GONDWANAN PALYNOMORPHS FROM THE PALEOGENE SEDIMENTS OF EAST JAVA: ?THE EVIDENCE OF EARLIER ARRIVAL

by

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ABSTRACT

The palynological investigation of the Paleogene sediments is based on cutting samples collected from the exploration wells which are drilled in East Java area. The occurrence of pollen Meyeripollis naharkotensis *and spore* Cicatricosisporites dorogensis *in the upper well sections suggests the pollen zone of Meyeripollis naharkotensis which is equivalent to Oligocene age. Meanwhile, the occurrence of pollen* Proxapertites operculatus *and spore* Cicatricosisporites eocenicus *below Meyeripollis naharkotensis zone indicates the appearance of Proxapertites operculatus zone within the lower sections which is equivalent to Eocene. In addition, foraminiferal and nannoplankton analyses confirm the Oligocene-Eocene age by identifying the occurrence of letter stage of Te4-Tb and nanno zone of NP20-NP25. 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 were firstly recorded in the younger sediments (Early Miocene) of other areas such as Northwest 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.*

Key words: Gondwanan palynomorphs, paleogene sediment, East Java

I. BACKGROUND RESEARCH

The area of the study is located in the East Java which is well known as a major hydrocarbon producer in Indonesia (Figure 1). However, its full hydrocarbon potential can be realised only when the stratigraphy of the region is properly understood. This study is intended to provide significant information which contributes positively to the exploration activity.

Hall (2002) reconstructed the collision between Australian and Asian plates in the Late Oligocene (Figure 2). 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). As a mater of fact, these pollen are recorded in Early Miocene successions of West Indonesia. Mean while, in order to investigate the occurrence of the Gondwanan/Australian taxa in the Paleogene sediments of East Java, this study focuses on some selected pollen including *Dacrydium* and *Casuarina* as they occur commonly and regularly along the studied wells. According to the previous researchers, both pollen were assumed to migrate to western Indonesia following the latest Oligocene collision between Australian plate and

Sundaland (Morley, 2000). In fact, *Dacrydium* and *Casuarina* were firstly recorder 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 3). 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. It is possible that this collision occurred earlier in East Java compared to that in other areas of the Sundaland.

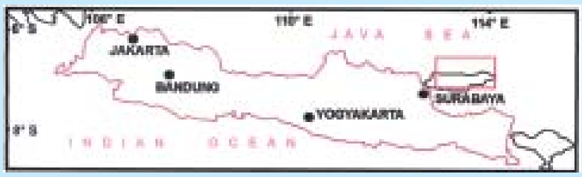


Figure 1
The location of well samples which are used for the study

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), 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

