OLIGOCENE CLIMATE CHANGES OF JAVA

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ABSTRACT

The study of palynology performed on the Oligocene marine sediment of the East Java Sea provides excellent recovery which allows the construction of palynological succession which applies regionally (Lelono et. al., 2011). In fact, this succession is characterized by assemblages that suggest climatic changes. These assemblages are divided into two major groups including mangrove and hinterland. The hinterland pollen group shows the most interesting succession, with elements on the one hand suggesting everwet climates (Dacrydium and Casuarina), and seasonal elements on the other (Gramineae, Schoutenia and Malvacipollis diversus). Mangrove pollen however suggests strong environmental control since mangrove pollen shows different abundance variations in the two wells. The age of the studied succession is independently defined using combined marine micro-fossils of foraminifer and nannoplankton which indicate Early to Late Oligocene. Although for most of the Oligocene in Southeast Asia, seasonal climate assemblages are the rule, this study interpretes the appearence of everwet climates. The Early Oligocene is characterized by common rain forest elements, suggesting an everwet rain forest climate at that time. The early part of the Late Oligocene, however, contains much reduced rain forest elements, and the presence of regular Gramineae pollen, suggesting a more seasonal climate, whereas for the latest Late Oligocene, rain forest (and peat swamp) elements return in abundance, suggesting a very wet rain forest climate. In fact, Java region experienced the wettest climate during Oligocene 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.

Keyword: *oligocene, climate changes, Java*

I. INTRODUCTION

The area of study is located on the off-shore of North Madura which is a part of East Java Basin (Figure 1). This is a back-arc basin situated on the southern margin of the Sundaland. This basin covers an area over 54,000 Km2 with an east-west alignment and accommodates sediment with a thickness of more than 2000m (Pusoko *et al.,* 2005).

A regional stratigraphy of East Java basin is shown in Figure 1. The stratigraphic succession follows an internal Lemigas report and also Yulianto, Martodjojo and Zaim (2000). Sedimentation started during the Middle Eocene unconformably over Cretaceous metasedimentary and igneous basement rocks and Paleocene/Late Cretaceous 'Pre-Ngimbang' sediments, with deposition of the Ngimbang Formation. The Ngimbang Formation consists of sands, coals and lacustrine shales in the lower part, and subsequently of marine shales and limestones deposited during the Late Eocene and Early Oligocene, and forming the syn-rift phase of deposition within the basin.

Subsequently, following a period of non-deposition/erosion during the mid Oligocene, during a period of post-rift tectonic quiescence, thick and extensive carbonates of the Kujung Formation formed over the major part of the area during Late Oligocene-Early Miocene (Johansen, 2003), followed

SCIENTIFIC CONTRIBUTIONS OIL & GAS
VOL. 34. NO. 3, DECEMBER 2011 : 169 - 176

by clastics of the Tuban Formation during the latest Early Miocene.

The Kujung Formation is divided into three units, generally termed Kujung Units III, II and I. Kujung unit III is the oldest (Late Oligocene) and consists of alternations of shale, sand and limestone. Kujung unit II is characterised by clastics and carbonates with a basal sandstone and formed during Late Oligocene-Early Miocene, whilst Kujung unit I is represented by widespread Early Miocene carbonate build-ups.

The Kujung Formation is conformably overlain by the Tuban Formation which is dominated by claystones with the intercalation of foraminiferal-rich marls forming during Early Miocene in a deep shelf setting (Firdaus, 2004), and widespread Rancak reef limestones. The younger Neogene succession consists of the Ngrayong, Wonocolo, Ledok and Mundu Formations.

The Oligocene marine succession occurring in the studied area is mainly defined using a combination of nannofossils and foraminifera. However, the occurrence of interbedded clastics allows the study of palynology as well as the usual microfossil groups. Samples from two wells, termed well X and well Y, have been studied at 60' intervals for each discipline, with some analyses of sidewall cores.

