PALYNOLOGICAL INVESTIGATION OF THE OLIGOCENE SEDIMENT IN EAST JAVA SEA

by

Eko Budi Lelono

ABSTRACT

The palynological study of the Oligocene sediments is based on cutting samples collected from the exploration wells which are drilled in East Java Sea. The occurrence of pollen Meyeripollis naharkotensis along the well sections suggests the pollen zone of Meyeripollis naharkotensis which is equivalent to Oligocene age. This is supported by the regular occurrence of the Oligocene marker of the trilete spore of Cicatricosisporites dorogensis along the studied well sections. In addition, foraminiferal and nannoplankton analyses confirm the Oligocene age by identifying the occurrence of letter stage of Tc-Te4 and nanno zone of NP21-NP25. On the other hand, most palynomorphs marking Eocene age disappear from the studied wells as they are stratigraphically older than the studied sediments. Unlike the Oligocene sediment of West Java and Central Sumatra which was formed in the freshwater swamp or lake under dry climate condition, the studied sediment was deposited in the transition to shallow marine environment as indicated by the moderate diversity of marine dinoflagellates coupled with the frequent occurrence of limestone along the sections. Furthermore, the regular appearance of back-mangrove pollen of Spinizonocolpites echinatus throughout the well sections supports the indication of marine influence. The appearance of the Australian immigrants including Dacrydium (common occurrence) and Casuarina (regular occurrence) may indicate earlier arrival of the Australian continent in this area compared to that in other areas of Indonesia.

Key words: palynology, oligocene sediment, East Java Sea

I. BACKGROUND RESEARCH

East Java has been well known as an important hydrocarbon province in Indonesia. However, its full hydrocarbon potential can be realized only when the stratigraphy of the region is properly understood. This paper intends to provide information which may clarify the stratigraphy of East Java area, especially Paleogene age from the view points of palynology. This study focuses on the Paleogene sediment as it is considered to be the main target of the exploration activity due to the previous discoveries within this sediment. The previous study indicates that the Paleogene sediment mostly consists of Eocene and Oligocene sections. Meanwhile, the Paleocene sediment has not been found yet, although it is believed to occur in East Java. The sedimentary record for the Paleocene (66-45 Ma) and Early Eocene (54-49 Ma) is very poor, and many of the sediments were probably deposited in basin floor setting off the present shelf margin. Those deposited to the south and west of the Sunda region may now be largely consumed by the subduction along the boundary with the Indian Plate (Morley, 2000). The previous studies on the Paleogene sediments were mainly concentrated on the Middle to Late Eocene sections. Therefore, the study of the Oligocene sediment as conducted in this research provides good opportunity to learn the palynology of the youngest Paleogene sediment. In the future, this study needs to be completed by the investigation of the oldest Paleogene sediment (Paleocene and Early Eocene sediments) in order to obtain the clear picture of Paleogene stratigraphy.

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 7 - 17

Study on Oligocene well sections drilled on Northwest Java Basin indicates the abundance of fresh water palynomorphs in the lower part which gradually decreases towards the upper part and changes with abundance brackish palynomorphs (Lelono, 2005). This relates to the geological condition during Oligocene which is marked by the formation of pull-apart basins to deposit syn-rift sediment. This deposit was formed in the freshwater environment such as lake or swamp. Therefore, abundant freshwater palynomorphs occur to indicate this freshwater deposit. Subsequently, basins subsided gradually to reduce land elevation. In addition, sea level raised significantly during the Late Oligocene-Early Miocene (Haq et. al., 1988). This situation drowned all sediments under shallow marine environment as indicated by the appearance of abundant brackish palynomorphs. Early Oligocene age with lake deposit is defined by high abundance of freshwater algae of Pediastrum. Furthermore, dry climate indicators appeared to mark dry condition within Early Oligocene, including pollen *Monoporites annulatus* and Cyperaceae. The opposite situation occurs in the Late Oligocene, in which transition-shallow marine deposit is indicated by significant occurrence of marine dinoflagellates and brackish elements such as *Rhizopora* and *Nipa*. In addition, freshwater elements provide good assemblage as shown by *Marginipollis concinus*, *Dicolpopollis* sp. and peat swamp elements of *Cephalomappa*, *Calophyllum* type, *Sapotaceoidaepollenites* spp. and *Striatricolpites catatumbus* suggesting wet climate condition (Lelono, 2005).

Apparently, the above conditions are also found in other localities with Oligocene sections such as South China Sea and Sumatra indicating similar events with those in West Java. Therefore, this study will prove the occurrence of those events as recorded in South China Sea, Sumatra and West Java. Due to space limitation, only selected palynomorphs are presented within this paper, especially those which derived from marine, mangrove, back-mangrove, riparian, peat swamp and freshwater vegetations. The lithology is inferred from wireline logs which were provided by the client. It is shown together with pollen diagrams as seen in Figures 4 and 5.

II. DATA AVAILABILITY

The area of the study is located in the East Java Sea (Figure 1). Data used in this study derivee from well samples obtained by our clients. Palynological data extracted from these samples was used by LEMIGAS to provide technical services for commercial works. Therefore, it is considered to be confidential and should not be public domain. This situation discourages the author to disclose the complete data as this will break the commitment between LEMIGAS and its client.

