

# STRATIGRAPHIC INTERPRETATION OF THE MIDDLE MIOCENE DELTAIC SEDIMENT IN THE SANGATTA AREA, BASED ON QUANTITATIVE PALYNOLOGICAL DATA

by  
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## ABSTRACT

This study demonstrates the ability of palynology in helping explorationist to comprehend the stratigraphic framework of the middle Miocene formation in the Sangatta area. Palynological analysis is performed on three different wells which are called X, Y and Z. With the exception of the samples situated in the lower part of the studied wells, most samples yield excellent palynomorph assemblages. High abundance of mangrove pollen suggests a good development of mangrove forest which indicates the occurrence of deltaic sediments within these three wells. The studied wells have been correlated based on the abundance of mangrove pollen *Zonocostites ramonae* and freshwater swamp pollen *Ilexpollenites* sp. This correlation allows reconstruction of the local palynological scheme for the Sangatta area. The combination between quantitative palynological analysis and lithological data (inferred from well logs) allows interpretation of sequence stratigraphic units including transgressive and highstand units. These units separate the studied sediments into three progradational units (Units 1, 2 and 3) which figure out the development of Middle Miocene deltaic facies in the Sangatta area.

## I. INTRODUCTION

Sangatta area is situated in East Kalimantan which is approximately 6 kilometers northeast of Balikpapan (Figure 1). Although this area is known to yield rich palynomorphs, little effort is offered to clarify the existing stratigraphy. This study is intended to demonstrate the influences of palynological data in improving the stratigraphy of the Sangatta area. For this particular pur-

pose, three wells representing Middle Miocene sediment have been selected for analyses. These wells were used by the previous authors (Biantoro et al., 1991) to develop the stratigraphic concept of this area (Figure 2). Data obtained during these analyses are considered to be confidential as these are provided for commercial work which are not public domain. Therefore, detail information of these wells can not be revealed within this paper. The wells are named using alphabetic codes such as X, Y and Z. The studied wells were drilled in the anticline structure which suggests structural trap. Well X is situated within the Melawan anticline, whilst well Y is located in the Pinang anticline (Figure 1). These two wells are similar to the wells selected by Biantoro et al. (1991) for reconstructing stratigraphic framework. Well Z is in the Sangatta anticline which is close to Biantoro et al.'s well as illustrated in their publication (1991).

Due to space limitation, only palynological data relevant to the correlation and sequence stratigraphic analysis of the studied wells (X, Y and Z) are presented within this paper (see Figures 5, 6 and 7). These data include the distribution of selected taxa such as *Zonocostites ramonae*, *Florschuetzia meridionalis*, *F. levipoli*, *F. trilobata* (brackish pollen), *Ilexpollenites* spp. and *Calophyllum* type (freshwater pollen). Detail lithological interpretation is based on wireline logs which were provided by the client. However, only lithological log is shown here in order to support sequence stratigraphic analysis (see Figures 5, 6 and 7).

## II. REGIONAL STRATIGRAPHY

The stratigraphy of this area has been proposed by Biantoro et al. (1991). They indicated several phases of transgression-regression during Eocene to Pleistocene in the Kutai basin (Figure 2). Sedimentation firstly occurred in Eocene to Oligocene which was characterised by the transgression with the direction from east to the west. By the end of Oligocene, sedimentation changed

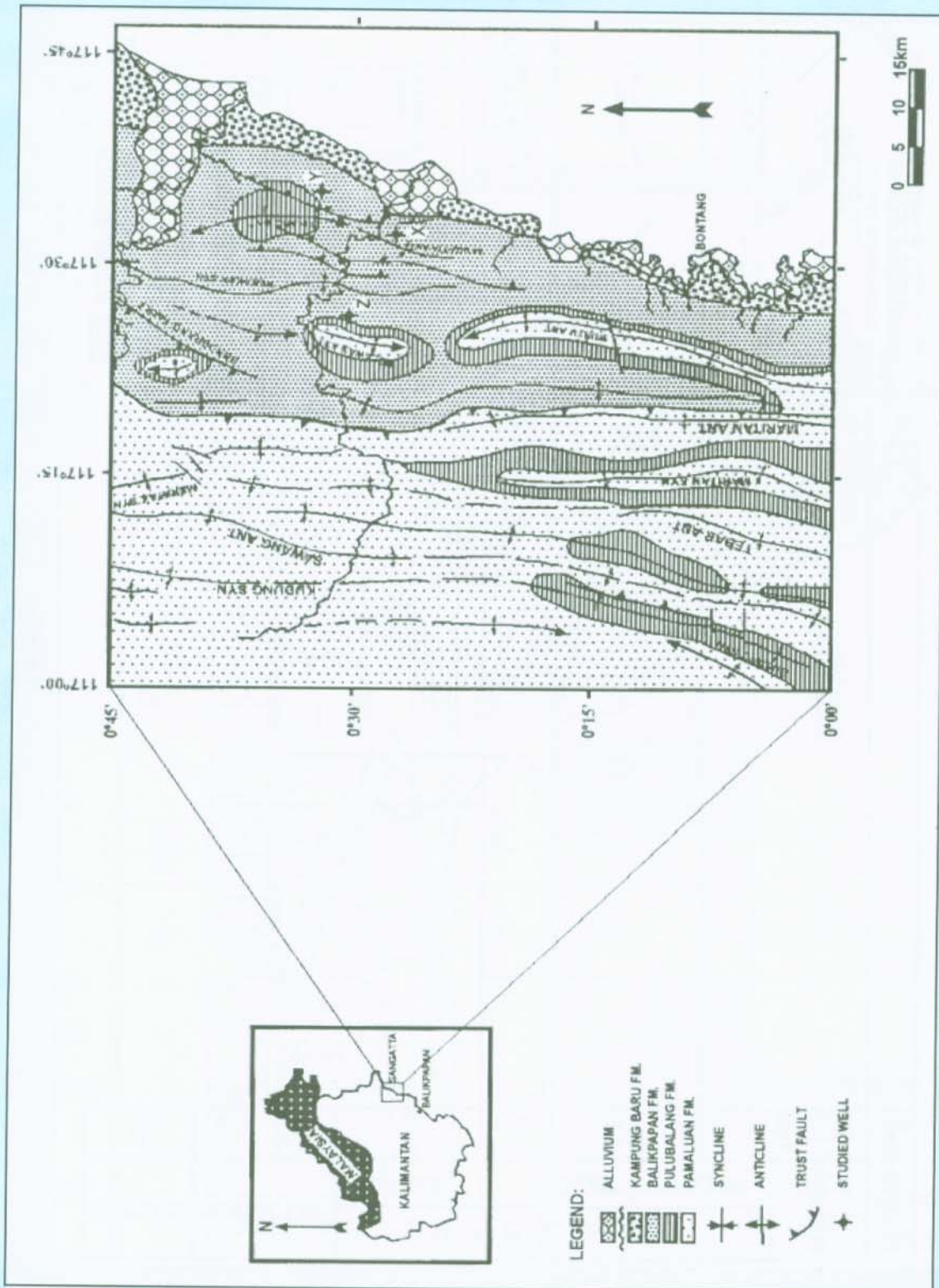


Figure 1  
 Area of study and local geological map (Adopted from Biantaro et al., 1991)

