SCIENTIFIC CONTRIBUTIONS OIL AND GAS
Vol. 40, Number 3, December 2017: 1 of 6
RESEARCH AND DEVELOPMENT CENTRE FOR OIL & GAS TECHNOLOGY LEMIGAS
Journal Homepage:http://www.journal.lemigas.esdm.go.id
ISSN: 2089-3361, e-ISSN: 2541-0520

POLLEN RECORDS FROM THE OLIGOCENE OF WESTERN INDONESIA AS THE EVIDENCES OF CLIMATE CHANGES

REKAMAN FOSIL POLEN UMUR OLIGOSEN DARI INDONESIA BARAT SEBAGAI PETUNJUK ADANYA PERUBAHAN IKLIM

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First Registered on November 8th 2017; Received after Correction on December 8th 2017
Publication Approval on: December 29th 2017

SARI

Telah dipahami bersama bahwa Asia Tenggara beriklim kering/seasonal selama Oligosen. Meskipun demikian, pernah dilaporkan adanya iklim basah selama periode kering tersebut. Tulisan ini merupakan hasil penelitian yang bertujuan untuk mengetahui secara tepat iklim yang terjadi pada Oligosen di Indonesia Barat agar dapat dipahami runtunan stratigrafinya. Penelitian ini menggunakan perconto keratan sumur lepas pantai Jawa Barat, Jawa Timur dan Natuna serta dari daratan Sumatera Tengah dan Jawa Barat. Perconto diproses menggunakan teknik preparasi standar sehingga menghasilkan kumpulan polen yang layak untuk analisis kuantitatif. Hasil penelitian menunjukan bahwa sedimen Oligosen kaya kandungan fosil polen dan spora, termasuk fosil penunjuk lingkungan dan iklim. Algae air tawar Pediastrum dan Bosedinia dijumpai melimpah pada Oligosen Awal menandai kehadiran lingkungan danau. Diperkirakan iklim kering/ seasonal berkembang pada umur ini yang ditandai dengan melimpahnya polen rumput Monoporites annulatus, tetapi jarang/ rendahnya polen-polen iklim basah (hutan hujan). Sebaliknya, Oligosen Akhir dicirikan dengan melimpahnya polen air payau yang menandai pergeseran lingkungan kearah transisi sampai laut dangkal. Iklim menjadi lebih basah pada Oligosen Akhir yang ditandai dengan melonjaknya jumlah polen Casuarina dan Dacrydium serta polen hutan hujan lainnya. Kemungkinan iklim paling basah terjadi di Jawa sebagai cerminan dari batas timur iklim basah yang terjadi di Daratan Sunda sesaat menuju tumbukan Benua Asia-Australia pada batas umur Oligo-Miosen. Meskipun demikian, secara keseluruhan iklim kering/ seasonal mendominasi umur Oligosen di Indonesia Barat.

Kata Kunci: *rekaman polen, oligosen, Indonesia barat, perubahan iklim*

ABSTRACT

In Southeast Asia, Oligocene climate is well known to be represented by dry/ seasonal climate. However, it was reported possible appearance of wet climate period during the expantion of dry condition. This work is aimed to confirm the Oligocene climate which occurred in western Indonesia. Climate change is useful to understand the Oligocene stratigraphy of Western Indonesia. This study uses cutting samples from off-shore exploration wells situated in West and East Java and West Natuna as well as on-shore Central Sumatera and West Java. Samples are processed using standard preparation methods to produce suitable pollen assemblage for quantitative analysis.This study proves that the Oligocene sediments yield rich pollen assemblages including those of environment and climate indicators. Abundant fresh water algae of *Pediastrum* and *Bosedinia* in Early Oligocene indicates the appearance of lacustrine sediments. This sediment was formed under dry/ seasonal climate as marked by rich grass pollen *Monoporites annulatus* in the absence or rare occurance of rain forest elements. Mean while, Late Oligocene is characterised by common brackish elements to indicate shifting paleoenvironment into transition to shallow marine. The climate was changing into wetter condition as evidenced by high appearance of *Dacrydium* and *Casuarina* as well as other rain forest palynomorphs. The wettest climate probably occured in Java region which reflected a wet climate fringe to the eastern margin of Sundaland prior to the collision of the Australian and Asian Plates at the Oligo-Miocene boundary. However, in general, dry/ seasonal climate is the rule for most of the Oligocene in Western Indonesia.

