THE CONTRIBUTION OF PALYNOLOGY IN FIELD DEVELOPMENT

by
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I. INTRODUCTION

The reliable interpretation of lateral reservoir distribution is required to gain high accuracy of reserve estimation in the oil field. Apparently, the geometry of reservoirs influences the volume of hydrocarbon. Widespread reservoirs are more preferred than isolated reservoirs because the former tend to store much larger volume of hydrocarbon than the later which usually produce limited volume of hydrocarbon. The lateral reservoir connectivity can be approached using various methods such as well log correlation, seismic correlation, biostratigraphic correlation, etc. In fact, each method sometime provides distinct result compared to that using another method. Therefore, the integration of those methods is actually needed to obtain reliable result. In the studied field, reservoir correlation was firstly constructed base on well log and seismic correlations. It was concluded that each reservoir could be traced along the studied wells. However, in order to cross-check this conclusion it is applied palynological correlation as the studied sections are well recognized to represent deltaic sediment which yields rich palynomorph assemblage. It is now believed that palynology will be able to refine the correlation which was reconstructed base on well log and seismic.

Data obtained during the analysis is considered to be confidential as this is provided for commercial work which is not public domain. Therefore, detail information of the studied wells can not be revealed within this paper. The wells are named using numbers such as 1, 2 and 3, whilst reservoirs are labelled in alphabetical order, for example A, B and C. The studied wells were drilled in the oil field, so called Field "X" (Figure 1).

Due to space limitation, only palynological data relevant to the correlation and sequence stratigraphic analysis of the studied wells (1, 2 and 3) are presented within this paper (Figures 3, 4 and 5). These data include the distribution of selected taxa, especially those which derived from marine, mangrove, back-mangrove, riparian, peatswamp and freshwater vegetations. Lithology is inferred from wireline logs which were provided by the client. These logs are shown together with pollen diagrams as seen in Figures 3, 4 and 5.

II. METHODOLOGY

Three main laboratory analyses, i.e. calcareous nannoplankton, foraminifera and palynology have been used for this study, and the results, then, can be integrated to the well sequence stratigraphy analysis.

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

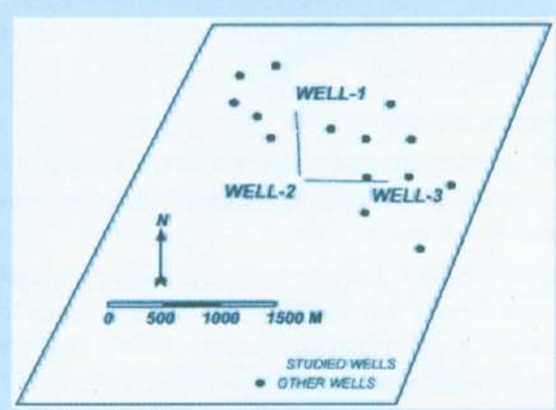

Figure 1
The location of the studied wells in the Field "X"

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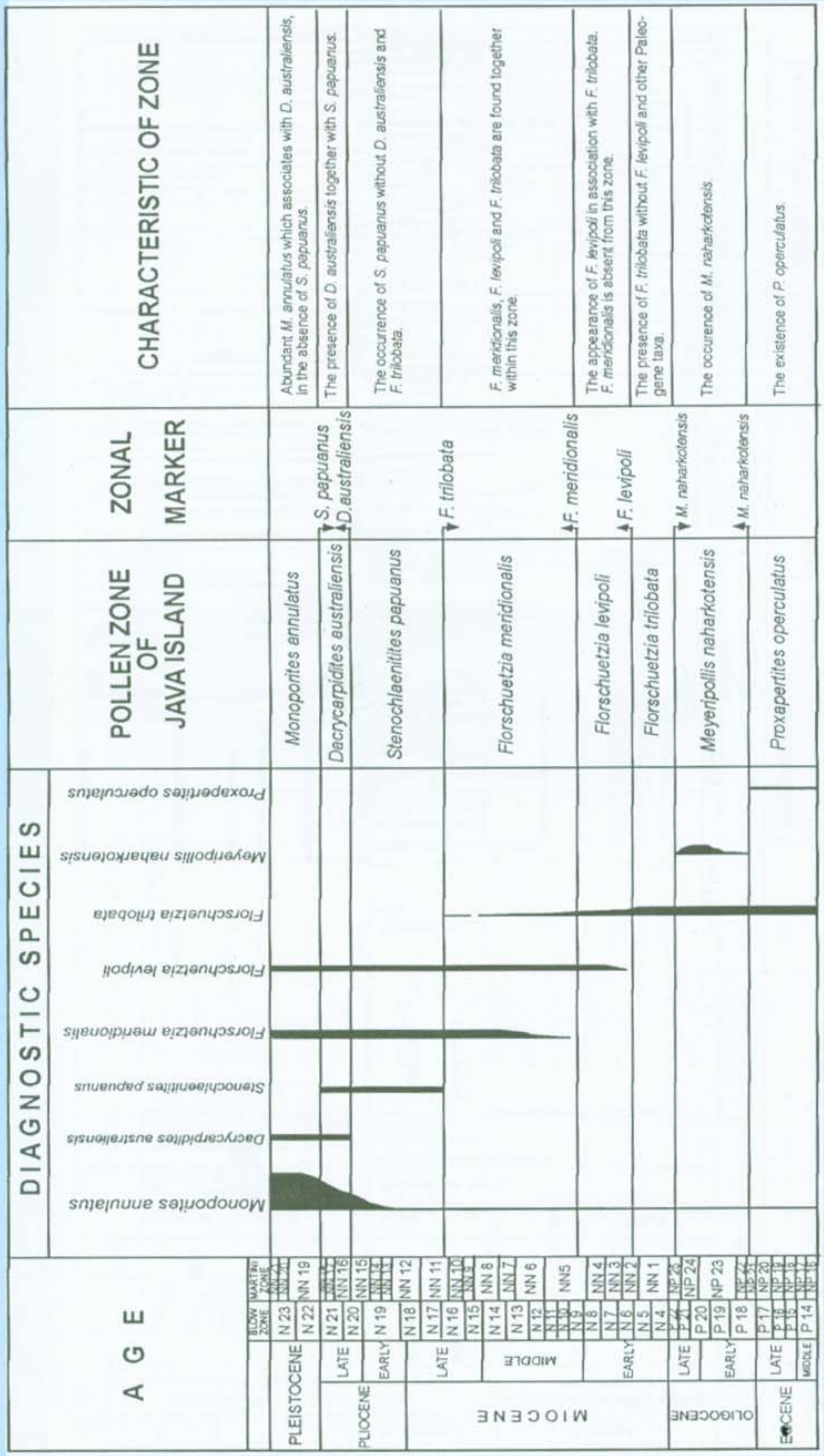

