MIOCENE PALYNOLOGY OF THE BARITO BASIN, SOUTH KALIMANTAN

PALINOLOGI UMUR MIOSEN DI CEKUNGAN BARITO, KALIMANTAN SELATAN

Eko Budi Lelono, Christina Ani Setyaningsih, and **L. Nugraha Ningsih**
"LEMIGAS" R & D Centre for Oil and Gas Technology
Jl. Ciledug Raya, Kav. 109, Cipulir, Kebayoran Lama, P.O. Box 1089/JKT, Jakarta Selatan 12230 INDONESIA
Tromol Pos: 6022/KBYB-Jakarta 12120, Telephone: 62-21-7394422, Faxsimile: 62-21-7246150
E-mail: ekobl@lemigas.esdm.go.id, E-mail: christina@lemigas.esdm.go.id,

First Registered on April 2nd 2014; Received after Corection on April 25th 2014
Publication Approval on : April 30th 2014

ABSTRAK

Studi ini telah berhasil mengungkapkan kandungan tinggi palinomorf pada sedimen berumur Miosen di Cekungan Barito, Kalimantan Selatan. Keberadaan palinomorf ini dicirikan oleh Kemunculan Akhir polen *Florschuetzia trilobata* (Batas Miosen Tengah/ Akhir) dan Kemunculan Awal polen *F. meridionalis* (Batas Miosen Awal/ Tengah). Selain itu, dicirikan pula oleh kehadiran spora penciri umur Miosen seperti *Stenochlaenidites papuanus* (Miosen Akhir) dan *Scolocyamus magnus* (Miosen Awal/ Tengah). Hal lain yang menarik adalah kemunculan palinomorf air payau sepanjang lintasan sumur yang menandai pengaruh lingkungan laut selama proses sedimentasi. Palinomorf ini antara lain *Zonocostites ramonae*, *Florschuetzia meridionalis* (mangrove), *Florschuetzia levipoli* dan *Spinizonocolpites echinatus* (back-mangrove). Secara rinci dapat dijelaskan bahwa pada awalnya sedimentasi terjadi di lingkungan air tawar dalam suatu *delta plain* selama umur Miosen Awal-Tengah (bagian bawah sumur) seperti ditunjukan oleh dominasi polen air tawar dan ketidak hadiran fosil marin. Selanjutnya secara bergradasi lingkungan pengendapan bergeser ke arah laut yang lebih dalam di lingkungan *delta front* sampai *pro delta* (kemungkinan sampai laut dangkal) selama umur Miosen Tengah-Akhir (bagian atas sumur) sebagaimana ditandai oleh peningkatan kehadiran polen air payau dan fosil marin. Studi ini juga sukses mengidentifikasi kelimpahan maksimum polen riparian *Myrtaceidites* sp. yang sangat berpotensi sebagai datum korelasi sumur. Melimpahnya polen ini di bagian bawah sumur menandai kehadiran endapan sungai (*channels*). Sementara itu, kehadiran polen air tawar dalam jumlah dan keragaman tinggi yang berhasil direkam dalam studi ini mengindikasikan kelebatan hutan dataran rendah di bawah pengaruh iklim basah.

Kata Kunci: *Palinologi, Miosen, Cekungan Barito, Kalimantan Selatan*

ABSTRACT

This study has succesfully disclosed the rich assemblage of palynomorph within the Miocene sediment of the Barito Basin, South Kalimantan. It is characterised by the the last occurrence of Florschuetzia trilobata (Middle/ Late Miocene boundary) and the first occurrence of F. meridionalis (Early/ Middle Miocene boundary). In addition, other Miocene markers appear to mark this age such as spores of Stenochlaenidites papuanus (Late Miocene) and Scolocyamus magnus (Early/ Middle Miocene). Mean while, the regular occurrence of brackish palynomorphs along the studied sections indicates marine influence during deposition including Zonocostites ramonae, Florschuetzia meridionalis (mangrove pollen), Florschuetzia levipoli and Spinizonocolpites echinatus (back-mangrove pollen). The depositional environment initially occurs in the freshwater environment of delta plain during Early to Middle Miocene (lower well sections) as suggested by domination of freshwater pollen in the absence of marine micro-fossils. It gradually shifts in to deeper marine setting in delta front to pro delta (with possible shallow marine environment) during Middle to Late Miocene (upper well sections) as indicated by the increase of brackish palynomorphs combined with marine micro-fossils. This study identifies peak of riparian pollen Myrtaceidites sp. which is potential for *well correlation. This pollen is common within the lower well sections suggesting the presence of river deposits. On the other hand, considerable appearance of freshwater palynomorphs may be an indication of well development of low land forests under wet climate condition.*

Keywords: *Palynology, Miocene, Barito Basin, South Kalimantan*

I. INTRODUCTION

Palynological research performed on the studied area is restricted as indicated by less publication regarding this research. This condition may be caused by the following circumstances. Firstly, the difficulty of data access, especially those provided by the oil companies (both well and surface data). Secondly, the fact that wells drilled in this area are limited. This prevents biostratigraphers from obtaining sufficient samples for comprehensive analysis. As a result, there are little samples that can be used for proper palynological examination. Therefore, it is required sufficient data to access palynology of the Barito Basin. Mean while, only Miocene samples are available for this study which were obtained from the exploration wells. Having said that, this paper is aimed to reveal palynological records of the Miocene sediments which will contribute to an understanding of the Tertiary palynology in South Kalimantan.

The area of study is located in South Kalimantan (Figure 1). This study is a part of geological investigation on Miocene sediment in South Kalimantan in order to evaluate hydrocarbon potential within this sediments of this area. Data used in this study derives from two wells namely P and Q. Three different disciplines are applied in this study including palynology, micropaleontology and nannoplankton analyses which are useful for crosschecking purposes. Apparently, the integration of these analyses gains accurate interpretation of stratigraphy and depositional environment.

Additional data generated from field work done by (Sunarjanto et al. 2007 & Ruswandi et al. 2013) is used to comprehend the geology of the area. In addition, regional stratigraphy of the Barito Basin was also investigated within this work which is useful to understand the stratigraphy of the studied area.

