TROPICAL EOCENE PALYNOMORPHS FROM THE TORAJA FORMATION, KALUMPANG, SOUTH SULAWESI

by
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ABSTRACT

This study enables to prove the occurrence of the tropical Eocene palynomorphs within the South Sulawesi area. Most key palynomorphs have Indian affinity and appear in the Eocene Nanggulan Formation of Central Java. These palynomorphs are Palmaepollenites kutchensis, Proxapertites operculatus, P. cursus, Retistephanocolpites williamsi, Lakiapollis ovatus, Diporoconia iszkaszentgyorgyi *and* Dandotiospora laevigata. *However, compared to those from the Nanggulan Formation, the number of palynomorphs occurring in the Toraja Formation significantly decreases some Middle Eocene markers including affinity.* Beaupreadites matsuokae, Ruellia *type,* Polygalacidites clarus and Cupanieidites cf. C. flacciditormis *are absent from the Toraja Formation. This may indicate that the age of the Toraja Formation is younger than that of the Nanggulan Formation, and hence it is predicted to be (?top most Middle Eocene-) Late Eocene. In addition, the interpretation of the Late Eocene age is supported by the appearance of pollen* Proxapertites operculatus *with fine reticulation which was also found in the Late Eocene Bayah Formation of West Java. This pollen is considered to be a new marker for the Late Eocene succession.*

From the palaeobiogeographic point of view, the similarity between palynomorphs from the Nanggulan Formation and those from the Toraja Formation suggests land connection between Java and South Sulawesi during Eocene.

I. INTRODUCTION

This study is a part of geological investigation in South Sulawesi in order to evaluate hydrocarbon potential within this area. It is financially supported by the Hydrocarbon Resources Project of LEMIGAS Exploration Department, known as PROSUDA. Basically, this study was inspired by the similar study conducted by the author in the Nanggulan area of Central Java. The Nanggulan study has successfully reconstructed Eocene palynological zonation (Lelono, 2001). However, this zonation needs to be extended in other areas. This will prove whether or not the Nanggulan zonation can be applied in the wider area. For this particular reason, the South Sulawesi project was proposed.

The palynological study on the Toraja Formation is intended to record all Eocene palynomorphs occurring within this formation and to extend the Eocene Nanggulan zonation. The area of study is located in the small town named Kalumpang and its surrounding area. It covers the area with the longitude ranging from 119°28' to 119°31' East and the latitude ranging between 2°27' and 2°33' North (Figure 1). The Kalumpang area was selected due to the occurrence of the Eocene exposures.

Most Eocene sediments were deposited in the non-marine and transitional environments which lack marine micro-fossils such as foraminifers and nannoplankton. This situation causes the problem in understanding the descent stratigraphy of these sediments due to the absence of biostratigraphic control and correlation markers. On the other hand, Paleogene lacustrine sediment is well known to be a source rock of hydrocarbon in the basins producing oil (Williams et al., 1985). Therefore, this study becomes essential as palynology is the best tool for analysing the non-marine to transition sediments. It will help explorers to understand the stratigraphy properly which is useful for evaluating its hydrocarbon potential.

Correlating the Toraja Formation in South Sulawesi and the Nanggulan Formation in Central Java is acceptable as both areas were located in the same plate (Sundaland) during Eocene (Hall, 1998). The lithological succession of these formations exhibit the same characterisation of transgressive sequence, in which the non-marine sediment in the lower section gradually changes into transition sediment and finally ends up with fully marine sequence (Lelono, 2001 and Calvert, 2000). These situations allow comparison of the Eocene palynomorphs which occur in both Toraja and Nanggulan Formations.

III. GENERAL STRATIGRAPHY

The stratigraphy of the studied area refers to that introduced by Ratman and Atmawinata (1993). It consists of sediments representing Late Cretaceous to Recent age. Based on its tectonic activities which influenced deposition, the sedimentary rocks are divided into pre-rift, syn-rift, post-rift and syn-orogenic sediments (Figure 2). The pre-rift sediments occurring in the Late Cretaceous is represented by the appearance of the Latimojong Formation which contains siltstone, claystone and shale. The Latimojong Formation unconformably overlies the Mesozoic basement.

The Latimojong Formation is then unconformably overlain by the Middle-Late Eocene Toraja Formation which represents syn-rift sediment. The Toraja Formation consists of the alternation of quarzt sandstone, shale and siltstone. This formation is also indicated by the occurrence of the intercalation of quarzt conglomerate, calcareous claystone, limestone, marl, green sandstone, calcareous sandstone and coal. Resin locally occurs within claystone. There is Rantepao Member within the Toraja Formation which contains nummulitic and crystalised limestones.

Subsequently, the post-rift phase occurs during Late Oligocene-Middle Miocene which is characterised by the appearance of volcanic rock of the Lamasi Formation and carbonaceous rock of the Riu Formation. The Lamasi Formation consists of andesitic-dasitic tuff and volcanic breccia. It is locally found the intercalation of calcareous sandstone and shale. Two members are recognised within the Lamasi Formation including Limestone and Rampi tuff. The Lamasi Formation is conformably overlain by Riu Formation which contains limestone and marl. Both lithologies are interfingering. Unlike limestone in the southern part of South Sulawesi which shows excellent development as indicated by the thick and widespread occurrence of limestone Tonasa or Makale Formation, limestone in the area of study is rare showing limited development. This could have happened due to the destruction of the stable shallow-water platforms which resulted in the minimum development of limestone.

Finally, the Riu Formation is unconformably overlain by the formations representing Late Neogene orogeny in Sulawesi as a result of the continental collision. These formations are well known to be "Celebes Molasse" which consist of Lariang, Sekala (divided into Talaya, Adang and Beropa Members), Mamuju and Budung-Budung Formations (Gerrard et. al., 1992 and Bergman et. al., 1996).

IV. METHOD

Two major works were conducted within this study. The first was fieldwork for collecting surface samples and the second was laboratory work to separate palynomorphs from the rock. Fieldwork was divided into two methods which include logging the lithology and collecting the samples. Logging was aimed to record the lithological variation and to estimate the lithological thickness. Therefore, it allows stratigraphers to reconstruct the lithological column of the studied area as shown in Figures 3 and 4. The result of logging was used to determine interval for sample collection (Figures 3 and 4). Here, sampling interval very much depended on lithological variation and lithological thickness. For palynological analysis, sampling was focused on the sediment with fine grain lithology. Ideally, every distinct lithology should be sampled. However, limestone and other coarse grain lithologies such as breccia, conglomerate and coarse sandstone were avoided as these sediments certainly provide poor recovery (Cross, 1962). In addition, samples with high organic contents as indicated by dark colour were preferable including brown or black shale, lignite and coal. It can be emphasised that sampling was done to the sediments consisting of fine grain lithology and yielding high organic content.