Figure 2
Palynological zonation of Java Island (Rahardjo *et al.*, 1994)

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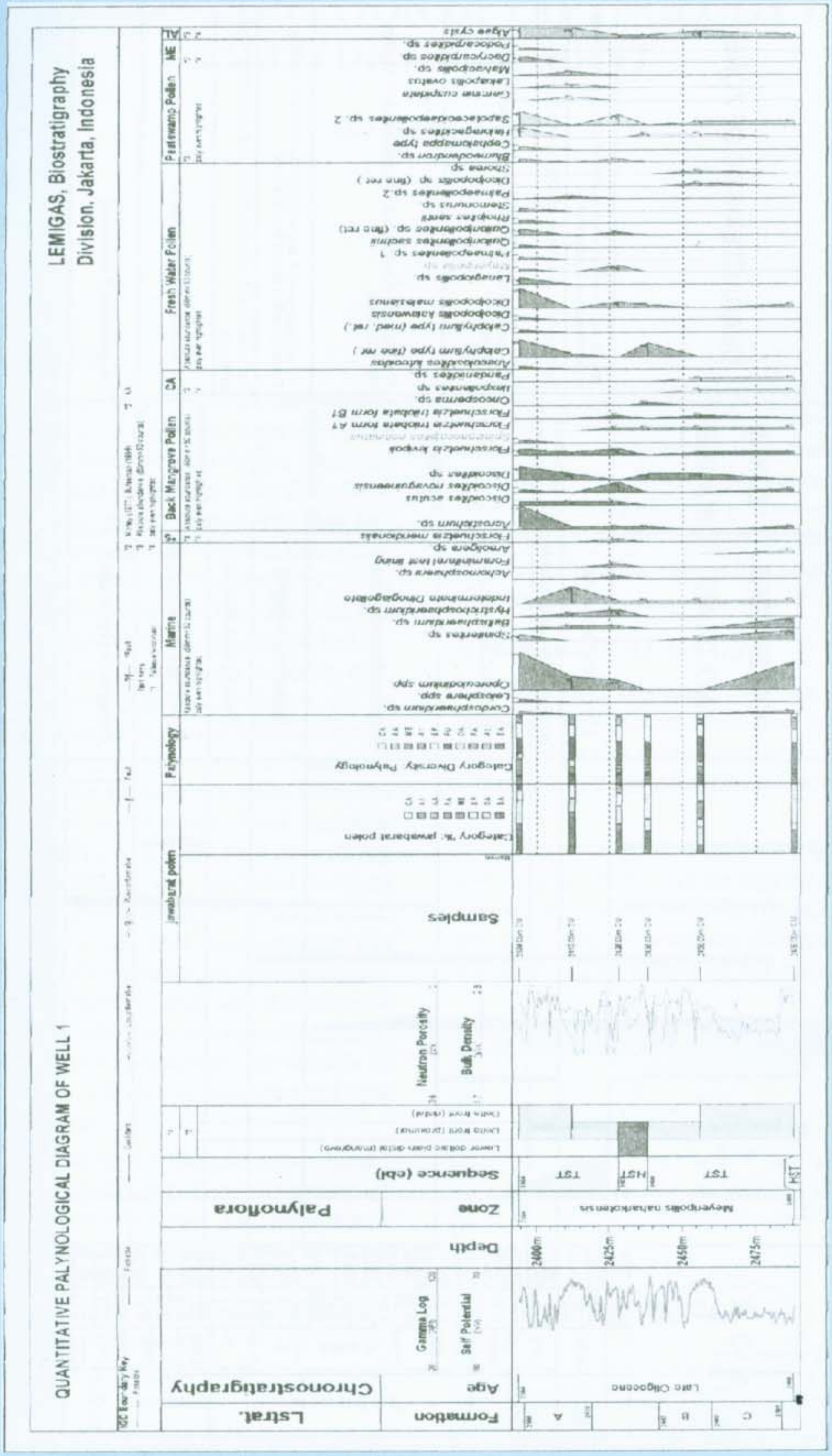