The traditional palynological zonation for SE Asia (Morley 1978; 1991) does not work well in this area, and so the succession has been divided into broad palynological assemblage zones, which appear to be controlled mainly by climate (Lelono *et al.,* 2011). The palynological zones appear to provide the best criteria for correlation of the observed stratigraphic succession between the two wells.

The age of the assemblage zones, however, is best determined on nannofossils, with support from larger foraminifera. Providing one of the first instances where an Oligocene palynological succession from the SE Asian region can be independently dated using marine fossils (Lelono *et al*., 2011).

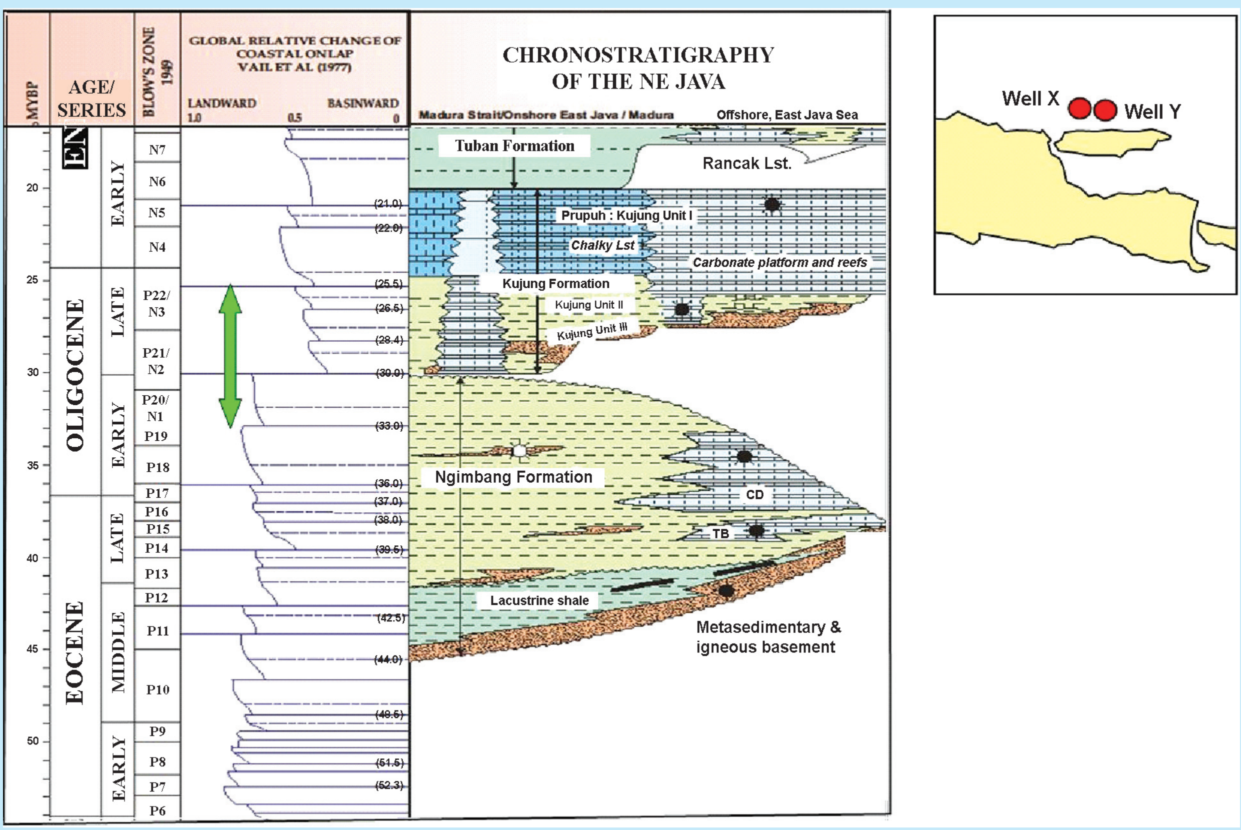

Figure 1
Wells location and lithostratigraphic succession. Arrow indicates interval studied