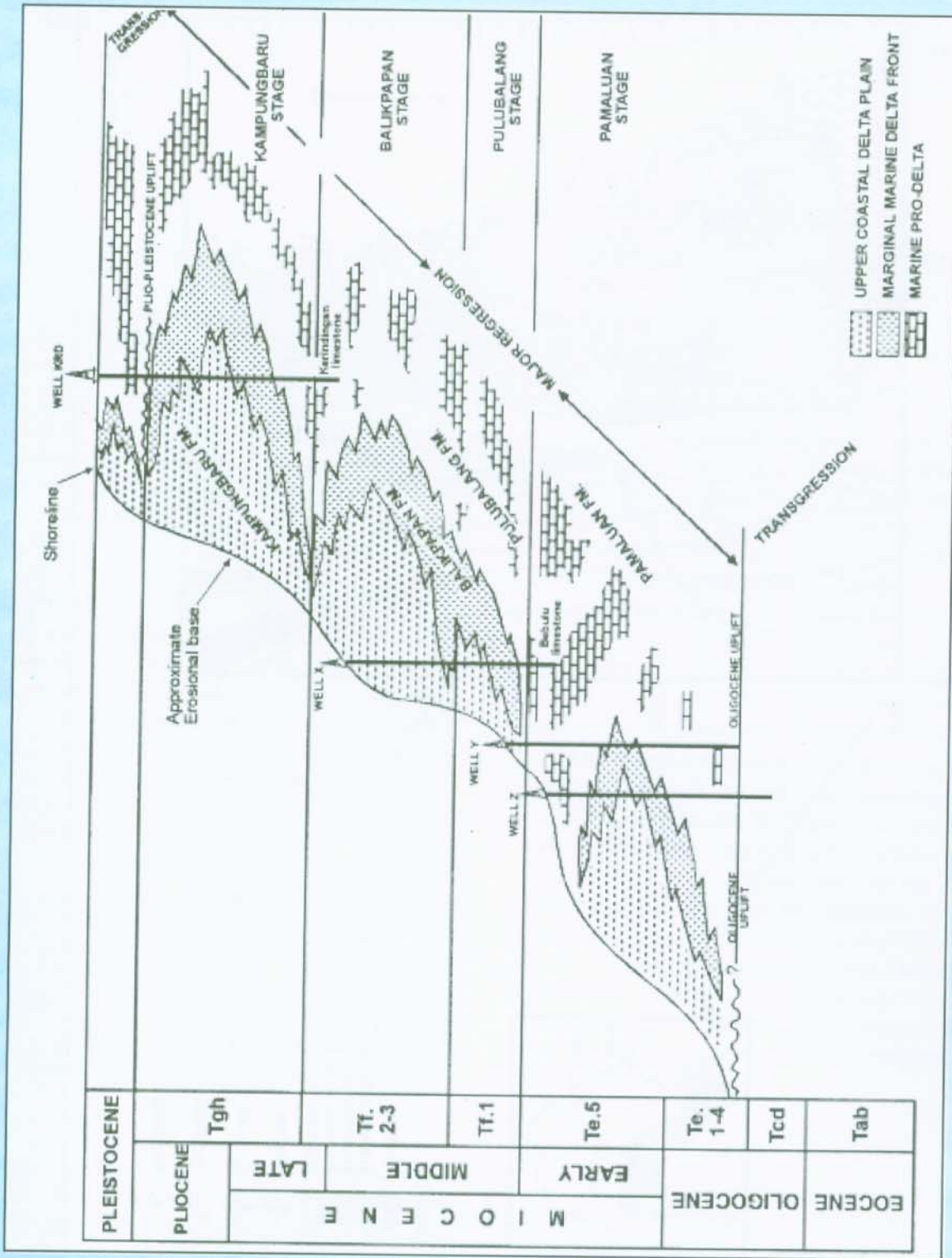


Figure 2  
Stratigraphic and sedimentation concepts which apply in the Sangatta area of East Kalimantan  
(L. Samuel, 1975 in Biantoro et al. 1991).

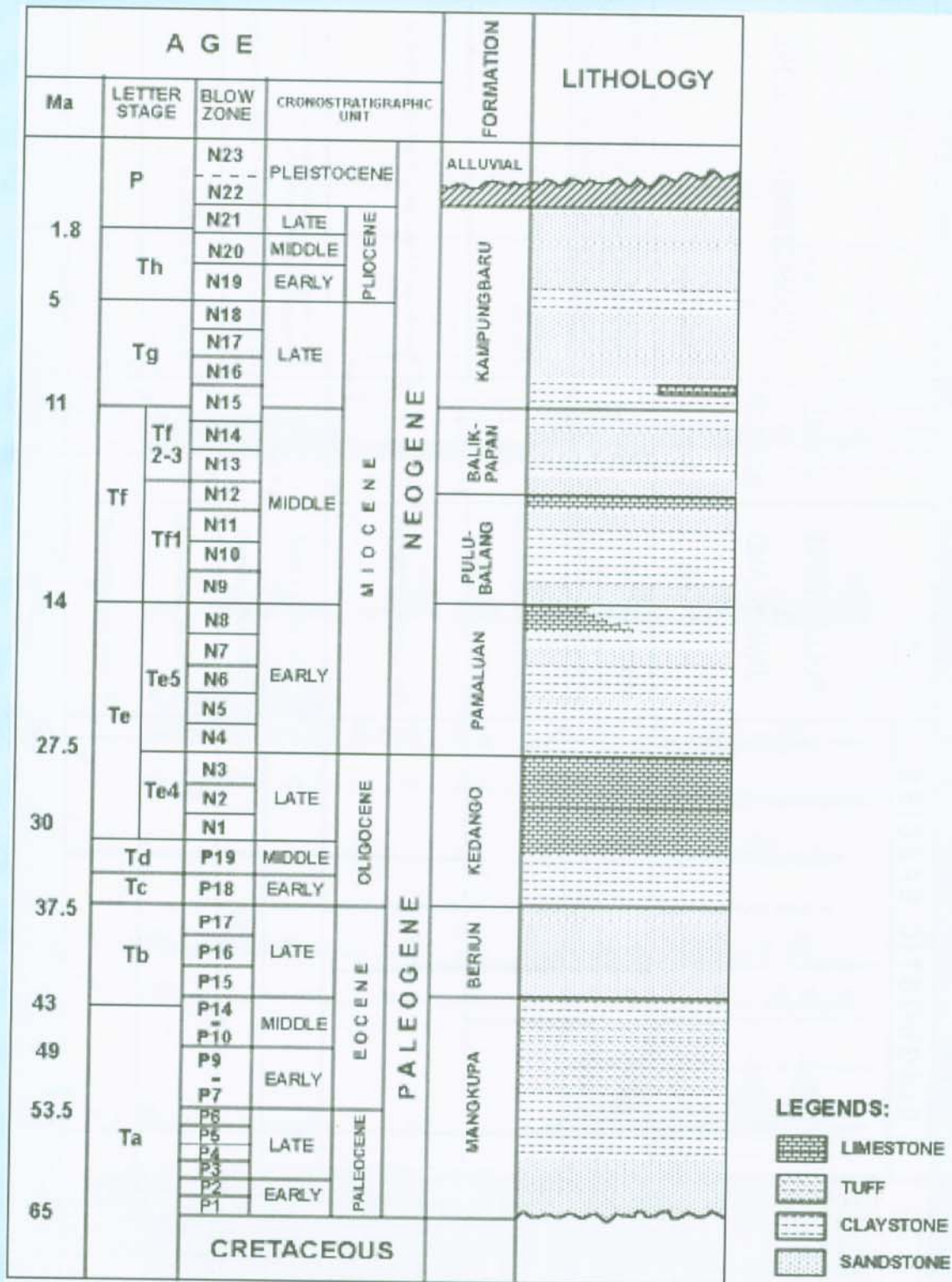


Figure 3  
 Regional stratigraphy of the Sangatta area, East Kalimantan  
 (adopted from Biantoro et al., 1991 with small modification)