Keyword: pollen records, oligocene, west Indonesia, climate changes

How to cite this article:

Lelono, E.B., 3, 2017, POLLEN RECORDS FROM THE OLIGOCENE OF WESTERN INDONESIA AS THE EVIDENCES OF CLIMATE CHANGES, *Scientific contributions Oil and Gas*, 40 (3) pp, 107- 115. DOI: 10.29017/SCOG.40.3.107-115.

I. INTRODUCTION

Tectonically, Western Indonesia was a southern margin of the Sundaland. In Oligocene, it was more or less in the similar position as its positions during Middle to Late Eocene which was in the tropical region (Hall 2013). Rifting commenced in the Eocene was continuing within Oligocene time. The occurrence of pull-apart basins marked the Oligocene geology as found in some areas such as South China Sea, Sumatera and West Java Sea. These basins were initially filled by syn-rift deposits which were formed in the freshwater environment such as lake or swamp. Therefore, abundant freshwater palynomorphs occur to indicate these freshwater deposits. In most regions, these syn-rift deposits usually consist of large, often deep, fresh water lakes, which gradually filled with often organic-rich muds, or with fluvial sands, during periods of low lake levels (Morley 2000). In fact, these deposits are responsible for generation of most source rock in Indonesia. Early Oligocene age with lake deposit is defined by high abundance of freshwater algae of *Pediastrum* and *Botryococcus* (Lelono 2006). The basins was then subsiding towards Late Oligocene to reduce land elevation. This event was followed by rising sea level depositing all sediments below shallow marine environment. Palynologically, the Late Oligocene sediment is characterised by high abundance of brackish palynomorphs. Mean while, in term of paleoclimates, Oligocene of Southeast Asia is mostly characterised by seasonal climate (Morley 2000; Morley et al. 2003; Morley and Shamsuddin, 2006; Spicer et al. 2017). However, essentially everwet climates have recently been interpreted for the Udang Formation in Block B, West Natuna (southernmost part of Natuna) by Morley et al. (2007). In addition, the wettest climates recorded for the Oligocene are from the Java region and probably reflect a wet climate fringe to the eastern margin of Sundaland prior to the collision of the Australian and Asian Plates at the Oligo-Miocene boundary (Lelono et al. 2011).

Palynomorphs are reliable tool to reconstruct past vegetation which is useful for paleoclimate interpretation (Adeonipekun et al. 2015). Pollen and spores indicate vegetation that grow in the certain area. The vegetation of the past had environmental requirements that are similar to their modern counterparts except where it can be demonstrated otherwise. Environmental interpretations deduced from individual taxa become more convincing when the floristic complex includes a number of taxa with similar ecological requirements, thereby highlighting a characteristic natural biome (Spicer et al. 2017). On the other hand, astronomically driven climatic changes have resulted in the successive sequestration of seawater into polar ice caps since Late Eocene or Oligocene (Abreu and Anderson 1978) and probably account for most eustatic change over this period (Morley et al. 2003). The effect of climatic changes in the low latitude has reduced the temperature and the moisture availability.

This paper is intended to interpret paleoclimate of Western Indonesia during Oligocene. Knowledge of paleoclimate can be correlated, in some cases with sea level changes which are in turn to have a relationship with regional stratigraphic and sedimentologic patterns.