The aim of laboratory work (here is sample preparation) is to release any palynomorphs from minerals or sediments which enclose them or obscure them in order to make them clearly visible and concentrated enough for microscope study and photography. Basically, the sample preparation adopted the modified technique which was proposed for Paleogene sediments by Lelono (2001). Approximately 5 g of sample was cleaned up to avoid surface contamination. It was then crushed to reduce

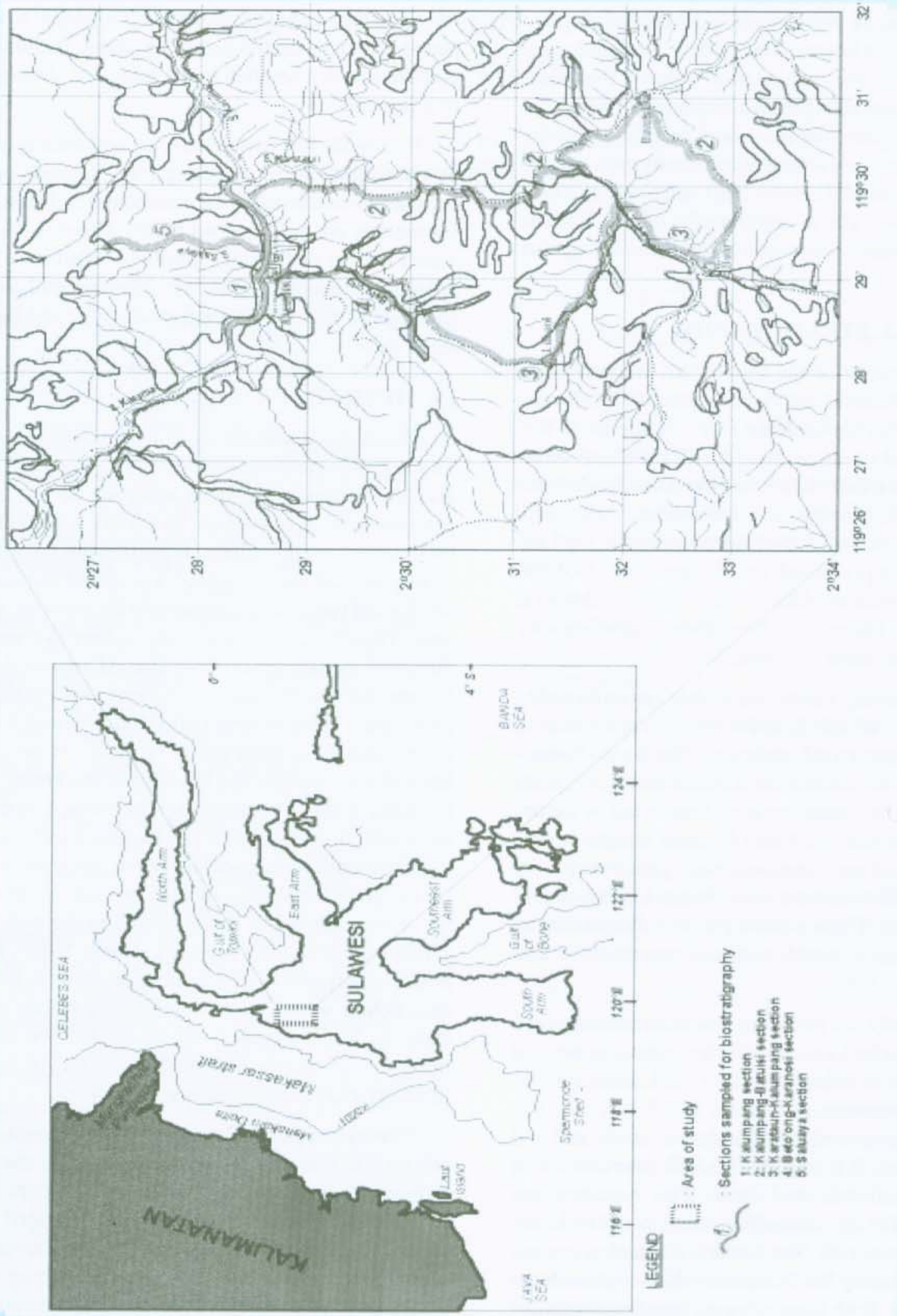

Figure 1
Location of the study area and its topographic map which shows surface sections where samples were collected for biostratigraphic analyses