SCIENTIFIC CONTRIBUTIONS OIL & GAS
VOL. 34. NO. 3, DECEMBER 2011 : 169 - 176

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II. PALYNOLOGICAL CLIMATIC ELEMENTS

The studied successions are characterised by high pollen and spore assemblages. In addition, these successions show well representation of dinoflagellates cysts and other marine palynomorphs. Pollen/spore assemblages can be divided into two groups including mangrove and hinterland. The hinterland pollen group shows the most interesting succession, with elements on the one hand suggesting everwet climates, and seasonal elements on the other. Mangrove pollen however suggests strong environmental control since mangrove pollen shows different abundance variations in the two wells (Figure 2). The following palynomorphs are the climate indicator:

A. *Dacrydium and Casuarina* – superwet elements

The hinterland pollen group shows pollen of Dacrydium and Casuarina to be particularly well represented in the upper part of the succession. These taxa are of Gondwanan origin, and following dispersal into the SE Asian region found niches in peat swamps and Kerangas vegetation, montane forests (*Dacrydium* spp and *Casuarina junghuhniana*) and also along beaches (*Casuarina equisitifolia*).

The occurrence of abundant Casuarina and Dacrydium pollen in the Well X and Well Y wells suggests a peat swamp derivation (e.g. these pollen types are common in coals from the laterally equivalent ‘coaly’ Talang Akar Formation in the Sunda Basin; Morley, 2000). *Casuarina* and *Dacrydium* do not occur in the communities of the domed topotrophic/ombrotrophic peat swamps which are widespread along the coasts of Kalimantan and Sumatra (e.g. Anderson, 1963), but characterise the less well known ombrotrophic (blanket bog type) ‘Kerapah’ or watershed peats which occur locally in Borneo on poorly drained podsolic soils (Brunig, 1990; Morley, 2000) in areas of ‘superwet’ climate (Richards, 1996). The occurrence of ‘Kerapah’ swamps is thus convincing evidence for an everwet climate (Figure 2).

B. Riparian elements

Pollen of riversides and alluvial swamps, especially of *Pandanus* and *Ilex* show distinct trends, being common in the topmost part, above the interval with common *Dacrydium* pollen, and also common in the interval with regular seasonal climate elements (Figure 3).

C. Seasonal climate elements

The regular occurrence of Gramineae and *Schoutenia* pollen (*Schoutenia* is an element of deciduous woodland) in the mid part of the succession suggest a more seasonal climate aspect to the mid part of the succession (Figure 3). This interval is also characterised by the regular occurrence of *Malvacipollis diversus*, which compares closely with pollen of Australian *Austrobuxus swainii* and *Dissiliaria baloghioides* (Martin, 1974), and differs from SE Asian *Austrobuxus* spp. These are both trees of drier rain forests/warm temperate sclerophyll communities in SE Queensland/NW New South Wales (Pickett *et al.,* 2004).

D. Algal and other marine palynomorphs

Dinoflagellates are common through both wells and consist mainly of *Operculodinium* spp., *Spiniferites* spp. and *Homotryblium* spp., but without useful age-indicative taxa, However, the dinoflagellate cysts do show two distinct acmes in the mid part of the succession (Figure 4). There is one very strong acme within both wells, with abundant *Operculodinium* spp and *Spiniferites* spp, and below this a second less pronounced acme of the same taxa, but also with common *Homotryblium* spp. These acmes parallel the events based on hinterland pollen discussed above.