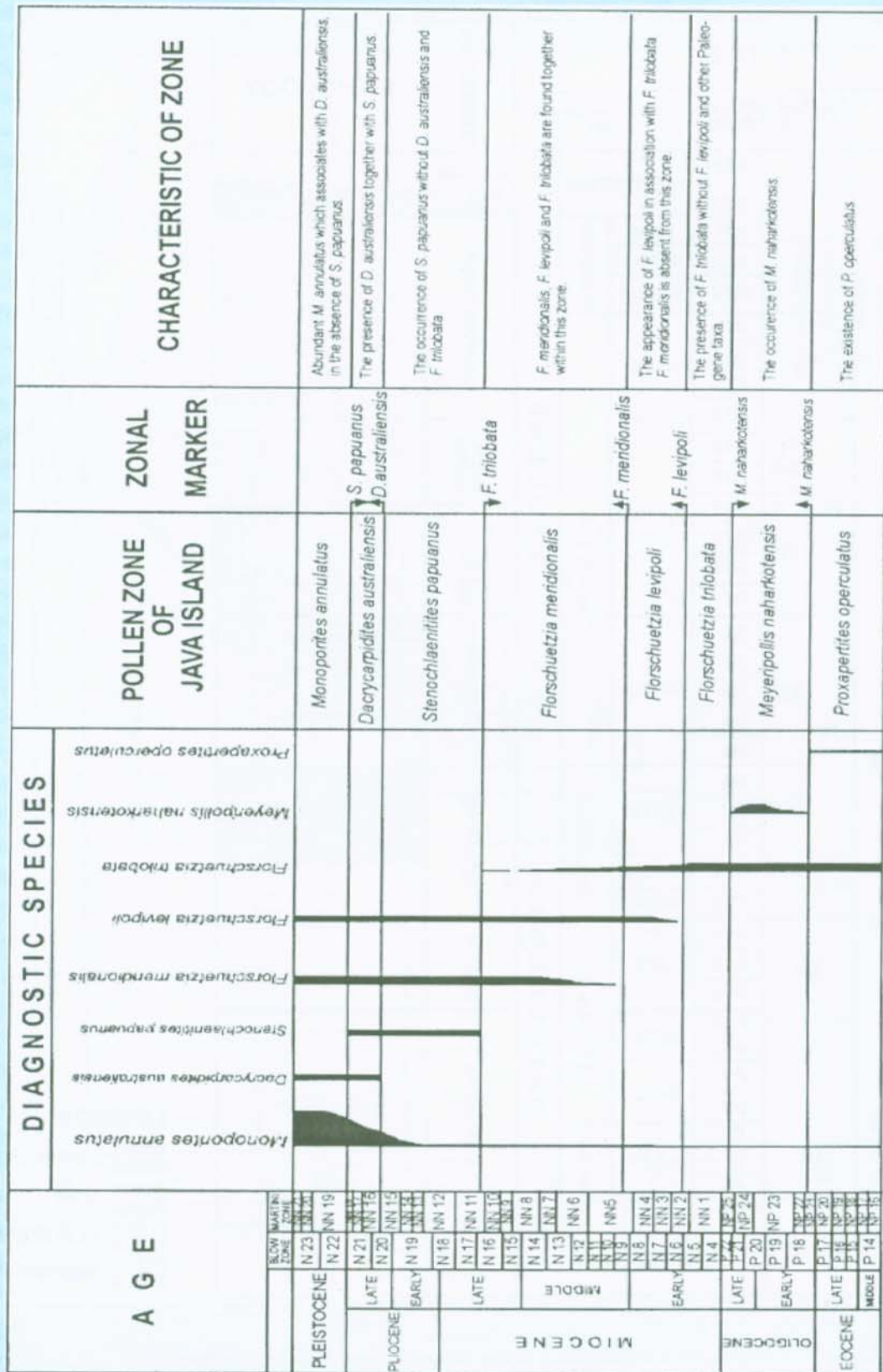


Figure 4  
Palynological zonation of Java Island (Rahardjo et al., 1994)

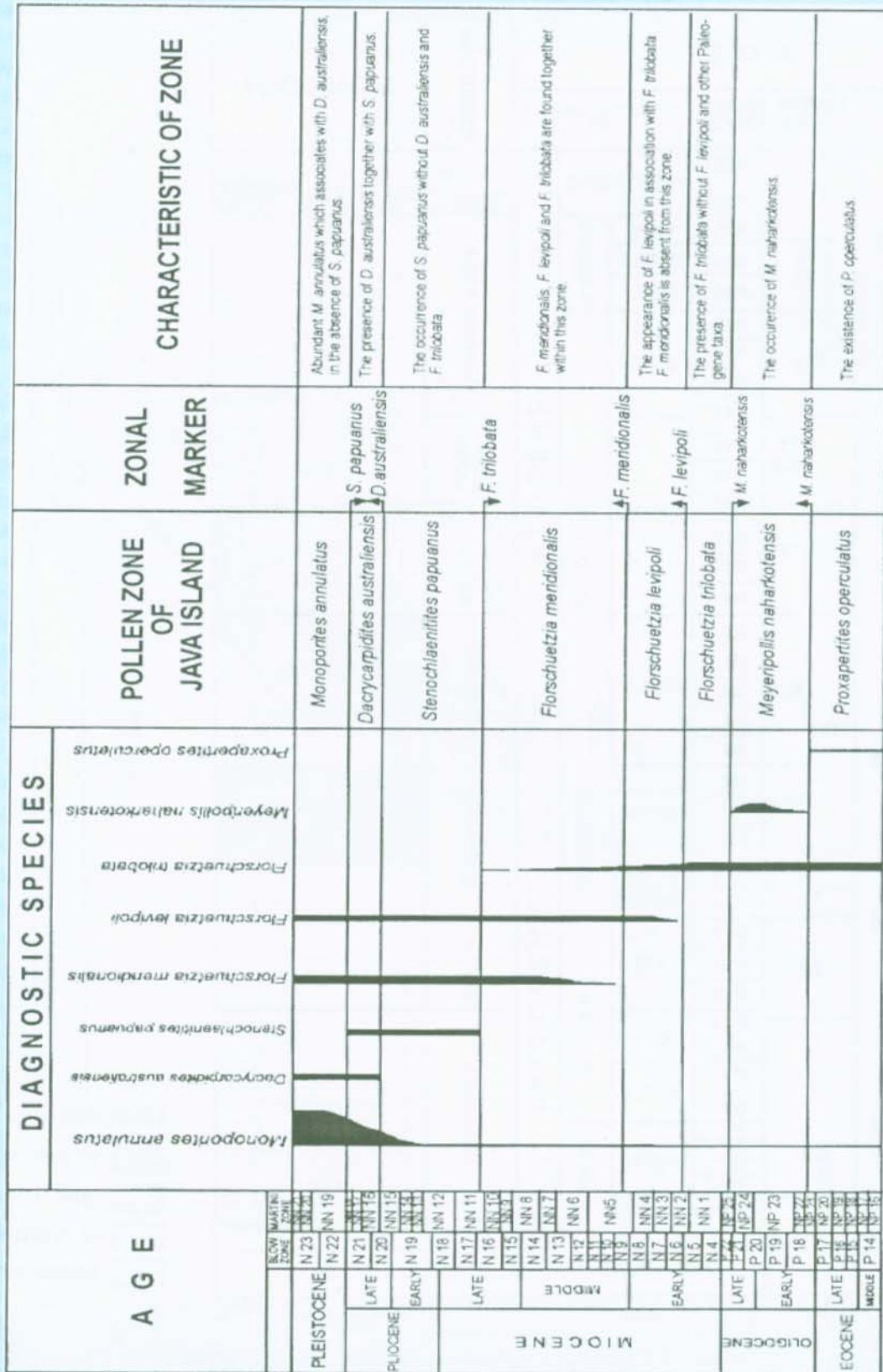


Figure 4  
Palynological zonation of Java Island (Rahardjo et al., 1994)

