PALYNOLOGICAL STUDY OF PEMATANG FORMATION OF AMAN TROUGH, CENTRAL SUMATRA BASIN

STUDI PALINOLOGI FORMASI PEMATANG, AMAN TROUGH CEKUNGAN SUMATRA TENGAH

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ABSTRAK

Studi palinologi Pematang Grup Aman Trough, Cekungan Sumatra Tengah dilakukan untuk menyusun biostratigrafi dari Pematang Group. Analisis palinologi ini memberikan hasil berupa pembagian zonasi dan bioevent serta interpretasi lingkungan pengendapan. Penelitian ini dilakukan pada percontoh cutting dan core dari 2 (dua) sumur yaitu Sumur A-1 dan B-1. Umur sedimen daerah penelitian berkisar antara "tidak lebih tua dari Eosen Tengah" sampai "tidak lebih muda dari Oligosen". Batas atas umur Oligosen ditandai dengan kemunculan terakhir dari *Meyeripollis naharkotensis*, sementara batas bawahnya tidak dapat ditentukan. Umur Eosen ditandai dengan kemunculan *Florschuetzia trilobata* pada bagian bawah area penelitian dan didukung oleh kemunculan terakhir *Cicatricosisporites eocenicus*. Batuan sedimen daerah penelitian diendapkan di lingkungan *aluvial fan* sampai *proximal lacustrine* selama umur Eosen Tengah sampai Akhir, yang kemudian berubah ke *deltaic* pada Akhir Oligocene. Menariknya, sedimen yang dipelajari tidak menghasilkan elemen *lacustrine* yang menunjukkan hilangnya endapan *lacustrine*. Hasil penelitian menghasilkan 5 events yang dapat dikorelasikan antar sumur, dari umur tua ke muda adalah sebagai berikut : *LO Cicatricosisporites eocenicus, freshwater apparent, freshwater prominent, first significant backmangrove, dan LO Meyeripollis naharkotensis.*

Kata kunci: Pematang, lacustrine, palinologi.

ABSTRACT

The palynological study of Pematang Group of Aman Trough, Central Sumatra Basin is carried out to construct biostratigraphy of Pematang Group. The palynological analysis provide a zonal subdivision and bioevent identification as well as environment of depositional interpretation. The study uses cutting and core samples which were collected from wells namely Well A-1 and Well B-1. The age of the sediment ranges from "not older than Middle Eocene" to "not younger than Oligocene". Top Oligocene age is identified by the last occurrence of Meyeripollis naharkotensis whilst the base Oligocene is uncertain. The Eocene age is defined by the occurrence of Florschuetzia trilobata and supported by the last occurrence of Cicatricosisporites eocenicus. The environment is deposited in alluvial fan to proximal lacustrine during Eocene to Late Eocene, then, changed into deltaic marine in Late Oligocene. Interestingly, the studied sediment lacks of lacustrine elements suggesting the disappearance of lake deposit. The studied wells can be separated into 5 events which are applicable within the studied area, from older to younger age as follow: the LO of Cicatricosisporites eocenicus, the fresh water apparent, and the freshwater prominent, the first significant backmangrove, and the LO of Meyeripollis naharkotensis.

Keywords: *Pematang, Lacustrine, Palynology.*

I. INTRODUCTION

In the Central Sumatra Basin, oil is mostly produced from the post rift reservoir of Early Miocene Sihapas Group. A small portion of production is generated from syn-rift sediments which is the clastic reservoir of Pematang Group. The specific character of Central Sumatra Basin is the absence of carbonate reservoirs, such as in the Basin of North Sumatra, South Sumatra, East and North Java (William and Eubank, 1995).

This study have been undertaken as part of a regional data acquisition and analysis effort to understand the stratigraphy of the Pematang Group of Aman Trough Central Sumatra Basin. The purpose of