The previous investigations on the Miocene sediments collected from areas in the western part of Indonesia showed well development of perhumid vegetation indicating the domination of moist climate (Morley, 2000). This differs from that of Oligocene-earliest Miocene sediments which are dominated by subhumid to moonsoonal vegetation sugesting dry climate (Figure 2). The evidence for Miocene wet climate is coming from the significant appearence of peat swamp vegetation with the extensive coal accumulation in Early Miocene Talang Akar Formation of Java Sea and South Sumatera. This vegetation is characterised by the occurrence of calamoid pollen (*Dicolpopollis*), *Durio*, *Cephalomappa* and *Calophyllum*. In addition, common swamp forest pollen of *Ilexpollenites* suggests well development of freshwater swamp forest under wet climate condition. In this case, coals are absent. Mean while, the streamside communities appear in the Middle Miocene onward as proved by the presence of *Pometia*, *Canthium* and *Pandanus* in association with *Myrtaceidites*. More over, mangrove and back-mangrove pollen are common in the Middle Miocene peat swamp forest of South Kalimantan indicating the influence of brackish environment during peat accumulation (Morley, 2000).

The Barito basin is geographically located in the South Kalimantan with the longitude of 113°20’ 27.3372” - 115°59’ 31.8732” and the latitude of -04°14’ 36.8556” - -00°05’ 55.0752”. It covers an area of approximately 70,000 kilometer square with northeast-southwest direction (Sunarjanto et al. 2007). In addition, it is bounded by the Adang

Figure 1
Area of study and wells location

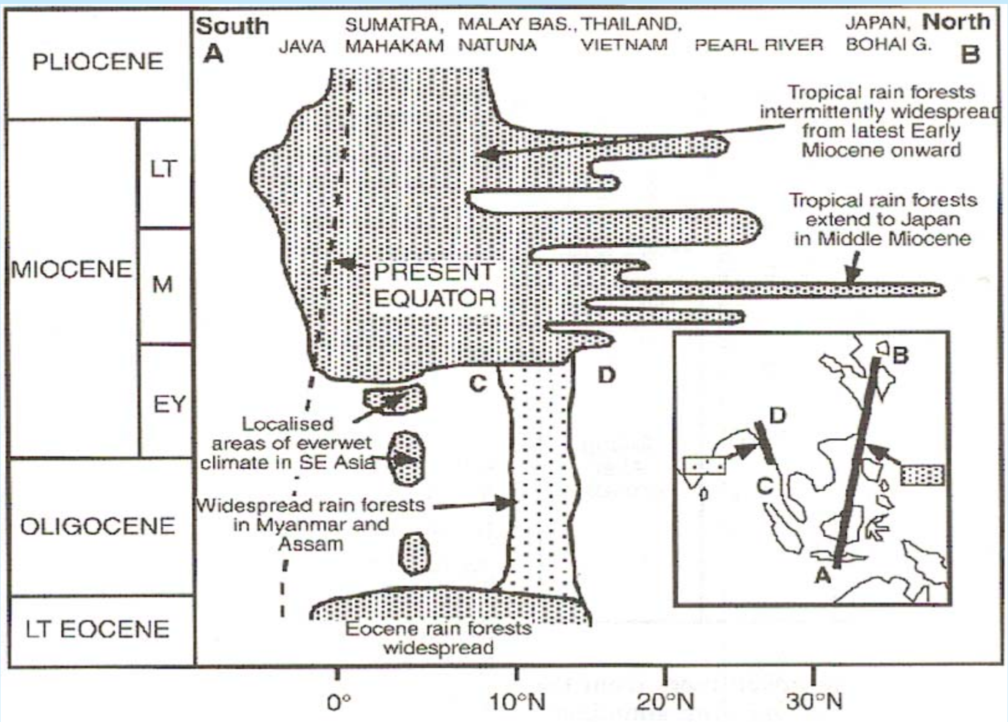

Figure 2
The development of tropical rain forests in the Sunda region during Tertiary to indicate wet/ dry climate (Morley, 2000)

Flexure (Paternoster High) to the north and by the Meratus Mountain to the east. The Java Sea limits the Barito Basin in the south, whilst Sunda Platform defines this basin in the west (Figure 3). The Barito Basin is a Tertiary basin which is formed as a result of the collision between Australian Plate and Asian Plate during Late Cretaceous as indicated by the northeast-southwest pattern of the existing structural elements. The subduction zone was interpreted to be positioned along the Meratus Mountain with northeast-southwest direction which extended to Java Island. The collision of these plates caused strike slip fault which was prependicular to the subduction zone. This fault with northwest-southeast orientation resulted in the formation of pull apart basin as shown by the occurrence of graben and horst.

The stratigraphy of the Barito Basin generally consists of Tertiery sediment which is the product of the transgression and regression phases (Wicaksono et al. 1998). This sediment unconformably overlies the pre-Tertiery basement (Figure 4). The early sedimentation occurred within the graben formation

Figure 3
Regional geology of the Barito Basin

which was commenced by transgression phase during Eocene as indicated by the appearance of the oldest sediment of alluvial-shallow marine Tanjung Formation. This sedimentation was followed by up lifting causing sea level fall during Early Oligocene. Sea level then rised during Late Oligocene-Early Miocene to form the shallow marine Berai Formation. Subsequently, this phase was changed by regression phase during Middle to Late Miocene as suggested by the occurrence of shallow marine to deltaic sediment of Warukin Formation. Following the formation of Meratus Mountain at Late Miocene, the Warukin Formation was up-lifted and eroded. This event was followed by subsidence and sea level rise which resulted in the deposition of the Late Miocene to Pleistocene sediment of the paralic Dahor Formation (youngest formation). The Tanjung Formation is separated into the Lower and the Upper Tanjung Formations. The Lower Tanjung Formation is considered to be syn-rift deposits consisting of quartz sandstone and clay stone with coal intercalation (Kusuma et al. 1989). The Upper Tanjung Formation is composed the alternation of sandstones and claystones with limestone intercalation containing marine fossils. The Tanjung Formation was deposited in fluvial to shallow marine environment and it reaches a thickness of 750 m (Siregar et al. 1980). The Tanjung Formation was unconformably overlain by Oligocene to Early Miocene Berai Formation consisting of limestone with large foraminifera and the intercalation of marls. This formation was deposited in the neritic environment with a thickness of about 1,000 m. Subsequently, the Berai Formation was unconformably overlain by the Middle to Late Miocene Warukin Formation containing quartz sandstone and claystone with coal intercalation. It was deposited in fluvial environment with a thickness of about 400 m. Finally, it appeared the Dahor Formation which was unconformably deposited on the Warukin Formation during Early Pliocene to Pleistocene consisting of loose and medium grain of quartz sandstone, loose conglomeratic quartz, soft claystones, lignite and limonite. The Dahor Formation was deposited in the fluvial environment