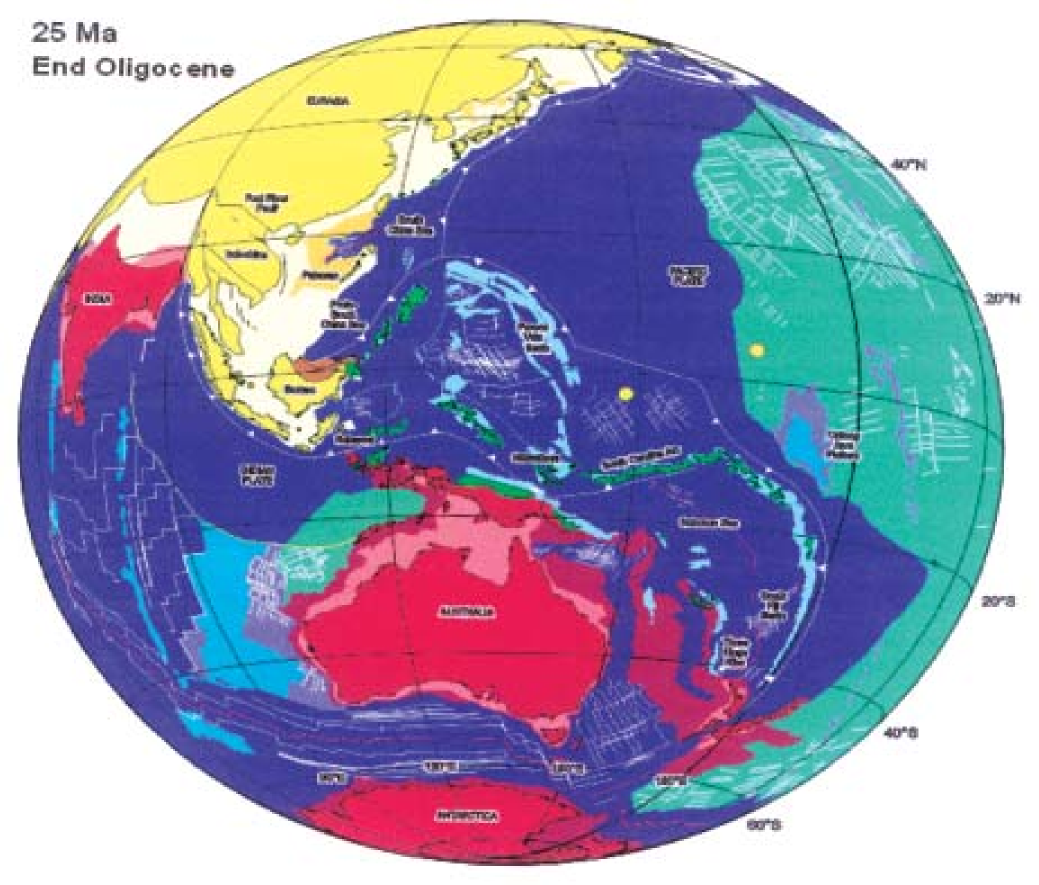


Figure 2
The plate recontruction of SE Asia and SW Pacific regions at about 25 Ma or end Oligocene, showing the first contact of Australian continetral crust with SE Asia (taken from Hall, 2002)

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 4). Furthermore, dating analysis of the intrusive rocks using a method of SHRIMP U-Pb zircon done by Smyth et al. (2003) indicated the possible occurrence of the Australian origin of this mineral. 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.

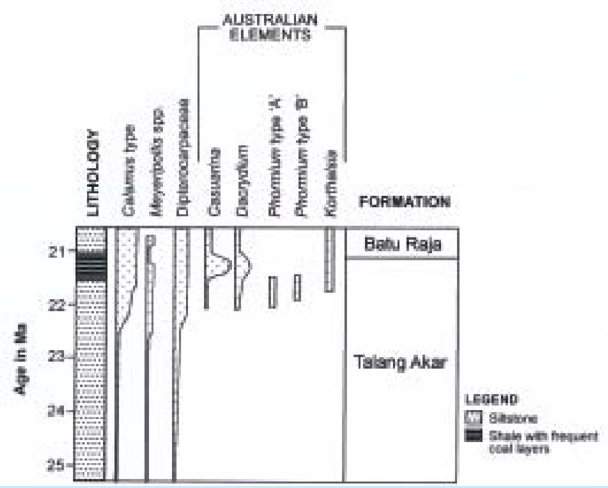
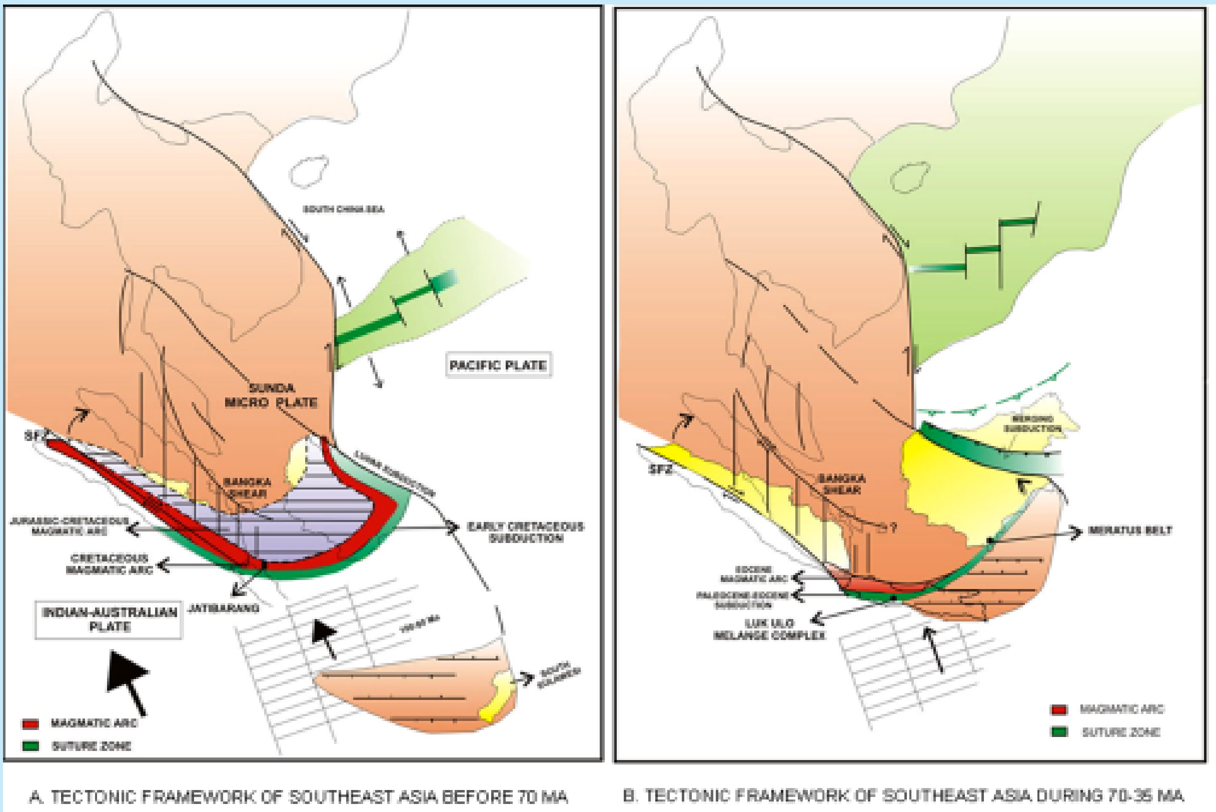


