benthonic foraminifers including *Ammonia umbonata*, *A. beccarii*, *Asterorotalia yabei* and *Pseudorotalia* sp.

The climate gradually changes to wetter climate throughout foram zone of N9 (Middle Miocene) as suggested by the increase of wet climate indicators such as *Blumeodendron* sp., *Cephalomappa* sp., *Durio* type and *Sapotaceoidaepollenites* spp. (Figures 5 and 6). Palynological abundance increases gradually toward younger section as shown by mangrove pollen *Zonocostites ramonae*, fresh water pollen *Calophyllum* type and rattan pollen *Dicolpopollis malesianus* and *Dicolpopollis* spp. (Lemigas, 2008). The wetter climate relates to rising sea level resulting in the submergence of wide area. This condition implies to the appearance of wide brackish environment which then subsequently increases the occurrence of mangrove element as mentioned above. In addition, as climate is getting wetter, fresh water palynomorph is getting diverse and abundant as shown in Figure 7.

VI. CONCLUSION

The Early/ Middle Miocene boundary represented by foraminifera zone of N8/ N9 and calcareous nannoplankton zone of NN4/ NN5 boundaries can be defined based on the last occurrence of planktonic foraminifera of *Globigerinoides bisphaericus* and the last occurrence of calcareous nannoplankton of *Helicosphaera ampliaperta*. This boundary is indicated by low sea level which partly causes the occurrence of shallow marine environment as proved by moderate to high abundance of shallow marine markers. This situation results in a significant decrease of foraminiferal (especially those of planktonic foraminifera) and calcareous nannoplankton assemblages. On the other hand, palynological record provides clear evidence of seasonal/ dry climate condition within the Early/Middle Miocene boundary. The climate was wet during zone N8 which is indicated by common occurrence of wet climate markers. This climate relates to sea level high resulting in a well development of mangrove and back-mangrove palynomorphs. In addition, the climate causes the increase of fresh water vegetation. Subsequently, seasonal/dry climate appears to mark the Early/ Middle Miocene boundary as suggested by the increase of dry climate indicators. The dry climate relating to low sea level causes the emergence of many submerging areas which reduces brackish floral assemblage. Dry climate may also prevent the development of fresh water vegetation. The climate tends to be wetter during zone N9 as indicated by the increase of wet climate indicators. Moreover, fresh water palynomorph gradually increases indicating recovery of fresh water vegetation.

VII. ACKNOWLEDGMENT

The author is grateful to the Stratigraphy Group of LEMIGAS Exploration Division for its great helps in identifying palynomorphs, calcareous nannoplankton and foraminifera from the studied wells situated on the on-shore area of South Sumatra Basin. The author wishes to thank Mohammad Taufiq for his helps in producing biostratigraphic diagrams.

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