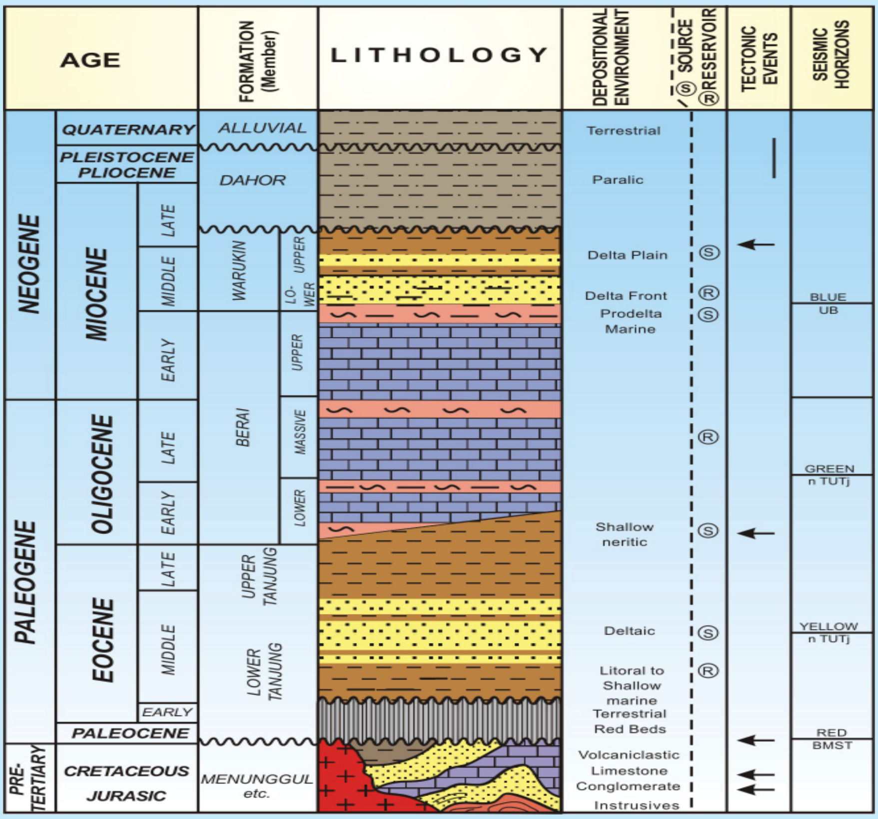

Figure 4
General stratigraphy of the Barito Basin (Sunarjanto et al. 2007)

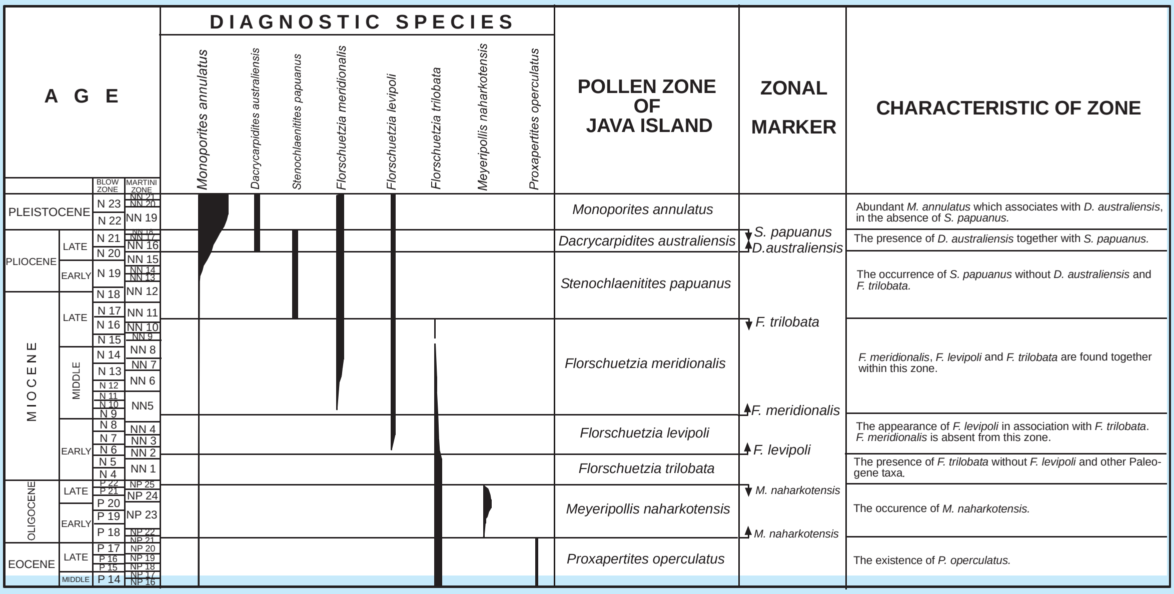

Figure 5
Palynological zonation of Java Island (Rahardjo et al. 1994)

with a thickness of about 250 m. In addition, Holocene alluvial deposits unconformably occured above the Dahor Formation. It contains kaolinitic clay and siltstones with sand intercalation, peat, gravel and loose chunks. These deposits were deposited in the river and marsh environments (Ruswandi et al. 2013).

II. METHODOLOGY

This study uses data that is generated from subsurface samples collected from two wells (termed P and Q). The biostratigraphic analyses employed in this study include palynology, foraminifer and calcareous nannoplankton. This is intended to cross check the result of each analysis. In this study, it is applied the quantitative method which involves logging and counting of the existing micro-fossils. For foraminiferal analysis, this method means weighing 100 grs of wet samples. For nannoplankton analysis, the quantitative method is counting the absolute occurrence of micro-fossil which occurs in 200 fields of view for each sample. On the other hand, palynological analysis requires 250 specimens per sample allowing quantitative application. Subsequently, the biostratigraphic data obtained from microscopic work was inputted into the computer using a software called StrataBug.

The composition and the abundance of each micro-fossil are plotted into biostratigraphic quantitative chart for identifying biostratigraphic zone and age of the sediment as well as interpreting depositional environment of the studied sediment. Foraminiferal and palynological quantitative charts include the interpretation of age and depositional environment, where as nannoplankton quantitative chart provides the age interpretation.