Figure 3
Some distinctive pollen types from the Early Miocene of the Java Sea, showing abundance of dipterocarp pollen, immigrants from Australia and the respresentation of Meyeripollis (taken from Morley, 2000 page 194)



A. TECTONIC FRAMEWORK OF SOUTHEAST ASIA BEFORE 70 MA

B. TECTONIC FRAMEWORK OF SOUTHEAST ASIA DURING 70-35 MA

Figure 4
Tectonic evolution of West Indonesia during Late Cretaceous-Early Tertiary (taken from Sribudiyani *et al.*, 2003)

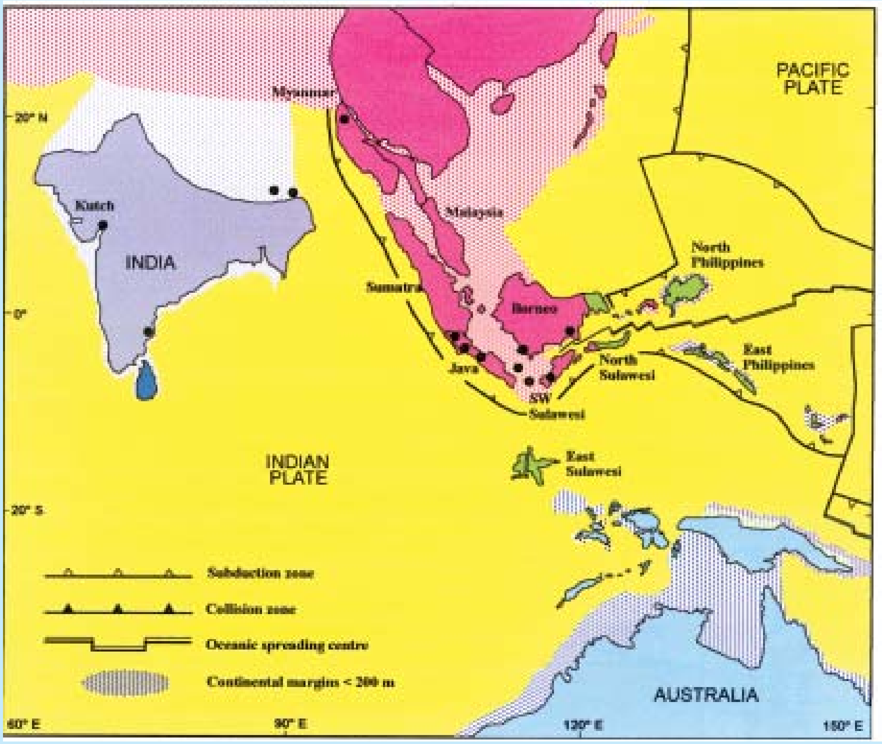


Figure 5
The distribution of Indian pollen of *Palmaepollenites kutchensis* during Middle to Late Eocene in Westem Indonesia (paleogeography of the SE Asian and Australian regions at about 40 Ma is reconstructed by Hall, 1988, whilst geographical distribution of *Palmaepollenites kutchensis* (black circles is taken from Harley and Morley, 1995)

II. DATA AND METHOD

Data used in this study mostly derives from well samples supplied by the oil companies for the purpose of the provision of the technical services. The studied wells were drilled on the Northeast Java Basin. In Addition, the material used in this research is cutting samples which were collected from the selected intervals of the studied wells. 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. 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.

The Age interpretation is based on palynological zonation which was proposed by Rahardjo *et al.* (1994), combined with pollen ranges of Morley (1991). More over, in order to get reliable age interpretation, this work employs marine micro-fossil analysis including foraminiferal and calcareous nannoplankton analyses. The integration of three biostratigraphic disciplines (palynology, foraminifera and calcareous nannoplankton) provides accurate age interpretation.