II. METHODOLOGY

The area of study is located in three diferent locations including West and East Java Seas, on-shore Central Sumatera and Natuna Sea (Figure 1). The samples are mostly fine grain with dark colour which were collected from exploration wells at 60' interval. The standard methods of maceration using

Figure 1
Locations of studied samples were obtained from on-shore and off-shore wells (X)

HCl, HF and HNO_3 were employed to get recovery of plant microfossils (Singer 1993). Acid treatments were followed by an alkali treatment of 10% KOH which clears up residue. A 5 micron sieve was used to collect palynomorphs by separating them from debris material. Finally, residue was mounted on the slides using polyvinyl alcohol and canada balsam. Palynomorph examination was conducted using a transmitted light microscope with an oil immersion objective and X 12. 5 eye piece. Mean while, palynological records of Natuna Sea and West Java Sea are obtained from publication and service reports which are classified as confidential.

As this study applies quantitative method, it is required to count 300 pollen grains per slide (sample). The number of pollen and spores are plotted into a diagram which is used for age and paleoenvironment interpretation as well as paleoclimate and sea level changes. The age of the studied samples refers to standard palynological zonation which was proposed by Rahardjo et al. (1994), whilst paleoenvironment is based on Morley (1978). In addition, it is performed marine fossil analyses to obtain reliable interpretation such as foraminifer and nannoplankton.

III. RESULTS AND DISCUSSION

Palynological records generated from Late Oligocene Kujung Formation of East Java Sea were obtained from cutting samples of 2 exploration wells, so called Wells X and Y. They are characterised by high pollen and spore assemblages with abundant dinoflagellate cysts and other marine palynomorphs. Pollen/spore assemblages used for paleoclimate interpretation can be divided into 4 groups including kerapah, riparian, seasonal and marine elements (Figure 2). The first three groups show the most interesting succession, with elements indicating both everwet and seasonal climate influences. Kerapah or watershed peats which occur locally in Kalimantan on poorly drained podsolic soils (Brunig 1990 and Morley 2000) in areas of superwet climate (Richards 1996). In this case, the occurrence of 'Kerapah' swamps is convincing evidence for an everwet climate. The paleoclimate occurring in the