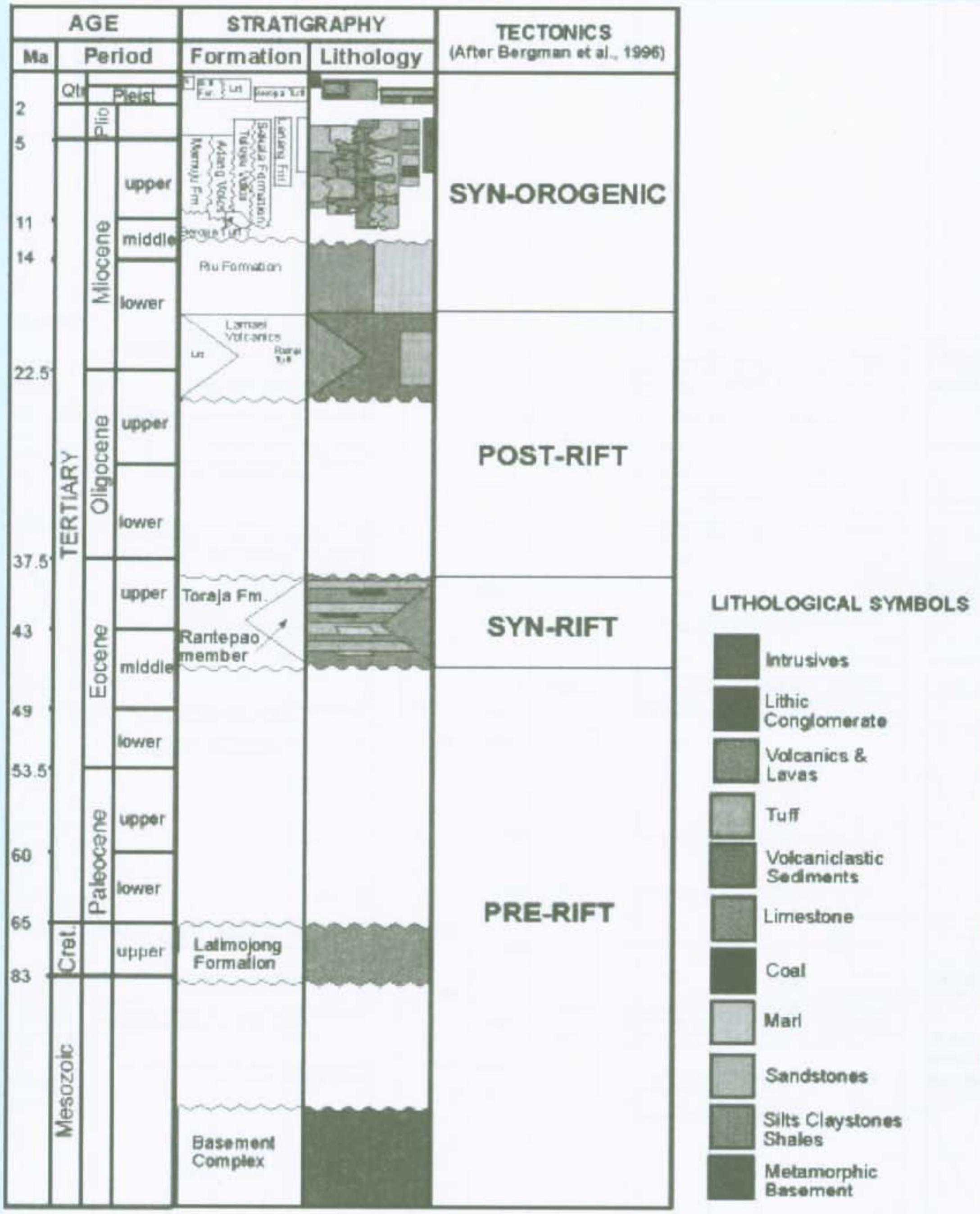

Figure 2
General stratigraphy of the Mamuju quadrangle which was proposed by Ratman and Atmawinata (1993), showing the the occurrence of formations within the Lariang-Karama area (after Calvert, 2000 with small modification)