III. PALEOGENE PALYNOLOGY OF WEST INDONESIA

Palynological investigation on the Paleogene sediments collected from western Indonesia provides comprehensive picture of abundance and diversity of Paleogene palynomorphs within this area which apparently reflect geological condition along this time. Generally, pre-Middle Eocene (older than 45 Ma) is indicated by limited abundance and diversity of palynomorph. On the other hand, Middle Eocene (45-40 Ma) is characterized by high abundance and diversity of pollen and spore which decrease significantly toward Late Eocene (40-35 Ma). In addition, the abundance and diversity of palynomorph continue to decline in Oligocene (35-20 Ma). Pre-Middle Eocene palynomorphs are dominated by Asian contenders including *Psilatricolporites kayanensis*, *Echitriporites trianguliformis*, *Retitriporites variabilis* (Muller, 1968), whilst Middle Eocene is enriched by the occurrence of Indian species such as *Palmaepollenites kutchensis*, *Proxapertites* group, *Lakiapollis ovatus* (Lelono, 2000 and 2003 and Morley, 2000). The appearance of Indian affinity was caused by the migration of vegetation from India to Asia vice a versa following the collision between Indian and Asian Plates which occurred in about Middle Eocene age (Figure 5). High abundance and diversity of palynomorphs in the Midde Eocene related to the appearance of wet climate over the broad low land which allowed the development of low land rain forest during this time. The decrease of palynomorph in the Late Eocene was caused by the reduction of land due to intensive subsidence and the change of climate in to relatively dry which presumably coresponded to the terminal Eocene cooling event as occurred in North America and West Europe (Collinson, 1992 and Wolfe, 1994).

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 6). In addition, sea level raised significantly during the Late Oligocene-Early Miocene (Haq *et al.,* 1988). 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

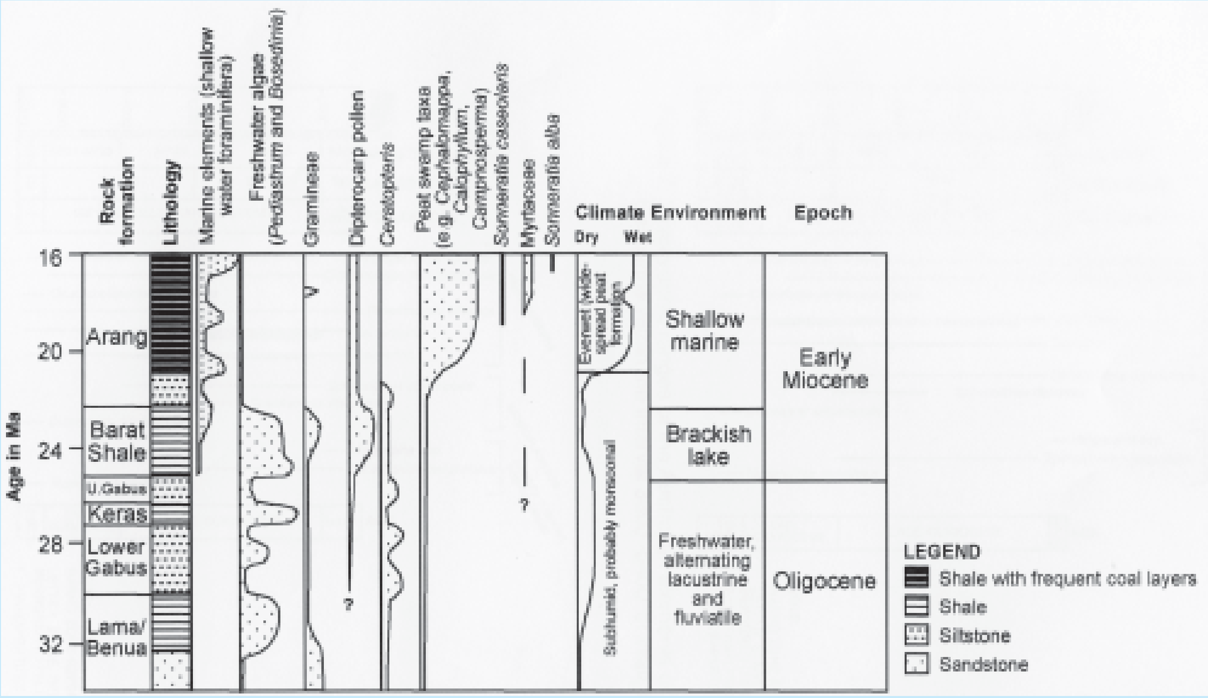


Figure 6
Distinctive features of the Oligocene and Early Miocene palynological record for the West Natuna Basin. This patern is closely mirrored in the adjacent Malay Basin and broadly similar climatic signatues are suggested by the palynological records in the Java Sea and Sumatra (taken from Morley, 2000, page 195)

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.

Lower Oligocene is indicated by high abundance of freshwater swamp palynomorphs such as *Barringtonia*, plants producing *Brownlowia* type and aff. *Lagerstroemia* pollen (*Florschuetzia trilobata* var) and Gramineae pollen (Morley, 2000). In addition, it is also marked by high abundance of algae of *Pediastrum* spp. suggesting the occurrence of lacustrine environment within the early stage of graben formation (Lelono, 2005). Subsidence combined with rising sea level during Upper Oligocene shifted the depositional environment in to shallow marine as marked by the increase of abundance and diversity of mangrove and back-mangrove palynomorphs as well as dinoflagellates. The mangrove and back-mangrove palynomorphs are represented by *Zonocostites ramonae* and *Spinizonocolpites echinatus* (Lelono, 2005).