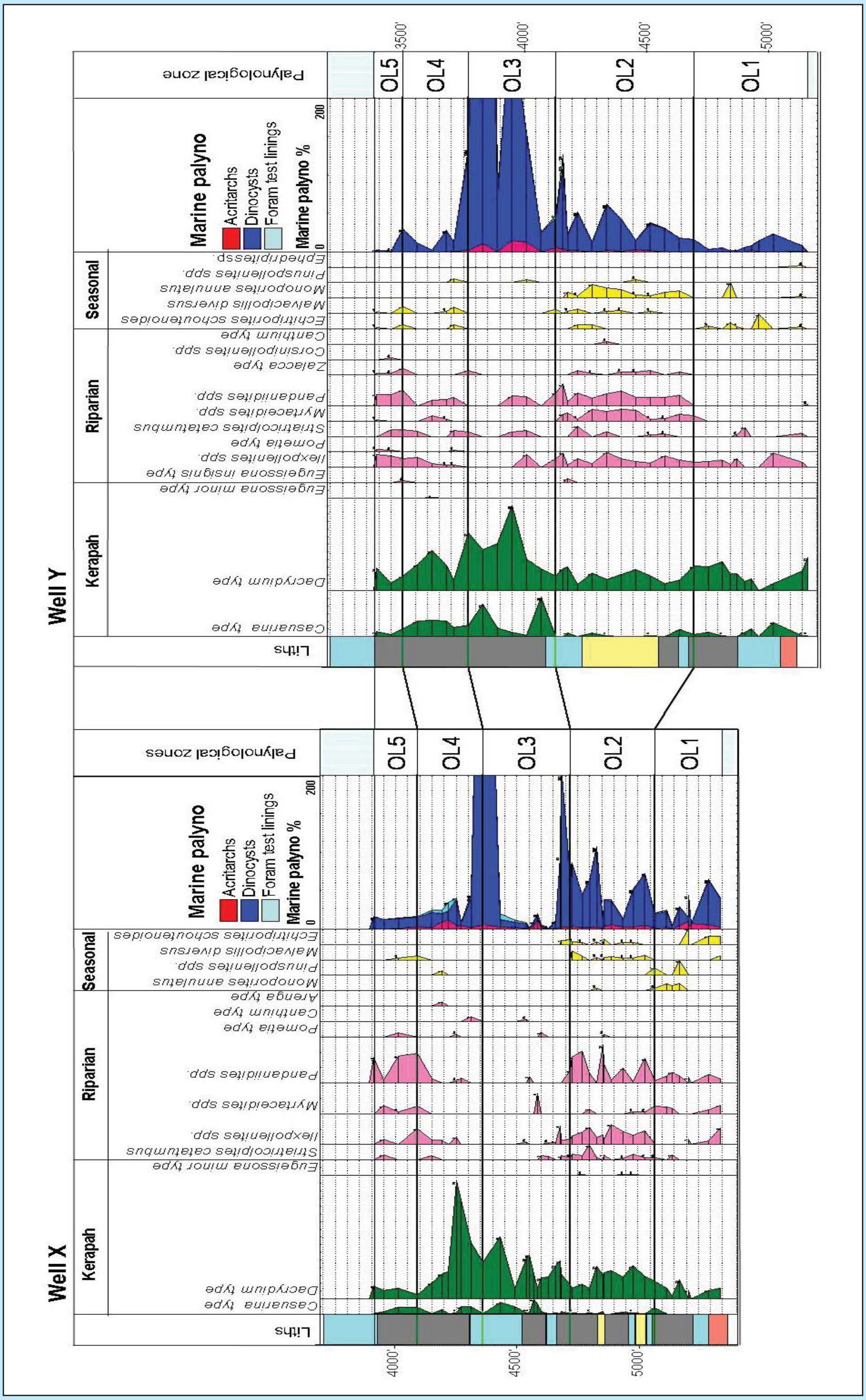

Figure 2
Palynological records from east Java sea show the occurrence of abundant climate indicators, which are useful for paleoclimate interpretation.

studied area is interpreted based on events within the palynological zone (Lelono et al. 2011). The palynological events are identified on the basis of assemblage changes, which are interpreted to indicate climate change, here are termed as OL (Lelono et al. 2011). The Late Oligocene climate of East Java Sea is described referring to OL zones. Zone OL-1 probably reflects a period with moderately wet climates since rain forest and peat swamp pollen dominate assemblages. In contrast, Zone OL-2 is interpreted to reflect a period of marginally seasonal climates. The assemblages through OL-2 are mainly dominated by everwet rain forest climate elements, but the consistent occurrence of pollen of Gramineae, *Schoutenia* and of *Malvacipollis diversus* and reduced representation of peat swamp elements suggests that vegetation characteristic of more seasonal climates must have had a distinct presence in the sediment source area. Within zones OL-3 and OL-4, the dominance of pollen of 'Kerapah' type peat swamp elements, such as *Dacrydium* and *Casuarina*, and the disappearance of riparian elements (ecologically replaced by the Kerapah group) suggests a period of everwet to superwet climates. With the reduction of the Kerapah group in zone OL-5, and return of riparian elements, a change to a slightly less wet (but still everwet) climatic regime is indicated for the uppermost interval.