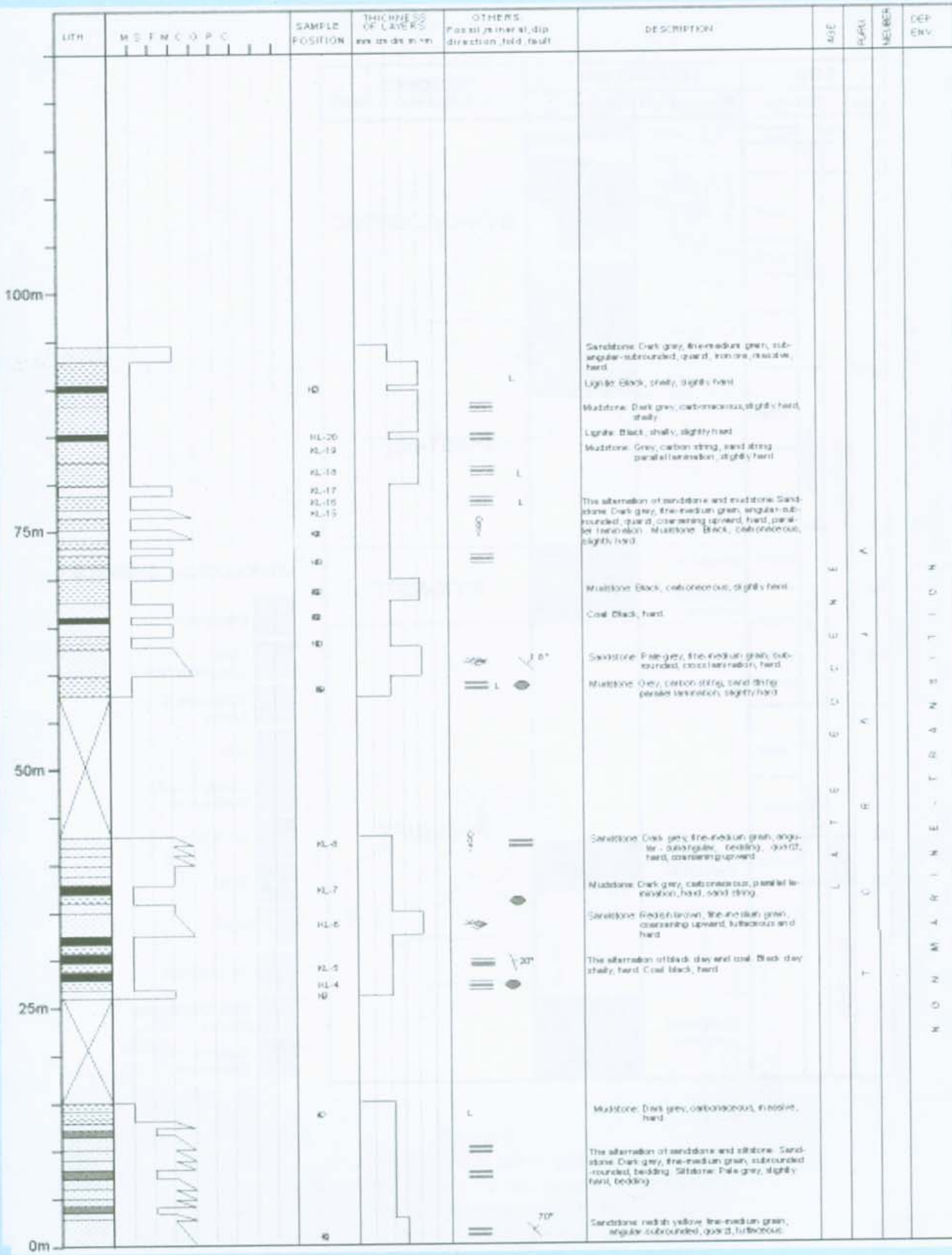

Figure 3
Lithological column of the Kalumpang section

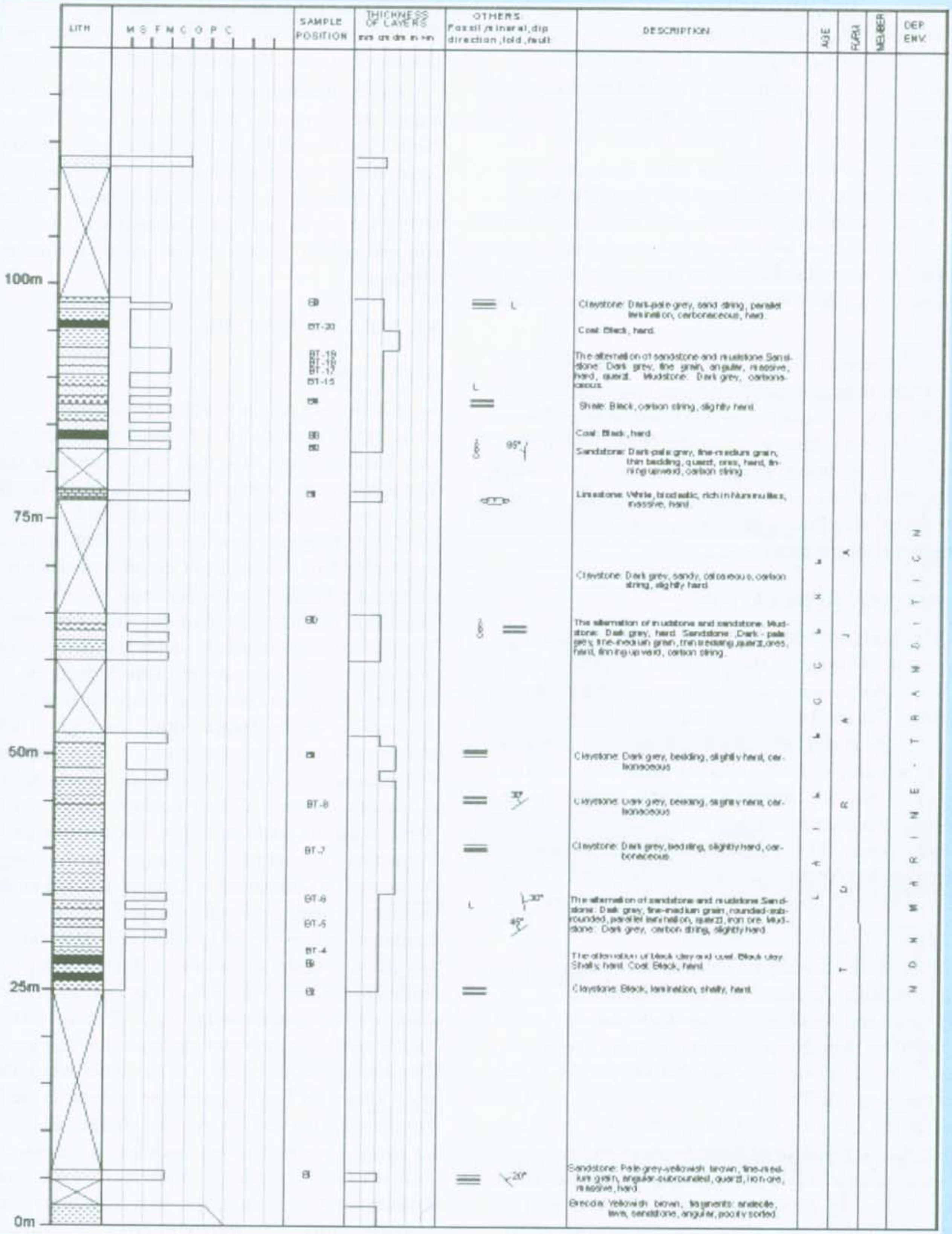

Figure 4