IV. PALEOGENE PALYNOLOGY OF EAST JAVA

The previous study indicates that the Paleogene sediment mostly consists of Eocene and Oligocene successions. Mean while, the

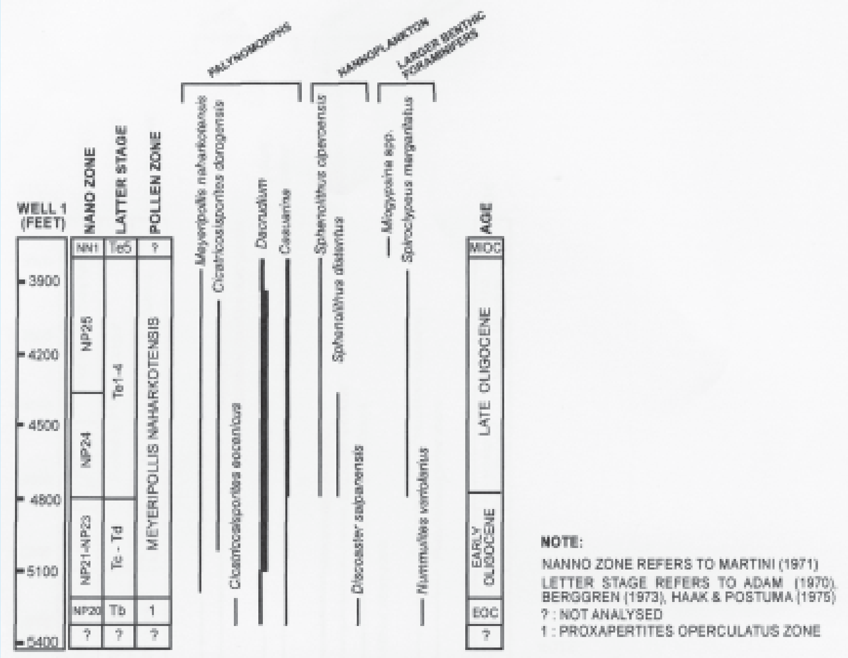


Figure 7
Stratigraphic ranges of the Australian elements of *Dacrydium* and *Casuarina* within the interval 3800'-5400'of Well 1

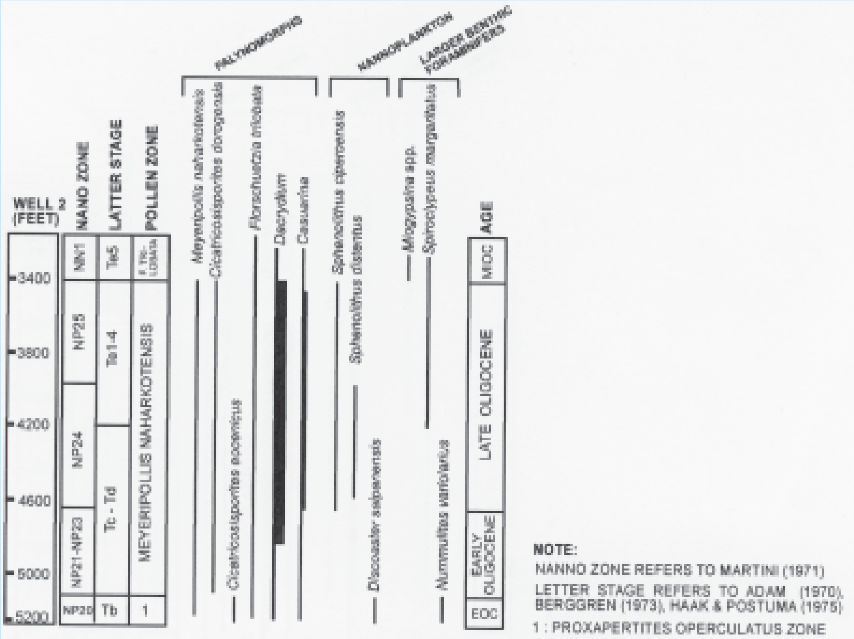
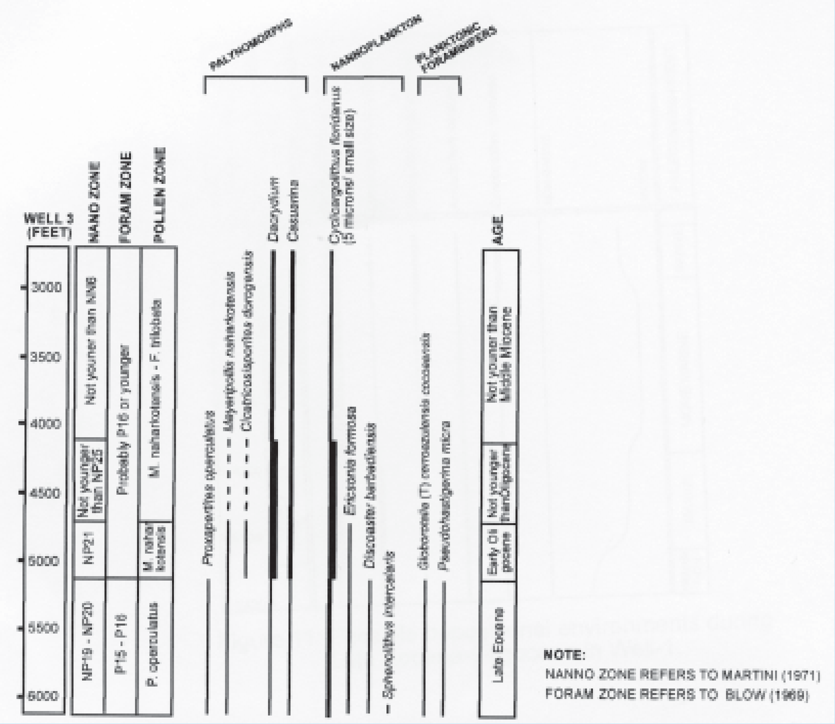


