PLEISTOCENE PALYNOLOGY OF THE WAIPONA BASIN, PAPUA

by
Eko Budi Lelono

ABSTRACT

The Pleistocene sediment from a single well drilled on the back bone of Papua provides good pollen recovery which shows the mixture of the Australian and Asian elements. The well drilled the sediment more than 3000 meter deep which is mostly assigned to Pleistocene age. Only small part of the basal section belongs to Pliocene age. In order to obtain accurate interpretation, the age interpretation is also defined using other disciplines including foraminifera and nannoplankton. The Australian affinity appears as an origin since this island has derived from the Australian continent. On the other hand, the existence of Asian palynomorphs within the studied sediment indicates the dispersal of Asian flora into East Indonesia following the arrival of the Australian plates at about the end of Oligocene. The Asian taxa then migrated to the land mass of New Guinea which rose above sea level from about Middle Miocene onward. In the studied section, shallow marine sediment in the upper interval contains sufficient palynological assemblages which clearly indicate climatic changes from dry or seasonal to wet climate as reflected on the changes of the proportion of dry/ seasonal and wet climate indicators. Unfortunately, due to low pollen recovery, the climate condition of the lower interval can be hardly interpreted. This could have happened because the sediment of the lower interval was deposited in deep marine environment, which was situated far away from the pollen sources in the continent.

Keywords: Pleistocene palynology, Waipona Basin, Papua.

I. INTRODUCTION

The area of study is located in the northern part of Papua island which is a part of Waipona Basin (Figure 1). Palynological research on the Quaternary and Late Neogene sediments existing in the studied area is limited mostly due to the difficulty of data access. In addition, limited number of wells drilled in this area prevents biostratigraphers to obtain sufficient samples for comprehensive analysis. Similar situation occurs in order to provide surface samples. Wild jungle and dense vegetations are the obstacles to find suitable outcrops for applying measure section method. In this case, transportation for reaching out the outcrops is the major problem. As a result, there are little samples that can be used for proper palynological examination. Therefore, it is required sufficient data to access Late Neogene palynology of northern Papua. Having said that, this paper is intended to reveal palynological records of Plio-Pleistocene sediments which will contribute to an understanding of the Quaternary and Late Tertiary palynology in East Indonesia generally and Papua specifically.

Papuan forest is today occupied by typical East Indonesian vegetation which is relatively closed to the Australian flora. This can happen as this island was a part of the Australian element which appeared in East Indonesian region at about Middle Miocene (Hall, 1995). It is well known that the Indonesian flora is separated into two provinces by Wallace line which is situated between Kalimantan and Sulawesi. The area situated in west of the Wallace line is mostly dominated by Asian flora, whilst the area located in the eastern line mostly possesses flora with Austra-

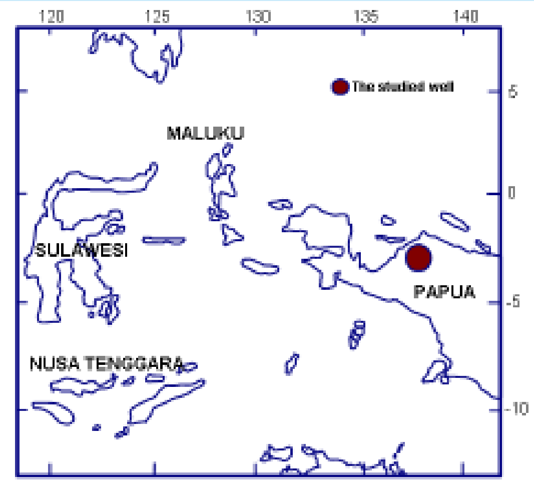

Figure 1
Map shows the area of study

lian affinity. The subduction of Australian plate into Sundaland as a result of the northward movement in the latest Oligocene promoted some Australian taxa into Sunda land vice versa (Figure 2). Both parts were isolated one to another before Late Oligocene. Therefore, in regard to pollen record, in the Sundaland, Australian palynomorphs hardly occur in the Oligocene sediments or older. On the contrary, Asian contenders will not appear in East Indonesia at least before Oligocene age. The existence of Asian flora present-day in Papua may have been triggered by the Late Oligocene collision which allows migration of some Asian flora into Papua. This could be the source of the appearance of Asian vegetation in Papua. However, this is not the only source for Asian elements as the Early Tertiary island arcs of the Philippines and Halmahera mostly dominated by Asian flora could also have been a primary source (Good, 1962). Mean