Figure 3
Palynological record of Well 1 interval 2394.00m

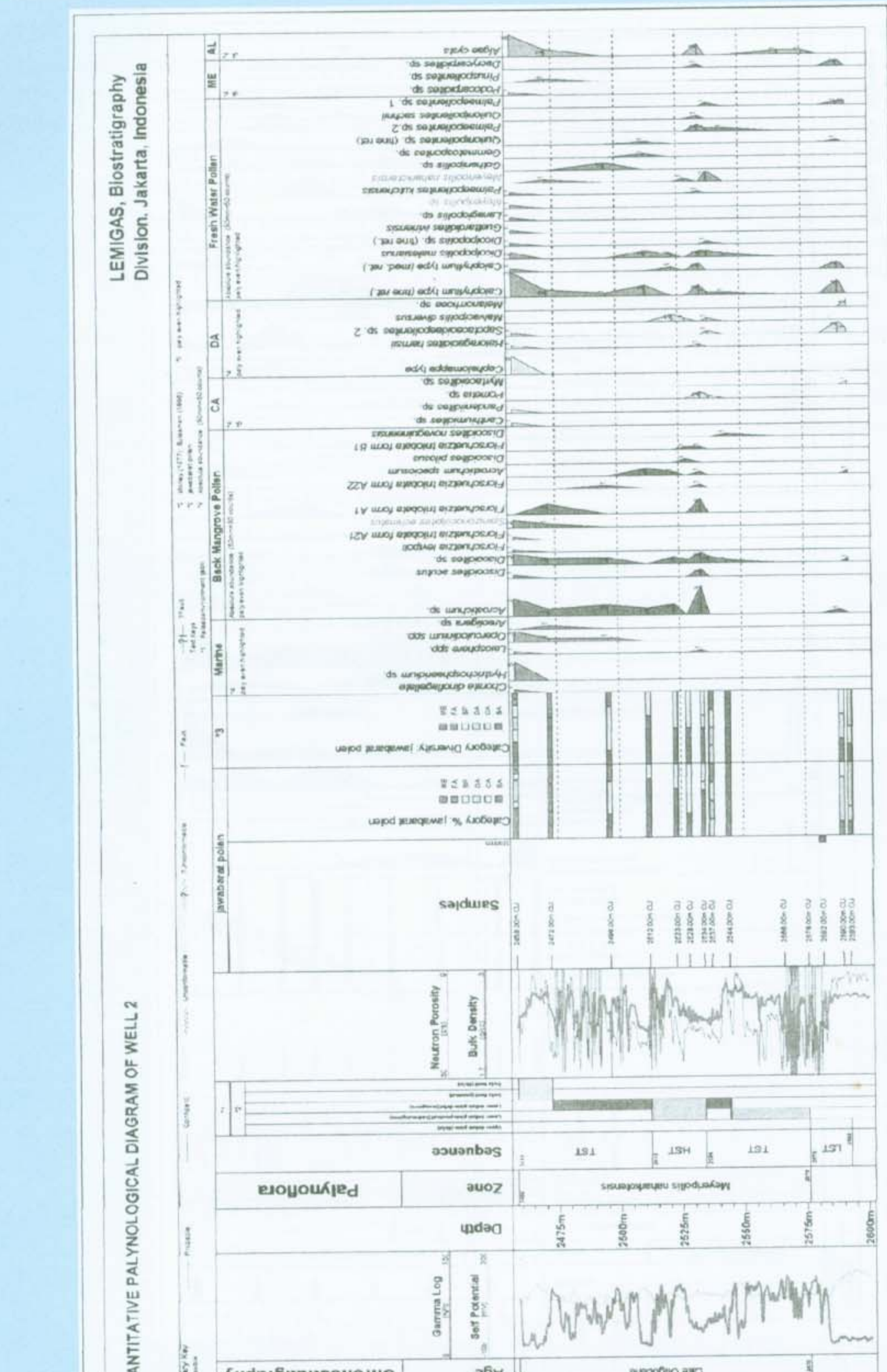

Figure 4
Palynological record of Well 2 interva 2458.00m-2583.00m

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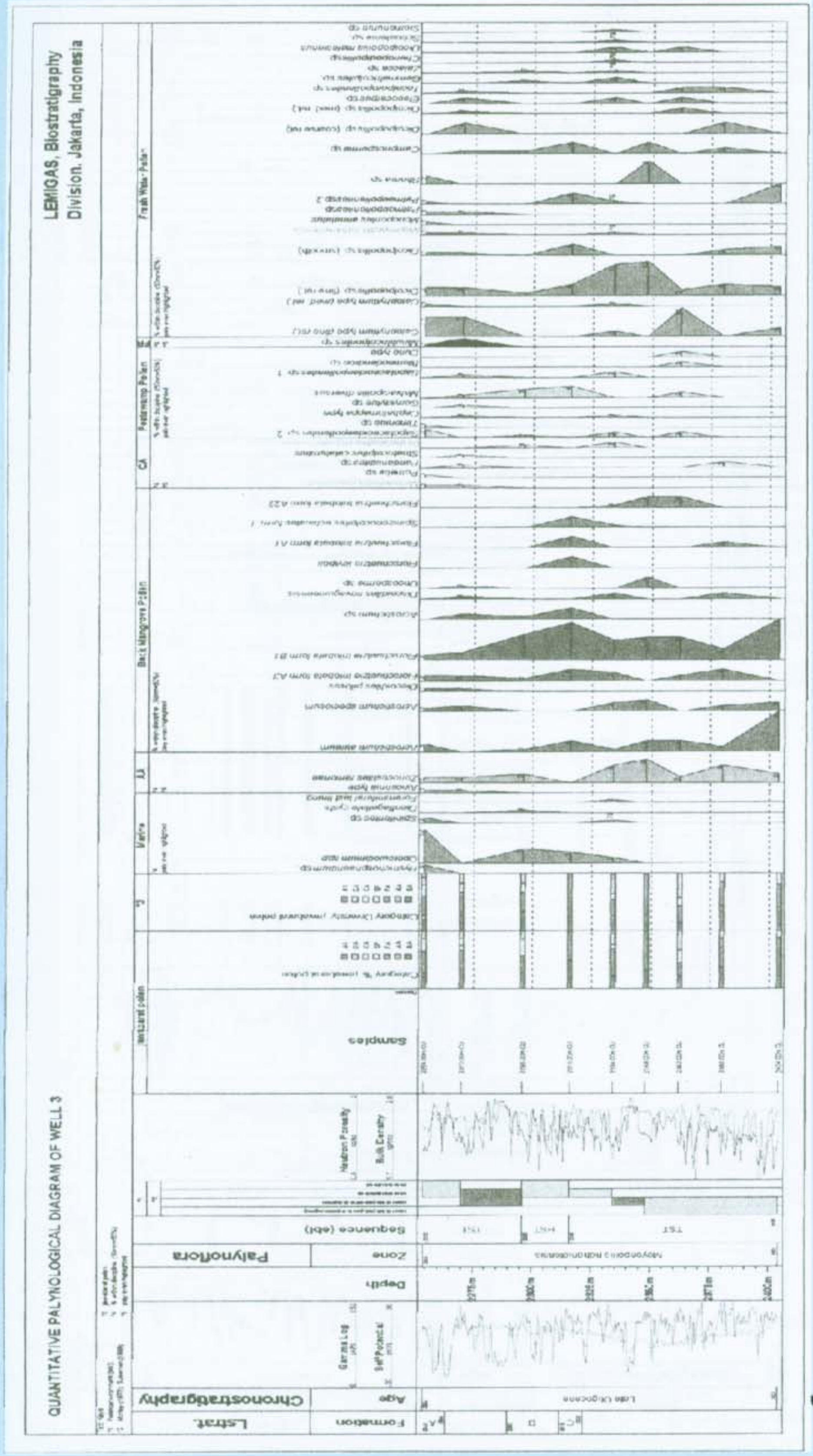