Figure 8
Stratigraphic ranges of the Australian elements of *Dacrydium* and *Casuarina* within the interval 3400'-5200'of Well 2

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).

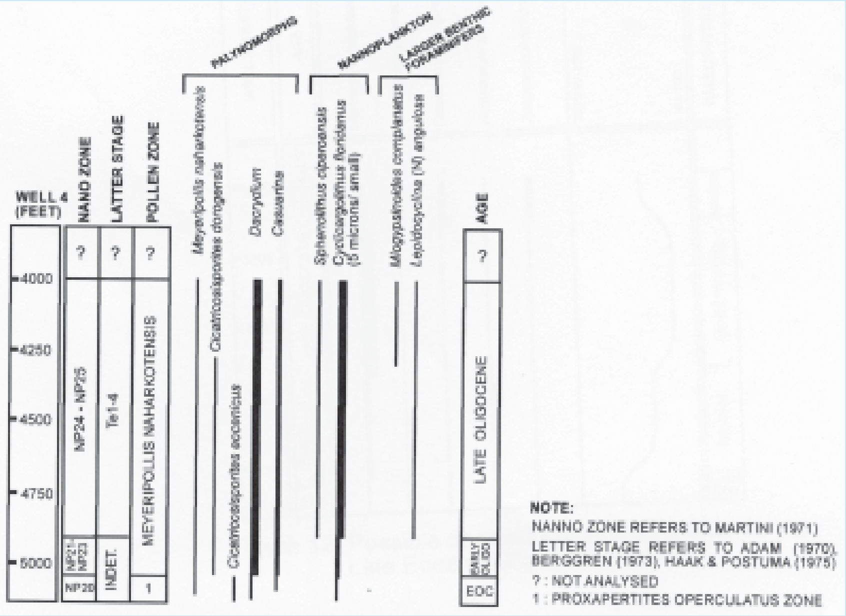
The study of the Paleogene sediment basically refers to the works on well samples obtained from onshore and off-shore drillings. In order to get reliable age of the studied sediment, this study applies other biostratigraphic disciplines including foraminifer and nannoplankton. The age interpretation is critical to confirm the existence of the Paleogene age within the studied sediments.

Based on the occurrence of pollen *Meyeripollis naharkotensis* along the middle and upper interval of Wells 1, 2, 3 and 4, it can be inferred that sediments situated in the middle to upper interval of these wells belong to pollen zone of Meyeripollis naharkotensis which equals to Oligocene age (Figures 7, 8, 9 and 10). In addition, Oligocene marker of trilete spore of *Cicatricosisporites dorogensis* regularly



NOTE:
NANNO ZONE REFERS TO MARTINI (1971)
FORAM ZONE REFERS TO BLOW (1969)

Figure 9
Stratigraphic ranges of the Australian elements of *Dacrydium* and *Casuarina* within the interval 3900'-6050' of Well 3



NOTE:
NANNO ZONE REFERS TO MARTINI (1971)
LETTER STAGE REFERS TO ADAM (1970), BERGGREN (1973), HAAK & POSTUMA (1975)
? : NOT ANALYSED
1 : PROXAPERTITES OPERCULATUS ZONE

Figure 8
Stratigraphic ranges of the Australian elements of *Dacrydium and Casuarina* within the interval 3900'-5100' of Well 4

appears along the middle to upper interval of the studied wells suggesting the occurrence of Oligocene age within this interval. Although most Eocene palynomorphs are absent nearly from the whole sections such as aff. *Beaupreadites matsuokae*, *Cupanieidites* cf. *C. flaccidiformis*, *Diporoconia iszkaszentgyorgyi*, *Polygalacidites clarus*, *Proxapertites cursus*, *Proxapertites operculatus* and *Ruellia* type (Lelono, 2001), the existence of Eocene marker of monolete spore of *Cicatricosisporites eocenicus* within the lower part of the studied wells indicates that the sediment of the lower well sections may be attributed to Proxapertites operculatus zone which equals to the Eocene age (Figures 7, 8, 9 and 10). In addition, another Eocene marker of *Proxapertites operculatus* occurs regularly in the lower part of Well 3 indicating the existence of Proxapertites operculatus zone or Eocene age (Figure 9).