Oil exploration in West Java Sea also encountered Oligocene sediments. The exploration wells penetrated Early to Late Oligocene sections which were characterised by excellent pollen recovery. Palynological assemblages separated Early Oligocene from Late Oligocene sediments (Figure 3). Early Oligocene sediment is indicated by a high abundance of the fresh water lake algae

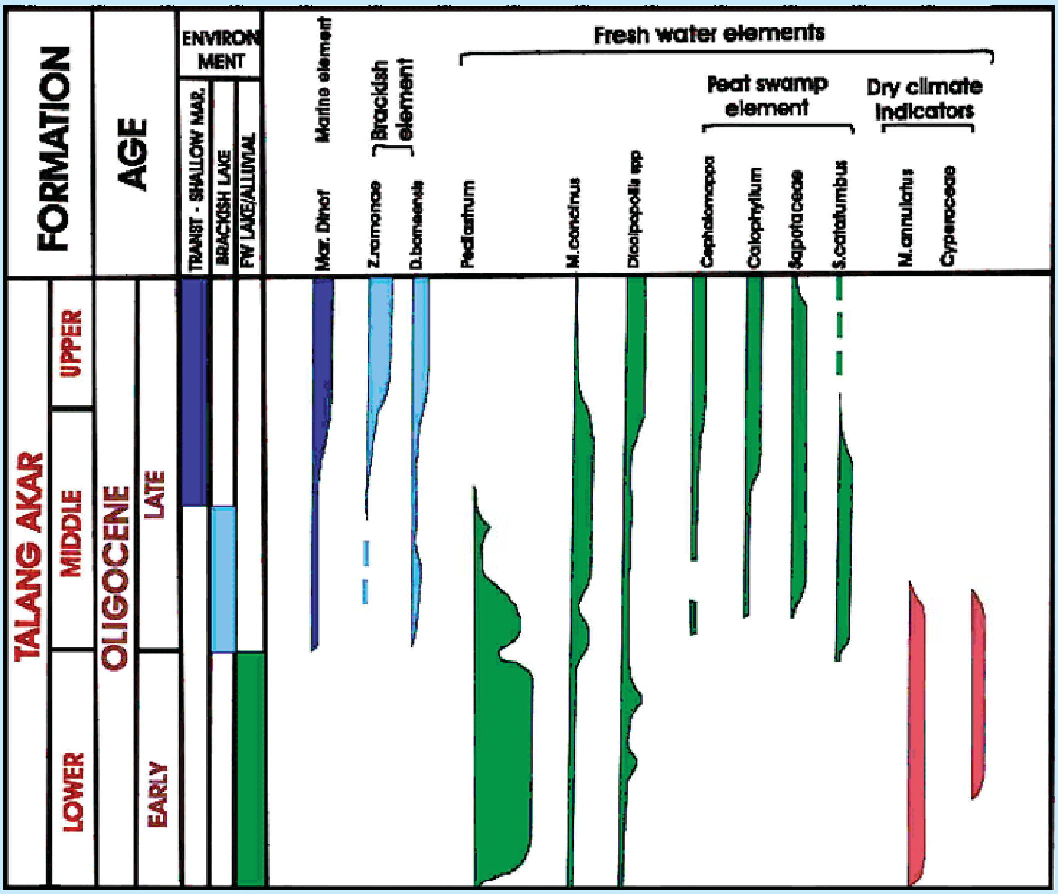

Figure 3
Summary of pollen record from the Oligocene sections of west Java sea.
Only selected taxa r elated to paleoenvironment and paleoclimate are shown in this diagram.