Figure 5
Palynological record of Well 3 interval 2254.00m-2404.00m

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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 certain software called StrataBug.

The composition and the abundance of calcareous nannoplankton as well as the age of each well were recorded in the Calcareous Nannoplankton Chart. Meanwhile, the composition and the abundance of foraminifer together with the age and environmental interpretation of each well were plotted in the Foraminiferal Chart.

The palynological data can be used to analyse sea level changes and palaeoclimate during sediment accumulation. The events of sea level changes can be recognised by the composition and the percentage of pollen/spores from fresh water, peat swamps, back-mangrove, mangrove, acritarch and dynoflagellate cysts. The rising of sea level can be indicated by the abundance of back-mangrove/mangrove species and/or the occurrence of foraminiferal lining, acritarch and dinoflagellate cysts. Vice-versa, the drop of sea level is suggested by the increasing abundance fresh water and peat swamps species and by the reducing frequencies of back-mangrove/mangrove species and the absence of foraminiferal linings, acritarch and dinoflagellate cysts (Lelono, 2000).

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 foram-zone proposed by Blow (1969) with some modification. For nannoplankton

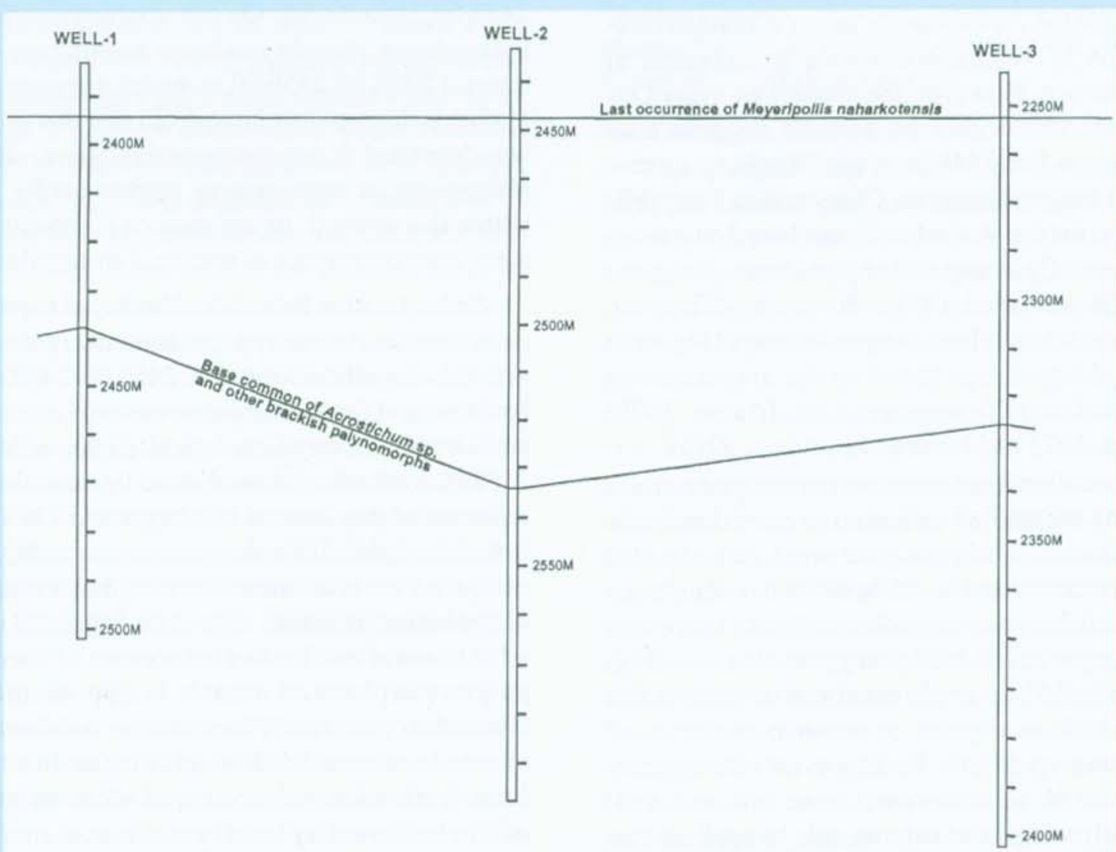

Figure 6
Stratigraphic correlation of the studied wells based on the last occurrence of index pollen of *Meyeripollis naharkotensis* and the quantitative distribution of back-mangrove spore of *Acrostichum* sp. and other brackish palynomorphs (see Figures 3, 4 and 5)

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analysis, these interpretations refer to nanno-zone of Martini (1971) with some modification. In addition, the pollen-zone proposed by Rahardjo et. al. (1994) is used to infer zonal subdivision as well as age interpretation (Figure 2). 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).