In Well 1, foraminiferal analysis showed the first appearance of larger benthic form of *Miogypsina* sp. at 3800' and *Spiroclypeus margaritatus* at 4800' suggesting the Late Oligocene age within the interval 3800'-4800'. In addition, the last appearance of larger benthonic form of *Nummulites variolarus* at 5200' indicates Early Oligocene age within the interval 4800'-5200' (Figure 7). Apparently, the sediment in interval 5200'-5300' can be attributed to Eoece. In Well 2, the first appearance of larger benthic form of *Miogypsina* spp. at 3400' and the appearance of larger benthonic form of *Nummulites variolarus* at 5050' define the occurrence of Oligocene succession within the interval 3400'-5050'. In this case, the samples situated below 5050' (down to 5200') can be assigned to Eocene age (Figure 8). On the other hand, the last occurrence of planktonic foraminifer of *Globorotalia* (*T*) *cerroazulensis cocoaensis* and *Pseudohastegerina micra* at 5100' of Well 3 suggests that the sediment located above this depth belongs to Oligocene, whilst the sediment situated below this depth represents Late Eocene (Figure 9).

Nannoplankton analysis on Well 1 provided the appearance of *Sphenolithus ciperoensis* within the interval 3800'-4800' suggesting that the sediment of this interval has Late Oligocene age. Further more, the last appearance of *Discoaster*

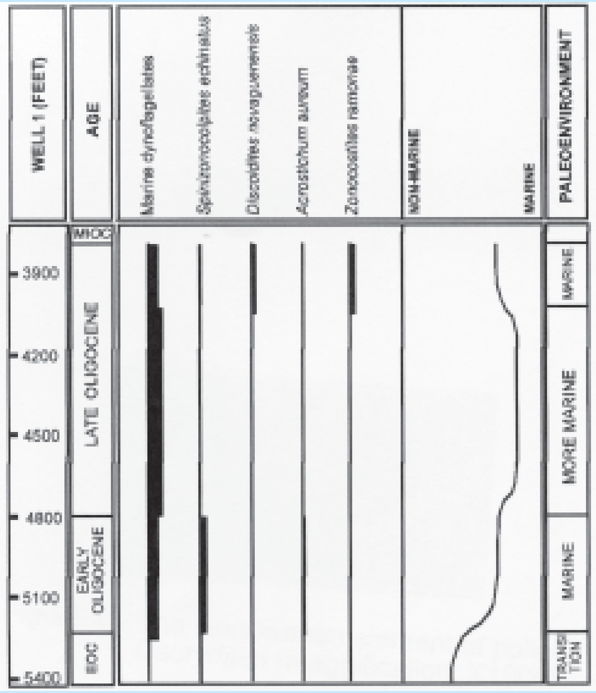


Figure 11
Possible depositional environments during Late Eocene-Oligocene in Well 1

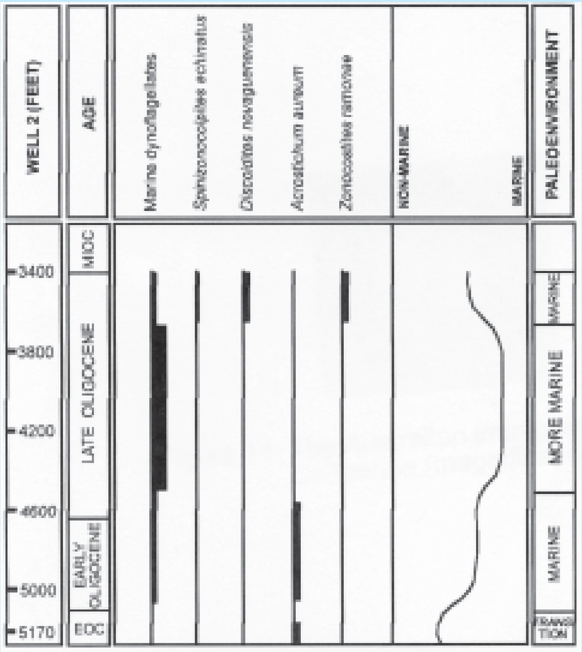


Figure 12
Possible depositional environments during Late Eocene-Oligocene in Well 2

saipanensis at 5200' indicates the occurrence of Early Oligocene within the interval 4800'-5200'. Therefore, the sediment in interval 5200'-5300' (lower interval) is assigned to Late Eocene (Figure 7). Mean while, in well 2, the occurrence of *Sphenolithus ciperoensis* within the interval 3400'-4600' indicating Late Oligocene age. More over, the last appearance of *Discoaster saipanensis* at 5050' marks the existence of Early Oligocene within the interval 4600'-5050'. Consequently, the sediment situated interval 5050'-5200' is assumed to have Late Eocene age (Figure 8). In Well 3, the last occurrence of *Discoaster barbadiensis* at 5100' suggests that the samples situated above this depth can be attributed to Oligocene, whilst those located below this depth can be assigned to Late Eocene (Figure 9).