Zonal and age interpretations refer to distinct zonations depending on the type of analysis. For foraminiferal analysis, zonal subdivision and age interpretation are based on foram-zone proposed by Blow (1969) with some modification. In case of the absence of index planktonic taxa, the zonal and age determination rely on benthonic zonation proposed by Billman et al. (1980). For nannoplankton analysis, these interpretations refer to nanno-zone of Martini (1971) with some modification. In addition, the pollen-zone proposed by Rahardjo et al. (1994) is used to infer zonal subdivision as well as age interpretation (Figure 5). Meanwhile, two different classifications are applied in this study for paleoenvironmental analysis. Firstly, paleoenvironment based on foraminifers refers to that classified by Tipword et al. (1966) and Ingle (1980). Secondly, paleoenvironmental analysis based on pollen assemblage uses the deltaic classification which was introduced by Morley (1977).

The biostratigraphic assessment using three different disciplines provides independent results which allow biostratigrapher to gain accurate interpretation. The result of palynological analysis can be easily tested with other analyses (foraminifer and nannoplankton) to get reliable picture of the Miocene palynology in South Kalimantan area.

III. RESULTS AND DISCUSSION

Palynomorphs recorded from the studied wells generally show moderate to high abundance and diversity. They derive from various sources including brackish water (mangrove and back-mangrove), river side, peat swamp and freshwater swamp, as well as undifferentiated fresh water and montane. Based on previous investigation by Lelono et al. (2009), this study provides higher abundance and diversity of palynomorphs compared to those in Oligocene to earliest Miocene. The palynomorph assemblage existing in the studied sections is demonstrated in Figures 6 and 7. The brackish palynomorphs appear along the studied sections indicating the influence of marine environment which include *Zonocostites ramonae*, *Florschuetzia meridionalis* (mangrove pollen), *Florschuetzia levipoli* and *Spinizonocolpites echinatus* (back-mangrove pollen). In addition, these palynomorphs are more abundant in the upper sections suggesting more marine influence compared to that in the lower sections.

This study also proves the appearance of river side community along the well section indicating the occurence of river sedimentation (Figure 8). The high abundance of riparian pollen of *Myrtaceidites* sp. as shown on selected depth strongly predicts the existence of river side deposit (Lelono, 2004). Mean while, common occurrence of peat swamp pollen as represented by *Cephalomappa* type, *Austrobuxus nitidus* and *Sapotaceoidaepollenites* spp. may corelate to the existence of peat deposits or coals (Morley, 2000). Further more, by considering the significant appearance of brackish palynomorphs across the well sections as stated above, it can be interpreted the influence of brackish environment during peat accumulation.

The studied wells show moderate to high abundance of fresh water palynomorphs such as *Calophyllum* types, *Casuarina* and *Dicolpopollis* spp. This evidence may be an indication of well development of fresh water forests under wet climate condition. In this case, peat deposits or coals may or may not occur. On the other hand, moderate abundance of *Casuarina* pollen in association with common Gramineae (*Monoporites annulatus*, see Figure 6 and 7) in the lower interval indicates the occurrence of heat forest (forest with impeded drainage) within this interval (Morley, 2000).

A. Age Interpretation

This study has succesfully found the age-restricted taxa for Miocene age such as *Florschuetzia trilobata*, *F. meridionalis* (pollen), *Stenochlaenidites papuanus* and *Scolocyamus magnus* (spores) as shown in Figures 6 and 7. Based on pollen zones proposed by Rahardjo et al. (1994), the last occurrence of pollen *F. trilobata* defines the F. meridionalis zone/ S. papuanus zone boundary (Middle/ Late Miocene boundary). This is supported by the occurrence of Late Miocene marker of spore *S. papuanus* above the last occurrence of *F. trilobata*. On the other hand, the first occurrence of *F. meridionalis* marks the zonal boundary of F. levipoli/ F. meridionalis (Early/ Middle Miocene). The existence of F. levipoli and F. meridionalis zones is proved by the occurrence of Miocene marker of spore *S. magnus* along the interval of these zones. Over all, it can be inferred that the sediment situated in the studied sections is attributed to F. levipoli zone up to S. papuanus zone which is equivalent to Early to Late Miocene age (Rahardjo et al.1994).

Unlike pollen assemblage, marine micro-fossil assemblages are poor including foraminifera and calcareous nannoplankton. Biomarkers of these fossils rarely appear through out the studied sections. In this case, the standard age interpreation using planktonic foraminifera is unable to be performed due to lack of planktonic index. Therefore, the age interpretation refers to benthic foraminifer (Figures 9). In well P, the first occurrence of Asterorotalia yabei defines the boundary of Ammonia umbonata zone and Ammonia umbonata-Asterorotalia yabei zone (Early/ Middle Miocene boundary). Mean while, the last occurrence of Ammonia umbonata suggests the boundary of Ammonia umbonata-Asterorotalia yabei zone and Asterorotalia yabei zone (Middle/ Middle-Late Miocene boundary). After all, in can be concluded that the studied sediment of well P ranges from Ammonia umbonata zone up to Asterorotalia yabei zone which equals to Early Miocene up to Middle/ Late Miocene (Billman et al., 1980). On the other hand, the occurrence of calcareous nannoplankton of Sphenolithus compactus, S. heteromorphus, Cyclicargolithus floridanus, Discoaster deflandrei and S. moriformis