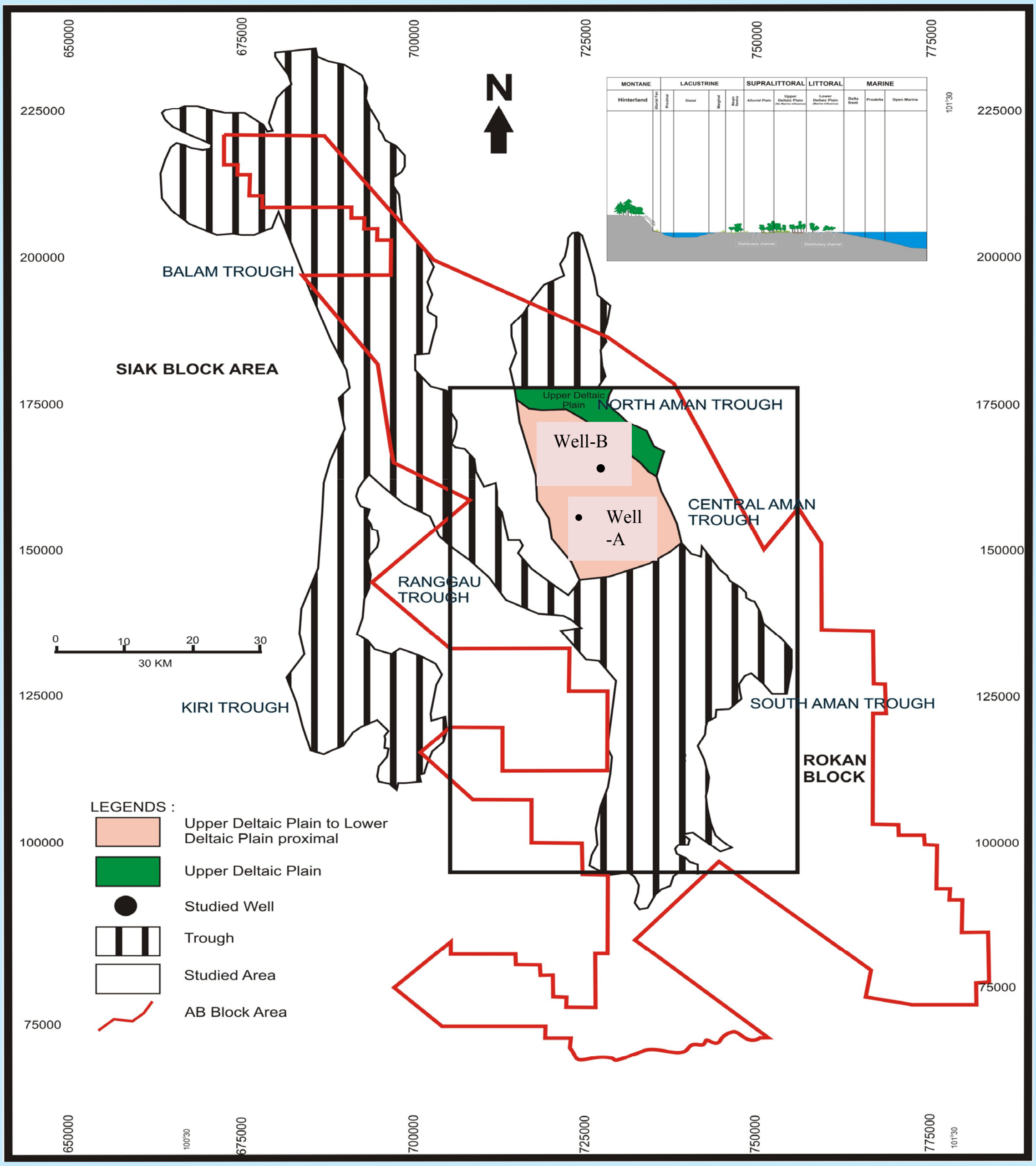

Figure 1
The location of well samples which are used for the study

this study is to determine biostratigraphy condition of Pematang Group of Aman Trough, Central Sumatra Basin. The palynological analysis will provide a zonal subdivision and bioevent identification as a tool for well correlation, and environment of depositional interpretation for sequence stratigraphic and paleogeographic analysis. The result of this analysis is integrated with wireline log and also tied into seismic data for sequence stratigraphic analysis

The study is conducted on sub surface samples obtaining from 2 (two) selected wells namely Well A-1 and Well B-1. The type of analyzed samples is cutting and cores. All samples were processed using standard palynological preparation technique in the Stratigraphy Laboratory of LEMIGAS, Jakarta.

A. Geology and Stratigraphy of Central Sumatra Basin

The Central Sumatra Basin is one of a series of back-arc basins which developed linearly along the leading edge of Sundaland, as a result of subduction of the Indian Ocean Plate beneath the Southeast Asian Plate. Numerous active structural elements of mainland Sumatra trend NW parallel to the Java trench and include: the outer-arc ridge, outerarch basin, the Barisan volcanic arc, and the Great Sumatran fault zone (Heidrick and Aulia, 1993). The NW structural and topographic grain is largely a late Cenozoic phenomenon that is superimposed upon the NNE-trending Asahan arch and Lampung High and ENE-trending Tigapuluh arch (Mertosono and Nayoan, 1974). These arches and high combine to effectively subdivide the Sumatran foreland into north, central, and south basins (Figure 2). The Central Sumatra Basin is bound to the southwest by the Barisan Mountain geoanticlinal uplift and volcanic arc, to the north by the Asahan arch, to the southeast by the Tigapuluh high, and to the east by the Sunda craton (Figure 2).

The Central Sumatra Basin was formed during the Early Tertiary (Eocene – Oligocene) as a series of half graben structures separated by horst blocks

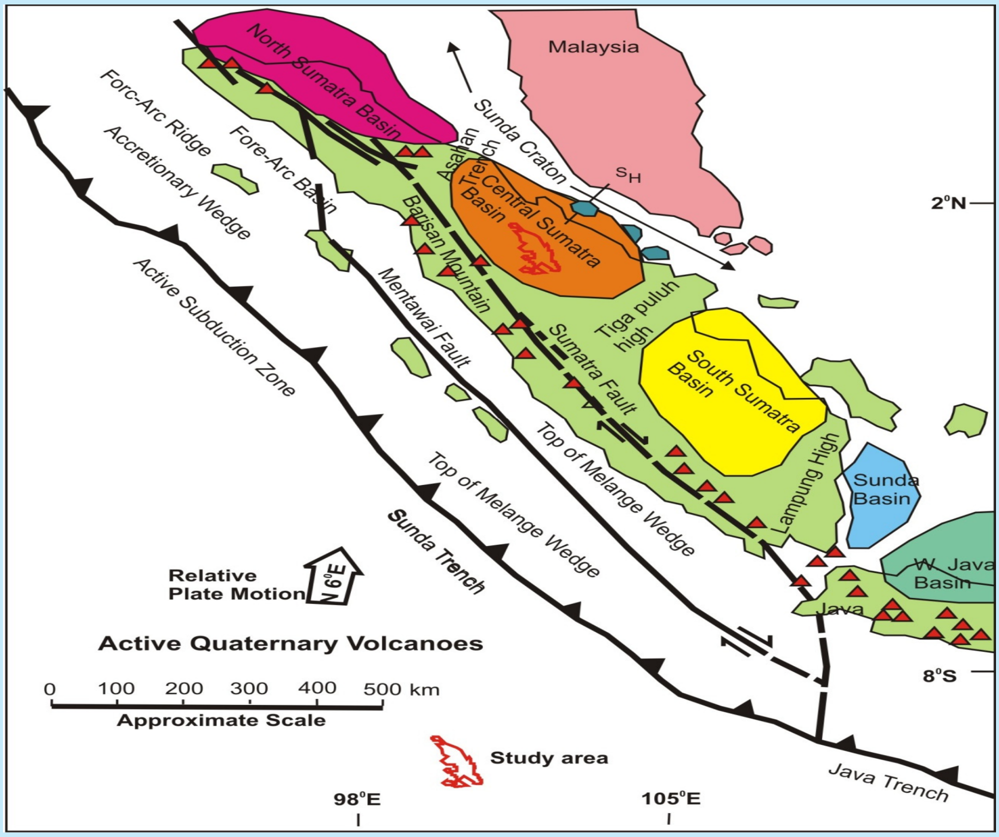

Figure 2
Map of southwest Sundaland showing the principal Tertiary basins of Sumatra and Java (Mertosono and Nayoan, 1974)