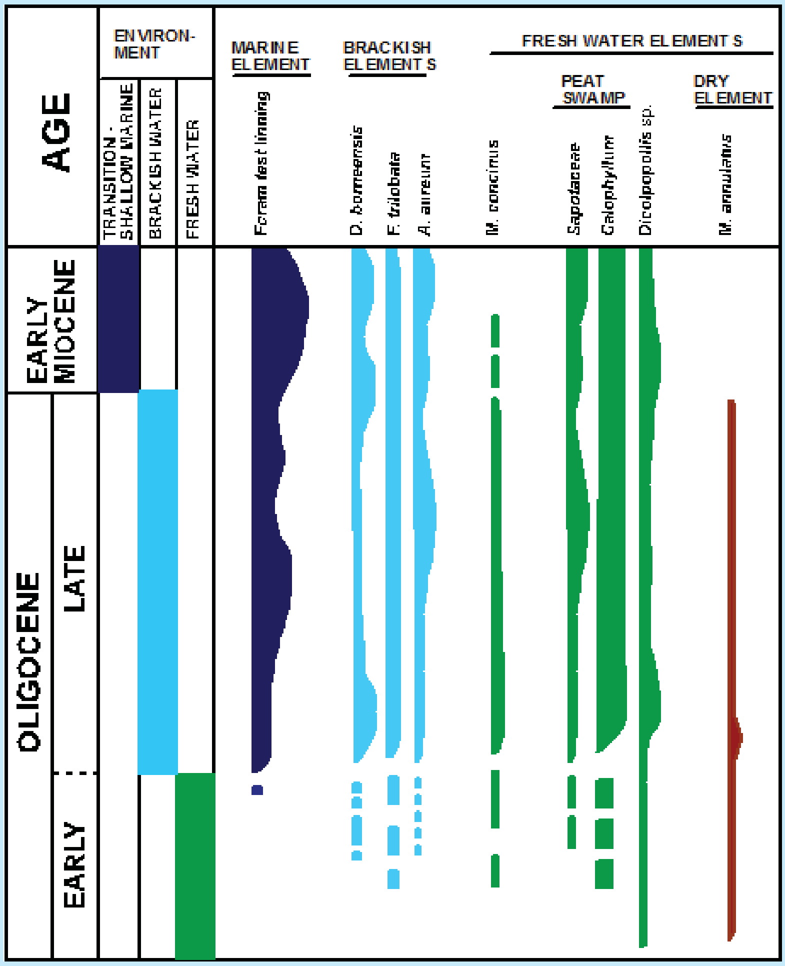

Figure 4
Summary of pollen assemblage derives from exploration wells situated in on-shore Central Sumatera.

Pediastrum which suggests a lacustrine depositional environment (Songtham et al. 2003). This lacustrine sediment might have occurred as a result of syn-rift during Early Oligocene. Dry/ seasonal climate indicators occur in moderate abundance as shown by *Monoporites annulatus* (Gramineae) and Cyperaceae. The appearance of environment and climate indicators concludes the formation of lacustrine sediment under dry climate influence (Lelono et al. 2011). On the contrary, fresh water algae of *Pediastrum* gradually decreases toward Late Oligocene successions. Simillar condition is also applied for dry climate elements such as *M. annulatus* and Cyperaceae. All of these palynomorphs are absent in sediment of the middle to upper parts of the Late Oligocene. In contrast, wet climate markers have a significant occurrance during Late Oligocene which suggests a wetter climate than that of Early Oligocene. These palynomorphs are *Campnosperma*, *Calophyllum* type, *Sapotaceoidaepollenites* spp. and *Striatricolpites catatumbus*. In addition, marine and brackish palynomorphs increase significantly. The marine element is represented by dinoflagellate, whilst brackish water pollen include *Zonocostites ramonae* and *Discoidites borneensis* (Figure 3). Referring to this data, Late Oligocene is indicated by the occurrence of transition to shallow marine sediment which was formed under wet climate condition. This is supported by pollen record obtained from Late Oligocene sections of on-shore Northwest Java where fresh and brackish water palynomophs are dominant and the lacustrine environmental indicator *Pediastrum* is absent. In addition, wet climate indicators are more abundant and diverse than the dry climate elements. It is interpreted that the Late Oligocene sediment of onshore Northwest Java was formed under wet climate conditions (Lelono 2006).