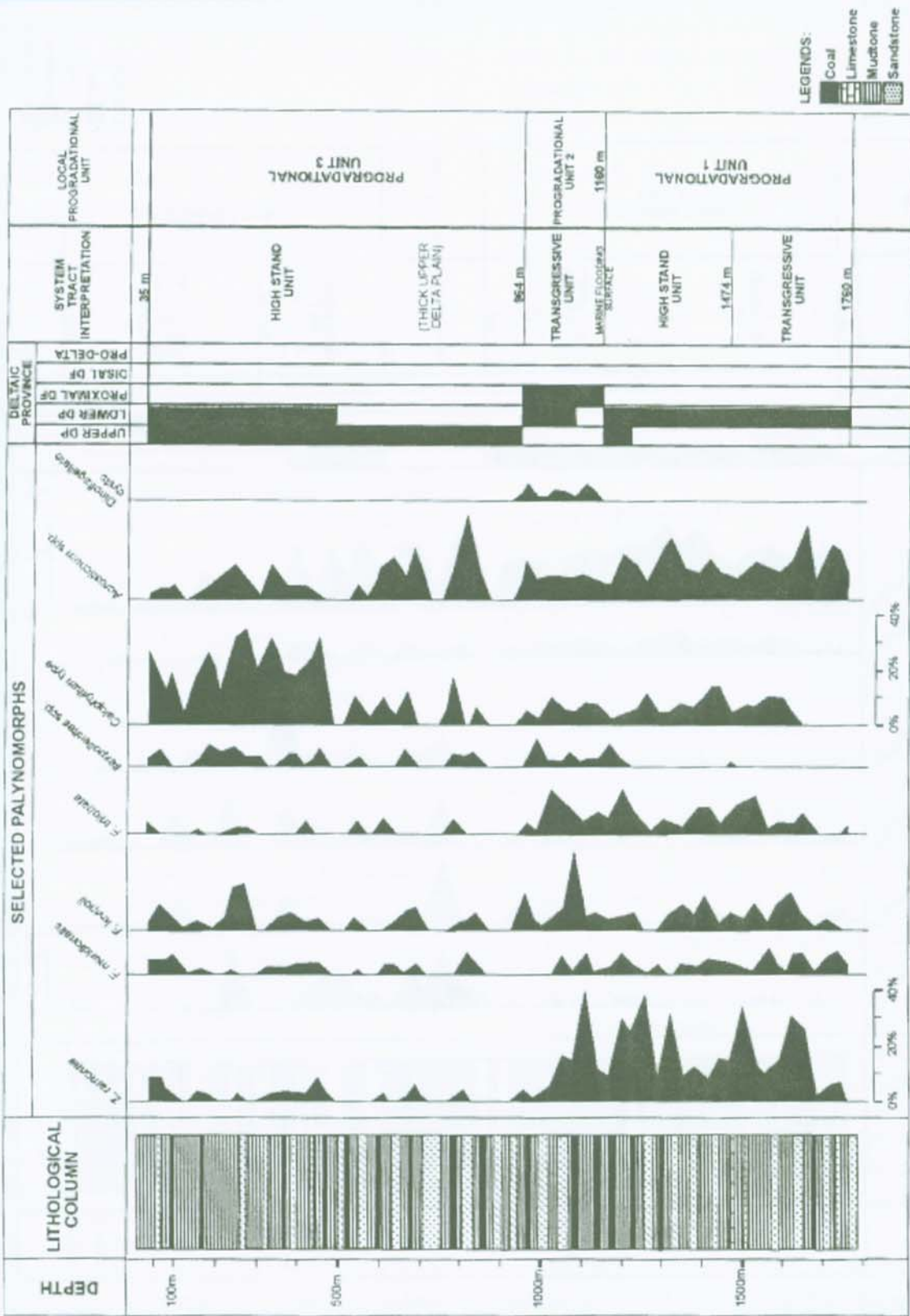


Figure 5  
 Quantitative palynological distribution chart of well X



Figure 6  
Quantitative palynological distribution chart of well Y



to regression with west direction. This regressive phase is predicted to cease in the Miocene. However, in the Late Miocene, sedimentation was indicated by the short period of transgression. Finally, sedimentation was ended by transgression starting from Pliocene up to Pleistocene (Figure 2).

Stratigraphy of the Sangatta area consists of Tertiary formations which cover Paleogene (Eocene-Oligocene) and Neogene (Miocene-Pleistocene) sediments as shown in Figure 3 (Biantoro et al., 1991 and Sukardi et al., 1995). The oldest sediment is called Mangkupa Formation which composes interbedded sandstone, tuff, siltstone, claystone and locally intercalation of coals and conglomerates (Sukardi et al., 1995). Biantoro et al., (1991) interpreted that the Mangkupa Formation was formed in the Early-Middle Eocene. On the other hand, based on the appearance of *Globigerina cf. G. acostaensis* and *Ga. nitapera*, Sukardi et al., (1995) inferred the age of Eocene-Oligocene within this formation. They also suggested that the Mangkupa Formation was deposited in the transitional environment. The Mangkupa Formation was conformably overlain by the Beruin Formation which was interpreted as a product of deltaic sedimentation during Late Eocene (Biantoro et al., 1991). Subsequently, Kedango Formation was conformably deposited above the Beruin Formation during Oligocene. It consists of limestone, intercalation of marl and calcareous siltstone. The Kedango Formation was formed in deep marine environment under turbiditic influence (Sukardi et al., 1995).

The Neogene formation is represented by the occurrence of Pamaluan, Pulubalang, Balikpapan and Kampungbaru Formations respectively. The Pamaluan Formation is the oldest Neogene sediment which composes claystone with intercalation of thin bedded of marl, sandstone and coal. It was conformably formed above the Kedango Formation during Early Miocene in the shallow to deep neritic environment (Sukardi et al., 1995). The Pamaluan Formation is then conformably overlain by the Pulubalang Formation which was deposited in pro-deltaic environment during Early Miocene to lower part of Middle Miocene (Sukardi et al., 1995). On the other hand, Biantoro et al. (1991) proposed the age of lower part of Middle Miocene within the Pulubalang Formation. The Pulubalang Formation encompasses interbedded sandstone, claystone and siltstone, locally intercalation of coal seam, limestone or calcareous sandstone. It is conformably overlain by the Balikpapan Formation which was deposited in delta front to delta plain environment. The Balikpapan Formation consists of

sand, clay, silt, tuff and coal. Biantoro et al. (1991) suggested that the age of the Balikpapan Formation was the upper part of Middle Miocene. On the contrary, Sukardi et al. (1995) proposed the age of Middle to Late Miocene for the Balikpapan Formation based on the appearance of larger benthonic foraminifers of *Cycloclypeus annulatus*, *C. innornatus*, *C. communis*, *Cycloclypeus sp.*, *Lepidocyclina ruteni*, *L. sumatraensis*, *Miogypsina irregularis*, *Operculina* and *Operculinella*. Finally, the Kampungbaru Formation was conformably deposited on the Balikpapan Formation during Late Miocene to Plio-Pleistocene (Sukardi et al., 1995). This formation is the youngest formation in the Sangatta area which encompasses sandy clay, sandstone with intercalation of coal and tuff. It was formed in the shallow marine to deltaic environment.

This study basically focuses on Middle Miocene sediment of the Balikpapan Formation which indicates deltaic succession (Sukardi et al., 1995).

### III. METHODOLOGY

Samples used in this study are cuttings which were collected from the selected intervals of three studied wells (X, Y and Z). These samples were processed in the LEMIGAS Stratigraphy Laboratory using the standard methods including HCl, HF and HNO<sub>3</sub> 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.