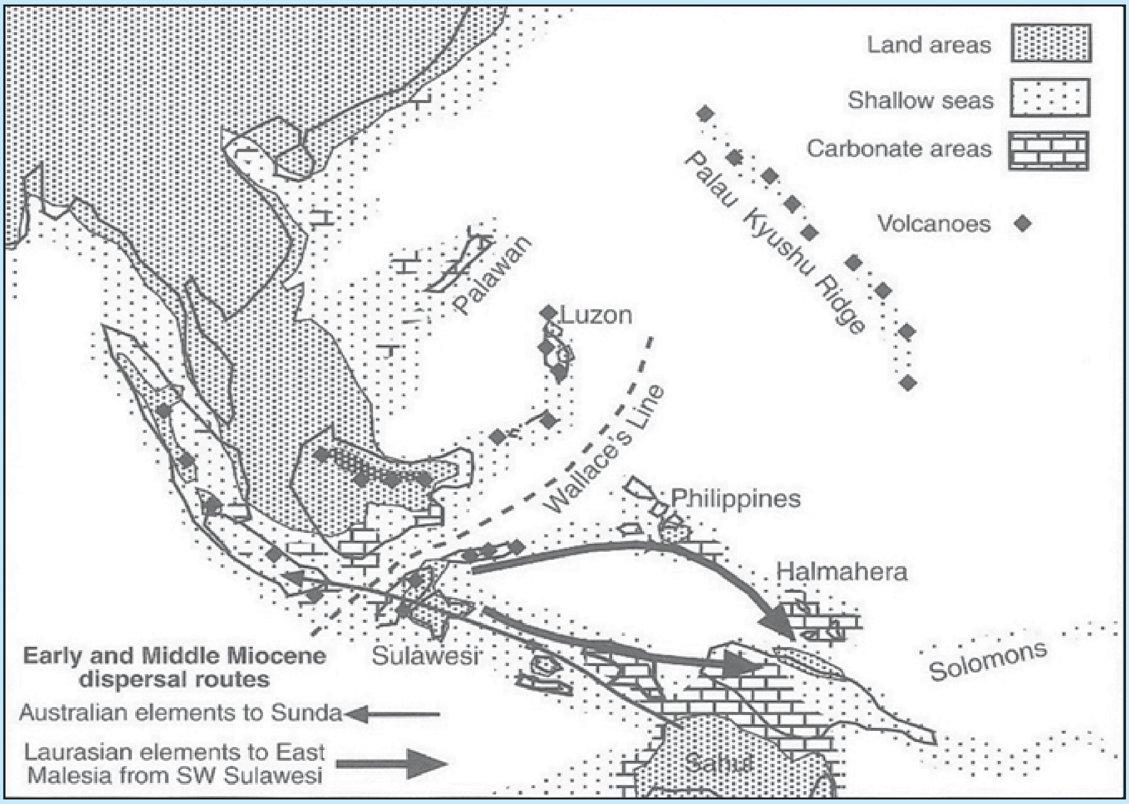

Figure 2
Possible dispersal paths for the Asian flora from Southwest Sulawesi into East Indonesian islands as they were formed during Middle Miocene, vice versa (taken from Morley, 2000). The map shows paleogeographical reconstruction of Southeast Asia during Early Miocene (Hall, 1998a) and the position of the Wallace's Line.

while, after carefully reviewing the Australian palynological data, Truswell et. al. (1987) inferred minimal evidence for invasion of elements from SE Asia at the time of collision.

The data was obtained from an exploration well which was drilled in the on-shore area. It penetrated more than 3000 meter thick of sediment which consists of various lithologies such as shale, sandstone and limestone. In fact some lithologies are in unconsolidated condition which might have been partly caused by rapid deposition. The sediments occurring in the studied well were deposited in the various environments ranging from transition to deep marine setting. In fact, most sediment yields rare to common pollen assemblage which allows biostratigraphic and paleoenvironmental interpretation. Moreover, the studied sediment also provides moderate assemblage of foraminifer and nannoplankton which is useful for independent interpretation. The integration of those micro-fossils allows biostratigrapher to obtain accurate results of zonation and depositional environment.

II. DATA AVAILABILITY

Data used in this paper originally derived from a single well which was drilled in the on-shore of North Papua. This data consists of three different biostratigraphic records including micropaleontology, nannoplankton and palynology. The integration of those records allows biostratigrapher to gain accurate biostratigraphic and paleoenvironmental interpretations.

Regarding data confidentiality, this paper only shows well depth with selected micro-fossil distribution. Detail information such as geographical position, formations, well log, etc. is hidden. Due to space limitation, only micro-fossils related to the purposes of this paper are shown.

III. METHODS

Three main laboratory analyses are employed in this study including palynology, foraminifer and calcareous nannoplankton.

The biostratigraphic analyses apply 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 specific software called StrataBug.

The diversity and abundance of micro-fossils 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 interpretations 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 foraminiferal zone proposed by Blow (1969) with some modifications. For nannoplankton analysis, these interpretations refer to calcareous nannoplankton zone of Martini (1971) with some modification. In addition, palynological zone proposed by Lelono et al. (1996) is used to infer zonal subdivision as well as age interpretation (Figure 3). 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 (1997).

The biostratigraphic assessment using three different disciplines provides independent results which allow biostratigrapher to cross-check one result to another to gain accurate interpretation. This means that the result of palynological analysis can be easily tested with other analyses (foraminifer and nannoplankton) to obtain reliable picture of the Pleistocene palynology in Northern Papua area.

IV. PALEOENVIRONMENT

Generally, according to foraminiferal analysis, paleoenvironment is separated into shallow marine setting situated in the upper part of the studied interval (90m-1224m) and deep marine setting in the lower interval (1224m-3200m) as shown in Figure 4. Shallow marine environment ranges from inner to shallow middle neritic (0m-50m) as indicated by the occurrence of shallow marine taxa including *Ammonia* sp., *Asterorotalia* sp., *Bolivina* sp., *Cibicides*