Having these interpretations, it is inferred that the age of the studied sediments situated in the studied wells (Wells 1, 2, 3 and 4) ranges from Late Oligocene to Late Eocene.

Unlike Oligocene sediment in most western Indonesian basins which was deposited in the non-marine (lower part) to transition (upper part) environment, the Oligocene sediment of East Java reflects shallow marine sediment as suggested by the significant appearance of marine and brackish palynomorphs along the successions (Figures 11 and 12). Further more, marine dinoflagellate shows rare occurrence within Late Eocene sediment which gradually increases to moderate and high abundance through out the Early Oligocene and Late Oligocene sediments respectively. Apparently, all sections contain mangrove and back-mangrove palynomorphs such as *Spinizonocolpites echinatus*, *Discoidites novaguenensis*, *Acrostichum aureum*, *Avicenia* type and *Zonocostites ramonae* (Figures 11 and 12). In addition, foraminiferal analysis shows the domination of benthonic form over the planktonic form (Lemigas, 2006). In the lower interval, the benthonic form is mostly represented by shallow water forms such as *Ammonia umbonata*, *Anomalinella rostrata*, *Asterigerina tentoria*, *Cibicides* spp. and *Elphidium craticulatum* marking littoral to inner neritic environment (0-20 m). In addition, larger benthonic form is also mostly represented by shallow marine taxa such as *Amphistegina* spp. and *Operculina ammonoides*. Mean while, in the middle and upper intervals of the studied wells, the diversity and abundance of foraminifer are increasing considerably suggesting deeper marine into middle neritic environment (Lemigas, 2006). Based on palynological data combined with foraminiferal data, it can be inferred that the sediment situated in the studied intervals was deposited in the transition environment in the lower intervals which gradually changed to more marine environment toward the upper intervals.

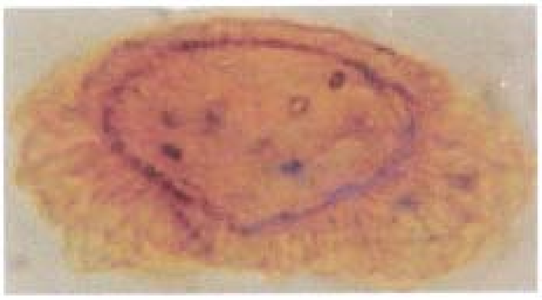


Figure 13
The Gondwanan element of pollen *Dacrydium* (magnification: X 1000)

Figure 14
The Australian immigrant of pollen *Casuarina* (magnification: X 1000)

V. EVIDENCE OF THE EARLIER ARRIVAL OF THE AUSTRALIAN ELEMENT

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 7, 8, 9 and 10). 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 13) and *Casuarina* (Figure 14) were firstly recorder in the basal Early Miocene as seen in the North west Java Basin and West natuna Basin (Morley, 2000). 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. Regarding these facts, the appearance of *Dacrydium* and *Casuarina* within the Oligocene to Late Eocene sections as found in this study is controversial. This appearance can be observed consistently in the Oligocene to Late Eocene sediments occurring in all wells (Figures 7, 8, 9 and 10). In addition, these pollen are not considered to be caving from the younger sediment as they regularly and commonly occur through out the studied 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. Would it be possible that this collision occurred earlier in East Java rather than in other areas of the Sunda region?

Considering the works done by Sribudiyani *et al.* (2003) and Smyth et al. (2003) which 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 to Late Eocene sections. This might result in the late dispersal of the Australian floras including *Casuarina* and *Dacrydium* into West Java and other areas in west Indonesia.

Having the evidences as discussed above, it can be assumed that the appearance of the Australian elements of *Casuarina* and *Dacrydium* in East Java during Paleogene may have been facilitated by the occurrence of land bridges following the collision of the continental fragment deriving from Gondwanan 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 3. However, it is required more sections to assay the consistence appearance of these elements within the Paleogene sediments. Another important point regarding this issue is to investigate surface sections in order to avoid caving problem as usually encountered in the well sections. The occurrence of these two Gondwanan elements in the surface samples improve the level of reliability of this work.

VI. CONCLUSION

Palynological study on Oligocene to Late Eocene 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 appearance of the Gondwanan/Australian elements including *Dacrydium* and *Casuarina* with common and regular occurrences throughout the studied sections are controversial as these pollen were firstly 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. Further more, 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.

Unlike other Oligocene sediments situated in most basin of western Indonesia which were sedimented in fresh water environment such as lake deposit or alluvial in Early Oligocene to transition environment in Late Oligocene, 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, *Spinizonocolpites echinatus*, *Discoidites* *novaguenensis*, *Avicenia* type *Acrostichum aureum* and *Zonocostites ramonae* Further more, moderate and regular existence of marine dinoflagellate combined with shallow water benthic foraminifer through out 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. Further more, 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.

VII. ACKNOWLEDGMENT

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