Having all conditions mentioned above, this paper will not reveal detailed information of the wells which are used in this study. The wells are named using number such as 1 and 2. In addition, only relevant information is shown in this paper due to space limitation. In this case, pollen diagrams only show selected palynomorphs which affect analysis and interpretation.

III. METHODOLOGY

The material used in this research is cutting samples which were collected from the selected intervals of two studied wells, so called Wells 1 and 2. These samples were processed in the LEMIGAS Stratigraphy Laboratory using the standard methods including HCl, HF and HNO_3 macerations, which were employed to get sufficient recovery of plant micro-fossils for palynological analysis. These acid treatments were followed by the alkali treatment using 10% KOH to clear up the residue. Sieving using 5 microns sieve was conducted to collect more palynomorphs by separating them from debris materials. Finally, residue was mounted on the slides using polyvinyl alcohol and Canada balsam.

The fossil examination was taken under the transmitted light microscope with an oil immersion objective and X 12. 5 eye piece.

Figure 1
Location of the study area

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 7 - 17

The result of examination is recorded in the determination sheets and used for the analyses. As this study applies quantitative analysis, it is required to count 250 palynomorphs in each sample. The percentage abundance of palynomorphs from every sample was plotted onto a chart to illustrate temporal abundance fluctuations of each palynomorph type, using a statistically viable population (=count number) of palynomorphs in every sample.

Chart analysis is focused on finding significant abundance of selected taxa which is believed to represent certain geological events such as the existence of marine influence (or transgression), non-marine domination during deposition and climatic changes. Age interpretation is based on palynological zonations which were proposed by Rahardjo et al. in 1994. On the other hand, palaeoenvironmental analysis refers to deltaic classification based on vegetational changes by Morley (1977).

IV. INTERPRETATION AGE

The studied section of Well 1 ranges from 3910' to 5340', whilst in Well 2 it covers interval 3390'-5170'. In order to get the reliable age of the studied sediment, this study applies other biostratigraphic disciplines including foraminifer and nannoplankton. The age interpretation is critical as this will determine the precise position of the studied sections within the Paleogene age.

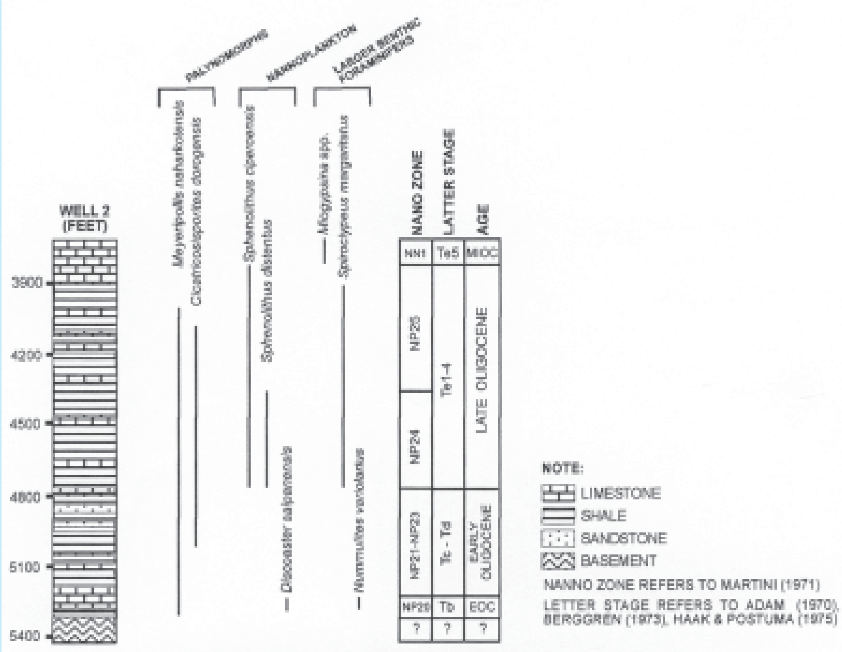

Figure 2
Vertical distribution of some index fossils to define Oligocene age within the sediment of interval 3910'-5340' of Well 1