Lithological column of the Beto'ong-Karanosi section

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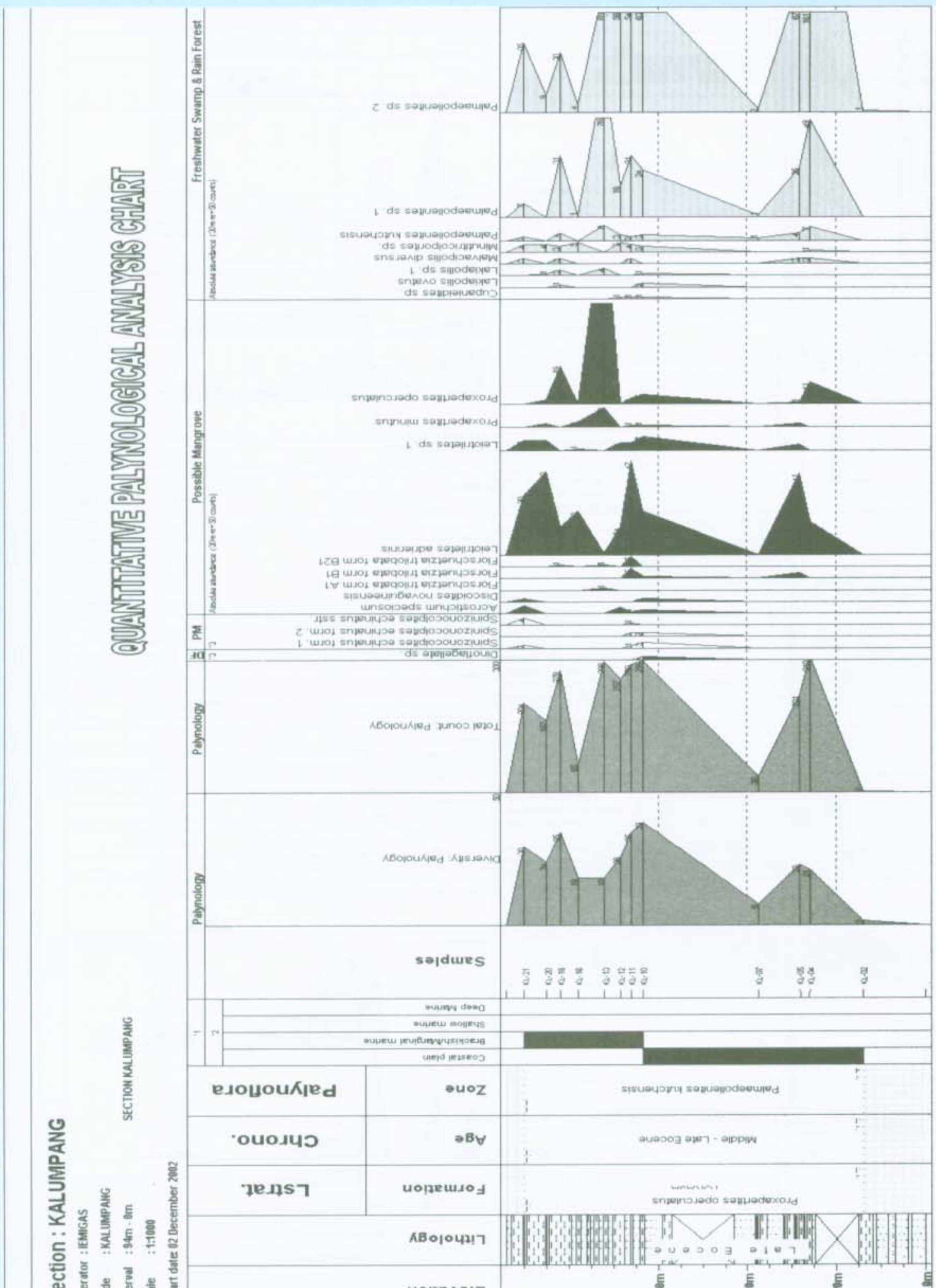
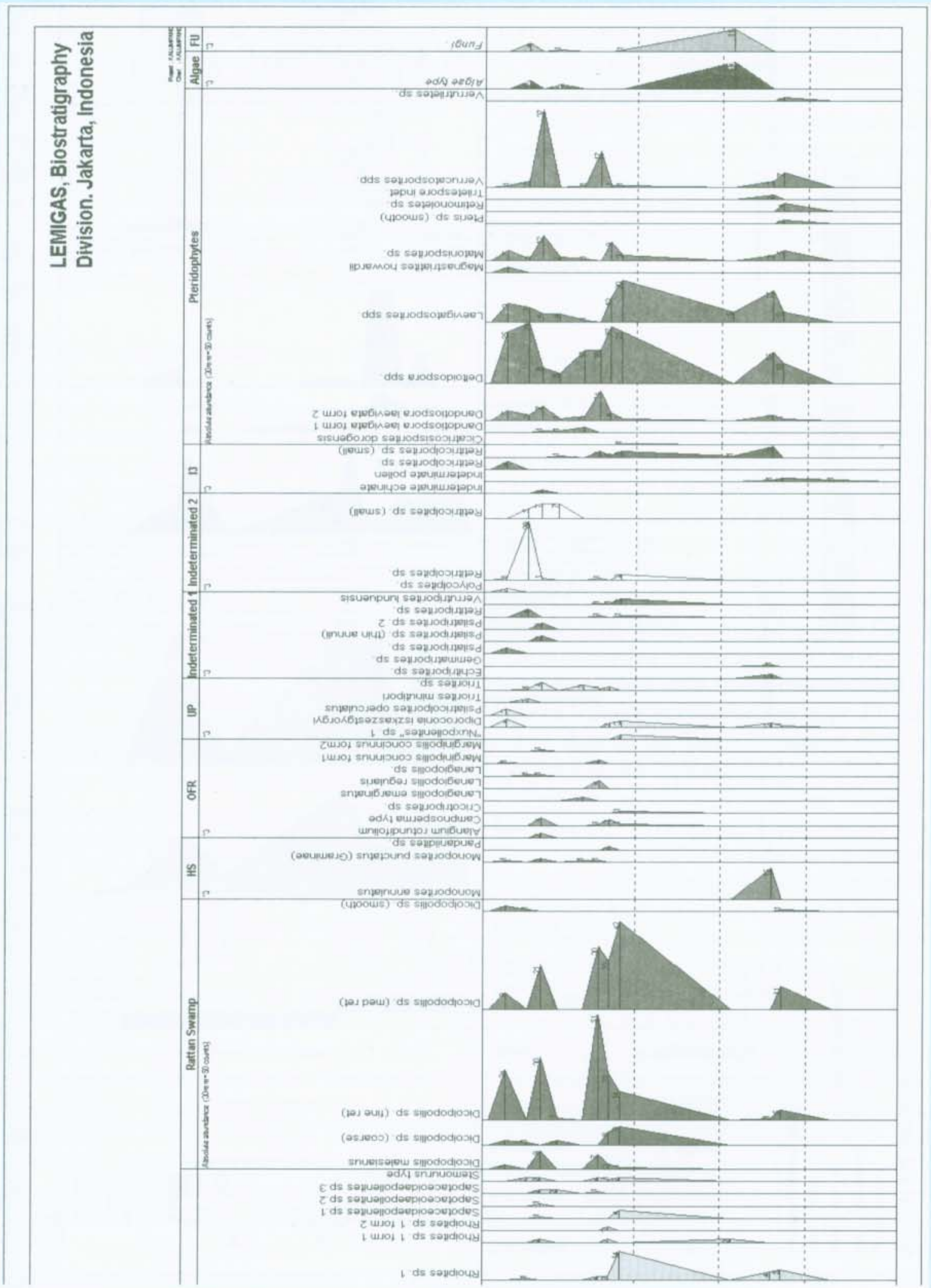