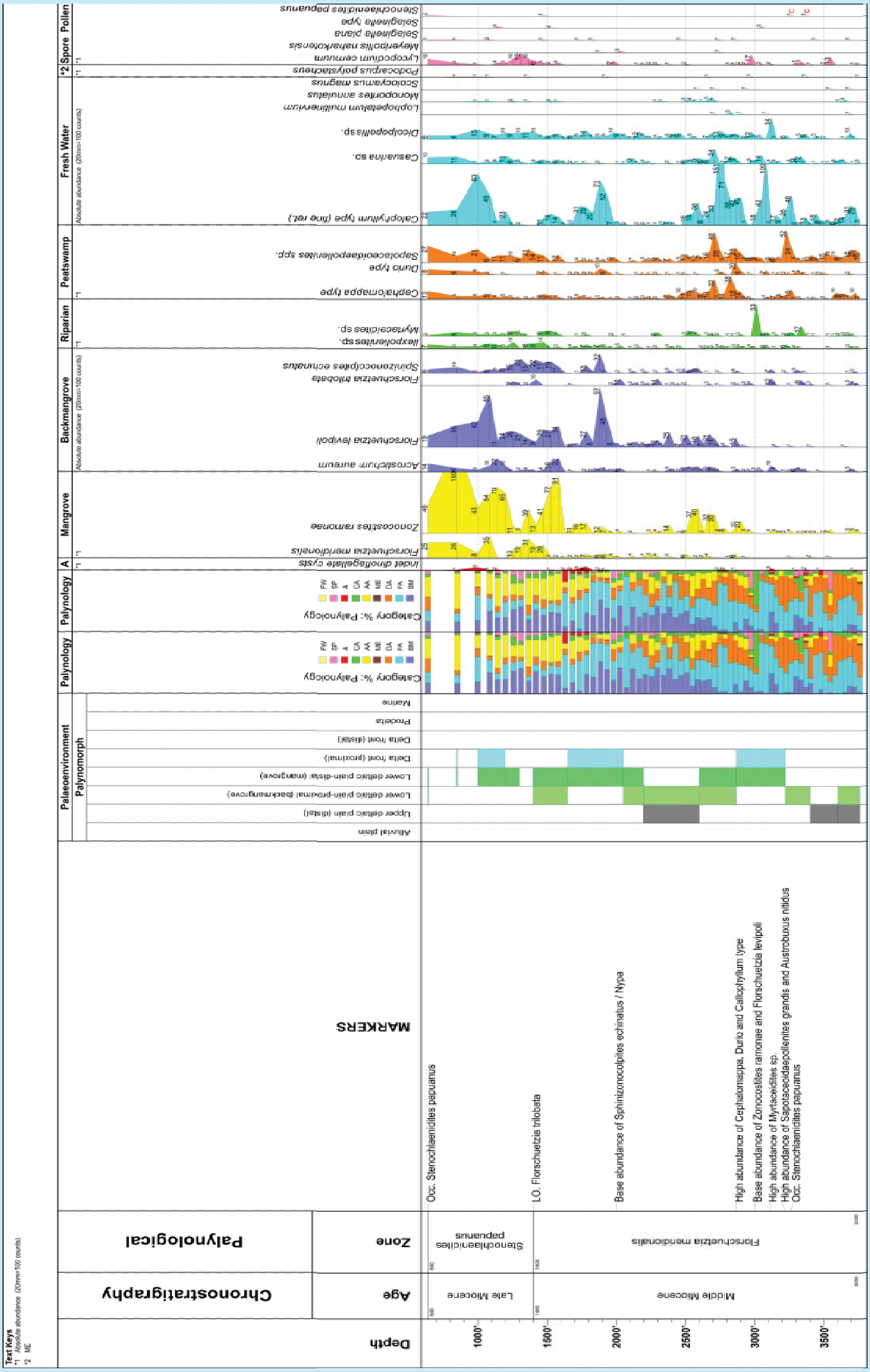

Figure 6
Pollen assemblage appears in well P

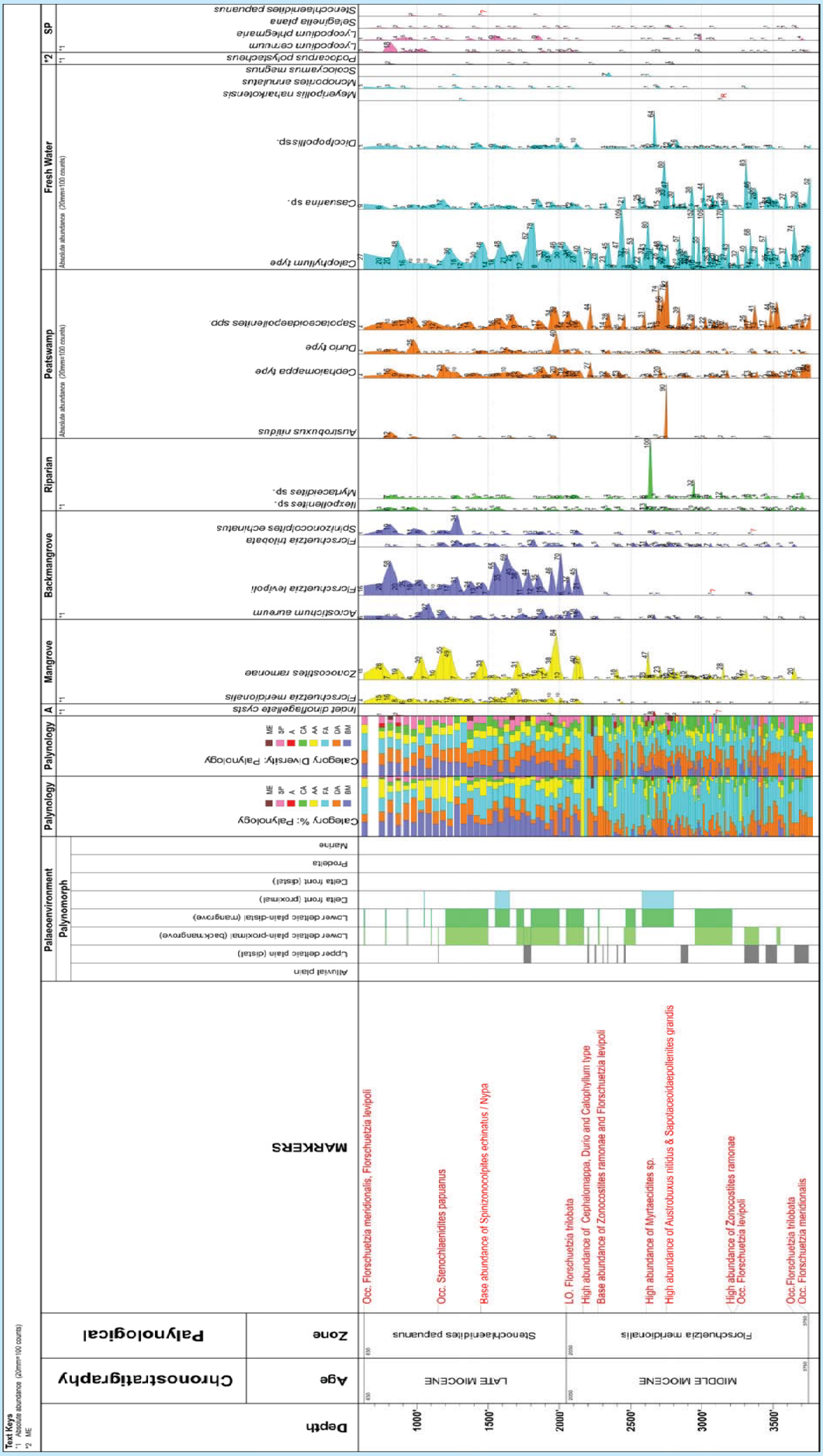

Figure 7
Pollen assemblage of well Q

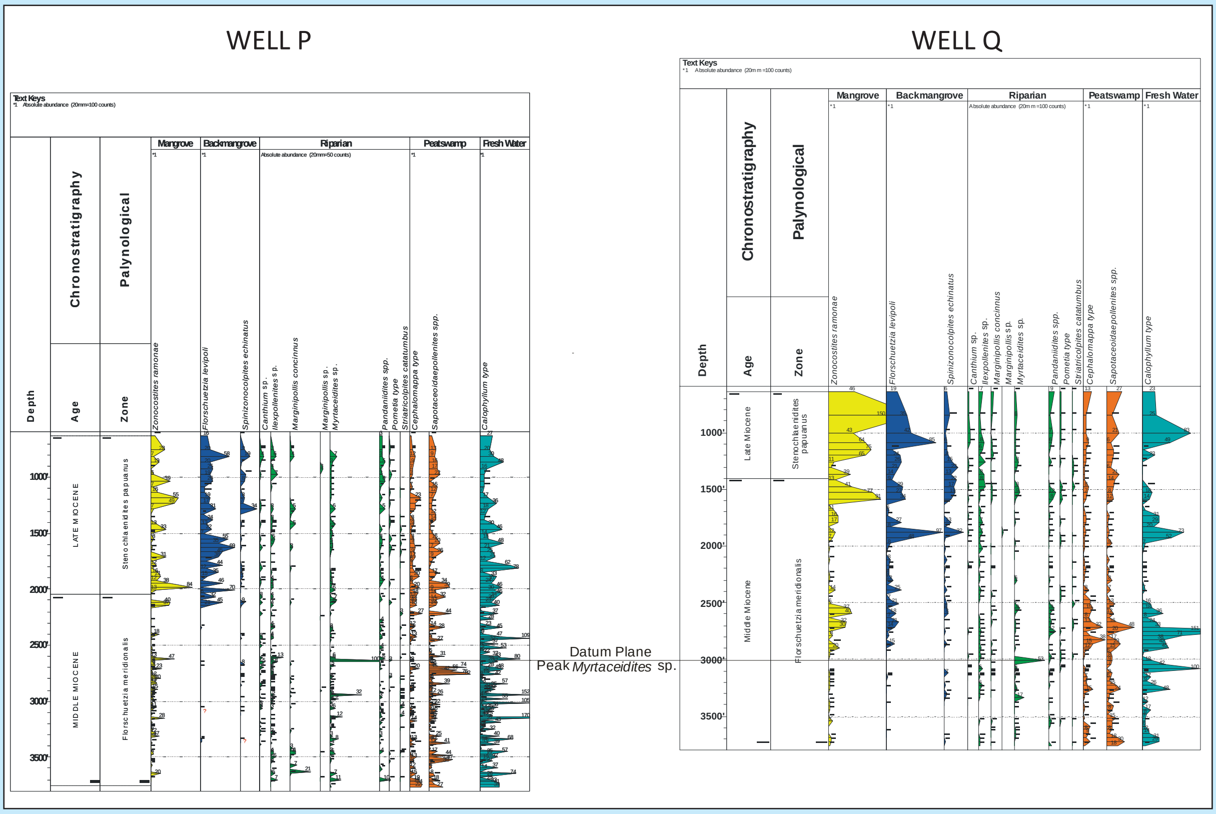

Figure 8
Correlation of well P and well Q using the datum plane of peak of riparian pollen of *Myrtaceidites sp.*

indicates that the studied samples of well P are not older than zone NN1 to not younger than zone NN11 or not older than Early Miocene to not younger than Late Miocene (Martini, 1971) as shown in Figure 10.

Having these interpretations, it is concluded that the sediment situated in the studied intervals represents Early to Late Miocene age.

B. Paleoenvironment

Generally, sedimentation occurring in the area of study was influenced by marine environment as indicated by the appearance of brackish palynomorphs (mangrove and back-mangrove) in the entire well sections. In this case, marine influence was getting stronger toward the upper sections (younger sediments) than that in the lower sections as proved by more abundance of mangrove (*Zonocostites ramonae* and *Florschuetzia meridionalis*) and back-mangrove pollen (*F. levipoli*, *F. trilobata* and *Spinizonocolpites echinatus*) in the upper sections (Figure 6). This is supported by more abundance and diversity of benthic foraminifers (marine environmental markers) in the upper well sections compared to those in the lower section (Figure 9). Comparing the result of age interpretation with regional stratigraphy, it is assumed that the studied sediment may be equivalent to the Warukin Formation which was formed in the deltaic to shallow marine environment (Rotinsulu et al., 1993). It is possible that the lower studied sections (Early to Middle Miocene) are dominated by fresh water deposits with slightly marine influence which is interpreted to be delta plain environment with slightly delta front occurrences. On the contrary, the upper sections (Middle to Late Miocene) with moderate to high abundance of brackish palynomorphs combined with the occurrence of shallow water markers (benthic foraminifers) may be an indication of delta front to pro delta environment (with possible shallow marine appearances) (Morley, 1977). The occurrence of shallow marine environment is confirmed by high representation of shallow water markers including *Ammonia beccarii*, *Asterorotalia yabei*, *Calcarina calcar*, *Ammobaculites* spp. and *Haplophragmoides* spp. Another shallow water indicators are some molluscs of Gastropods and Ostracods. More over, benthonic/ planktonic presentation is high suggesting