III. CLIMATE HISTORY

The paleo-climate occurring in the studied area is interpreted based on the palynological events which

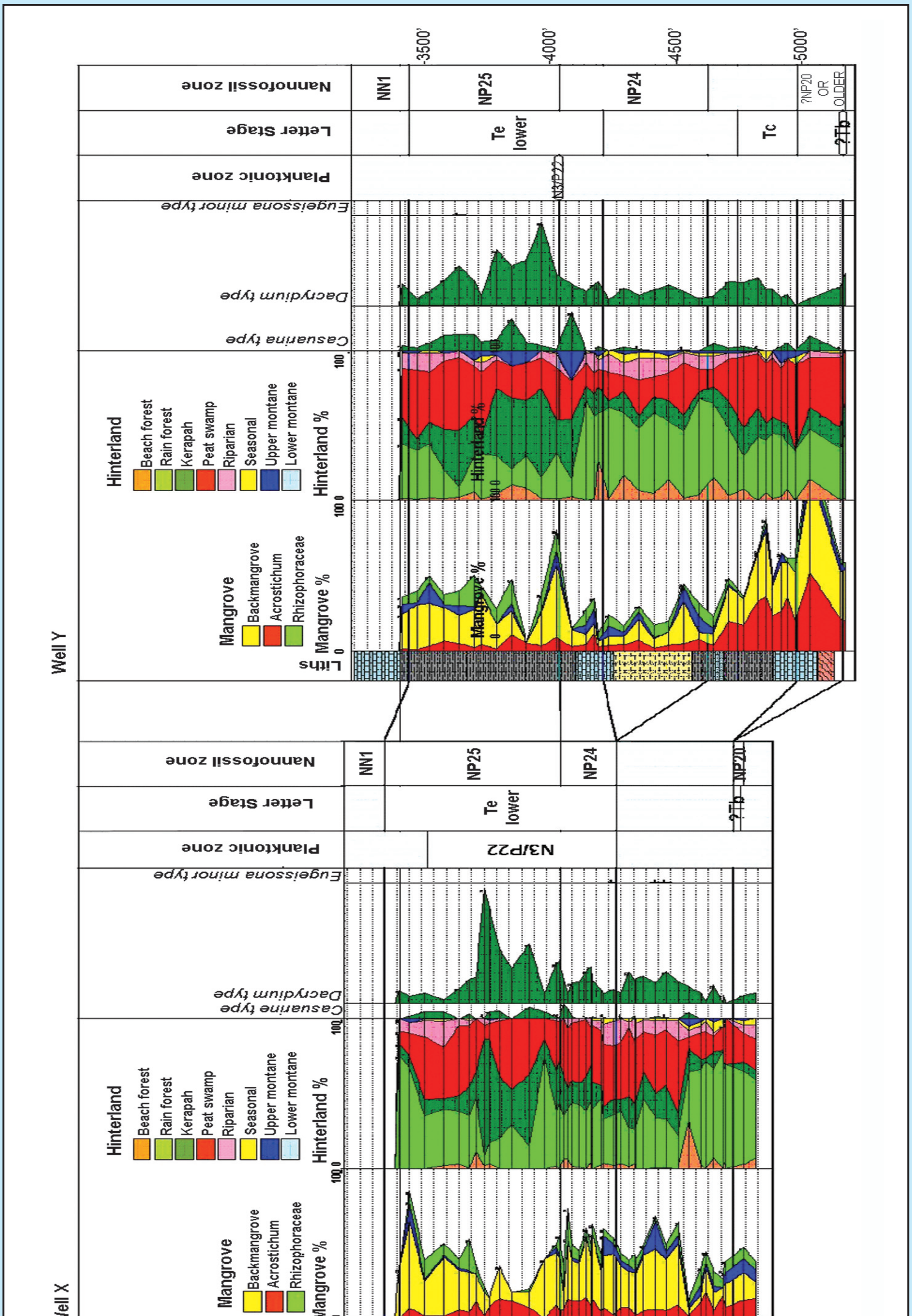

Figure 2
Mangrove, hinterland pollen and *Dacrydium*/*Casuarina* from Well X and Well Y