III. PALYNOLOGICAL SCHEME

The studied sediment situated in the selected wells namely Wells 1, 2 and 3 is assigned to *Meyeripollis naharkotensis* zone. This interpretation is based on the occurrence of *M. naharkotensis* and *Florschuetzia trilobata* forms in the absence of *F. levipoli* and *F. meridionalis* (Rahardjo et. al., 1991). *M. naharkotensis* derives from peatswamp vegetation, whilst the *Florschuetzia* group is brackish element. The *M. naharkotensis* zone is equivalent to Oligocene age. However, the absence of many Oligocene markers within the sections suggests Late Oligocene to Early Miocene age. Similarly, nannoplankton analysis suggests Oligocene to Early Miocene age for the studied sediment based on the occurrence of *Cyclicargolithus floridanus* along the well sections (Martini, 1971 with some modification). In addition, foraminiferal analysis indicates Oligocene to Early Miocene age based on the appearance of larger benthic of *Spiroclypeus* sp. (Adam, 1970; Berggren, 1973 and Haak and Postuma, 1975).

On the other hand, quantitative analysis enables separating the studied sections into more detail subdivision based on palynological event. Actually, this event is reconstructed based on distinctive abundance of *Acrostichum* sp. of back mangrove spore and other mangrove and back-mangrove elements (Figures 3, 4 and 5). A single event can be built in this study which is regular common occurrence of *Acrostichum* sp. (Figure 6). This event subsequently subdivides *M. naharkotensis* zone into two subzones. Palynological event may only be applicable in the studied field which is useful for local correlation as demonstrated in Figure 6. In fact, this event can be easily observed in the studied wells (Wells 1, 2 and 3) which then prove the application of this event in the studied field.

IV. SEQUENCE STRATIGRAPHIC INTERPRETATION

Sequence stratigraphy is constructed based on quantitative palynological, foraminiferal and nannoplankton data which is combined with lithology interpreted from SP and Gamma Ray logs. Sequence stratigrahy occurring in each well is described as follows:

A. *Well 1*

Well 1 penetrates sediment situated within interval 2394.00-2488.00 m. Palynological analysis of this interval provides moderate pollen recovery (Figure 3). On the other hand, foraminiferal and nannoplankton analyses show poor marine micro-faunal assemblage. Lithologically, this interval consists of sand layer in the lower part and the intercalation of sand and shale in the middle and upper parts. Sedimentation was commenced in the delta front environment as indicated by low pollen and spore recovery (interval 2488.00-2456.00 m). On the contrary, marine dinoflagellates provide moderate assemblage within interval 2488.00-2456.00 m which suggests strong marine influence. It is interpreted that this sediment was deposited during transgressive phase, although *Rhizophora* as transgressive marker hardly occurs within this interval. Its appearance is substituted by significant occurrence of marine dinoflagellates.

Sedimentation then shifted landward to proximal delta front as shown by significant decrease of marine dinoflagellates (interval 2456.00-2438.00 m). Brackish and freshwater palyonomorps consistently provide low recovery. Lithologically, interval 2456.00-2438.00 m consists of sand shale intercalation. The sediment of this interval is interpreted to be formed in the latest period of transgression prior to highstand period. As sea level rises drowning much wider area of deposition, brackish vegetation expanded rapidly which resulted in the increase of brackish palynomorphs and hence is represented by *Discoidites* group and *Florschuetzia trilobata* forms as seen in interval 2438.00-2428.00 m. In addition, some fresh water palynomorphs show an increase of their diversity and abundance including *Calophyllum* type, *Dicolpopollis malesianus* and *Sapotaceoidaepollenites* spp. This situation suggests the latest phase of highstand period (Lelono, 2003). It is interpreted that the sediment of interval 2438.00-2428.00 m was deposited in distal lower delta plain-proximal delta front. Sediment with interval 2428.00-2412.00 m is characterised by an increase of marine dinoflagellates indicating sea level rise. This sediment was deposited in proximal delta front. Sea level continued to rise in interval 2412.00-2394.00 m (top interval) as shown by significant increase of *Operculodinium* spp. and *Spiniferites* sp. of marine dinoflagellates. In addition, foraminifer appears in more various forms as proved by the occurrence of *Globigerina praebulloides* (planktonic), *Nonion elongatus*, *Asterigerina* sp. (calcareous benthic), *Lepidocyclina* (*N*) *tournueri*, *Operculina ammonoides* and *O. granulose* (larger benthic). The sediment in the top interval was formed in delta front (Figure 3).

B. *Well 2*

Well 2 drilled the sediment situated within an interval of 2458.00-2593.00 m. Apparently, Gamma log of Well 2 shows similar pattern to that of Well 1. However, the studied sediment penetrated by Well 2 is thicker than that drilled by Well 1 (Figures 3 and 4). Sedimentation in Well 2 is initiated by the formation of distal upper delta plain deposit which is inferred as a product of lowstand phase (interval 2593.00-2576.00 m). This sediment lacks brackish palynomorph as it was deposited in freshwater environment (Figure 4). Lithologically, interval of 2593.00-2576.00 m is characterized by massive body of coarse material which is recorded as blocky shape in Gamma log. Depositional environment shifted seaward into proximal lower delta plain (interval 2576.00-2544.00 m). Brackish palynomorph appears in a low abundance and diversity as shown by *Discoidites novaguenensis* and *Discoidites* sp. in the upper interval. The sediment of this interval consists of shale with sand intercalation. The depositional environment continued to shift seaward into distal lower delta plain (interval 2544.00'-2534.00'). This is suggested by the occurrence of various back mangrove element such as *Florschuetzia trilobata* forms, *Discoidites Novaguenensis* and *Discoidites* spp. In fact, sedimentation in this environment occurred during transgressive phase. Sea level kept rising to form highstand sediment which was deposited in lower delta plain (interval 2534.00'-2512.00'). This interpretation is based on the increase of abundance and diversity of back mangrove palynomorphs as previously mentioned. Freshwater palynomorph consistently appears in the same assemblage as found in the previous interval. The highstand sediment is assumed to terminate the first sequence (Figure 4).