Age interpretation is based on palynological zonations which were proposed by Rahardjo et al. in 1995 (Figure 4). On the other hand, palaeoenvironmental analysis refers to deltaic classification based on vegetational

changes by Morley (1977). Sequence stratigraphy is interpreted on the basis of the combination of pollen record and lithological aspect referring to Morley (1995) and Azmi et al. (in-press).

#### IV. PALYNOLOGICAL SCHEME

Sediment in the selected well sections (wells X, Y and Z) is attributed to *Florschuetzia meridionalis* zone based on the concurrent occurrence of brackish pollen of *Florschuetzia meridionalis* and *F. trilobata* in the absence of spore of *Stenochlaenidites papuanus* (Rahardjo et al., 1991; see Figures 4, 5, 6 and 7). This zone is equivalent to Middle Miocene age. In addition, since *F. meridionalis* is common throughout the well sections, it is inferred that the major part of the studied sections belongs to the upper part of the Middle Miocene.

On the other hand, based on quantitative distribution of the selected palynomorphs it can be proposed some palynological events which are applicable in the Sangatta area (Figure 8). These events apparently subdivide the *Florschuetzia meridionalis* zone into detail pollen zones which are valuable for local correlation. Palynomorphs used in reconstructing the events are *Zonocostites ramonae*, *Florschuetzia levipoli*, *F. trilobata*, *Ilexpollenites* and *Calophyllum* type (Figure 8). Six events are proposed in this study including (from older to younger): (1) Base common of *F. meridionalis*, (2) Base abundance of *Z. ramonae*, (3) Base regular occurrence of *Ilexpollenites* sp., (4) top abundance of *Z. ramonae*, (5) Base abundance of *Calophyllum* type and other peat swamp pollen and (6) top regular occurrence of *F. trilobata*. In fact, the proposed events can be easily observed in wells X, Y and Z which subsequently strengthen the application of these events in the Sangatta area. These events are useful for stratigraphic analysis such as well correlation as demonstrated in Figure 9.

#### V. SEQUENCE STRATIGRAPHIC INTERPRETATION

Sequence stratigraphy is described based on quantitative palynological data and lithological data. Each well is interpreted for sequence occurrences which are as follows:

##### A. Well X

Well X penetrates sediment from 35m down to 1760m which mostly performs excellent pollen recovery (Figure 5). This pollen recovery combined with lithological data allows sequence stratigraphic interpretation. High abundance of mangrove palynomorphs of *Zonocostites*

*ramonae* and *Acrostichum* sp. characterises interval 1760m-1474m suggesting transgressive event (Morley, 1995). Lithologically, this interval predominantly consists of mudstone with thin sandstone intercalation. Limestone and minor coal occur within this interval. It is inferred that interval 1760m-1474m represents transgressive unit. Following interval 1760m-1474m is interval 1474m-1160m which is characterised by the reduction of the abundance of mangrove pollen *Zonocostites ramonae* (Figure 5). However, this mangrove pollen increases in the upper part of interval 1474m-1160m. In addition, freshwater pollen of *Ilexpollenites* sp. appears with common abundance in the upper most part of this interval suggesting the expansion of upper delta plain during late phase of highstand period. The intensive occurrence of upper delta plain is supported by the existence of coal seams in interval 1240m-1160m (Figure 5). After all, it is interpreted that the occurrence of transgressive unit in interval 1760m-1474m and highstand unit in interval 1474m-1160m represents progradational unit 1 (Figure 5).

Interval 1160m-964m is characterised by high abundance of brackish pollen of *Z. ramonae*, *Florschuetzia levipoli* and *F. trilobata* indicating transgressive unit (Morley 1995). The base of this interval may represent marine flooding surface as marked by the existence of moderate abundance of marine dinoflagellates and the occurrence of mudstone unit (interval 1160m-1100m). This marine flooding surface characterises the presence of progradational unit 2 which includes the transgressive unit within interval 1160m-964m.

The upper interval of this well section (interval 964m-35m) provides low mangrove pollen as demonstrated by *Zonocostites ramonae* and *Florschuetzia meridionalis*. On the other hand, *Calophyllum* type appears with common to high abundance suggesting freshwater domination. Lithologically, interval 964m-35m is characterised by the frequent occurrence of coal seams. These data suggest that sediment in interval 964m-35m was deposited in the upper delta plain environment. Interval 964m-35m may have represented highstand unit. This thick upper delta plain sediment is interpreted as progradational unit 3.

##### B. Well Y

This well penetrates sediment situated in interval 35m-1350m. Most interval of the well section provides good pollen assemblage, except for the lower interval (1024m-1350m) which shows low pollen recovery (Figure 6). Here, interval 1024m-1350m is insufficient for sequence stratigraphic interpretation. Therefore, this in-