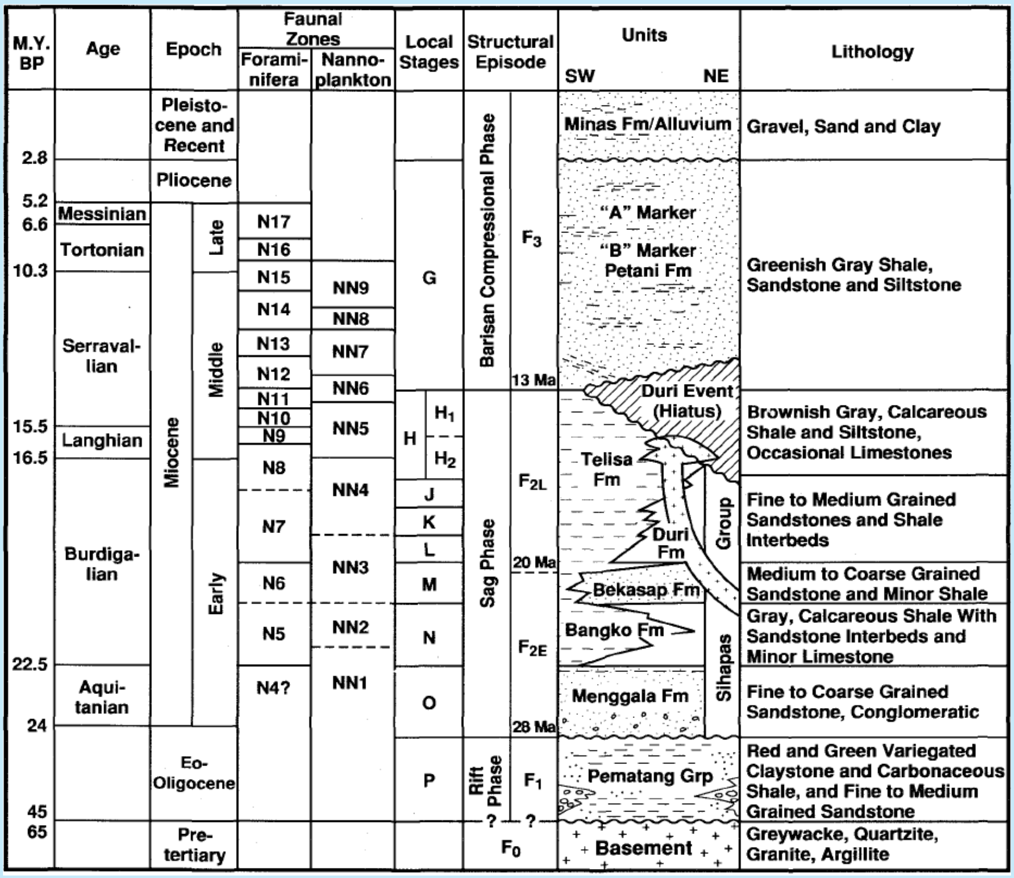

Figure 3
Cenozoic time-stratigraphic chart of the Central Sumatra basin showing major formations, coeval deformational episodes recognized in the Coastal Plain areas, and brief lithologic description of respective formations. (Modified after: Mertosono and Nayoan (1974), White (1975) and Wongso Santiko (1976); ime Scale from VaiVMitchum (1979), Eubank and Makki (1981), Suryanto and Wycherley (1984) in Heidrick and Aulia, 1993)

(Williams, *et al*., 1985). Tertiary sedimentary succession rest overlying a complex pre-Tertiary lithology of Paleozoic and Triassic marine and continental strata with associated intercalated volcanic and local subduction-related mélange.

Tertiary rock-stratigraphic units in the Central Sumatra Basin are divided into five subdivisions (Mertosono and Nayoan, 1974). From oldest to youngest, i.e. the Pematang formation, Sihapas group, and Telisa, Petani, and Minas formations. The Pematang formation directly overlies basement in the Central Sumatra Basin and consists of two continental-dominated facies: 1) varicolored mottled claystone and fine grained sandstone that are locally interbedded with organic-rich lacustrine shale, and 2) a sequence of conglomerate, coarse grained sandstone, and variegated claystone. Sediments in deep transtensional pull-apart grabens or shallow extensional rifts formed during a phase of regional Eocene - Oligocene (50-24 Ma) extension (Williams *et al*, 1985). Local footwall uplifts, intrabasinal highs, and coeval transpressional anticlinal culminations strongly influenced the distribution of synrift alluvial and braided stream sediments. The Pematang is often separated from the overlying Sihapas group by a distinct regional angular unconformity at the onset of Menggala sedimentation at 28-29 Ma (Eubank and Makki, 1981).

The filling of half-grabens, grabens and pull-apart rifts was followed immediately by the Middle

Tertiary marine transgression, which eventually lead to the deposition of clean fluvial-deltaic reservoir sandstone, and subsequent regional subsidence and deposition of shales and mudstones which provide the regional seal.

The transgressive phase of the Neogene is represented by the Sihapas group and overlying partially diachronous Telisa formation. The lower portion of the Miocene Sihapas is represented by an upward fining conglomeratic, coarse to fine grained sandstone succession (Menggala formation) that is capped by calcareous shale of the Bangko formation. A fluviodeltaic depositional environment is suggested for the Menggala whereas the Bangko has a more intertidal to marine influence. The Upper Sihapas records a continuation of the early Miocene transgression with medium to coarse grained micaceous sandstone and the Bekasap representing marginal facies of the more basinal shales of the Telisa formation (Lee, 1982).