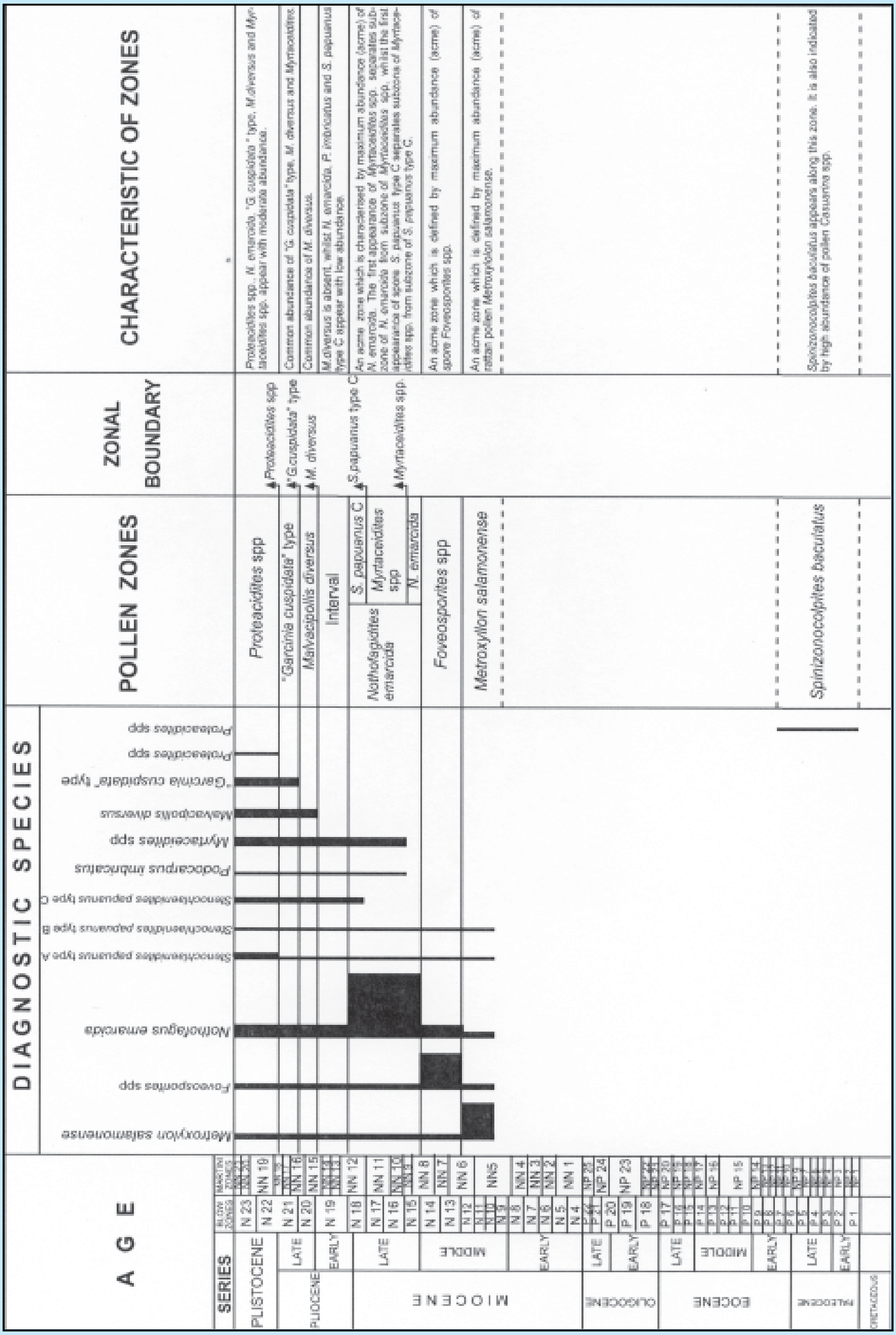

Figure 3
Palynological zonation of Papua (Lelono et al., 1996)