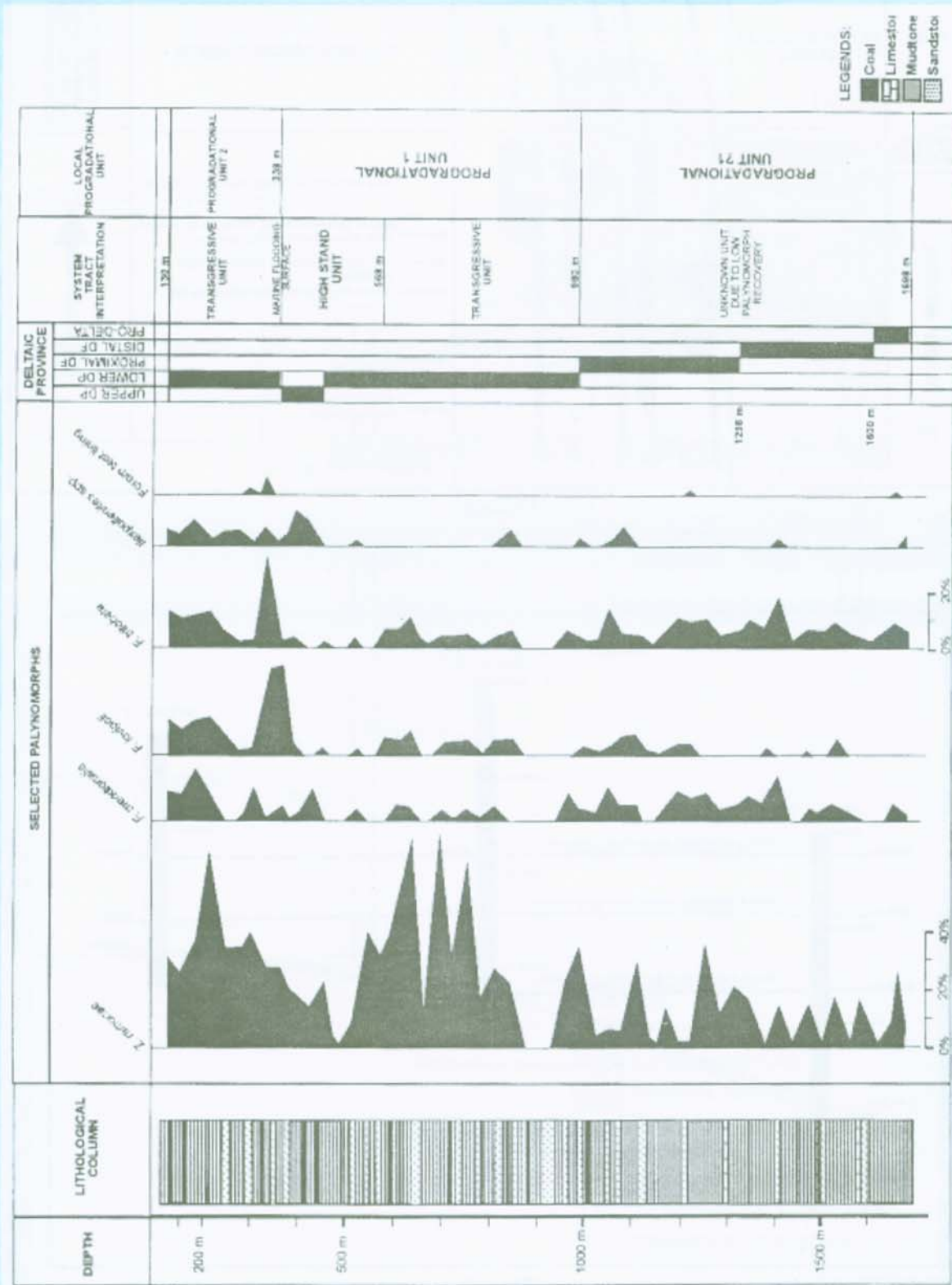


Figure 7  
Quantitative palynological distribution chart of well Z

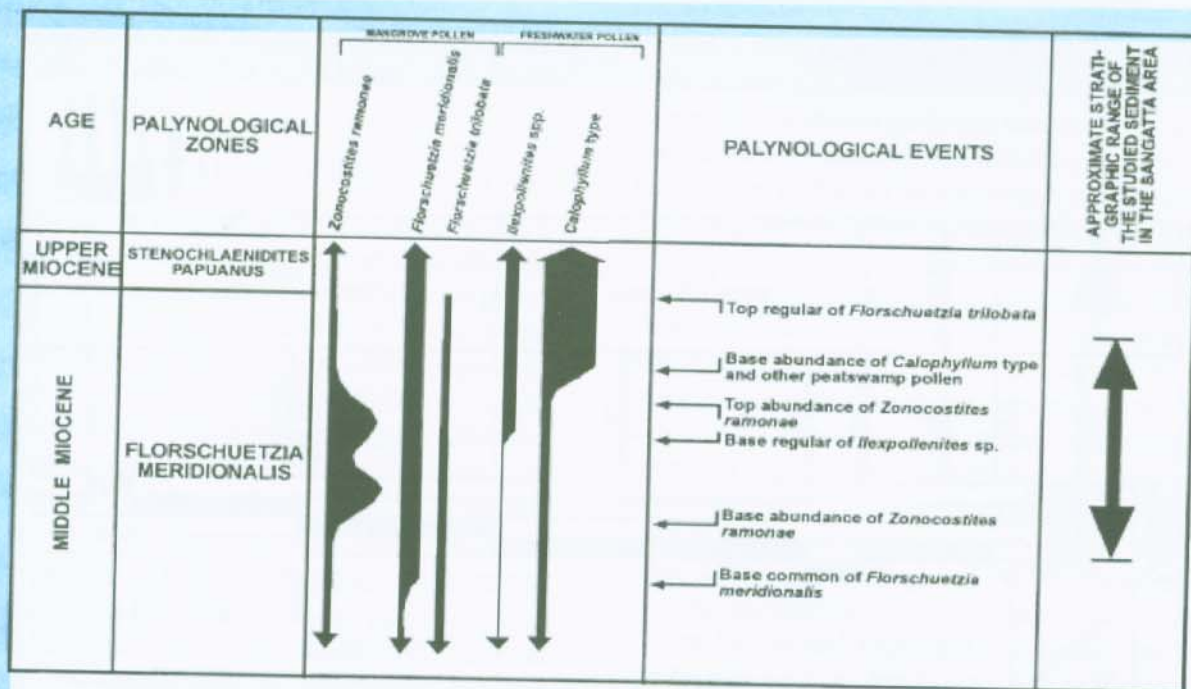


Figure 8  
Quantitative palynological events which are useful for detail stratigraphic correlation

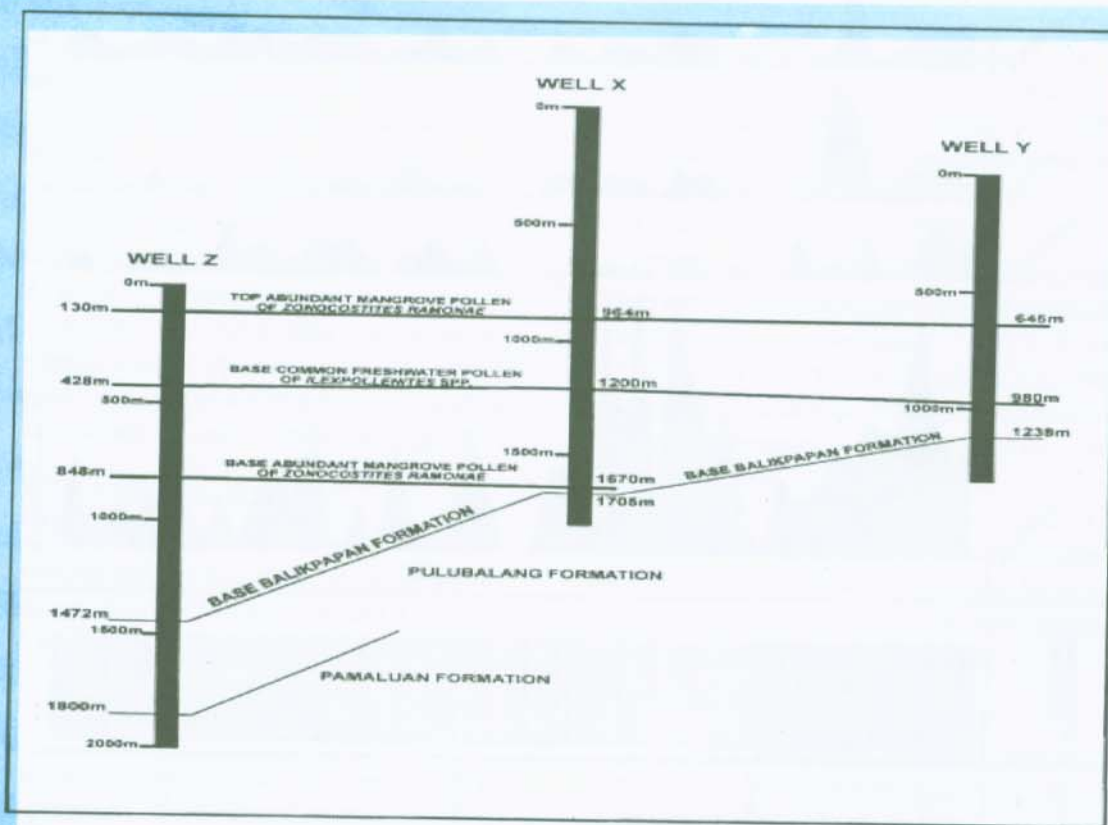


Figure 9  
Well correlation based on the quantitative distribution of the selected palynomorphs (i.e. *Zonocostites ramonae* and *illexpollenites* sp.)