The lower to middle Miocene Telisa formation consists of a shale-dominated succession with interbeds of limestone and fine grained glauconitic sandstone. Depositional environments range from inner to outer littoral conditions with more marine influence towards the top. The upper contact of the Telisa formation is marked by a distinct lithological and faunal break corresponding to the middle Miocene regressive phase of the Neogene cycle. The overlying sediments of the Petani formation constitute a monotonous sequence of shale-mudstone containing minor sandstone and siltstone intercalations that show a progressive upwards shallowing and general waning of marine conditions.

Top Neogene is characterized by a pronounced erosion unconformity overlain by a thin veneer of Holocene Minas alluvial sandstone and gravel. The regional nature of the unconformity and marked increase in sediment coarseness suggest that considerable uplift of the basin margins occurred at the end of Pliocene time (Lee, 1982).

B. Paleogene Pematang Group

Paleogene stratigraphic succession of Pematang Group is divided into five lithology units, i.e. Lower Red Beds, Brown Shale, Lake Fill, Coal Zone, and Fanglomerate formations (Williams *et al*., (1985). Paleogene Pematang Group and the overlying Sihapas Group is frequently marked by an angular

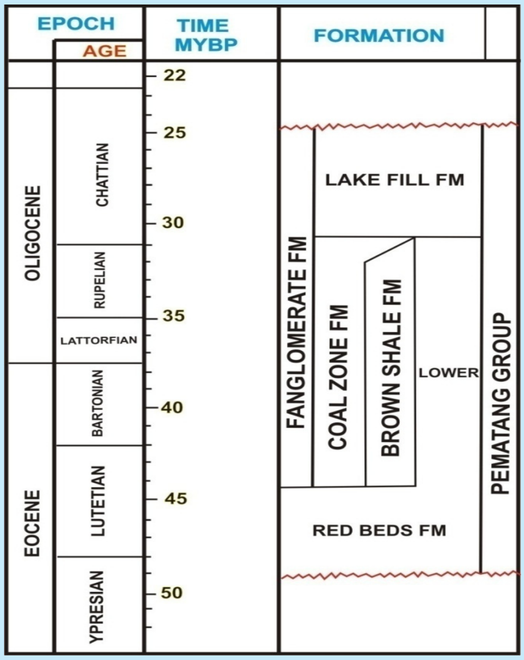

Figure 4
The schematic illustration of the Paleogene stratigraphic section of Pematang Group, Central Sumatra Basin (Williams *et al.*, 1985)

unconformity, however, this unconformity is not always readily apparent. Erosion appears to have been relatively minor but an episode of westward tilt and tectonic activity during the Oligocene imparts a pronounced local unconformity, particularly along the eastern margins of the Pematang Basins.

The Central Sumatra Basin has been generated from organic-rich shales of lacustrine origin within the Palaeogene Pematang Group. During Palaeogene time, large freshwater lake systems developed within structurally controlled rift graben. Palynology indicates freshwater conditions prevailed, however, occurrences of slightly saline conditions suggest minor climatic changes, chemical stratification, or occasional marine incursions. (Williams and Eubank, 1995)

C. Pematang Depositional Model

The sedimentology of the Pematang Group is intimately related to the regional basinal tectonic development and history, and humid, tropical climatic conditions. The Aman Trough is recognized as deep basin geometry. It is characterized by a rapid rifting phase, where rate of deposition was less than rate of subsidence and the development of an anoxic lacustrine facies (Figure 5).

At least three structural events which relate to this development are recognized. These are the pregraben stage/Lower Red Beds Formation deposition), graben stage of intensive rifting/Brown Shale and Coal Zone Formations deposition, and lake fill stage/Lake Fill Formation deposition (Figure 4).

During the intial rifting stage, fault scarps began to develop along the southwest margins of the subsiding basins. During this stage, the interior basins were probably poorly interconnected and characterized by swamps and lakes interconnected by small streams and numerous small deltas giving rise to the very complex widespread distributary plain and shallow lacustrine facies.

The graben stage of intensive rifting is characterized by the extensive development of the lacustrine facies with minor platform and delta front facies. In the Aman Trough, deep lacustrine basin, with rate of deposition less than rate of subsidence developed deep anoxic lakes where the organic-rich Brown Shale formation was deposited. Tropical climatic conditions with no annual lake turnover resulted in anoxic bottom water conditions favoring accumulation of organic matter. Sedimentation rates of 4 to 5 cm/1,000 years are indicated for the Brown Shale Formation. Slow sedimentation rates with limited clastic input are primarily attributed to intense chemical weathering during a relatively stable tectonic period and heavy vegetation cover under tropical climatic conditions.

The final stage of sedimentation was the Lake Fill stage. The sedimentary sequence is characterized by shallow lacustrine, fluvial, distributary plain, delta front, and alluvial facies. This stage was partially preceded by the Pematang structuring which gave rise to the structures in the Brown Shale and Coal Zone formations and the local unconformity relationships between these and the Lake Fill Formation. Sedimentation may have changed as a result of the tectonic activity, resulting in rapid deposition of the Lake Fill Formation. The worldwide cooling trend during the Oligocene as indicated by oxygen isotope data (Habicht, 1979) may have contributed to the increased mechanical erosion by decreasing the stabilizing vegetative cover. Tectonics continued throughout the Lake Fill stage culminating with the regional Pematang unconformity.