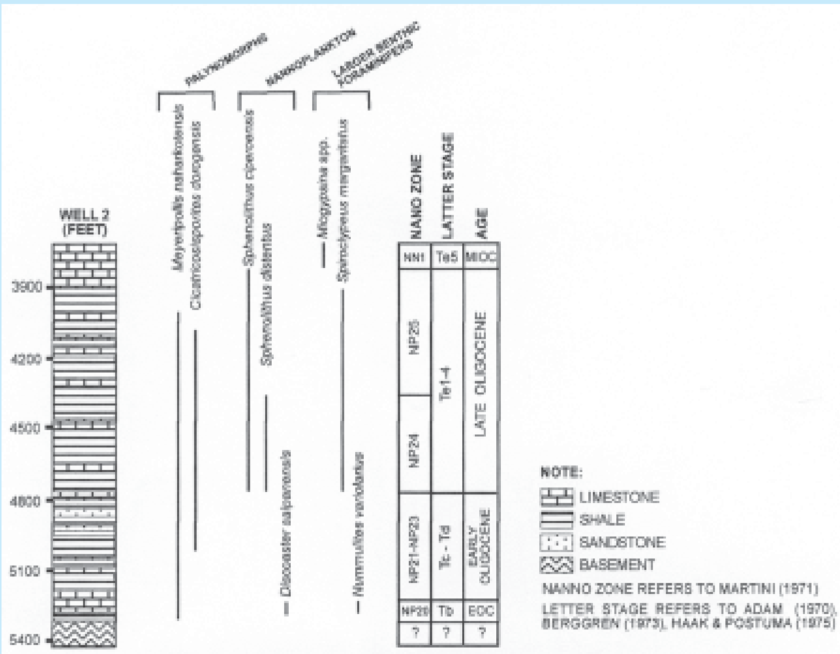

Figure 3
Vertical distribution of some index fossils to define Oligocene age within the sediment of interval 3390'-5170' of Well 2