Figure 5
Pollen diagram from the Kalumpang section shows the palynomorph assemblage existing in the Toraja Formation (Continu to page 16)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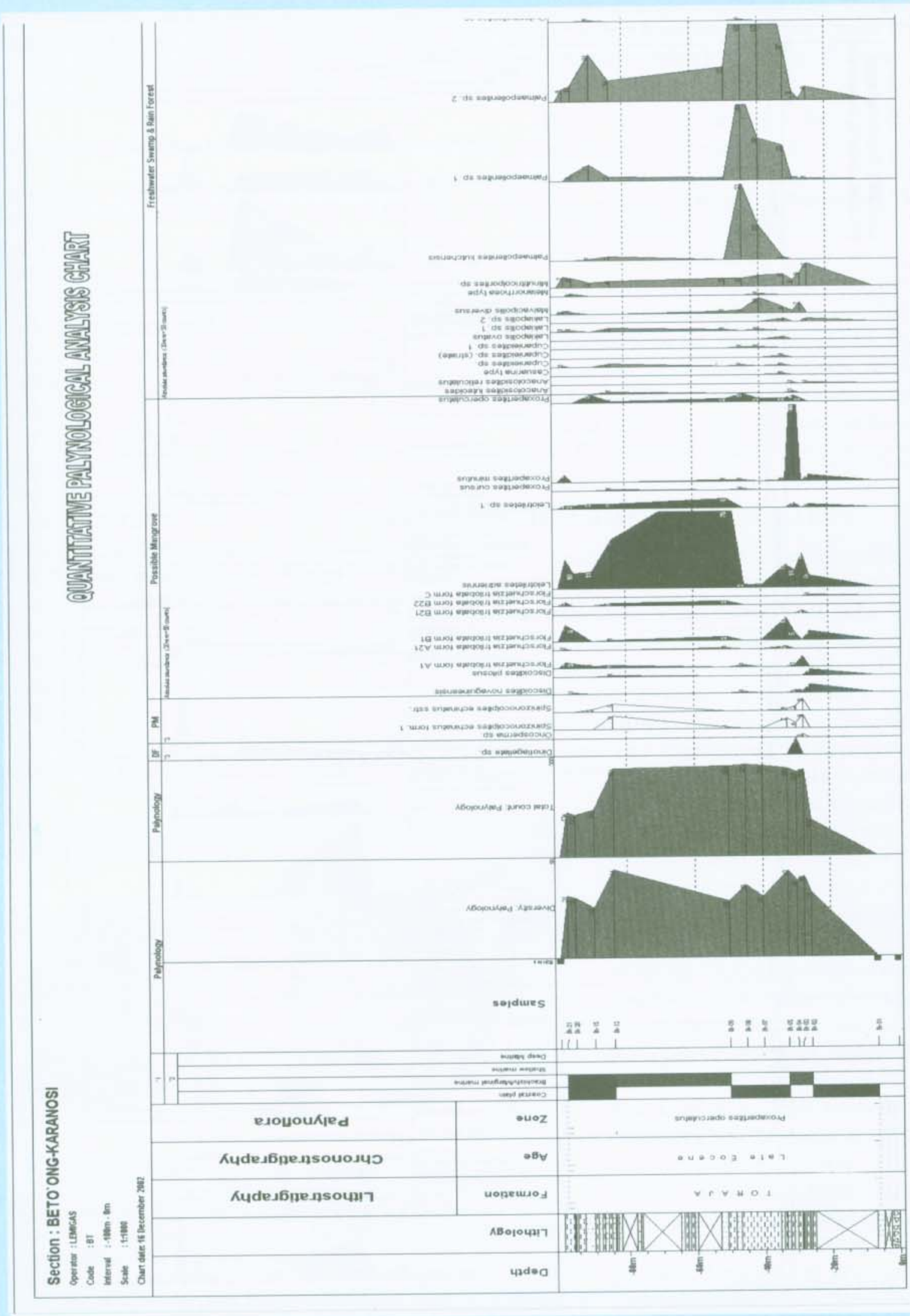
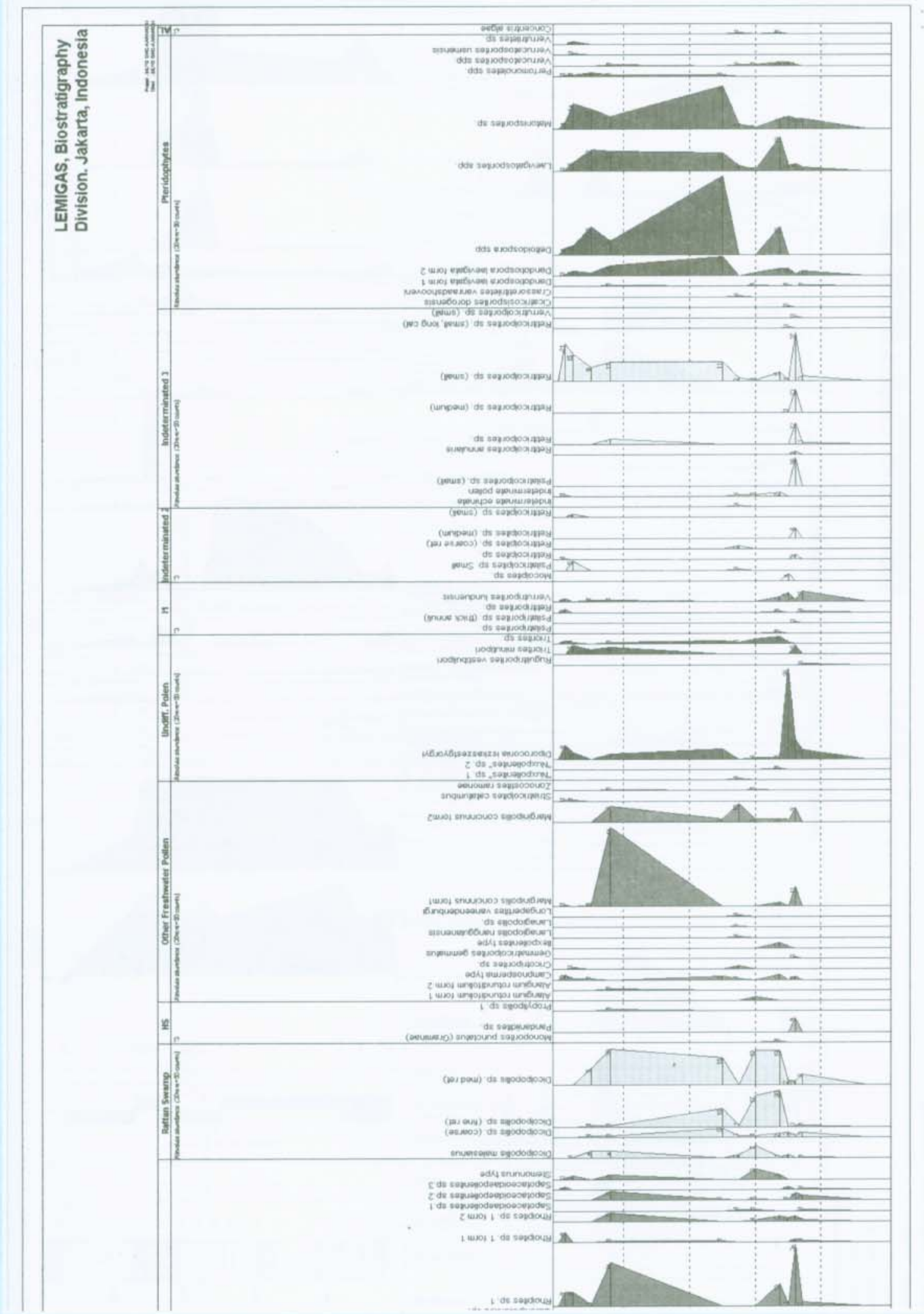


Figure 6
Pollen diagram from the Beto'ong-Karanosi section exhibits palynomorph assemblage which occurs in the Toraja formation
(Continu to page 18)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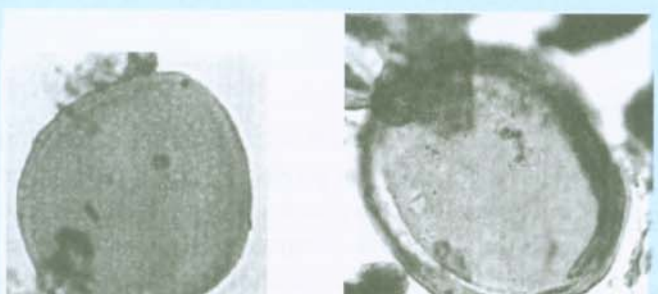
Other Freshwater Pollen
Rattan Swamp

interpreted by Morley, 1998; Germeraad et al., 1968).