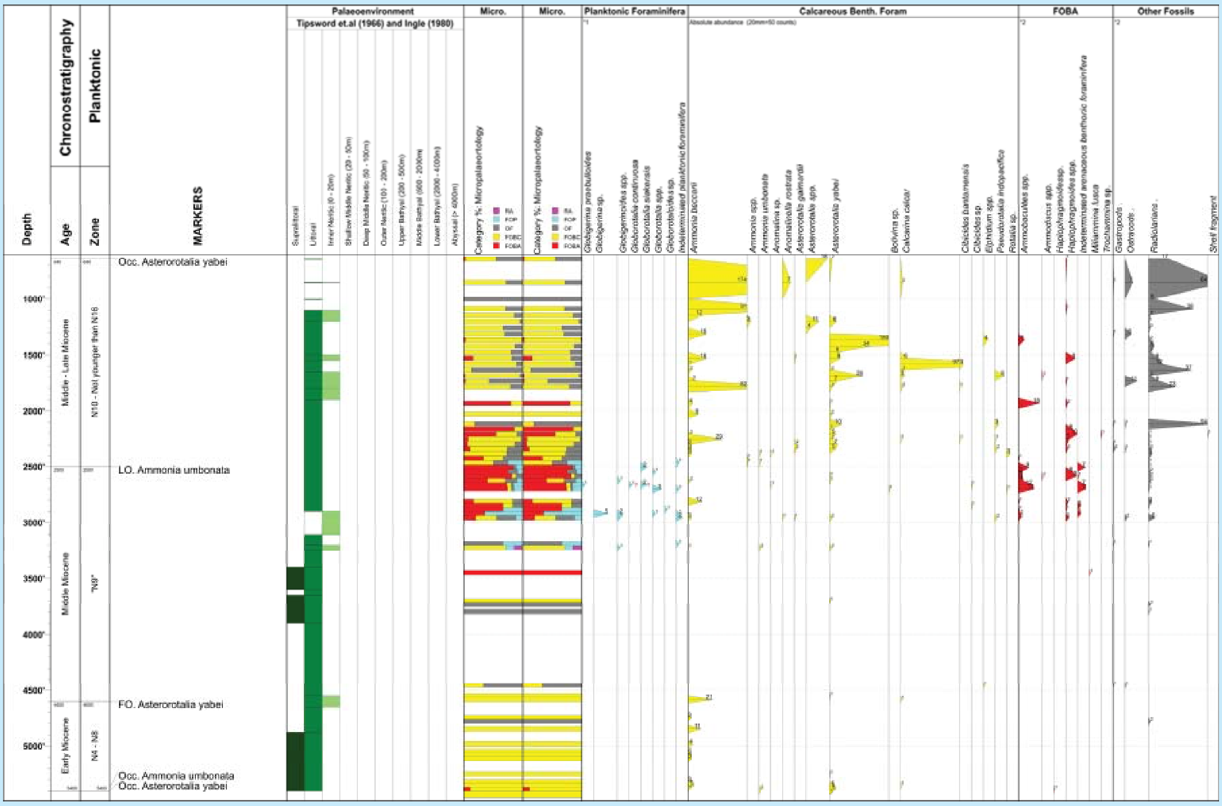

Figure 9
The distribution of marine micro-fossils of foraminifer in well P suggests non-marine to shallower marine environment in the lower section and deeper marine environment in the upper section

less development of planktic forams in the shallow water condition. These data indicate depositional environment within bathimetry up to 20 m or classified as littoral to inner neritic (Tipsword et al. 1966 & Ingle, 1980).

Significant occurrence of freshwater pollen combined with poor occurrence of brackish pollen in the lower sections suggests the domination of freshwater environment during sediment accumulation. In fact, most samples within the lower sections are barren of marine micro-fossils such as foraminifers and calcareous nannoplankton indicating less marine influence. Common peat swamp pollen may represent the existence of peat deposits or coals. These peat swamp pollen are *Cephalomappa* type, *Austrobuxus nitidus* and *Sapotaceoidaepollenites* spp. In addition, abundant freshwater swamp pollen suggests the development of low land forest indicating fresh water (non-marine) sediments with or without peat (coal) deposits (Morley, 2000). The top of non-marine environment is indicated by peak abundance of riparian pollen of *Myrtaceidites* sp. as seen in both wells. Significant apperance of this pollen suggests the existence of river deposits. Apparently, peak abundance of pollen *Myrtaceidites* sp. is potential for well correlation. Subsequently, brackish pollen of *Zonocostites ramonae*, *Florschuetzia meridionalis* (mangrove), *F. levipoli* and *F. trilobata* (back-mangrove) gradualy increase toward the upper part of well sections. This is followed by significant occurrence of marine microfossils as proved by the occurrence of *Ammonia beccarii*, *Asterorotalia yabei*, *Calcarina calcar*, *Ammobaculites* spp. and *Haplophragmoides* spp. (benthonic foraminifers) and some calcareous nannoplankton. In addition, planktonic foraminifers appear to indicate more open marine environment. This is supported by significant increase of another floating marine micro-fossils of calcareous nannoplankton (Figure 10).

Domination of wet climate indicators over dry climate elements suggests wet climate influence during sedimentation. Wet climate palynomorphs are represented by moderate to high abundance of *Calophyllum* type, *Casuarina* and *Dicolpopollis* spp. Mean while, dry climate indicators are less appearance as shown by grass pollen of *Monoporites annulatus* and pollen *Margocolporites vanwijey* (Morley 1990).

After all, it can be concluded that the studied sediment was initially deposited in the freshwater environment of delta plain during Early to Middle Miocene (lower sections). Depositional environment gradually shifted in to deeper marine setting in delta front to pro delta (with possible shallow marine environment) during Middle to Late Miocene (upper sections).

IV. CONCLUSION

This research provides significant findings on palynological aspect of the Miocene sediment of the South Kalimantan Basin. It proves considerable appearance of palynomorphs within this sediment which vary from brackish to fresh water elements. The studied sediment is ranging from Florschuetzia levipoli zone up to Stenochlaenidites papuanus zone which is equivalent to Early to Late Miocene age. This interpretation is suggested by the last occurrence of *F. trilobata* (Middle/ Late Miocene boundary) and the first occurrence of *F. meridionalis* (Early/ Middle Miocene boundary). In addition, the Late Miocene age is characterised by spore of *Stenochlaenidites papuanus*, whilst Early to Middle Miocene age is marked by spore of *Scolocyamus magnus*. Although nannoplankton is rare, the occurrence of *Sphenolithus compactus*, *S. heteromorphus*, *S. moriformis*, *Cyclicargolithus floridanus* and *Discoaster deflandrei* indicates not older than zone NN1 to not younger than zone NN11 or not older than Early Miocene to not younger than Late Miocene.