Similar trend occurs in the Oligocene sediments of Central Sumatera in which pollen assemblage differentiates Early and Late Oligocene age (Figure 4). Early Oligocene section is characterised by minimum or rare appearance of palynomorphs of both brackish and fresh water elements. In addition, marine palynomorph of foraminiferal test linning disappears from the section. Mean while, dry climate indicator of grass pollen *Monoporites annulatus* regularly appears throughout Early Oligocene marking the development of drier climate. This condition might indicate that Early Oligocene sediment was formed in the fresh water environment under dry/seasonal climate influence. Unlike Early Oligocene of West Java Sea, the Early Oligocene of Central Sumatera does not contain any fresh water lake algae (e.g. *Pediastrum*) which indicates lack of lacustrine sediment. Late Oligocene assemblage of Central Sumatera is much more abundant than that of Early Oligocene assemblage which suggests rich vegetations under wetter climate influence. This is supported by common occurrence of wet

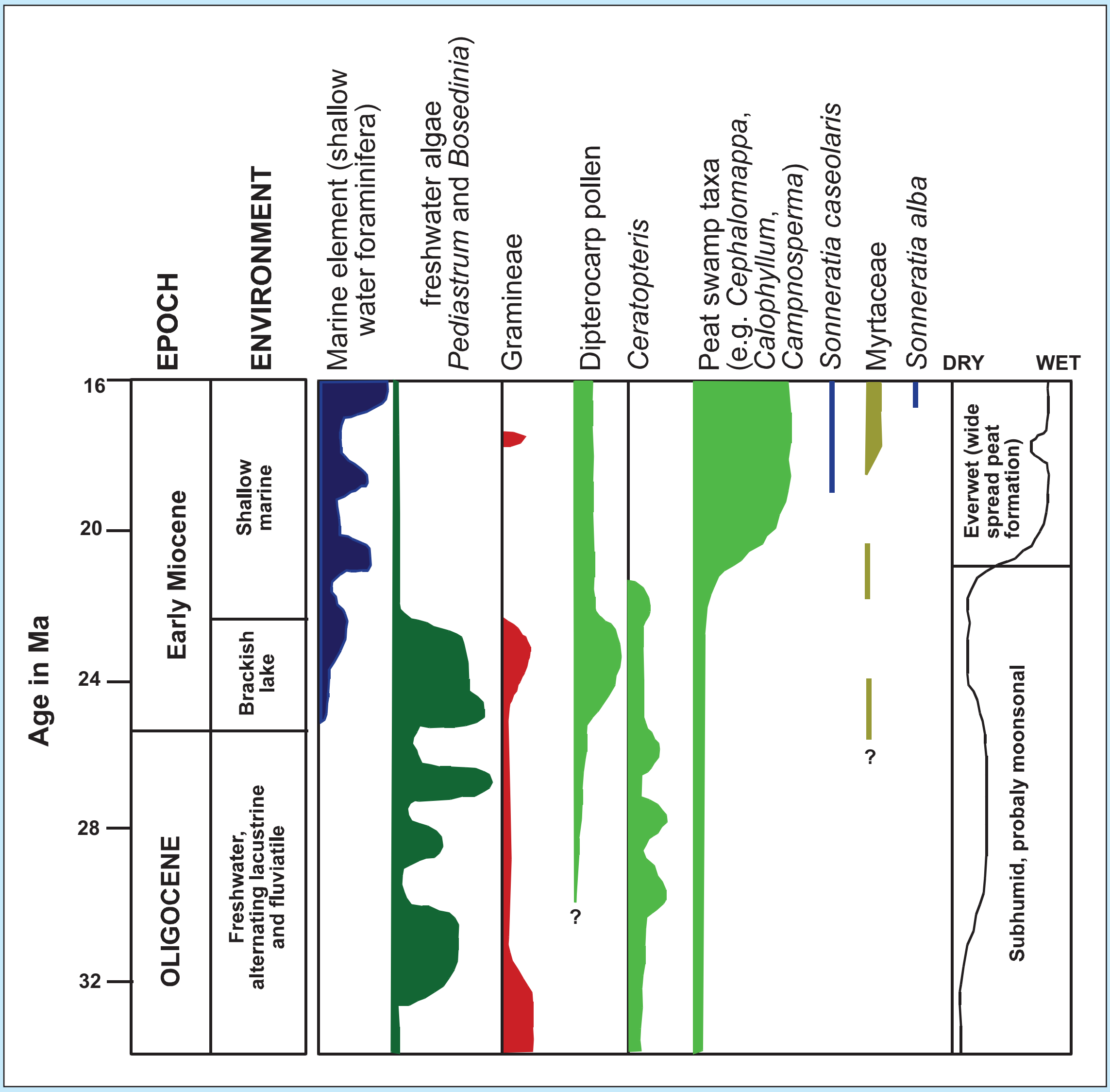

Figure 5
The occurence of selected palynomorphs from west Natuna sea to analyse paleoenvironment and paleoclimate of the Oligocene sediments (taken from Morley, 2000).

climate indicators including *Sapotaceae* and *Calophyllum*. More over, significant increase of marine and brackish elements indicates a high sea level which correlates with wetter climate event. However, regular appearance of dry climate indicator of *Monoporites annulatus* along the Oligocene section defines the rule of dry/ seasonal climate within this age (Morley 2000). This interpretation is strengthened by reguler appearance of riparian pollen of *Marginipollis concinus* as recorded in the Late Oligocene of East Java Sea (Figure 2).

In the Natuna Sea, dry/ seasonal climate assemblage is the rule for Oligocene as proved by regular appearance of Gramineae (Figure 5). The Early Oligocene sediment (from about 30 Ma to older) is marked by abundant fresh water algae of *Pediastrum* and *Bosedinia*, especially in its upper part indicating the occurrence of lacustrine environment. In addition, dry climate indicator of Gramineae is rich suggesting the influence of dry/ seasonal climate. This is supported by the facts that fresh water palynomorphs deriving from higher plants are rare or absent including *Ceratopteris*, *Cephalomappa*, *Calophyllum* and *Campnosperma*. Dipterocarp pollen disappeared from Early Oligocene section. This situation resembles that appearing in Early Oligocene of West Java Sea (Figure 2). It is interpreted that during Early