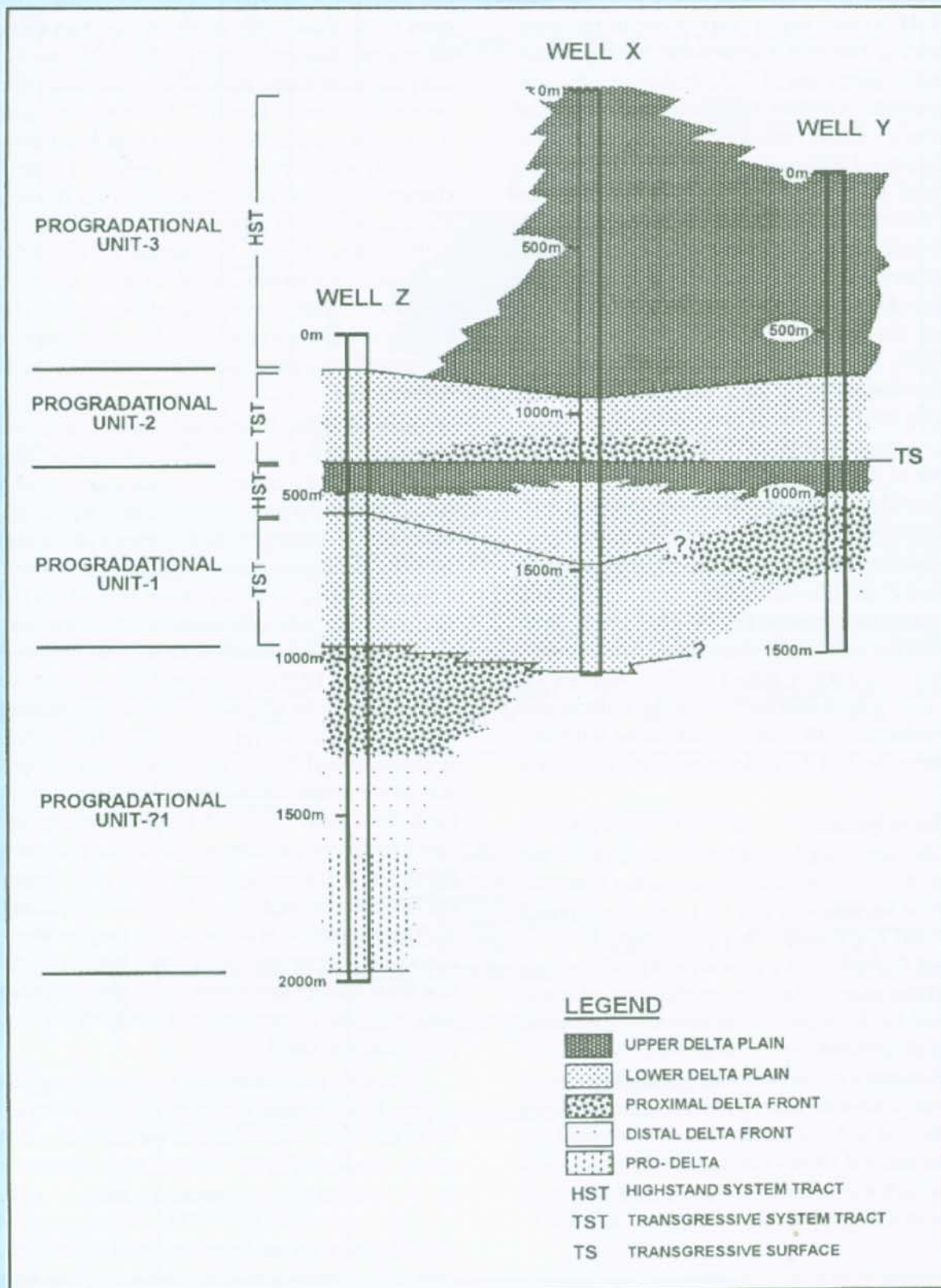


Figure 10  
System tract events and possible development of progradational units within three studied wells

interval lacks sequence interpretation. The pollen assemblage of this well resembles that of the previous well (Figure 5). However, well Y may occur in the more proximal setting than well X as indicated by high abundance of freshwater pollen of *Calophyllum* type through out the section. Another freshwater indicator of *Ilexpollenites* sp. shows common occurrence across the entire well. Interval 1024m-814m is marked by common abundance of brackish pollen such as *Zonocostites ramonae*, *Florschuetzia meridionalis* (mangrove pollen), *F. levipoli* and *F. trilobata* (back-mangrove pollen). This interval is lithologically characterised by the intercalation of sandstone, mudstone and thin coal. It is interpreted that interval 1024m-814m represents highstand unit. The common abundance of freshwater pollen *Ilexpollenites* sp. in the upper part of this interval indicating the expansion of upper delta plain deposit within the late highstand phase. This is strengthened by the presence of thick sandstone in the upper part of interval 1024m-814m (Figure 6). This highstand unit is attributed to progradational unit 1.

The maximum abundance of mangrove pollen of *Z. ramonae* and *F. meridionalis* occurs in interval 814m-645m indicating transgressive unit (Morley, 1995). Similar to well X, this unit is also characterised by common occurrence of freshwater pollen of *Ilexpollenites* sp. (Figure 6). Lithology of interval 814m-645m is dominated by thick mudstone with coal and sandstone intercalation. It is interpreted that this unit represents progradational unit 2.

Brackish palynomorph occurring in interval 645m-35m provides low pollen abundance as shown by rare occurrence of mangrove pollen *Zonocostites ramonae*, *Florschuetzia meridionalis* and back-mangrove pollen *F. levipoli* and *F. trilobata*. On the contrary, freshwater pollen of *Calophyllum* type shows high abundance through out this interval. In addition, this interval is also characterised by the common abundance of freshwater indicator of *Ilexpollenites* sp. Interval 645m-35m is lithologically dominated by the alternation of thick mudstone and coal with sandstone intercalation (Figure 6). Based on palynological and lithological data, it is inferred that sediment in interval 645m-35m represents upper delta plain unit which was possibly formed during highstand phase. This unit is interpreted as progradational unit 3.

### C. Well Z

Well Z is split into two intervals based on palynomorph assemblage. The first interval is an interval with rich pollen recovery (interval 980m-130m) and therefore, it

is available for quantitative analysis (Figure 7). The second interval contains poor palynomorph which is insufficient for sequence interpretation based on quantitative palynological analysis (interval 1698m-980m). However, this poor assemblage allows interpretation of the deltaic province as seen in Figure 7. It shows some gradations from more marine environment into less marine environment, where pro-delta in interval 1698m-1600m changes into distal delta front in interval 1600m-1298m and finally ends up with proximal delta front in interval 1298m-980m (Figure 7). Interval 1698m-980m is assumed to represent progradational unit 1, although it may consist of more than one progradational unit. Therefore, detail marine micro-fossil analyses (foraminifera and nannoplankton) are required to obtain more reliable interpretation.

Interval 980m-568m is indicated by high abundance of mangrove pollen *Zonocostites ramonae*. This interval lithologically comprises mudstone, channel sands (some are thick) and coals. These palynological and lithological data suggest the occurrence of a broad, brackish lower delta plain which might have developed during a phase of rising sea level (Azmi et al., 1994). In addition, sediment with rich mangrove pollen as seen in interval 980m-568m usually indicates transgressive condition (Morley, 1995). Following transgression, sea level continued to rise which resulted in the occurrence of highstand unit in interval 568m-338m. This highstand unit is characterised by the decrease of the abundance of mangrove pollen *Zonocostites ramonae*. On the other hand, freshwater pollen of *Ilexpollenites* sp. increases considerably, especially in the upper part of interval 568m-338m suggesting upper delta plain expansion at the late phase of highstand depositional system (Figure 7). This hypothesis is supported by the presence of thick coals within upper interval (450m-338m). It is interpreted that these transgressive and highstand units compose a single broad progradational unit which is termed progradational unit 1.