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 7 - 17

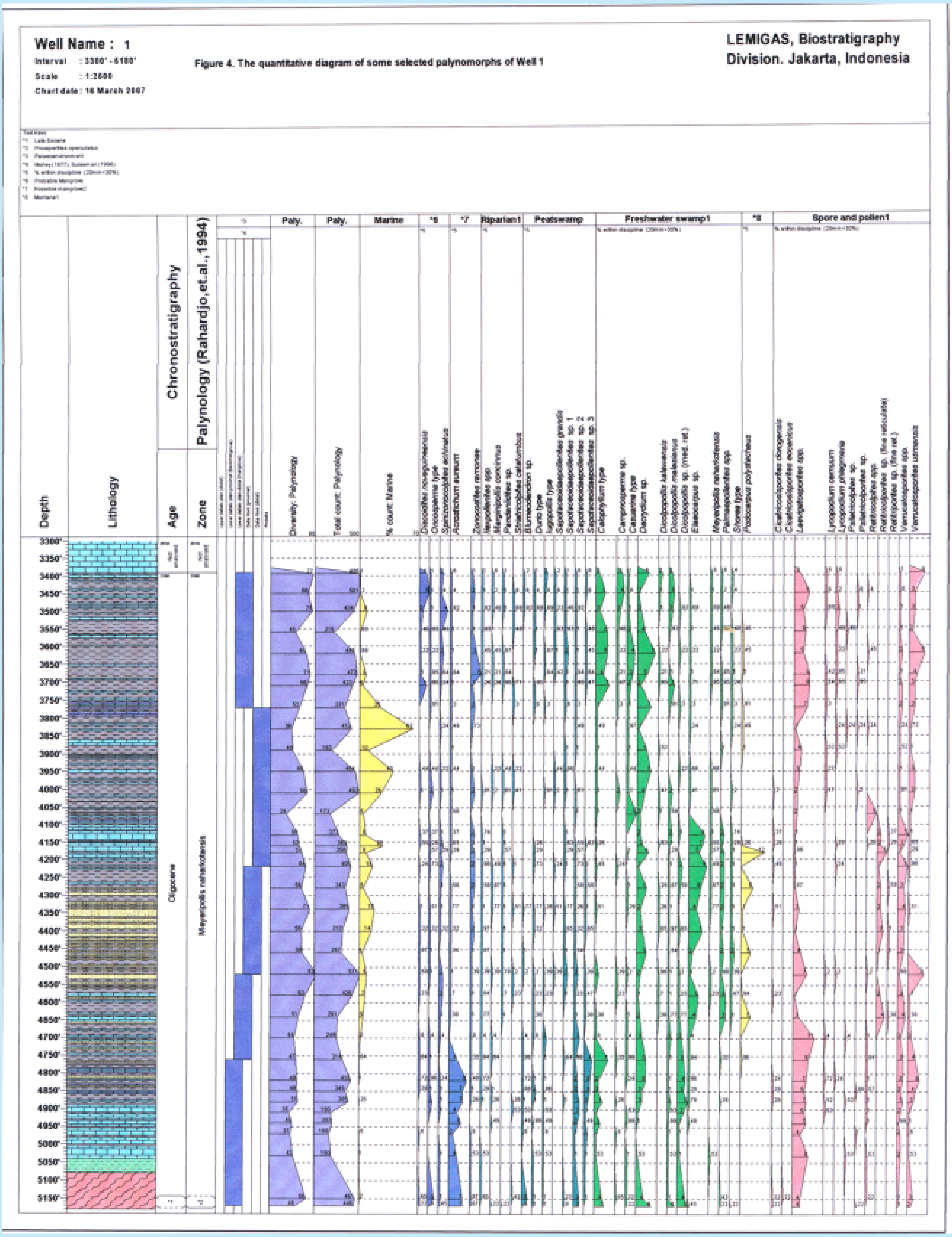

Figure 4
The quantitative diagram of some selected palynomorphs of Well 1

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 7 - 17

Based on the occurrence of pollen *Meyeripollis naharkotensis* along the interval 3910'-5340' of Well 1 and in the interval 3390'-5170' of Well 2, it can be inferred that sediments situated in Wells 1 and 2 belong to pollen zone of Meyeripollis naharkotensis which equals to Oligocene age (Figures 2 and 3). In addition, Oligocene marker of trilete spore of *Cicatricosisporites dorogensis* regularly appears along both sections suggesting the occurrence of Oligocene age. On the other hand, Eocene palynomorphs are absent from these sections such as aff. *Beaupreadites matsuokae*, *Cupanieidites* cf. *C. flaccidiformis*, *Diporoconia iszkaszentgyorgyi*, *Polygalacidites clarus*, *Proxapertites cursus*, *Proxapertites operculatus* and *Ruellia* type. Referring to the negative evidence, the studied sediments may not be formed in the Eocene age. However, the existence of Eocene marker of monolete spore of *Cicatricosisporites eocenicus* at 5150' of Well 2 indicates that the sediment of the interval 5150'-5170' may be attributed to the Eocene age (Figure 3).

In Well 1, foraminiferal analysis showed the first appearance of larger benthic form of *Miogypsina* sp. at 3850' and *Spiroclypeus margaritatus* and *Spiroclypeus tidoenganensis* at 4780' suggesting the Late Oligocene age within the interval 3850'-4780'. In addition, the last appearance of larger benthonic form of *Nummulites variolarus* at 5250' indicates Early Oligocene age within the interval 4780'-5250' (Figure 2). In Well 2, the first appearance of larger benthic form of *Miogypsina* spp. at 3420' and the appearance of larger benthonic form of *Nummulites variolarus* at 5040' define the occurrence of Oligocene succession within the interval 3420'-5040' (Figure 3).

Nannoplankton analysis on Well 1 provided the appearance of *Sphenolithus ciperoensis* within the interval 3850'-4780' suggesting that the sediment of this interval has Late Oligocene age. Furthermore, the last appearance of *Discoaster saipanensis* at 5250' indicates the occurrence of Early Oligocene within the interval 4780'-5250' (Figure 2). Meanwhile, in Well 2, the occurrence of *Sphenolithus ciperoensis* within the interval 3420'-4620' indicates Late Oligocene age. Moreover, the last appearance of *Discoaster saipanensis* at 5040' marks the existence of Early Oligocene within the interval 4620'-5040' (Figure 3).

Having these interpretations, it is inferred that the studied sediments situated in the interval 3910'-5250' of Well 1 and in the interval 3390'-5040' of Well 2 have an age of Oligocene.

V. POLLEN DIVERSITY

This study records 183 distinct palynomorphs with approximately 15% of them remain unknown as they have not been described yet by the previous authors. Those palynomorphs comprise brackish and freshwater elements such as mangrove, back-mangrove, riparian, peat swamp and freshwater palynomorphs (Figures 4 and 5). In addition, this study also discovers marine dinoflagellates within the studied sections which indicate the influence of marine environment during deposition. Mangrove element appearing significantly within these wells is *Zonocostites ramonae*, whilst back-mangrove element is represented by *Acrostichum aureum*, *Discoidites novaguenensis*, *Oncosperma* and *Spinizonocolpites echinatus*. However, it must be noted that *Zonocostites ramonae* and *Acrostichum aureum* might have been produced by the freshwater vegetation during Paleogene (Lelono, 2000). Therefore, they are unsuitable for identifying the occurrence of brackish environment. Some selected riparian pollen which occur regularly within the studied sections are *Illexpollenites* spp., *Marginipollis concinus*, *Pandaniidites* sp. and *Striatricolpites catatumbus*. Peat swamp pollen includes *Blumeodendron*, *Durio* type, *Iugopollis* and *Sapotaceoidaepollenites* spp. Several freshwater elements appear with common occurrence such as *Calophyllum* types, *Campnosperma*, *Casuarina*, *Dacrydium* and *Dicolpopollis* spp. Other freshwater elements appearing consistently with low abundance are *Meyeripollis naharkotensis*, *Elaeocarpus* type, *Palmaepollenites* spp. and *Shorea* type. Montane pollen is represented by *Podocarpus polystacheus*. There are spores which lived in various environments (freshwater undifferentiated) including *Laevigatosporites* spp., *Lycopodium cernuum*, *Lycopodium phlegmaria*, *Verrucatosporites* spp. and *Verrucatosporites usmensis*. Other spores marking the occurrence of Paleogene sediment are *Cicatricosisporites eocenicus* and *Cicatricosisporites dorogensis*. Meanwhile, this study discovers palynomorphs which have not been described yet by the previous researchers. Here, they are named