The next sequence is started by the formation of distal lower delta plain sediment which was sedimented during transgressive phase (interval 2512.00'-2472.00'). Dinoflagellate cysts are getting increase toward the top of the interval. In fact, it continues to increase exceeding this interval into the next interval (2472.00'-2458.00'). In addition, small and larger benthic forams appear significantly within this interval indicating stronger marine influence. Finally, sedimentation in the top interval (2472.00'-2458.00') occurred in delta front environment during the transgressive phase. The presence of this environment is indicated by the significant increase of marine dinoflagellate assemblage including *Hystrichosphaeridium* sp., *Operculodinium* spp. and *Leiosphere* sp. (Figure 4). More over, small benthic forams suggesting deeper water setting present within the top interval such as *Bathysiphon* sp. and *Clavigerinella* sp. Planktonic forams also appear to mark more marine environment compared to that of the previous interval.

C. *Well 3*

The studied interval of Well 3 ranges from 2254.00'-2404.00' (Figure 5). Sedimentation was initiated by the deposition of lower delta plain sediment within interval 2404.00'-2348.00' which consists of the intercalation of sand and shale. Brackish palynomorph is represented by *Zonocostites ramonae* (mangrove), *Florschuetzia trilobata* forms, *Acrostichum aureum*, *A. speciosum* and *Discoidites novaguenensis* (back mangrove). Freshwater swamp element occurs in moderate abundance and diversity including *Calophyllum* type and *Dicolpopollis* spp. Subsequently, sedimentation slightly moved seaward into distal lower delta plain (2348.00'-2334.00') as suggested by the increase of *Z. ramonae* of mangrove pollen. Back mangrove element shows low to moderate assemblage including *Acrostichum aureum*, *A. speciosum*, *F. trilobata* forms and *Oncosperma*. On the other hand, *Dicolpopollis* sp and *Shorea* type of freshwater pollen provide maximum abundance in interval 2348.00'-2334.00'. Depositional environment continued to shift seaward into proximal delta front which is indicated by the occurrence of various marine dinoflagellates such as *Operculodinium* spp. and *Spiniferites* sp in interval 2334.00'-2316.00'. Another marine indicator occurring in this interval is foraminiferal test lining. More over, larger benthic foram presents to identify shallow middle neritic environment, including *Operculina ammonoides*, *O. granulose* and *Amphistegina gibbosa*. Generally, it is interpreted that the sediment situated in three intervals mentioned above was deposited during transgressive phase as suggested by the change of depositional environment into deeper marine setting toward top interval. The highstand period occurred in interval 2316.00'-2296.00' to complete the first sequence. Sedimentation of this interval took place in delta front environment as indicated by the increase of *Operculodinium* spp. of marine dinoflagellate (Figure 5).

The sediment within an interval of 2296.00'-2270.00' is characterized by the decline of marine dinoflagellate which indicates shallower setting than that of the previous interval. The sediment of this interval might have been deposited in distal lower delta plain-proximal delta front. Depositional environment was getting deeper in the youngest interval (2270.00'-2254.00') as suggested by the significant increase of *Operculodinium* spp. of marine dinoflagellate. Another dinoflagellate occurring in this interval is *Hystrichosphaeridium* sp. Meanwhile, most palynomorphs decrease due to long distance transportation from land source to depositional setting. Over all, it is inferred that the sediment situated in two intervals stated above was deposited during trans-