II. DATA AVAILABILITY

This study generated data from well samples provided by oil company. Palynological data extracted from these samples were used by LEMIGAS to provide technical services for commercial purpose. Therefore, they are considered to be confidential and

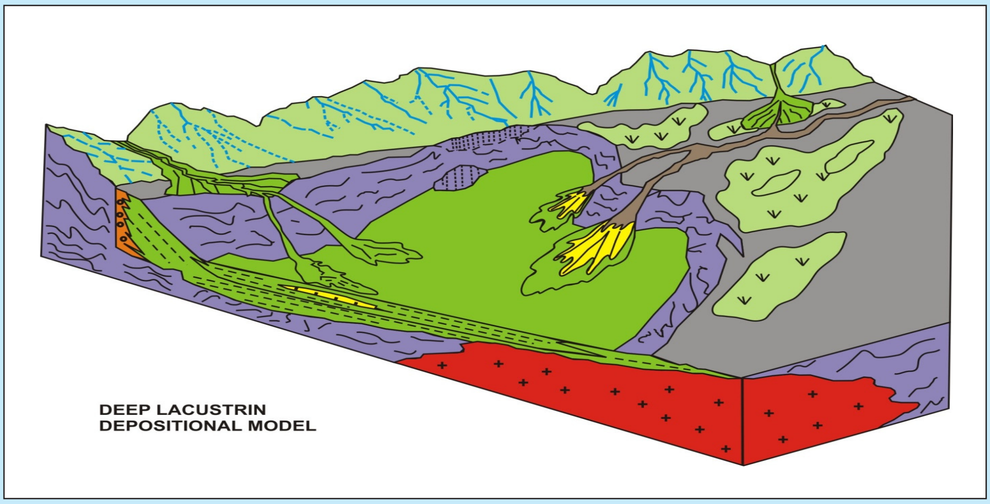

Figure 5
Deep lacustrine depositional model of the Aman Trough
(Williams *et al.,* 1985, modified by Lemigas).

Depth Interval (Feet)	Age	Palynological Zone	Environment	Remarks
4860 - 4880	Indeterminate	Indeterminate	Lower Deltaic Plain-Proximal	
4890				
4903				
4911				
4919				
4966.50				
4966 - 4966.5				
4970 - 4980				LO. Meyeripollis naharkotensis (4980')
5030 - 5040	NOT OLDER THAN MIDDLE EOCENE-NOT YOUNGER THAN OLIGOCENE	Not older than Proxapertites operculatus-not younger than Meyeripollis naharkotensis		
5150 - 5160				
5250 - 5260			Lower Deltaic Plain-Proximal - Lower Deltaic Plain Distal	
5319.30				
5340 - 5350				
5460 - 5470			Upper Deltaic Plain-Lower Deltaic Plain Proximal	
5540				
5680				
5760				
5870			Upper Deltaic Plain-Lower Deltaic Plain Proximal	5870'
5940				First significant backmangrove (5870')
6000				
6110			Alluvial Plain	Prominent Freshwater (6110') seismic correlation
6220				
6350				
6440				
				6450'
6550			Margin Swamps Lacustrine	
6620 - 6630				
6790 - 9800				
6822.3				
6832.8				
6846.9				
6880 - 6890				
7090 - 7100				
7170 - 7180				
7260 - 7270				
7400 - 7410			Marginal Lacustrine-Margin Swamps Lacustrine	Occ. F. trilobata (7410')
7500 - 7510				
7630 - 7640				
7720 - 7730				Apparent freshwater (7730')

Figure 6
Palynological Analysis Summary of Well A-1

Depth Interval	Age	Palynological Zone	Environment	Remarks
3890			Lower Deltaic Plain Proximal	
4330			Lower Deltaic Plain Proximal	LO *Meyeripollis naharkotensis* (4330')
4700			Upper Deltaic Plain-Lower Deltaic Plain Proximal	
4810			Lower Deltaic Plain Proximal	Prominent freshwater (4810') seismic correlation
5240			Lower Deltaic Plain Proximal	
5300				
5610	Indeterminate	Indeterminate	Barren	
5690	Not Older Than Middle Part Middle Eocene to Not Younger Than Oligocene	Not Older Than Proxapertites Naharkotensis to Not Younger Than Meyeripollis naharkotensis	Upper Delta Plain	
5730				
5790				
5820			Lower Deltaic Plain Proximal	
5860				
5900				
5990				
6060			Upper Delta Plain - Lower Deltaic Plain Proximal	
6100				
6140				
6210			Alluvial Plain-Upper Delta Plain	
6250				6250'
			Alluvial Fan	
6340-6350				
6380-6390				Apparent freshwater (6380') seismic correlation
6460-6470				
6510-6520				
6590-6600				
6650-6660			Alluvial Fan - Proximal Lacustrine	
6740-6750				
6860-6870			Barren	
6940-6950			Alluvial Fan - Proximal Lacustrine	
7060-7070			Proximal Lacustrine	
7110-7120				
7180-7190			Barren	
7260-7270				
7360-7370			Alluvial Fan - Proximal Lacustrine	Occ. *F trilobata* (7370')
7420-7430				

Figure 7
Palynological Analysis Summary of Well B-1

should not be public domain. Hence, this paper will not reveal detail information of the wells which are used in this study (including well name, well location, operator, etc). Two wells are selected to cover the selected sediment and named by using alphabetical codes such as Well A-1 and Well B-1. In addition, due to space limitation, only pollen diagrams with selected palynomorphs which marked analysis and interpretation are shown in this paper.

III. METHODOLOGY

The type of analyzed samples in this study is cutting and cores. The samples were collected from the selected intervals of 2 (two) studied wells (A-1 and B-1). All samples were processed using standard palynological preparation technique in the Stratigraphy Laboratory of LEMIGAS including HCl, HF and HNO3 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 astatistically viable population (=count number) of palynomorphs in every sample. Age interpretation is based on palynological zonations which were proposed by Rahardjo *et al*. in 1994. On the other hand, the environmental classification used in this paper refers to Haseldonckx (1974) and Lacustrine Depositional System (Modified by Lemigas, 2012).