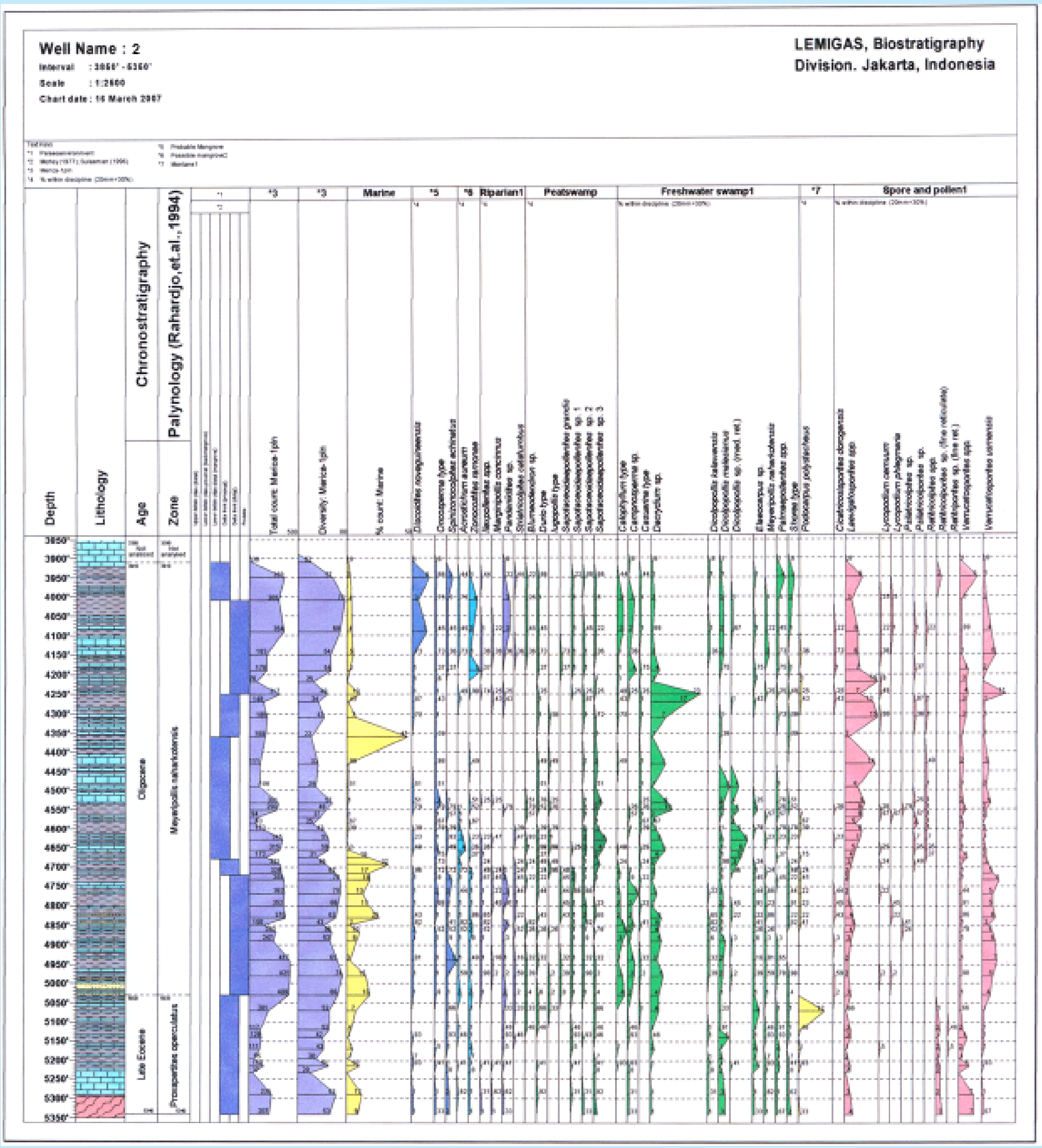

Figure 5
The quantitative diagram of some selected palynomorphs of Well 2

according to their morphology such as *Psilatricolpites* spp., *Psilatricolporites* spp., *Retitricolpites* spp., *Retitricolporites* spp. and *Retitriporites* sp. (Figures 4 and 5).

On the other hand, this study proves the absence of Eocene markers such as aff. *Beaupreadites matsuokae*, *Cupanieidites* cf. *C. flaccidiformis*, *Diporoconia iszkaszentgyorgyi*, *Ixonanthes*, *Polygalacidites clarus*, *Proxapertites operculatus*, *Proxapertites cursus* and *Ruellia* type (Lelono, 2001 and 2003). These pollen were found in the Eocene Nanggulan Formation of Central Java and the Eocene

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 7 - 17

Toraja Formation of South Sulawesi. Therefore, this clearly indicates that the studied sediment is younger than the Eocene formations above.

VI. NEW STRATIGRAPHIC RECORD

This work shows new stratigraphic record of some selected pollen. The Gondwanan element of *Dacrydium* occurs commonly along the studied wells, whilst the Australian pollen of *Casuarina* presents regularly within these wells (Figures 4 and 5). Both pollen were assumed to migrate to western Indonesia following the latest Oligocene collision between Australian plate and Sundaland (Morley, 2000). In fact, *Dacrydium* (Figure 6) and *Casuarina* (Figure 7) were firstly recorded in the basal Early Miocene as seen in the North west Java Basin and West Natuna Basin (Morley, 2000). Therefore, many palynologists often refer to the first appearance of these pollen for separating Early Miocene from Oligocene succession (Figure 8). Regarding these facts, the appearance of *Dacrydium* and *Casuarina* within the Oligocene sections (? even older section of Late Eocene) as found in this study is controversial. This appearance can be observed consistently in the Oligocene sediments occurring in all wells (Figures 4 and 5). In addition, these pollen are not considered to be caving from the younger sediment as they regularly and commonly occur throughout the Oligocene sections. This situation raises question of the existence of the pathway which allows dispersal of these pollen from their origin in the Australian plate into the Sundaland. Hall (1998) reconstructed the collision between Australian and Asian plates in the Late Oligocene. It is possible that during and after the time of collision, the Australian affinity continental fragments Banggai-Sula, Tukang-Besi/ Buton, Timor or Ceram may have maintained localised emergent areas which allowed some Australian taxa to be introduced directly into East Indonesia. Possible candidates to be considered are *Eucalyptus deglupta* (Myrtaceae) and other *Eucalyptus* spp. in the Maluku and *Casuarina junghuhniana* in Nusa Tenggara and East Java (Morley, 2000). These pollen are recorded in Early Miocene successions of west Indonesia. Would it be possible that this collision occurred earlier in East Java rather than in other areas of the Sunda region?