The studied sediment might have been deposited in the freshwater to transition environment. In fact, sedimentation experienced marine influence as

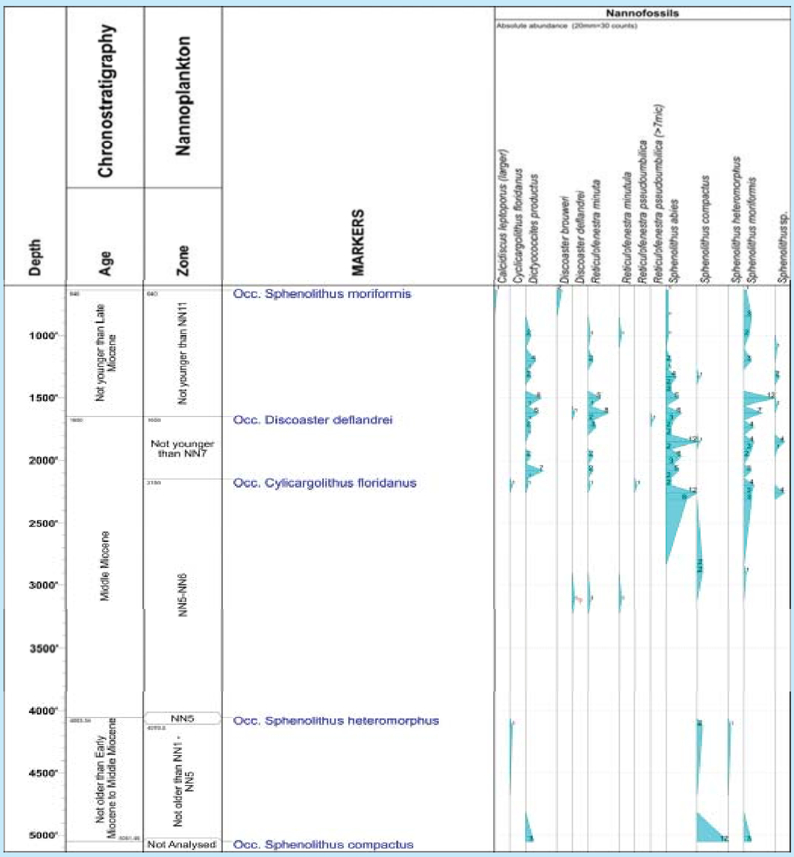

Figure 10
The occurrence of calcareous nannoplankton in well P suggests the age of Early to Late Miocene

indicated by significant occurrence of brackish palynonomorphs throughout the studied sections. It is supported by low assemblage of marine microfossils including foraminifers and nannofossils. Sedimentation commenced in the freshwater environment of delta plain during Early to Middle Miocene (lower sections) as indicated by domination of freshwater palynomorphs in the absence of marine microfossils. Sedimentation gradually shifted in to deeper marine setting in delta front to pro delta (with possible shallow marine environment) during Middle to Late Miocene (upper sections) as suggested by the increase of brackish palynomorphs and marine microfossils. The top of freshwater environment is marked by peak abundance of riparian pollen of *Myrtaceidites* sp. which is potential for well correlation. Significant apperance of this pollen suggests the existence of river deposits. Sedimentation might have occurred under wet climate condition as indicated by domination of wet climate indicators over dry climate elements.

ACKNOWLEDGMENT

The authors wish to thank colleagues from LEMIGAS Stratigraphy Group for their effort in performing biostratigraphic analyses of the studied area. Palynological work performed on the Miocene sediment of the studied area is limited. Therefore, palynological work done by LEMIGAS is very valuable.

REFERENCES

Billman, H., Hottinger, L. & Oesterle, H. 1980, Neogene to Recent Rotaliid Foraminifera from the Indopacific Ocean; their Canal System, their Classification and their Stratigraphic Use. *Schweizerische Palaontologische Abhandlungen, vol. 101*, pp. 71-112.

Blow, W.H., 1969, Late Middle Eocene to Recent Planktonic Foraminiferal Biostratigraphy. In *Proc. 1st Int. Conf. Plank. Microfossils*. pp. 191-422.

Ingle, J. C. Jr., 1980, Cenozoic Paleobathymetri and Depositional History of Selected Sequences within the Southern California Continental Borderland. *Cushman Foundation Special Publication, vol. 19*, Memorial to Orville, L. Bandy, pp. 163 - 195.

Kusuma, I. & Darin, T., 1989, The Hydrocarbon Potential of the Lower Tanjung Formation, Barito Basin, S.E Kalimantan: *Proceedings of the 18th Annual Convention, Indonesian Petroleum Association*, Vol 1.

Lelono, E. B., 2004, Palynological Events of the Talang Akar Formation in the On-Shore Area of the South Sumatera Basin. *Lemigas Scientific Contributions to Petroleum Science and Technology,* Vol. 27, No. 2, pp. 10-18.

Lelono, E. B. & Morley, R. J., 2009, Oligocene Palynological Succession from the East Java Sea. In: Hall, R., Cottam, M. and Wilson, M. (eds). *The SE Asian gateway: History and Tectonic of Australia-Asia Collision*. *Geological Society of London,* Special Publication, Vol. 355, pp. 333-345.

Martini, E., 1971, Standard Tertiary and Quaternary Calcareous Nannoplankton Zonation in Farinacci, A. (Ed), *Proc. 2nd Plank. Conf. Roma*, pp. 739-784. Edizioni Tecnoschienza, Roma.

Morley, R. J., 1977, Floral Zones Applicable to Neogene of Eastern Kalimantan. *Unpublished Report*. pp. 1-5.

Morley, R. J., 1990, Introduction to Palynology (with Emphasis on Southeast Asia). *Short Course Mannual Book*.

Morley, R. J., 2000, *Origin and Evolution of Tropical Rain Forests*. Wiley, London.

Rotinsulu, L.F, Sarjono, S. & Heriyanto, N., 1993, The Hydrocarbon Generation and Trapping Mechanism within the Northern of Barito Basin, South Kalimantan. Proceeding of the 22nd Annual Convention, *Indonesian Petroleum Association*, Vol 1.

Ruswandi, A. & Lelono, E. B., 2014, Lemigas Pilot Project of Shale Gas Reservoir. *Scientific Contributions Oil and Gas*. In-press.

Siregar, M.S & Sunaryo, R, 1980, Depositional environments and hydrocarbon Prospects, Tanjung Formation, Barito Basin, Kalimantan. Proceedings of the 9th Annual Convention, *Indonesian Petroleum Association*, Vol 1.

Sunarjanto, D., Munadi. S. & Wicaksono, B., 2007, Pemutakhiran Cekungan Sedimen Tersier Indonesia. In-house Research, *Lemigas Report*.

Tipsword, H. L., Setzer, F.M. & SMITH, F.M. Jr., 1966, Interpretation of Depositional Environment in Gulf Coast Petroleum Exploration from Paleoecology and Related Stratigraphy. *Trans. Gulf Coast Ass. Geol. Soc.* Vol. XVI, pp. 119-130.

Wicaksono, B., Prasetyo, H. & Sundoro, 1998.,Pemodelan Geologi Reservoir Formasi Tanjung Cekungan Barito Bagian Utara, Kalimantan Selatan. In-house Research, *Lemigas Report*.