IV. POLLEN ASSEMBLAGE

In general, the studied sections provide low to moderate pollen assemblages with good preservation. Palynomorphs occurring in these sections derived from various vegetations including mangrove, backmangrove, riparian, peat swamp, freshwater fresh water and montane. Some selected palynomorphs which significantly appear in these sections are *Zonocostites ramonae* (mangrove pollen), *Florschuetzia trilobata* (back-mangrove), *Marginipollis concinus* (riparian), *Sapotaceoidaepollenites* type (peatswamp) and *Callophyllum* spp. (freshwater pollen). Mangrove taxa continuosly occur all the way through the studied sections indicating strong marine influence. Meanwhile, freshwater algae of Pediastrum and Bosedinia as lacustrine elements is not found throughout the studied area. This data confirms that the deposition occurred under marine influence during Middle Eocene to Late Oligocene. It is possible that lacustrine facies might occur in the older sediment (Early Eocene sediment).

The significant occurrence of fresh water pollen of *Callophyllum* type indicates the development of freshwater swamp vegetation under wet climate condition. In addition, considerable appearance of peatswamp pollen *Sapotaceoidaepollenites* spp. strongly supports wet climate indication.

V. AGE INTERPRETATION

Palynological zonation of the studied area is assigned to “not older than *Proxapertites operculatus”* – “not younger than *Meyeripollis naharkotensis”* zones, which is equivalent to “not older than Middle Eocene” to “not younger than Oligocene” age. Top Oligocene age is identified by the last occurrence of *Meyeripollis naharkotensis*. However, the base of Oligocene age may not be correlable with the first occurrence of *M. naharkotensis* as this pollen continuosly appears down to Late Eocene age. Meanwhile, Eocene age is defined the occurrence of *Florschuetzia trilobata* at the bottom part of the studied area, this is supported by the last occurrence of *Cicatricosisporites eocenicus* according to seismic record. In addition, the appearance of pollen *Palmaepollenites kutchensis* at the base of the studied sections marked Eocene age (Lelono, 2012).

VI. PALEOENVIRONMENT

The study shows that the studied sediment was formed in various environments ranging from Alluvial fan to lower deltaic plain depositional environments.

The depositional environment changed from alluvial fan to marginal lacustrine during Eocene into deltaic in Late Oligocene. According to seismic records, an unconformity is developed within the studied sections. The sedimentation is commenced in alluvial fan to proximal lacustrine environment (lower sections). Local up-lifting causes the unconformity. Subsequently, subsidence occurs to shift the depositional environment intp deeper setting which finally ends in lower deltaic plain (littoral) environment (upper sections).

Brackish palynomorphs commonly appear on Top Oligocene indicating the influence of marine environment during sedimentation, including *Zonocostites ramonae* (mangrove), *Spinizonocolpites echinatus* and *Acrostichum aureum* (back-mangrove) as seen in Well-A (Figure 8).

The studied sections are also marked by significant occurrence of some freshwater pollen produced by peatswamp and freshwater swamp vegetation such as *Cephalomappa* type, *Dicolpopollis* spp. and *Palmaepollenites* spp. Riparian elements regularly appear in low abundance as shown by *Marginipollis concinus* and *Pandaniidites* spp. The lacustrine markers of freshwater algae such as Pediastrum and Bosedinia are not found within the sections. Therefore, it is assumed that the studied sediments are lesslikely to have correlation with lake deposit as these two important markers for lacustrine environment are not represented.

VII. WELL CORRELATIONS AND EVENTS

Related to the Integrated Study of Pematang Biostratigraphy in Aman Trough, well correlation has been performed to understand the subsurface stratigraphy thus biostratigraphic framework of the studied area can be constructed. In this study, well correlation is mainly conducted based on biostratigraphic data, though several horizons of the seismic stratigraphic analysis result involved. This work is done to divide a rock section into a series of lithologic units bounded by chronostratigraphic units based on combination of the occurrence of zonal markers and palynological events.

Palynological zonation and age biomarkers can be identified in this study consisting of the last occurrence (LO) of *Meyeripollis naharkotensis* (and indicator of the top of *Meyeripollis naharkotensis* zone/Top Oligocene), the occurrence of *Cicatricosisporites dorogensis* (a marker of the upper part *Meyeripollis naharcotensis* zone/the middle part of Late Oligocene), and the last occurrence (LO) of *Cicatricosisporites eocenicus* (signal of the top of *Proxapertites operculatus* zone/Top Eocene). On the other hand, palynological events are identified based on significant abundance of certain species or group of species which reflect climatic, paleoenvironmental or facies changes. Climatic changes may occur regionally, whilst paleoenvironmental and facies changes may only be recognized locally. The events recognized within the studied section are include the *first significant backmangrove pollen*, *prominent freshwater pollen* and *apparent freshwater pollen.*

The event of *first significant backmangrove* is placed at the horizon which is equivalent to Early Oligocene. This horizon represents transitional sediments which is situated at Upper deltaic plain to Lower deltaic plain (proximal). Horizon of *prominent freshwater* consists of lacustrine sediments that formed Alluvial plain to Margin swamps lacustrine depositional environments, whilst the *apparent freshwater* horizon generally forms lacustrine depositional setting sediments which is situated at alluvial fan to Lake margin swamps.

VIII. CONCLUSSIONS

This study provides low to moderate pollen assemblages with good preservation which are assume to derive from various vegetations including mangrove, backmangrove, riparian, peat swamp, freshwater fresh water and montane. The sediment of studied area is assigned to “not older than Middle Eocene” to “not younger than Oligocene” age. Top Oligocene age is identified by the last occurrence of *Meyeripollis naharkotensis* whilst the base Oligocene is uncertain. The Eocene age is defined by the occurrence of *Florschuetzia trilobata* at the bottom part of the studied section which is supported by the last occurrence of *Cicatricosisporites eocenicus*.