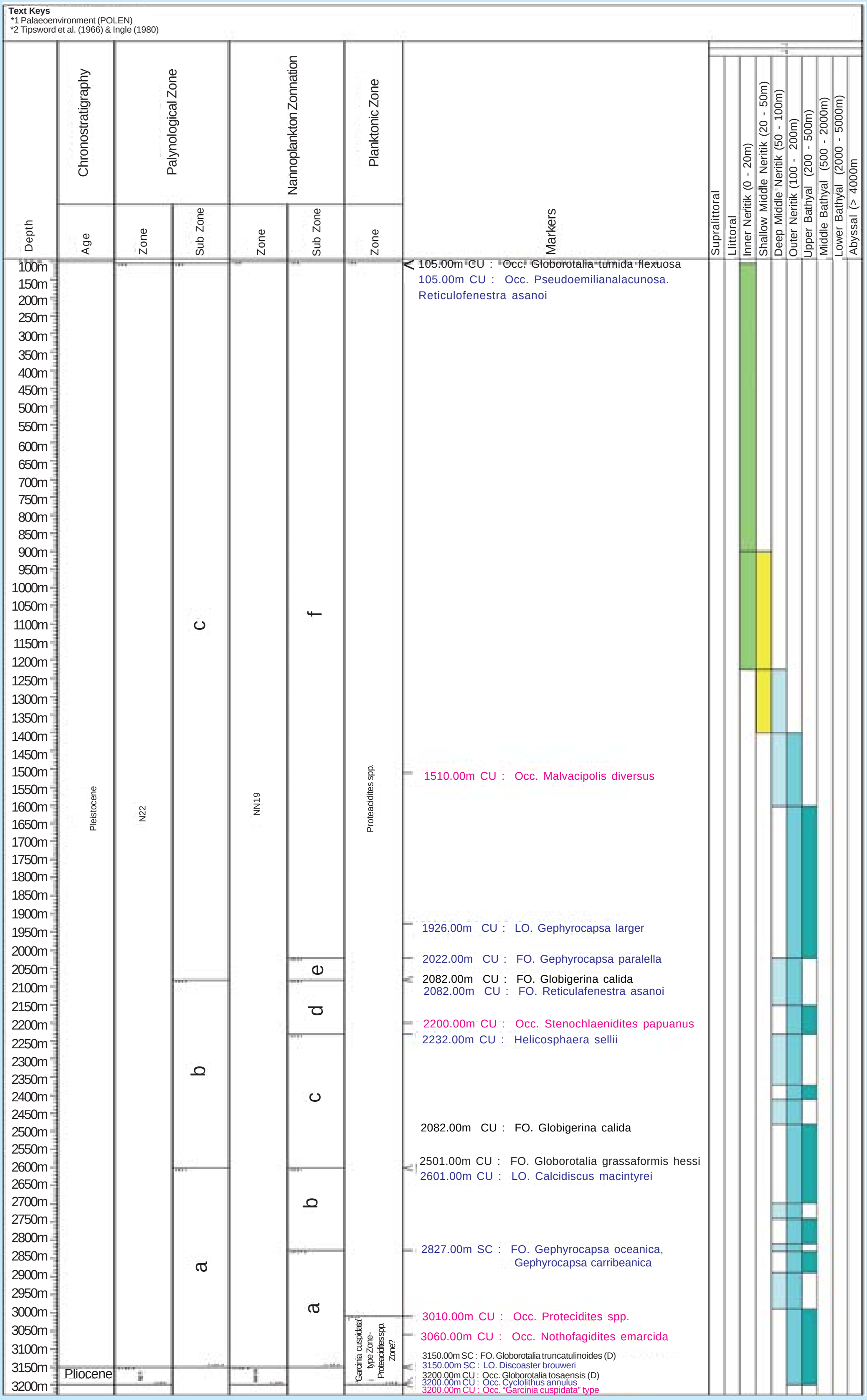

Figure 4
Summary of biostratigraphy and depositional environment of the studied well

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 2, AUGUST 2008 : 7 - 18

praecinctus, *Elphidium* sp., *Operculina ammonoides* and *Quinqueloculina* sp. This environment is also characterised by low planktonic foraminiferal assemblage (Lemigas, 2007). On the other hand, deep marine environment includes deep middle neritic to upper bathyal (50m-500m) as suggested by the appearance of deep marine markers such as *Bolivina robusta*, *Bulimina marginata*, *Bulimina striata*, *Cassidulina pasifica*, *Cancris indicus*, *Planulina wuellerstorfi* and *Uvigerina peregrina*. Planktonic foraminifer is abundant in this environment (Lemigas, 2007). In addition, this situation is reflected on its palynological record in which shallow marine setting provides higher pollen assemblage compared to that of deep marine setting. Shallow marine exhibits common abundance of mangrove pollen *Zonocostites ramonae*, where as deep marine sediment shows low abundance of this pollen indicating long distance of transportation from the pollen source (continent). The high abundance of pale bissacate pollen and *Casuarina* type within deep water sediment may suggest contaminant forms which will be ignored in palynological interpretation (Figure 5).

Although the sediment in the lower interval was deposited in the deep water environment, it contains low palynomorph assemblage which is considered as in-situ. Palynomorphs mostly supplied from the land were deposited together with the sediment in the deep water environment. Therefore, the occurrence of age-restricted pollen in this environment is available for zonal subdivision and age determination. Basically, paleoenvironmental interpretation refers to the foraminiferal content especially environmental markers of the benthic forms which appear in each sample. However, paleoenvironment based on palynological content may be applied for shallow water sediment which is situated in the upper interval. Based on palynological analysis, the depositional environment of the shallow water sediment ranges from pro-delta to delta front (Figure 5).

V. AGE INTERPRETATION

The Papuan palynological zonation proposed by Lelono et al. (1996) is different compared to the Javanese zonation of Rahardjo et. al. (1994). The Papuan zonation is mostly characterised by the appearance of Australian elements especially in the Neogene (Figure 3), whilst the Javanese zonation strongly refers to the occurrence of the Asian palynomorphs (Figure 6). This is because Papua originally derives from the Australian continent which bears the Australian floras. On the basis of the occurrence of pollen *Proteacidites* spp. in 3010m, most studied sediment is mainly assigned to Proteacidites spp. zone which equals to Pleistocene (interval 90m-3010m) as exhibited in Figure 5. Mean while, the appearance of pollen "*Garcinia cuspidata*" along the basal section (interval 3010m-3200m) suggests "Garcinia cuspidate" type to Proteacidites spp. zone within this interval which is equivalent to Pleistocene or older (Lelono et al., 1996). Referring to the appearance of planktonic foraminifer *Globorotalia tumida flexuosa* in 100m and the first occurrence of planktonic foraminifer *Globorotalia truncatulinoides* (D) in 3150m, the studied section is mostly designated to zone N22 or Pleistocene (interval 100m-3150m). Only small part of the lower section (interval 3150m-3200m) indicates zone N21 or Pliocene based on the occurrence of *Globorotalia tosaensis* (D) in 3200m (Figure 4). In addition, nannoplankton analysis supports the result of foraminiferal analysis, in which most section (interval 100m-3150m) indicates zone NN19 (Pleistocene) based on the occurrence of *Pseudoemiliana lacunosa* and *Reticulofenestra asanoi* in 100m and the last occurrence of *Discoaster brouweri* in 3150m. Mean while, a small part of the basal section (interval 3150m-3200m) shows zone NN18 (Pliocene) as marked by the occurrence of *Cyclolithus annulus* in 3200m (Figure 4).