After all, it can be inferred that the age of the Toraja Formation is Late Eocene. From the palynological point of view, the Late Eocene age provides lower pollen diversity than that of the Middle Eocene age.

B. New "marker" of the Late Eocene age

An advantage of conducting this study is finding the new marker for the Late Eocene age. This marker is a pollen of *Proxapertites operculatus* which shows fine reticulation. *P. operculatus* was firstly described by Van der Hammen (1956). It has a few synonyms such as *Monocolpites operculatus* Van der Hammen (1954) and *Proxapertites hammenii* Ventkatachala and Rawat (in Thanikaimoni et al., 1983). This pollen represents an extinct group of palm which is possibly related to *Nypa* (Muller, 1968). Therefore, it is interpreted that this may have been produced by mangrove vegetation. In western Indonesia, *P. operculatus* appears to identify the Eocene succession (Morley, 1991). Detail description of *P. operculatus* occurring in the Middle Eocene Nanggulan Formation is as follows (Figure 7. a): Single grain, anisopolar with bilateral symmetry. The grain is flat and oval-rounded in polar view. Zonocolpate aperture encircles the equator dividing the grain into two almost equal parts. The colpus is ektexinous and is bordered by a narrow and indistinct margin of thinned sexine. Sculpture is reticulate to finely perforate-reticulate. Exine ranges between 1.5 and 2.5 µm with distinct structure and thinning towards the colpus margin. Exine is clearly divided into 1 mðm thick nexine and 1 µm thick sexine with columellae less than 1 mðm long. Lumina are less than 1 mðm in diameter. The grain size varies from 34-38 to 48-49 µm.



a) b)

Figure 7
Proxapertites operculatus **that appears in the Middle Eocene Nanggulan Formation of Central Java (7. a).** ***P. perculatus*** **with finer reticulate sculpture occurs to haracterise the Late Eocene Toraja Formation of South Sulawesi and the Late Eocene Bayah Formation of West Java (7. b).**

P. operculatus appearing in the Late Eocene of the Toraja Formation resembles *P. operculatus* from the Middle Eocene of the Nanggulan Formation. Both palynomorphs provide similar description. They are only distinguished one to another by their reticulation. Apparently, *P. operculatus* from the Toraja Formation has finer sculpture, narrower lumina and less visible columellae than that from the Nanggulan Formation (Figure 7. b). It has lumina with the diameter of less than 0.5 µm. *Proxapertites operculatus* with fine reticulate is assumed to widely distribute across the western part of Indonesia as it is reported to appear in the Late Eocene Bayah Formation of West Java (Morley, pers. commun., 2002).

VII. PALAEOBIOGEOGRAPHY

Research on the Late Eocene Toraja Formation cropping out in South Sulawesi shows the occurrence of palynomorphs which derive from India. Most of them are key palynomorphs including *Lakiapollis ovatus*, *Palmaepollenites kutchensis*, *Proxapertites operculatus*, *P. cursus*, *Longapertites vaneedenbergi*, *Anacolocidites luteoides*, *Retistephanocolpites williamsi* and *Dandotiospora laevigata* (Table 1). These Indian taxa are also found in the Middle Nanggulan Formation of Central Java (Lelono, 2001). The similarity between palynomorphs from the Toraja and Nanggulan Formations is an evidence of land connection between South Sulawesi and Java during Middle to Late Eocene. In addition, study by Morley (1998) on the Middle Eocene Malawa Formation from Southwest Sulawesi also shows similar pollen assemblages to those of the Toraja and Nanggulan Formations, including the appearance of *Lanagiopollis* cf. *L. regularis*, *Retistephanocolpites williamsi*, *Quillonipollenites* sp., *Lakiapollis ovatus*, affinity. *Beaupreadites matsuokae*, *Polygalacidites clarus*, *Dandotiospora laevigata* and *Palmaepollenites kutchensis*. These data suggest that, during Middle to Late Eocene, Sunda land extended as far as South Sulawesi. This land connection allowed the spread of Southeast Asian flora which finally ceased fol-