Oligocene, the studied sediment was deposited in lacustrine environment under drier climate influence (Lelono 2006). On the contrary, Late Oligocene sediment (25 Ma to 30 Ma) is identified by significant decrease of dry climate element of Gramineae. Palynomorphs from higher plants occur with low abundance. It seems that Late Oligocene climate was somewhat wetter than Early Oligocene climate. Fresh water algae fluctuated from low to high abundance which might reflect the alternation of fluviatile (marked by low fresh water algae) and lacustrine environment (high fresh water algae). After all, it can be concluded that Oligocene climate in West Natuna Sea was initiated by drier climate during Early Oligocene which then slightly changed into wetter climate during Late Oligocene.

IV. CONCLUSIONS

The studied samples contain excellent pollen recovery which is available for paleoenvironment and paleoclimate interpretations. Generally, dry/ seasonal climate is the rule for most of the Oligocene in Western Indonesia However, this research demonstrates that although Southeast Asia was dominated by seasonal climate during Oligocene, Java region experienced everwet climates which probably reflected a wet climate fringe to the eastern margin of Sundaland prior to the collision of the Australian and Asian Plates at the Oligo-Miocene boundary.

Early Oligocene of Western Indonesia is characterised by dry/ seasonal climate as marked by rich grass pollen *Monoporites annulatus* in the absence or rare occurance of rain forest elements. The sediments might be deposited in the lacustrine environment as indicated by abundant fresh water algae of *Pediastrum* and *Bosedinia*.

Late Oligocene climate was somewhat wetter than Early Oligocene climate as suggested by high abundance of *Dacrydium* and *Casuarina* as well as other rain forest elements. Mean while, dry climate indicator of *Monoporites annulatus* decreased significantly or even disappeared. Paleoenvironment gradually changed from lacustrine (freshwater) to brackish or shallow marine as evidenced by the increase of brackish/ marine palynomorphs.

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