VI. CLIMATE IDENTIFICATION

Plio-Pleistocene sediments of West Indonesia are characterised by high abundance of grass pollen of *Monoporites annulatus* indicating the expansion of savanna vegetation during dry climate phase (Figure 6). This is often combined with abundant charred gramineae cuticles which possibly indicate savanna fire (Lelono, 2006). In Java, abundant grass pollen is usually found together with abundant *Casuarina* pollen in the Pliocene sections suggesting an open sclerophyllous savanna with the domination of *Casuarina* (Morley, 2000). The appearance of *Casuarina* savanna may relate to the phases of forest destruction due to volcanic activity, as *Casuarina junghuhniana* dominantly lives on the present volcanoes of East Java and Nusa Tenggara which is

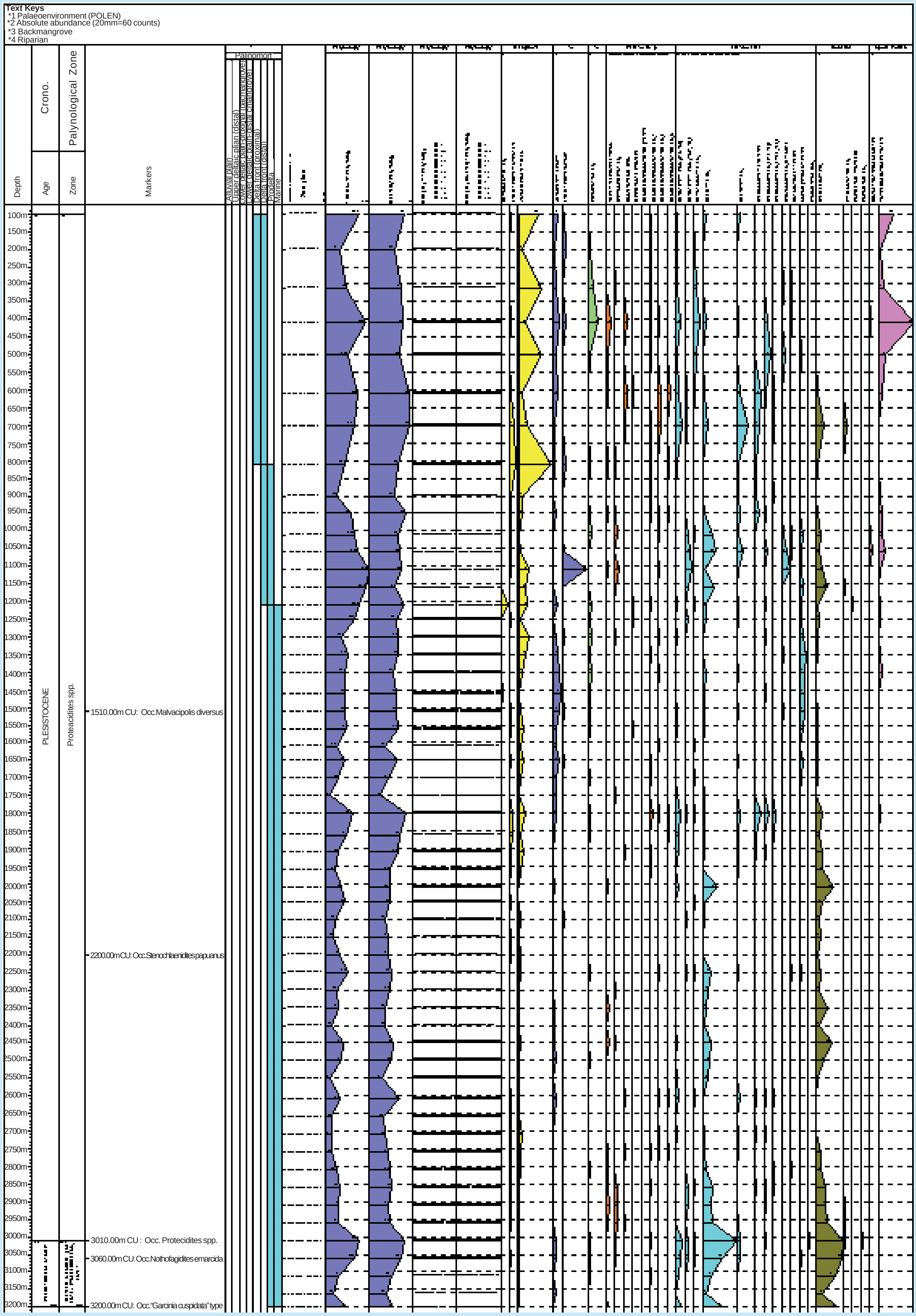

Figure 5
Quantitative palynological distribution chart of the selected palynomorphs which are used in this paper