The regional tectonic study of East Java carried out by Sribudiyani et al. (2003) indicates that from the end of Cretaceous to Early Eocene (70-35 Ma),

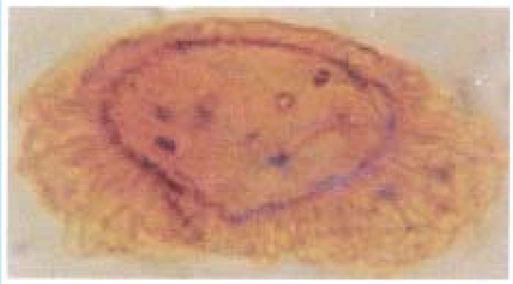

Figure 6
The Gondwanan element of pollen *Dacrydium* (magnification: X1000)

Figure 7
The Australian immigrant of pollen *Casuarina* (magnification: X1000)

a continental fragment, possibly detached from the Gondwana super-continent to the south, drifted northeastward approaching the Late Cretaceous to early Tertiary subduction complex (Lok Ulo-Meratus belt). The collision of this micro-continent with the eastern margin of the Sunda Microplate caused the Eocene magmatic activity to cease and uplifted the subduction complex, creating the Meratus Mountains in the eastern part of Kalimantan and The Lok Ulo mélange complex in the central Java (Sribudiyani et al., 2003). During this period, the contemporaneous northeastward movement of the Australian plate resulted in its subduction under the Sunda Microplate along Java-Meratus suture (Figure 9). Furthermore, dating analysis of the intrusive rocks using a method of SHRIMP U-Pb zircon done by Smith (2003) indicated the possible occurrence of the Australian origin of this min-

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 7 - 17

eral. This would imply transport of the sediment far to the north onto the Indian plate during the Paleogene. These works suggest that East Java was a continental fragment deriving from Gonwana which collided with the eastern part of the Sundaland during the end of Cretaceous to Early Eocene. Australian palynomorphs especially *Casuarina* and *Dacrydium* survived in East Java and extended through the Late Neogene. In this case, Asian flora was much more aggressive than the Australian counterpart as indicated by domination of Indian and Asian palynomorphs over the Australian one within the Oligocene sections. This might result in the late dispersal of the Australian floras including *Casuarina* and *Dacrydium* into West Java and other areas in West Indonesian.

Having above discussion, it can be assumed that the appearance of the Australian elements of *Casuarina* and *Dacrydium*

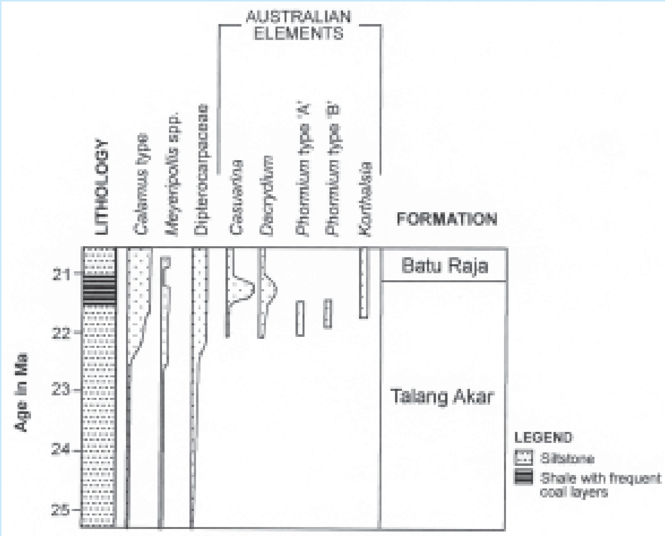

Figure 8
Some distinctive pollen types from the Early Miocene of the Java Sea, showing abundance of dipterocarp pollen, immigrants from Australia and the representation of Meyeripollis (taken from Morley, 2000 page 194)