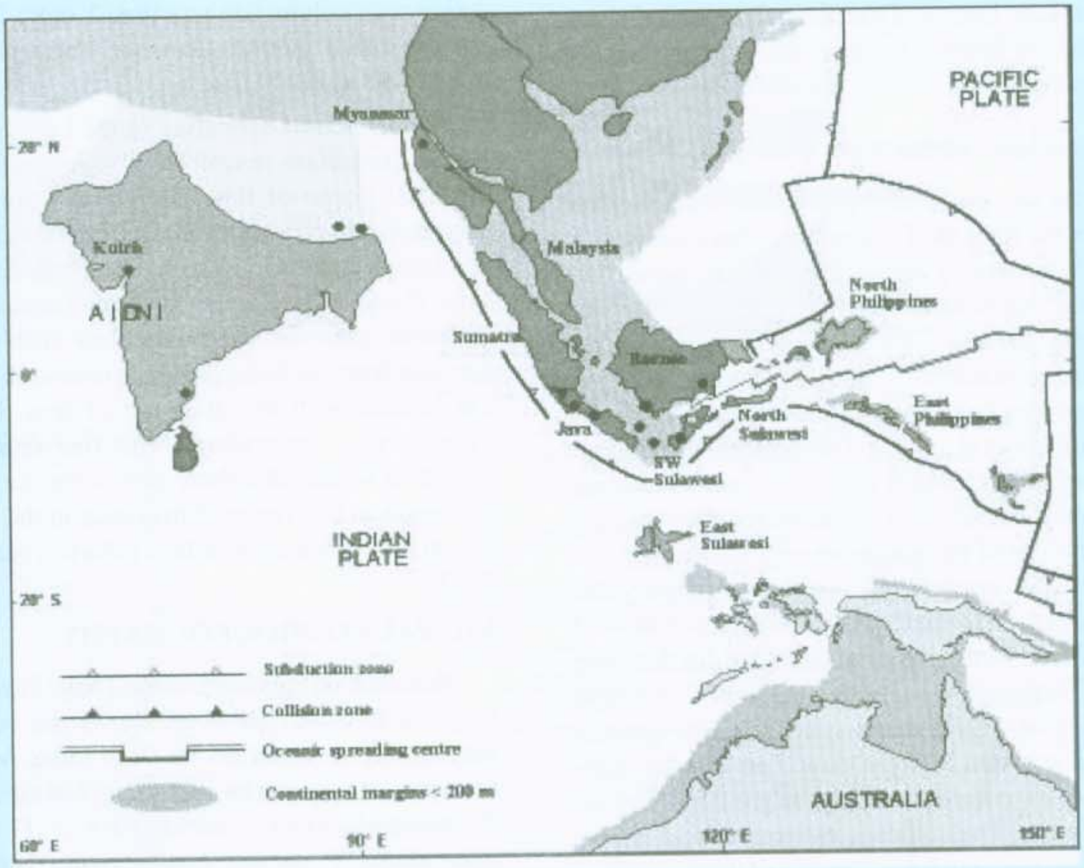


Figure 8
The appearance of *Palmaepollenites kutchensis* (O) within the study area confirms the possibility of vegetational migration patern from India to SE Asia such as indicated by the distribution of this species (●) in both regions (Harley and Morley, 1995), following the collision between Indian and Asian plates at about 40 Ma as reconstructed by Hall (1998)

lowing the opening of the Makassar Strait (Situmorang, 1982). It is believed that South Sulawesi contributed to the migration of Southeast Asian vegetation across Wallace's Line into Eastern Indonesia (Morley, 2000).

In Central Java and South Sulawesi, palynomorphs with Indian affinity occur in the Middle to Late Eocene succession, but are recorded from Palaeocene to Early Eocene of India as shown in Table 2 (Morley, 1998). This supports the timing of the arrival of the Indian Plate against the Eurasian Plate in the Early Tertiary as suggested by Hall (2002). As North India and Southeast Asia experienced the same ever-wet and equatorial climate during Middle Eocene (Morley, 2000), some Indian vegetation spread into Southeast Asia vice versa. The Indian vegetation was more aggressive than the Asian contender, as proven by the greater number of Indian Elements in Southeast Asia than Asian elements in India. Figure 8 illustrates the distribution of palm *Palmaepollenites kutchensis* throughout Southeast Asia and India which suggests the vegetational migration pattern from India to Southeast Asia (Harley and Morley, 1995), following the collision between India and Asian plates at about 40 Ma (Hall, 1998).

VIII. CONCLUSION

The result of this study enriches the understanding of the Eocene palynology in western Indonesia. It allows differentiation between the Middle and Late Eocene

Family/ Tribe	Fossil taxon/ extant taxon
Olaceae	*Anacolocidites luteoides* Cookson and Pike 1954
Sapindaceae	*Cupanieidites* cf. *C. flaccidiformis* Frederiksen 1994
Indeterminated	*Dandotiospora laevigata* Morley 1998
Bombacaceae	*Lakiapollis ovatus* Venkatachala and Kar 1969
Palmae/ Calamoidae	*Longapertites vaneedenbergi* Germeraad et al. 1968
Palmae/ Iguanurinae	*Palmaepollenites kutchensis* Venkatachala and Kar 1969
Palmae	*Proxapertites cursus* Van Hoeken-Klinkenberg 1966
Palmae	*Proxapertites operculatus* Van der Hammen 1956
Palmae/ Calamoidae	*Quillonipollenites* sp Rao and Ramanujam 1978
Ctenolophonaceae	*Retistephanocolpites williamsi* Germeraad et al. 1968

Table 1
Palinomorphs with Indian affinity which are found in the Nanggulan Formation of Central Java and the Toraja Formation of South Sulawesi

Family / tribe	Fossil taxon/ extant taxon
Olaceae	*Anacolocidites luteoides* Cookson and Pike 1954
Proteaceae	aff. *Beaupreadites matsuokae* Morley et al. 2000
Sapindaceae	*Cupanieidites* cf. *C. flaccidiformis* Frederiksen 1994
Indeterminated	*Dandotiospora laevigata* Morley 1998
Linaceae	*Ixonanthes* type
Bombacaceae	*Lakiapollis ovatus* Venkatachala and Kar 1969
Palmae/ Calamoidae	*Longapertites vaneedenbergi* Germeraad et al. 1968
Palmae/ Iguanurinae	*Palmaepollenites kutchensis* Venkatachala and Kar 1969
Podocarpaceae	*Podocarpidites* Couper 1953 spp
Polygalaceae	*Polygalacidites clarus* Sah and Duta 1968
Palmae	*Proxapertites cursus* Van Hoeken-Klinkenberg 1966
Palmae	*Proxapertites operculatus* Van der Hammen 1956
Palmae/ Calamoidae	*Quillonipollenites* sp Rao and Ramanujam 1978
Ctenolophonaceae	*Retistephanocolpites williamsi* Germeraad et al. 1968

Table 2
Palinomorphs with Indian affinity which occur in the Nanggulan and Toraja Formations. They first appear in Paleocene of India, but Middle Eocene of Southeast Asia (Morley, 1998; Thanikaimoni, 1983; Venkatachala et al., 1996)

successions. The Middle Eocene age is represented by the Nanggulan Formation of Central Java whilst the Late Eocene age is represented by the Toraja Formation of South Sulawesi. Key palynomorphs characterising the Middle Eocene age clearly disappear from the Late Eocene age such as aff. *Beaupreadites matsuokae*, *Ruellia* type, *Polygalacidites clarus*, *Ixonanthes*, *Cupanieidites* cf. *C. flacciddiformis*, *Cicatricosisporites eocenicus*. In addition, the Late Eocene is also indicated by the occurrence of pollen *Proxapertites operculatus* with finely reticulate sculpture. This pollen also appears to characterise the Late Eocene Bayah Formation of West Java. However, index taxa indicating the Eocene age occur in both Middle and Late Eocene ages including *Diporoconia iszkaszentgyorgyi*, *Palmaepollenites kutchensis*, *Proxapertites operculatus*, *P. cursus* and *Dandotiospora laevigata*.

The study proves the appearance of many Indian affinities within the Toraja Formation such as *Palmaepollenites kutchensis*, *Proxapertites operculatus*, *P. cursus* and *Retistephanocolpites williamsi*. These palynomorphs also occur in the Nanggulan Formation of Central Java. The similarity between palynomorphs from the Toraja Formation and the Nanggulan Formation suggests land connection between South Sulawesi and Java during Middle to Late Eocene. In addition, the occurrence of Indian taxa in both Toraja and Nanggulan Formations indicates the possible period of collision between Indian continent and Asian plate in Eocene age.

IX. ACKNOWLEDGEMENT

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