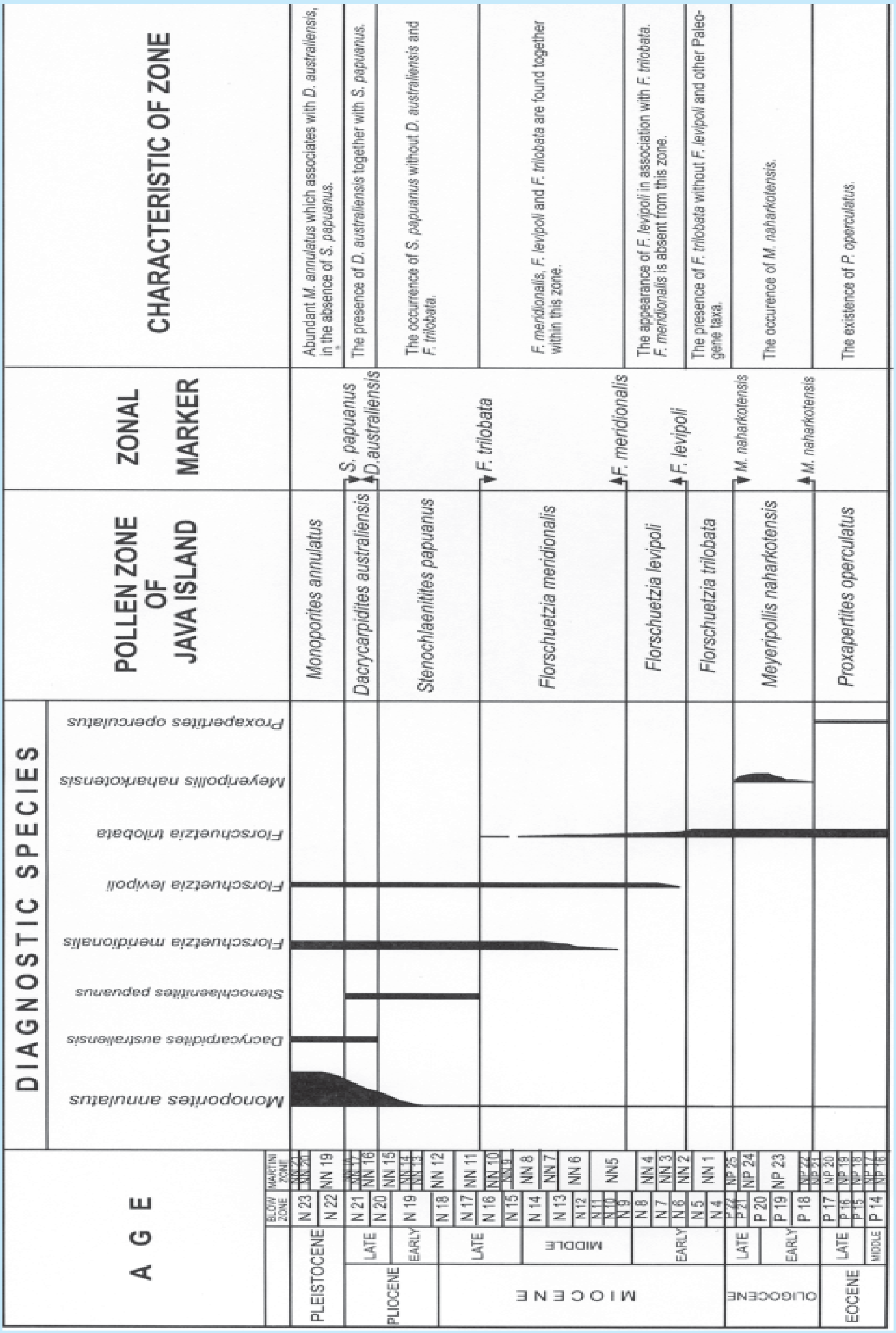

Figure 6
Palynological zonation of Java Island (Rahardjo et al., 1994).

called fire-climax forest (Morley, 2000). In addition, the distribution of the mangrove genus *Camptostemon* (Bombacaceae) may relate to phases of dry climate within the Late Miocene and Pliocene of Sarawak (Morley, 2000). This pollen shows successive phase of expansion, coinciding with low sea level periods (Chow, 1996).

Unlike Plio-Pleistocene sediment of Western Indonesia which was mostly formed in the transition to shallow marine environment with excellent palynomorph records, the studied sediment was deposited in a much deeper environment in upper bathyal in the lower interval to inner neritic in the upper interval. Therefore, palynomorph recovery varies from rare in upper bathyal to common in inner neritic. This can happen because upper bathyal is situated further from pollen source (continent) compared to inner neritic. Having this condition, rare occurrence of palynomorphs may be considered as significance. The climate indicators occur in low abundance throughout well section which results in the difficulty in differentiating changes. Possible seasonal climate indicators appearing in this well are *Monoporites annulatus*, *Casuarina*, *Camptostemon* and montane pollen of *Pinuspollenites* sp. and *Podocarpus imbricatus*.

Mean while, the sediment in the upper interval yields moderate abundance and diversity of palynomorphs as shown by mangrove pollen of *Zonocostites ramonae* and *Florschuetzia meridionalis*, back-mangrove palynomorphs of *Florschuetzia levipoli* and *Acrostichum aureum*, riparian pollen of *Ilexpollenites* sp., peatswamp pollen of "*Garcinia cuspidata*", *Cephalomappa* type and *Sapotaceoidaepollenites* spp. and freshwater pollen of *Calophyllum* types, *Campnosperma* sp., and *Dicolpopollis* sp (Figure 5). These angiosperms may have been an evidence for the wet climate development during the deposition of the sediment situated in the upper interval. With the exception of the lower interval (1200m-3200m) which indicates deep water environment of upper bathyal to outer neritic, the climatic changes of the upper interval (90m-1200m) can be recognised as follows (Figure 7): It was commenced by sea level fall (interval 1200m-1150m) which is suggested by the increase of mangrove element *Camptostemon*. The expansion of this pollen during sea level drop coincided with the period of dry climate (Chow, 1996). The dry climate turned to wet in interval 1150m-1050m as indicated by considerable increase of pollen *Florschuetzia levipoli* suggesting the development of back-mangrove vegetation. This is supported by the decrease of seasonal climate indicators such as *Casuarina* and *Dacrydium*. Mean while, peat swamp pollen of *Blumeodendron* and *Cephalomappa* increase marking wet climate condition. Subsequently, seasonal climate took place in interval 1050m-940m which is suggested by the increase of *Casuarina* combined with grass pollen of *Monoporites annulatus*. In addition, montane pollen of *Dacrydium* and spore of *Verrucatosporites usmensis* increase significantly to mark this climate. The climate then was back to wet as indicated by the increase of mangrove pollen *Zonocostites ramonae* and back-mangrove *Florschuetzia meridionalis* (interval 940m-690m). On the other hand, some seasonal climate markers decrease considerably including *Casuarina* and *Dacrydium*. The seasonal climate in interval 690m-600m is defined by the decrease of *Zonocostites ramonae*. On the contrary, seasonal indicators increase to indicate this climate including *Casuarina*, *Dacrydium*, *Pinuspollenites* sp. and *Podocarpus polystachyus*. Finally, the wet climate condition dominates the top interval (600m-90m) as marked by the increase of the brackish palynomorphs such as *Zonocostites ramonae*, *Florschuetzia levipoli* and *Acrostichum aureum*. More over, some fresh water pollen also increase including *Dicolpopollis malesianus* and *Dicolpopollis* spp. Pteridophyte spore of *Verrucatosporites usmensis* suggesting moist condition is abundant throughout this interval. Mean while, most seasonal climate indicators decline significantly as shown by *Casuarina*, *Dacrydium* and montane elements of *Pinuspollenites* sp., *Podocarpus polystachyus* and undifferentiated bissacate pollen (Figure 7).