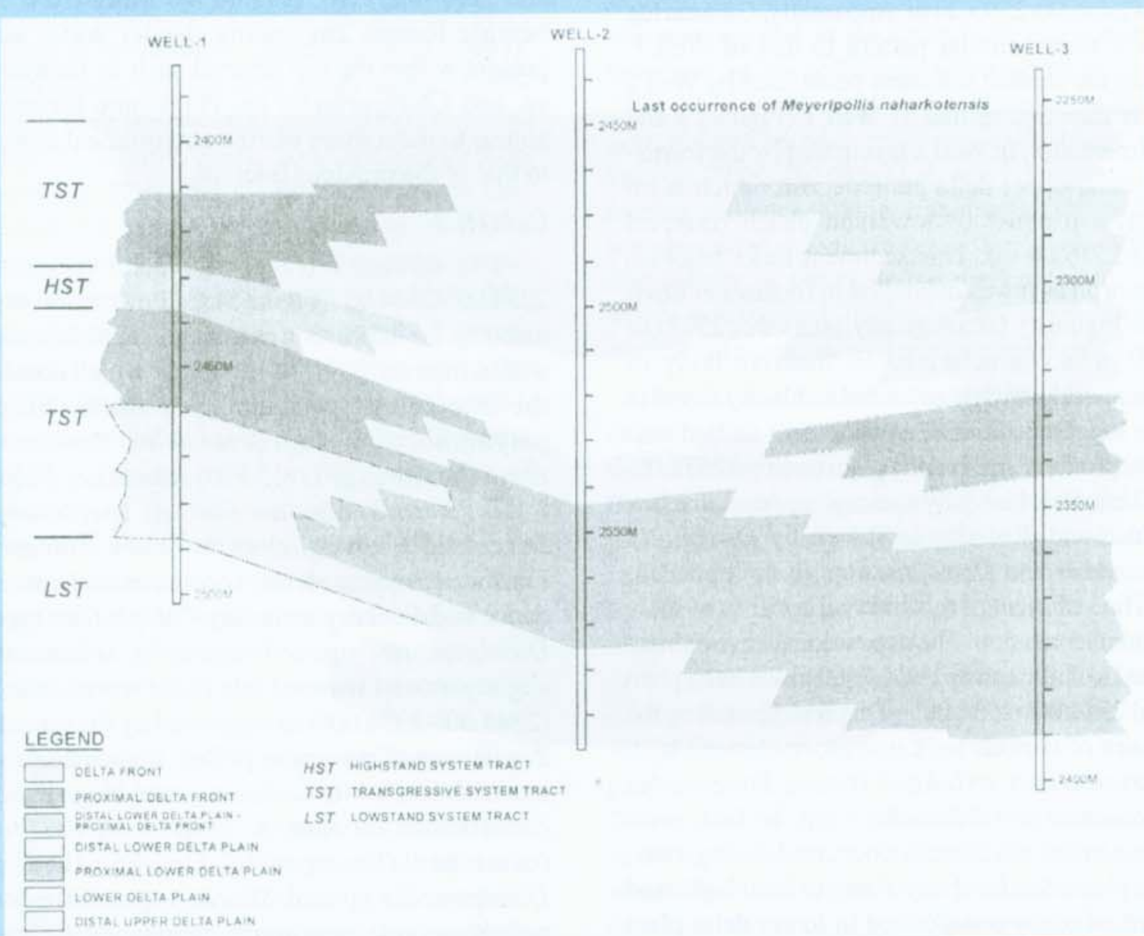

Figure 7
System tract events and possible lateral facies changes across the studied wells. Facies correlation is tied to the last occurrence of polen *Meyeripollis naharkotensis* which defines Oligo/ Miocene boundary

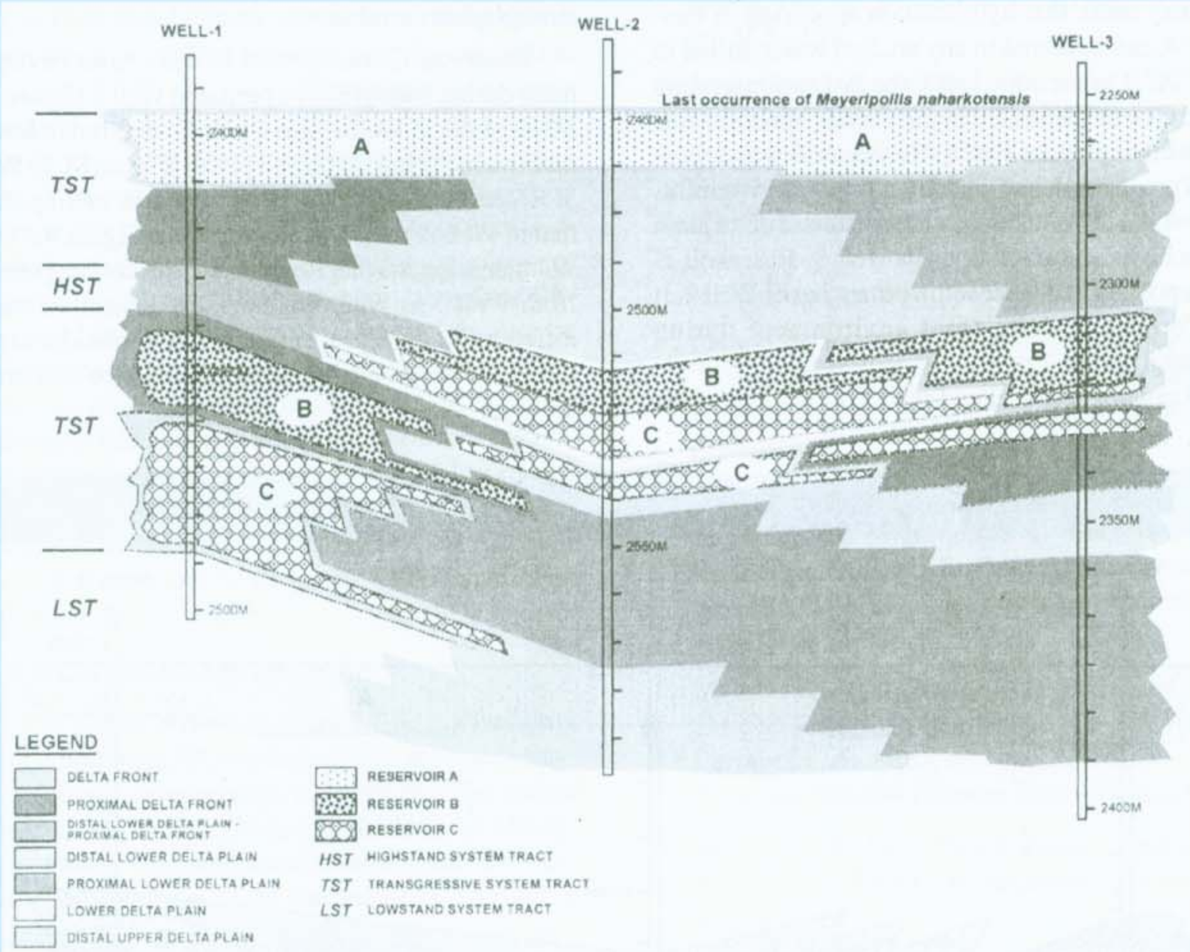

Figure 8
Facies changes and the lateral distribution of the objective reservoirs (A, B and C) demonstrate the possible connectivity of these reservoirs along the studied wells

gressive phase. The indication of the deepening process of the depositional environment is clearly seen in Gamma log which provides bell shape indicating fining upward lithology, especially shown in interval 2296.00'-2270.00' (Figure 5).

V. STRATIGRAPHIC MODEL FOR FIELD "X"

Stratigraphic model of the Field "X" is reconstructed by correlating the studied wells (1, 2 and 3) based on palynological scheme and system tract interpretation. This model allows explorationist to observe the connectivity of the existing reservoirs (A, B and C). The last occurrence of *Meyeripollis naharkotensis* indicating Miocene/ Oligocene boundary is selected for correlation datum as it widely applies in western Indonesia. In addition, the last occurrence of *M. naharkotensis* is recorded in all wells which assist to build up the correlation framework (Figures 6). Having system tract interpretation (Figures 3, 4 and 5), the studied wells are correlated to observe facies changes across these wells. With the exception of the upper sections which shows homogeneous facies of delta front, most facies regularly changes from one well to another (Figure 7).