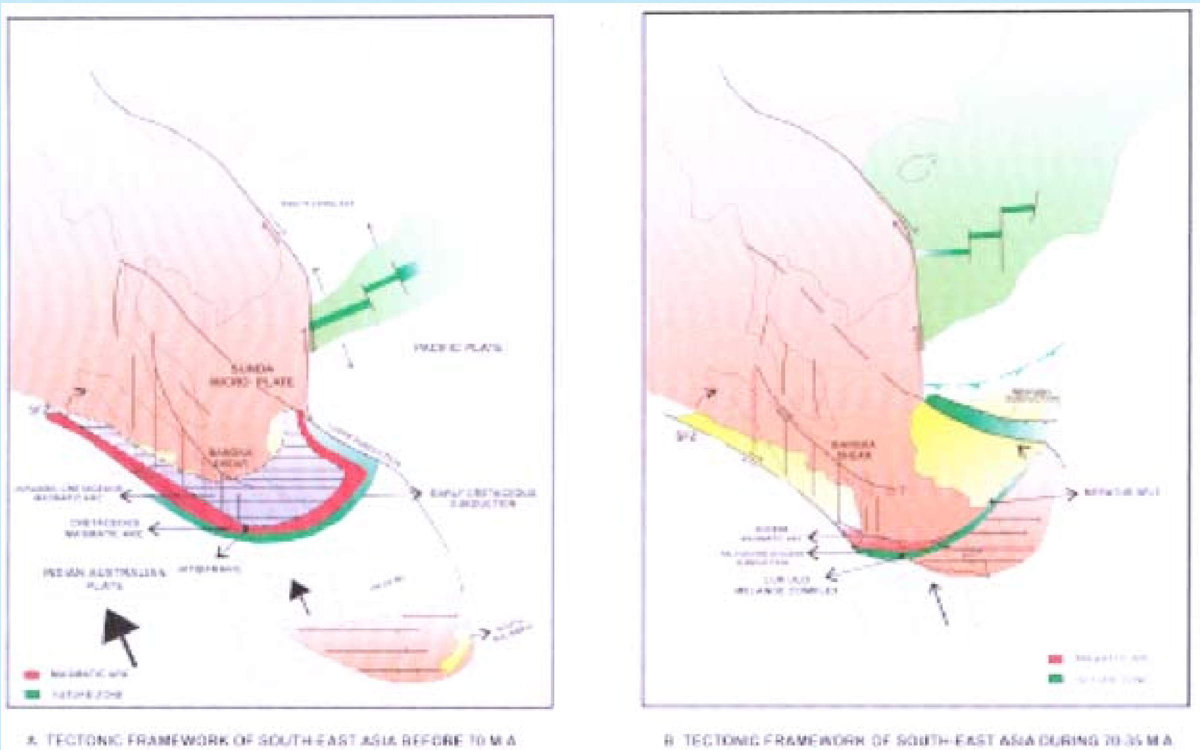

Figure 9
Tectonic evolution of West Indonesia during Late Cretaceous-Early Tertiary (taken from Sribudiyani *et al*., 2003)

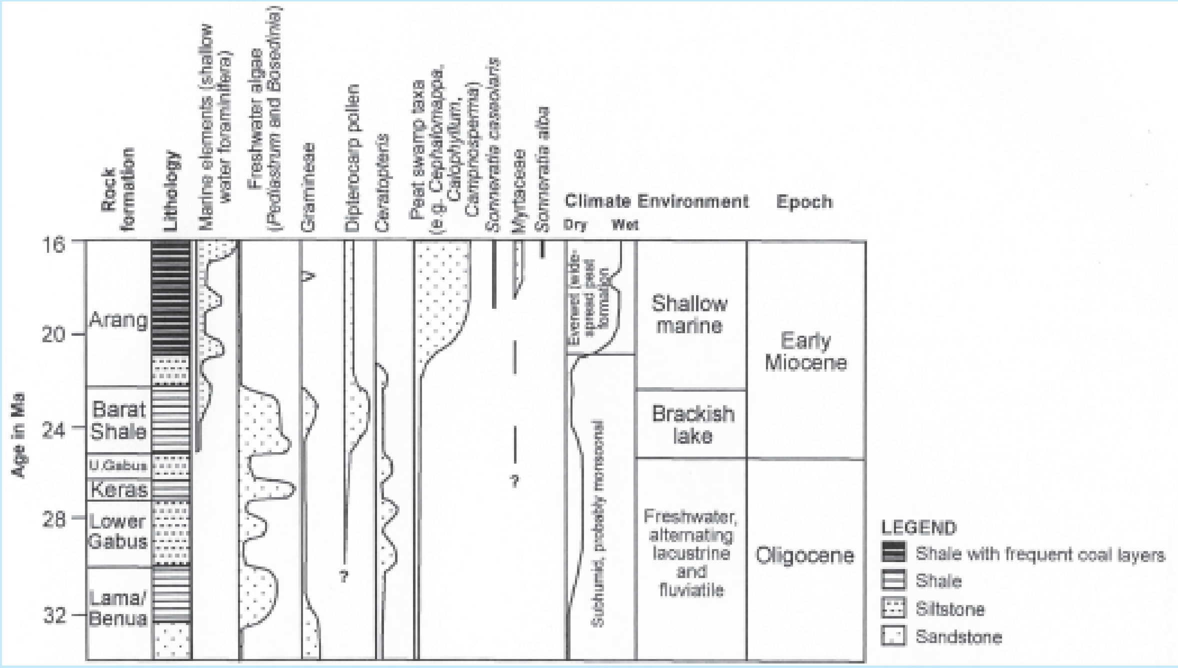

Figure 10
Distinctive features of the Oligocene and Early Miocene palynological record for the West Natuna Basin. This patern is closely mirrored in the adjacent Malay Basin and broadly similar climatic signatures are suggested by the palynological records in the Java Sea and Sumatra (taken from Morley, 2000 page 195)

in East Java during Paleogene may have been facilitated by the occurrence of land bridges following the collision of the continental fragment deriving from Gondwana and the Eastern Sundaland. In West Java and other areas of West Indonesia such as Natuna and Central Sumatra, these pollen were firstly recorded in Early Miocene sediments as shown in Figure 8.