The depositional environment changed from alluvial fan to proximal lacustrine during Eocene to Late Eocene, then, then shifted to deltaic environment in Late Oligocene. The studied section yields 5 palynological events which can be correlated among the study wells, from the bottom to the top are as follow: the last occurrence (LO) of *Cicatricosisporites eocenicus*, the fresh water apparent, and the freshwater

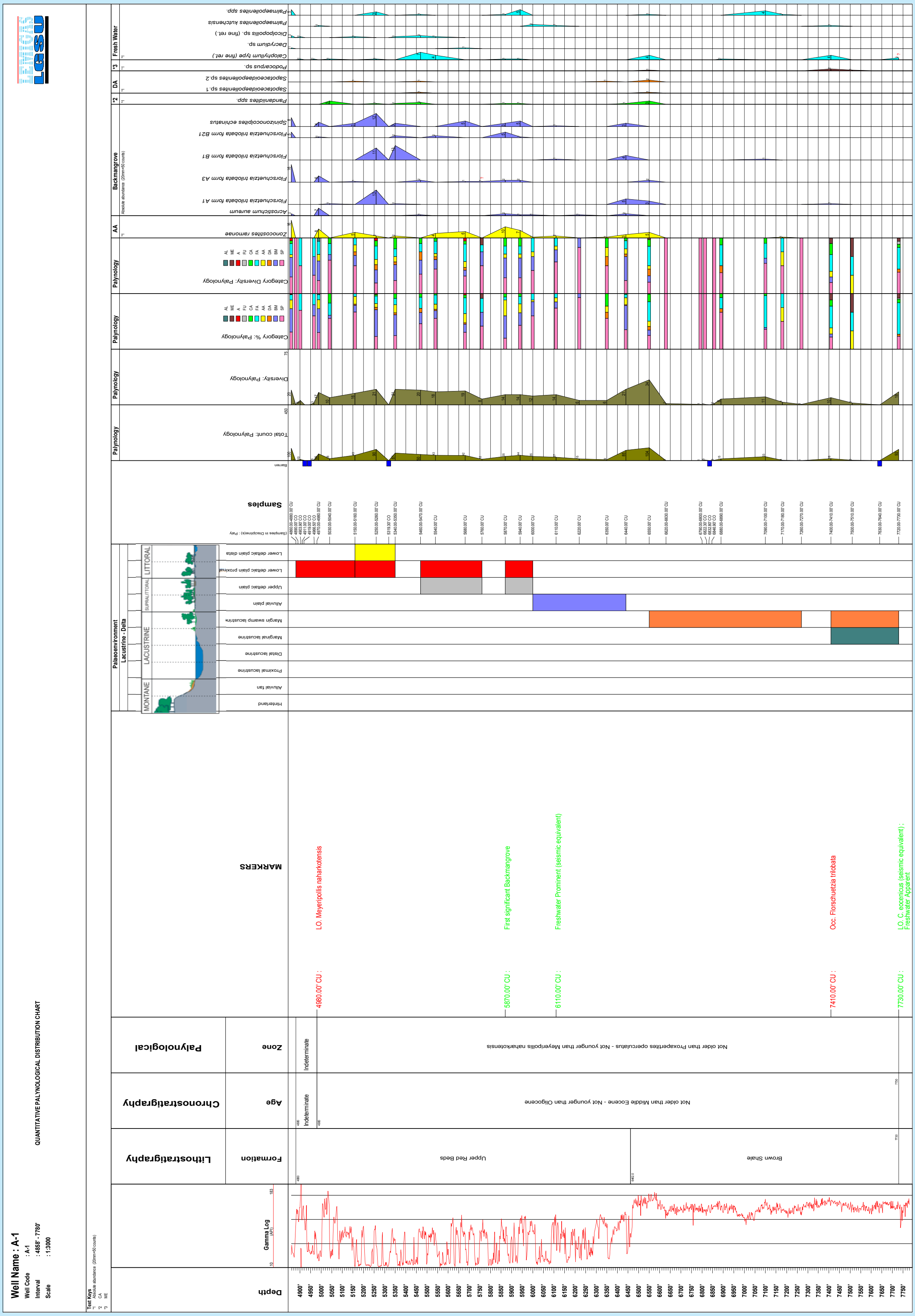