The climatic changes may relate to the sea level curves which affect the deposition of the studied sediment. The dry or seasonal climate may indicate low sea level, whilst wet climate may represent high sea level (Morley, 1995). For examples, low sea level in interval 1200m-1150m as indicated by an expansion of mangrove pollen of *Camptostemon* suggests that the sedimentation of this interval occurred during low stand period. Mean while, high sea level in interval 600m-90m may represent high stand and transgressive phases. The high stand phase occurs in interval

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 2, AUGUST 2008 : 7 - 18

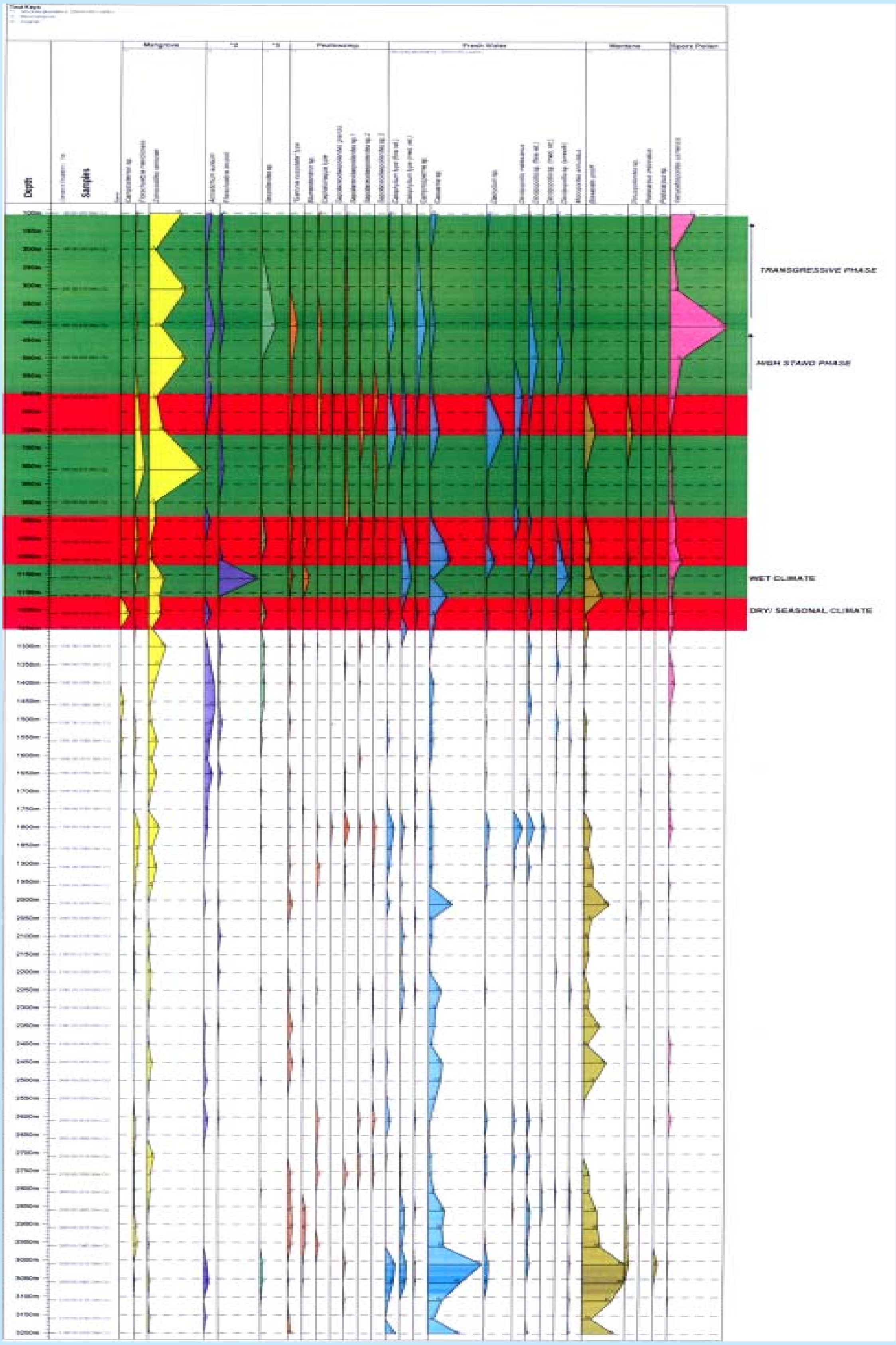

Figure 7
Possible climatic changes appear throughout the upper interval

600m-400m which is defined by the significant increase of freshwater pollen *Ilexpollenites* sp. indicating an expansion of upper delta plain during the end of high stand period (Figure 7). This is supported by high abundance of pteridophyte spore *Verrucatosporites usmensis*. The high stand period is taken over by the transgressive period occupying interval 400m-90m as indicated by high abundance of mangrove pollen *Zonocostites ramonae* along this interval.