Brackish palynomorphs increase significantly to achieve high abundance in interval 338m-130m as proved by *Z. ramonae*, *Florschuetzia meridionalis*, *F. levipoli* and *F. trilobata* (Figure 7). In addition, freshwater pollen of *Ilexpollenites* sp. remains common in this interval. Lithologically, interval 338m-130m mainly consists of mudstone with sandstone and coal intercalation. The base of this interval is characterised by the significant occurrence of marine indicator of foraminiferal test lining indicating marine flooding surface or transgressive surface. Based on these data, it is concluded that sedi-

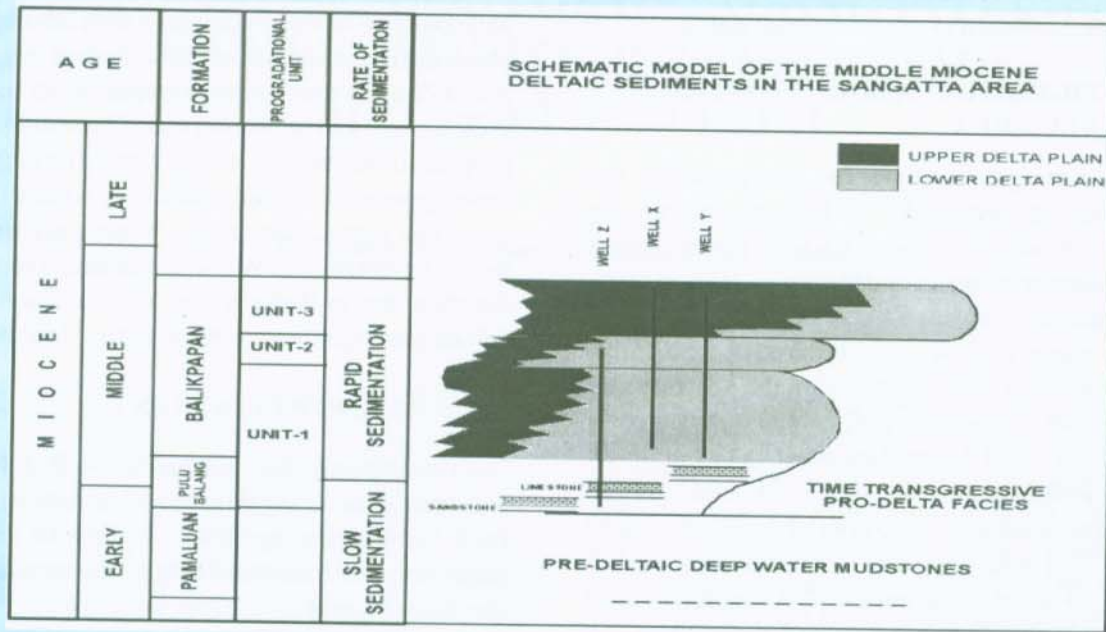


Figure 11  
Lithostratigraphic scheme which is proposed for the middle miocene deltaic sediment in the study area

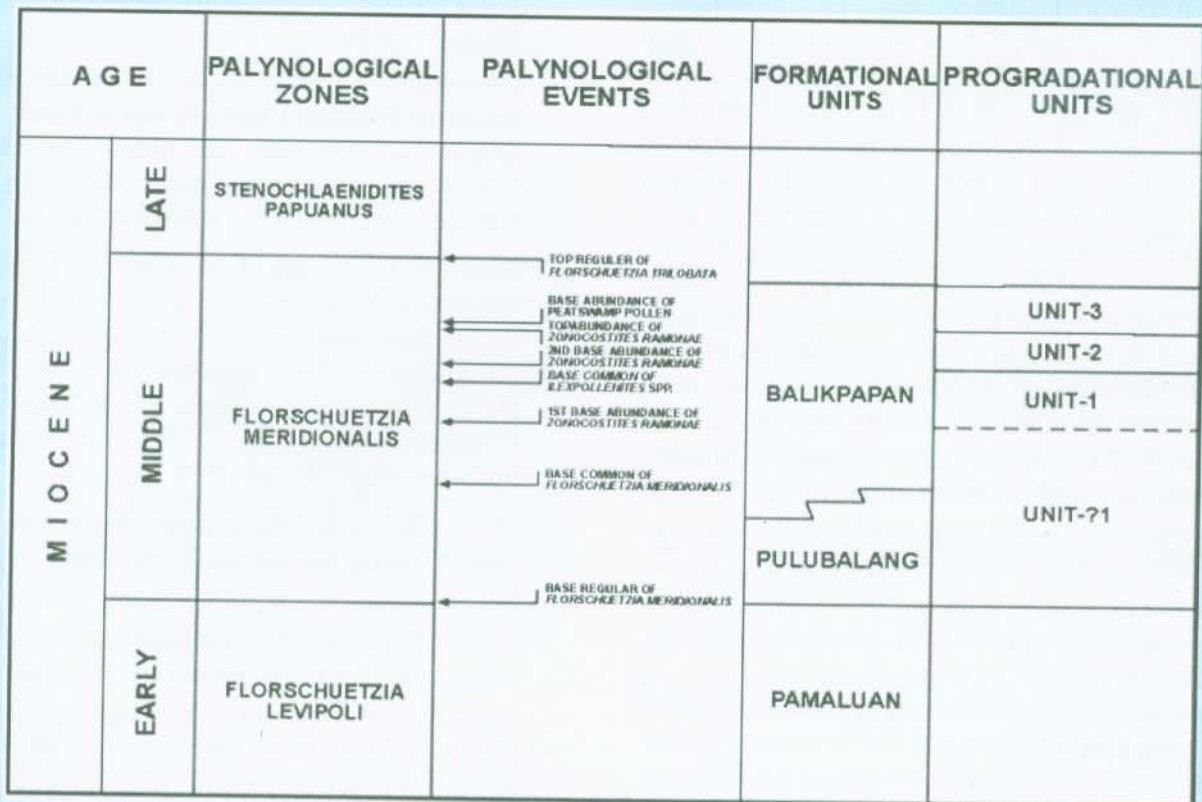


Figure 12  
Local palynological zonation which is applied in the middle miocene sediment in the study area

ment in interval 338m-130m represents transgressive unit which can be attributed to progradational unit 2.

## VI. STRATIGRAPHIC MODEL FOR THE SANGATA AREA

Having sequence stratigraphic interpretation, the studied wells are correlated in order to reconstruct the stratigraphic model of the Sangata area. Correlation is based on system tract events and the progradational units. The transgressive surface is selected for correlation datum as it occurs in most wells (Figure 10). This correlation shows that well Z is situated in the deeper water setting than that of other two wells which is indicated by the presence of distal deltaic deposits in the lower interval of this well including pro-delta and delta front. In addition, progradational unit 3 consisting of upper delta plain (proximal delta province) disappears from well Z (Figure 10). The disappearance of this unit might have been caused by the deeper position of well Z than that of other wells.

Correlation of progradational units existing in the studied wells is able to illustrate the schematic model of the development of deltaic sediment in the Sangata area as shown in Figure 11. This schematic model emphasises the chronostratigraphic character of individual progradational unit, but the time-transgressive nature of the delta front and pro-delta facies of the Pulubalang Formation. Apparently, the schematic model suggested in this paper has many similarities with that proposed by Biantoro et al. (1991; see Figure 2). However, there is a difference between this study and the study conducted by Biantoro et al. (1991) regarding the age of the deltaic packages which appear in the studied wells. This study infers that the deltaic packages in the Sangata area occurred in Middle Miocene, whilst Biantoro et al. (1991) suggested the age of Early to Middle Miocene for these packages. In this study, the Early Miocene sediment is interpreted as a deep water mudstone of the Pamaluan Formation which can be considered to be a pre-deltaic deep water succession (Figure 11).

In order to summarise the analyses discussed above, this paper provides a table which demonstrates the relationship between palynological events and lithostratigraphic units in the Early to Middle Miocene of the Sangata area (Figure 12).

## VII. CONCLUSION

Palynological study plays an important role in the Sangata area in order to reconstruct a proper stratigra-

phy of the Miocene deltaic sediment. The quantitative palynological analysis combined with lithological data is able to separate sediments in the studied wells (Wells X, Y and Z) into sequence stratigraphic units such as transgressive unit and highstand unit. These units build three progradational units (Units 1, 2 and 3) which reflect the development of deltaic sediments within the Sangata area. The correlation of the deltaic packages suggests that sedimentation in Well Z commenced somewhat earlier than that in Wells X and Y. In addition, the whole deltaic packages were formed during Middle Miocene.

## VIII. ACKNOWLEDGMENT

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