Figure 8
Quantitative Palynological Distribution of Well A-1

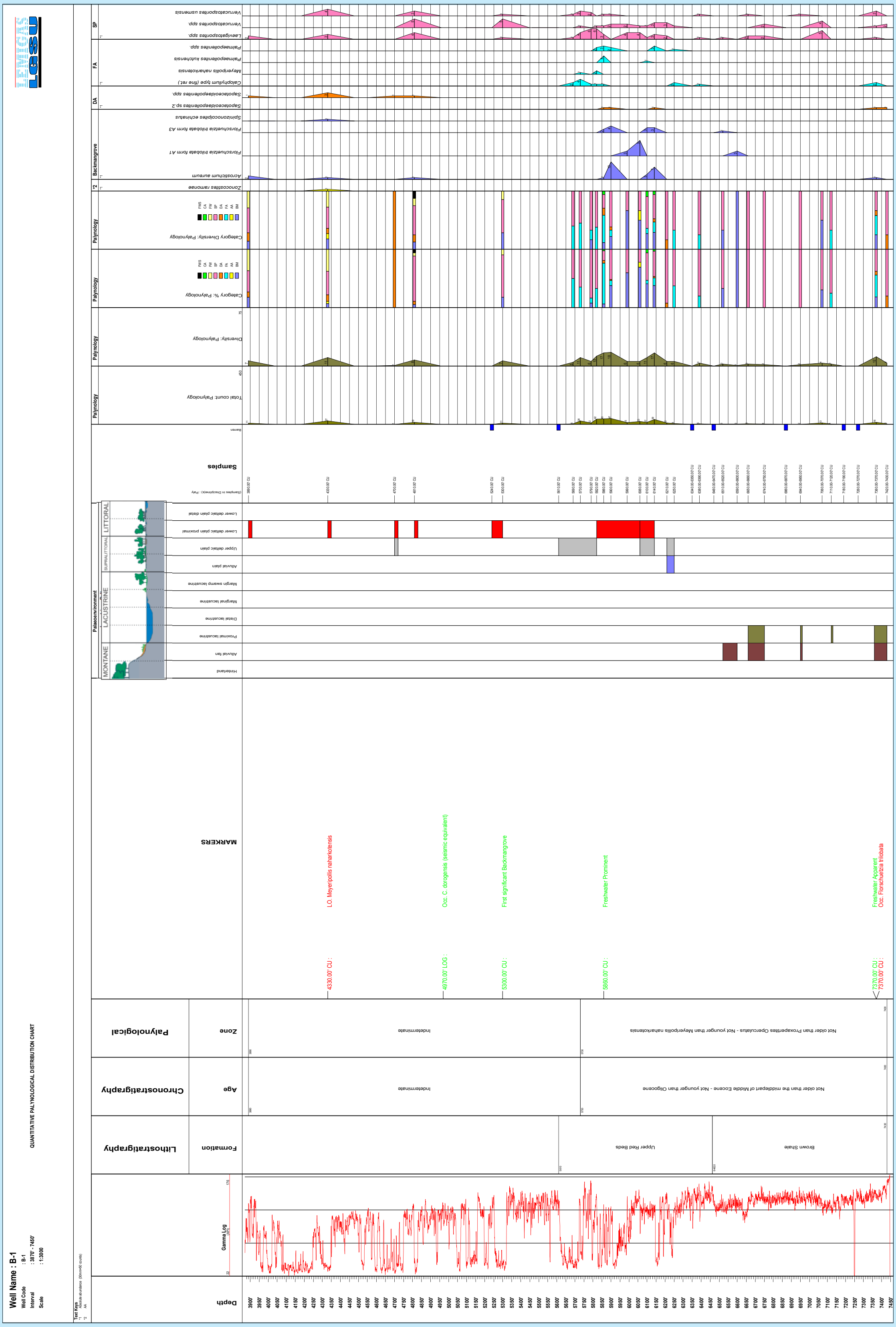

Figure 9
Quantitative Palynological Distribution of Well B-1

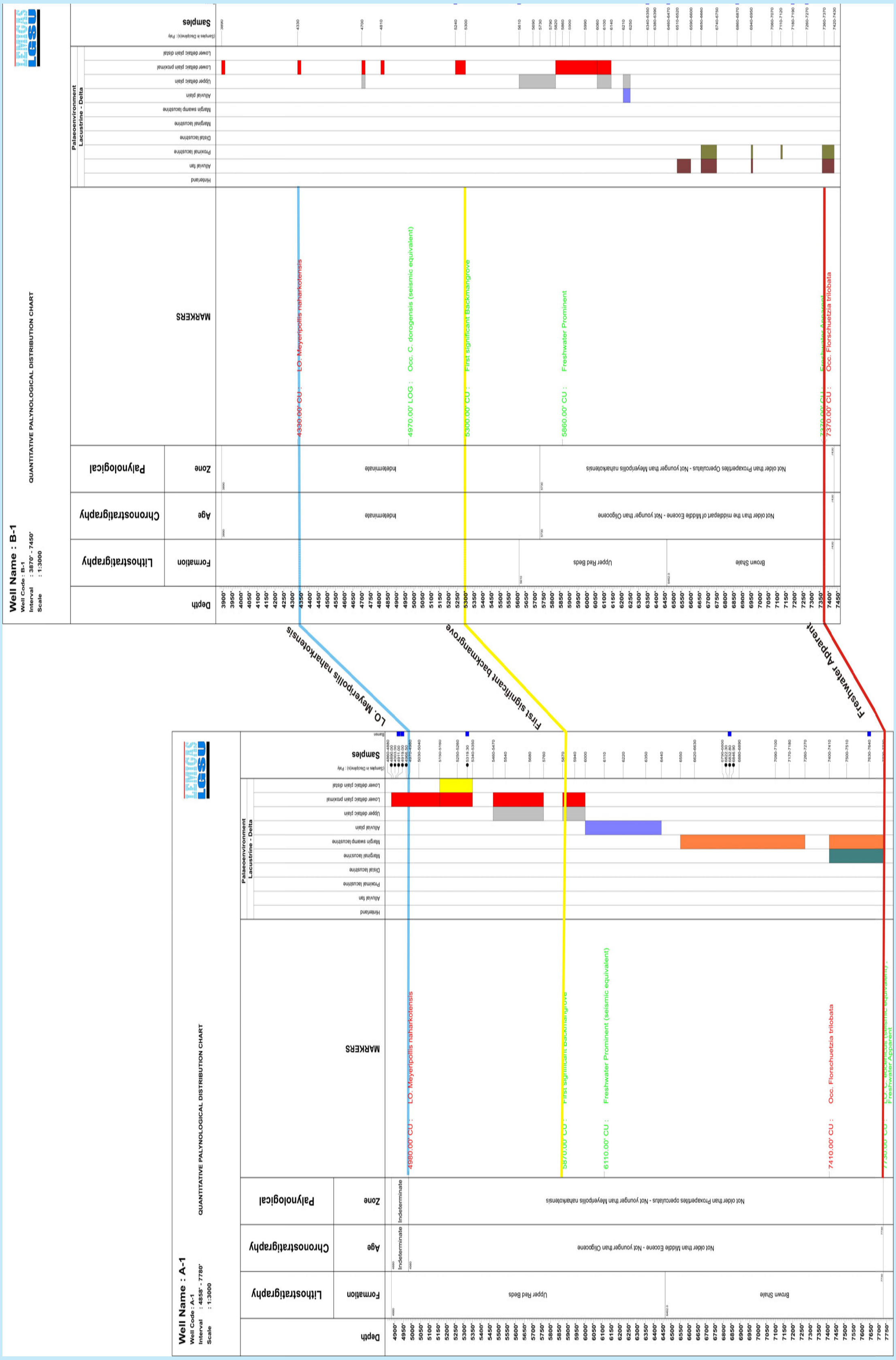

Figure 10
Well correlation based on palynological events

prominent, the first significant backmangrove, and the last occurrent (LO) of *Meyeripollis naharkotensis*.

ACKNOWLEDGMENT

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