The stratigraphic correlation is able to illustrate the horizontal distribution of the potential reservoirs from well to well (Figure 8). Reservoir A situated in the top sections was consistently formed in delta front province during the second transgressive phase across

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the studied wells. Therefore, reservoir A is inferred to connect through out the studied wells (Figure 8). This may mean that hydrocarbon appearing in Reservoir A can be found in any studied wells drilled in Field "X". On the other hand, the last two reservoirs (B and C) were deposited in the various environments from well to well. In Well 1, Reservoir B was deposited in proximal delta front under transgressive influence, whilst in Well 2, it occurred in lower delta plain within highstand condition. In Well 3, Reservoir B was deposited in deeper setting than that of Well 2. It was formed in delta front environment during highstand period. Environmentally speaking, Reservoir B can not be correlated across the studied wells. Therefore, disconnection of Reservoir B in reserve calculation is strongly recommended based on the stratigraphic correlation.

Reservoir C was formed in delta front environment during transgressive period in Well 1 (figure 8). Meanwhile, in Well 2, Reservoir C occurred in lower delta plain during highstand phase (Figure 8). In Well 3, Reservoir C was deposited in deeper setting than that of Well 2, which was delta front (Figure 8). This situation suggests that Reservoir C can not be spanned from Well 1 to Well 3 as they are environmentally different. In this case, engineer must consider separating the reservoir in reserve calculation to obtain accurate result.

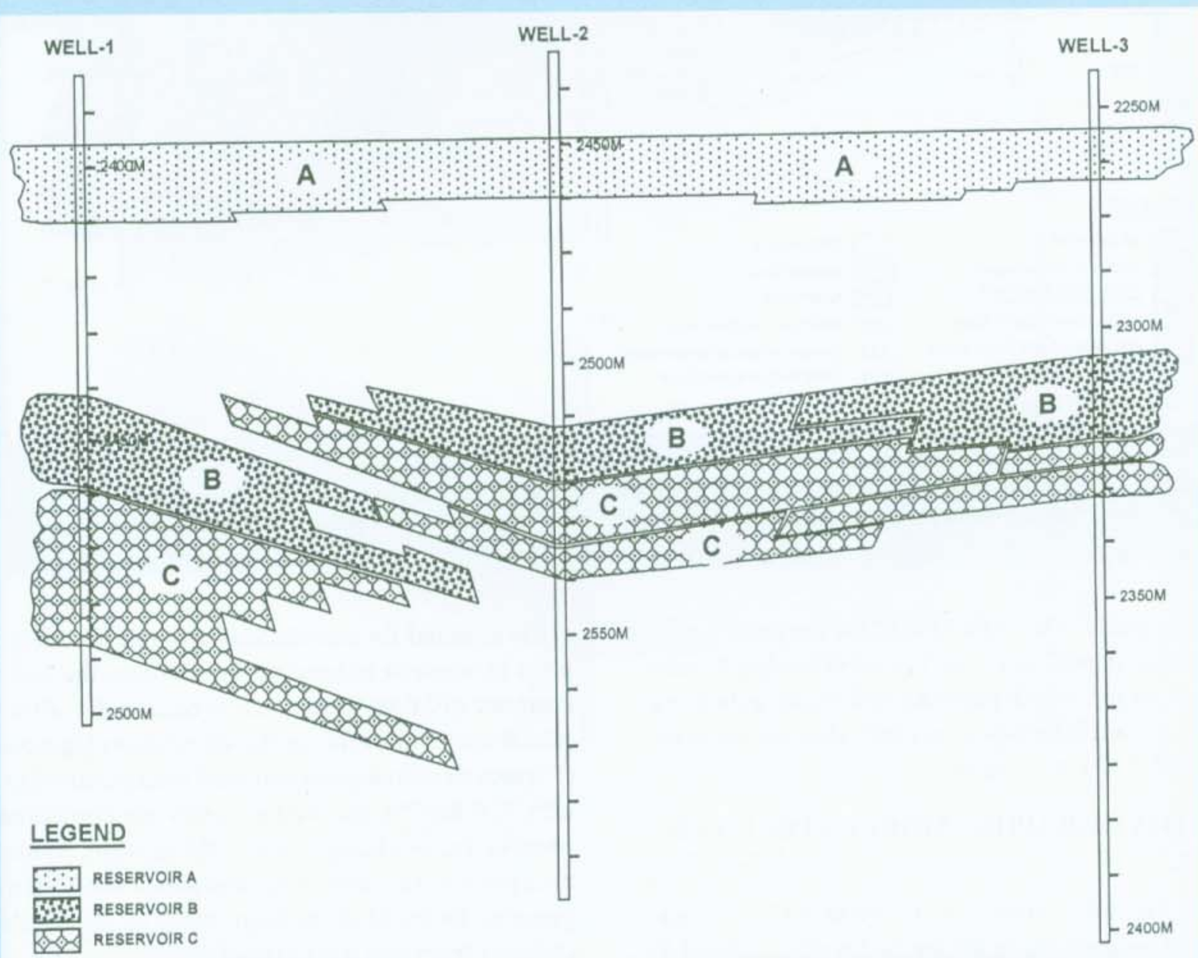

Figure 9
Stratigraphic correlation of the studied reservoirs shows the connectivity of Reservoir A across the studied wells. This correlation proves the disconnectivity of Reservoirs B and C which have to be considered as separating reservoirs

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VI. CONCLUSSION

This study illustrates the contribution of palynology in field development as it determines reservoir connectivity to obtain accurate reserve calculation (Figure 9). Palynology and micropaleontology combined with lithology inferred from Gamma log enable revealing the stratigraphic framework of the studied field. This framework was reconstructed based on stratigraphic correlation which refers to system tract subdivision. It is inferred that potential reservoirs were deposited within the deltaic sediment during Late Oligocene (? to Early Miocene) on the basis of regular occurrence of pollen *Meyeripollis naharkotensis*. Reservoir A situated on the top well sections is widely distributed within the studied wells. On the other hand, this research suggests disconnection of Reservoirs B and C from Well 1 to 3 (Figure 9). The result of this study allows reservoir engineer to obtain accurate calculation and to determine drilling program within the studied field.

VII. ACKNOWLEDGMENT

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