VII. CONCLUSION

Palynological investigation on the well samples drilled in Waipona Basin discloses pollen record throughout Plio-Pleistocene sediment with more than 3000m thick. Most part of the studied sediment has pollen zones of Proteacidites spp. which equals to Pleistocene (90m-3010m). Only small part of the section (basal section) is assigned to Proteacidites spp-"Garcinia cuspidata" zone which is equivalent to Pleistocene or older (3010m-3200m). This interpretation is supported by foraminiferal analysis which suggests zone N22 (Pleistocene) covering most interval (90m-3150m) and zone N21 (Pliocene) situated in the basal interval (3150m-3200m). In addition, nannoplankton study indicates that zone NN19 (Pleistocene) for most part of the studied interval (90m-3150m) and zone NN18 (Pliocene) for small part situated in the base interval (3150m-3200m). Referring to the occurrence of the environmental marker of benthonic foraminifers combined with planktonic foraminiferal assemblage and the appearance of palynomorphs and nannoplankton, it is inferred that the sediment in the upper interval (90m-1224m) was deposited in the shallow marine environment (inner neritic to shallow middle neritic), whilst that situated in the lower interval (1224m-3200m) was formed in deep marine environment (deep middle neritic to upper bathyal).

Some palynomorphs with the sensitivity to climatic condition appear to provide signals for identification on the possibility of changes. The climate interpretation is only available for shallow marine sediment in the upper interval (90m-1200m) which contains suitable pollen record. The climate condition in the lower interval (1200m-3200m) can hardly be identified due to poor pollen recovery. Based on the occurrence of these palynomorphs some series of dry/ seasonal climate and wet climate are recognised along the upper interval which presumably relates to the sea level changes during deposition. The dry climate may indicate low stand period, whilst wet climate may represent transgressive and high stand periods.

VIII. ACKNOWLEDGMENT

Data used in this paper is provided for Lemigas's client to support the geological analysis for evaluating hydrocarbon potential of the Plio-Pleistocene sediment of the Waipona Basin. The author is grateful to colleagues in Lemigas Stratigraphy Group for their effort in doing biostratigraphic analyses of the studied area. The author wishes to thank Mohammad Taufik of the Lemigas Stratigraphy Group for his kindly helps with computer programs to produce various biostratigraphic charts.

REFERENCES

1. Blow, W. H., 1969. Late Middle Eocene to Recent Planktonic Foraminiferal Biostratigraphy. In *Proc. 1st Int. Conf. Plank. Microfossils*. pp. 191-422.
2. Chow, Y. C., 1996. Application of Climatic Biosignals to Stratigraphic Studies Offshore Sabah/ Sarawak, Malaysia. *Proceedings of the 9th International Palynological Congress*, Houston Texas, June 1996, Abstract, p. 25
3. Good, R., 1962. On the Geographical Relationships of the Angiosperm Flora of New Guinea. *Bulletin of the British Museum (Natural History), Botany 12*, pp. 205-226.
4. Hall, R., 1995. Plate Tectonic Reconstructions of the Indonesian Region. *Proceedings 24th Annual Convention, Indonesian Petroleum Association*, pp. 71-84.
5. Hall, R., 1998. The Plate Tectonics of Cenozoic SE Asia and the Distribution of Land and Sea. In: Hall, R. and Holloway, J. (eds.), *Biogeography and Geological Evolution in SE Asia*. Bukhuys Publishers, Amsterdam, pp. 99-124.
6. 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.
7. Lelono, E. B., Nugrahaningsih, L., Sukmo Rasyanto, T. B., Wijono, S., Rahardjo, A. T. and Polhaupessy, A. A., 1996. Usulan Zonasi Polen

Kawasan Timur Indonesia. Studi Kasus: Sulawesi dan Irian Jaya. *Dalam Kumpulan Makalah Seminar Nasional, Peran Sumberdaya Geologi Dalam PJP II*, pp. 311-324.

8. Lelono, E. B., 2006. Pleistocene Palynology of East Java. *Lemigas Scientific Contribution to Petroleum Science and Technology*, vol. 29, no. 3, pp. 3-14.

9. Lemigas. 2006. Biostratigraphic Analyses of Well X Located in Waipona Basin, Indonesia. *Unpublished Service Reports*.

10. 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.

11. Morley, R. J., 1995. Biostratigraphic Character ization of System Tracts in Tertiary Sedimentary Basins. *Proceedings of the International Symposium on Sequence Stratigraphy in SE. Asia*, pp. 49-71.

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

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

14. Rahardjo, A. T., Polhaupessy, A. A., Wiyono, S., Nugrahaningsih, L. and Lelono, E. B., 1994. Zonasi Polen Tersier Pulau Jawa. *Proc. IAGI, 23rd Annual Convention*.

15. Tipsword, H. L., Setzer, F.M. and 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.

16. Truswell, E. M., Kershaw, A. P. and Sluiter, A. R., 1987. The Australian-Southeast Asia Connection: Evidence from the Paleobotanical Record. In Whitmore, T. C. (ed.), *Biogeographical Evolution of the Malay Archipelago*. Oxford Monographs on Biogeography 4, Oxford Scientific Publication, pp. 32-49.ˇ