VII. PALEOENVIRONMENT

The pattern of rifting and subsidence which began in the Late Eocene continued in Oligocene with the opening of pull-apart basins in the region of the South China Sea, Sumatra and West Java Sea. Most basins contained large, often deep, freshwater lakes, which gradually filled with often organic-rich muds (which following cooking by subsequent burial, produced most of the hydrocarbons of Southeast Asia), or with fluvial sands, during the periods of low lake level (Morley, 2000). Furthermore, subsidence continued over a wider area where by the beginning of Early Miocene most basin submerged by a very shallow, brackish-water sea (Figure 10). The geological features appearing during Oligocene-Early Miocene are reflected on their type of sediment. The sediment occurring in Oligocene is lake deposit or fluvial deposit. On the other hand, Early Miocene is dominated by shallow marine or brackish water sediment. These lithologies can be observed clearly in the West Natuna Basin, Central Sumatra Basin and the Northwest Java Basin.

Unlike Oligocene sediment in the above basins which was deposited in the non-marine environment, the Oligocene sediment of East Java reflects shallow marine sediment as suggested by the significant appearance of brackish palynomorph along the succession. Furthermore, marine dinoflagellate shows moderate and regular existence through out the Oligocene sediment. Apparently, all sections contain mangrove and back-mangrove palynomorphs such as *Zonocostites ramonae*, *Avicenia* type, *Spinizonocolpites echinatus*, *Discoidites acutus*

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 7 - 17

and *Discoidites novaguenensis* (Figures 4 and 5). In addition, foraminiferal analysis shows the domination of benthonic form over the planktonic form. The benthonic form is mostly represented by shallow water forms such as *Ammonia umbonata*, *Anomalinella rostrata*, *Asterigerina tentoria*, *Cibicides* spp. and *Elphidium craticulatum*. marking inner neritic environment (0-20 m). In addition, larger benthonic form is mostly represented by shallow marine taxa such as *Amphistegina* spp. and *Operculina ammonoides*. Based on palynological data combined with foraminiferal data, it can be inferred that the sediment situated in the studied interval was deposited in transition to inner neritic environment.

Some freshwater pollen produced by peatswamp and freshwater swamp vegetation appear in significant abundance including *Cephalomappa*, *Durio* type, *Sapotaceoidaepollenites* spp., *Calophyllum* type, *Dicolpopollis* spp., *Casuarina* and *Dacrydium* (Figures 4 and 5). Their appearances could indicate the development of low land forest during sea level rise. This might have happened under wetter climate condition. On the other hand, common *Dacrydium* combined with regular occurrence of pollen of *Casuarina* suggests the occurrence of Kerangas or heat forest during the development of peatswamp vegetation (Morley, 2000). Furthermore, the consistent appearance of spore of *Lycopodium cernuum* supports the occurrence of heat forest along the studied sections (Muller, 1972).

VIII. CONCLUSION

Palynological study on Oligocene sediments of East Java provides new information regarding the diversity and abundance of palynomorph which reflects the tectonic situation and the paleoenvironment during this time. The existence of the Oligocene sediments is defined by the consistent appearance of pollen *Meyeripollis naharkotensis* and spore *Cicatricosisporites dorogensis* along the studied sections. Unlike other Oligocene sediments situated in most basin of western Indonesia which were sedimented in fresh water environment (lake deposit or alluvial), the Oligocene sediments of East Java Basin were deposited in the marginal marine to shallow marine environment as suggested by the occurrence of various brackish palynomorphs such as *Zonocostites ramonae*, *Avicenia* type, *Spinizonocolpites echinatus*, *Discoidites acutus* and *Discoidites novaguenensis*. Furthermore, moderate and regular existence of marine dinoflagellate combined with shallow water benthic foraminifer throughout the Oligocene sediment supports the influence of the marine environment.

The appearance of the Gondwanan/ Australian elements including *Dacrydium* and *Casuarina* with common and regular occurrences throughout the studied sections are controversial as these pollen are recorded in the younger sediments (Early Miocene) of other areas such as Java sea, South Sumatra and Natuna sea following the collision of the Australian plate and the Sundaland in the latest Oligocene. Furthermore, the absence of these palynomorphs within the Paleogene sediments of Central Java and South Sulawesi strengthens the above assumption. Therefore, in regard to East Java, the appearance of *Dacrydium* and *Casuarina* may indicate earlier arrival of the Gondwanan/ Australian fragment in this area compared to that in other areas of Indonesia.

IX. ACKNOWLEDGMENT

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