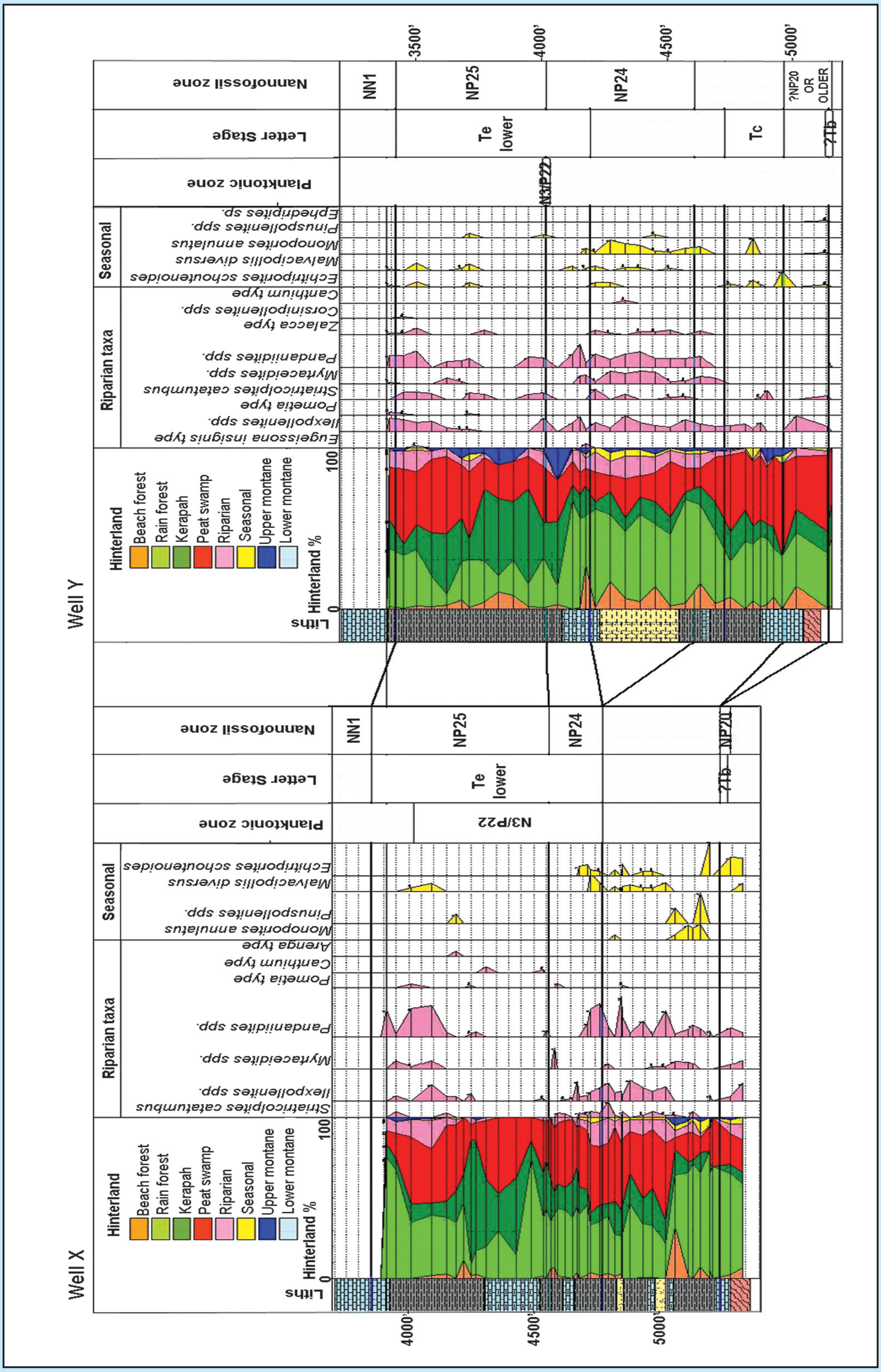

Figure 3
Riparian and seasonal climate pollen from Well X and Well Y

SCIENTIFIC CONTRIBUTIONS OIL & GAS
VOL. 34. NO. 3, DECEMBER 2011 : 169 - 176

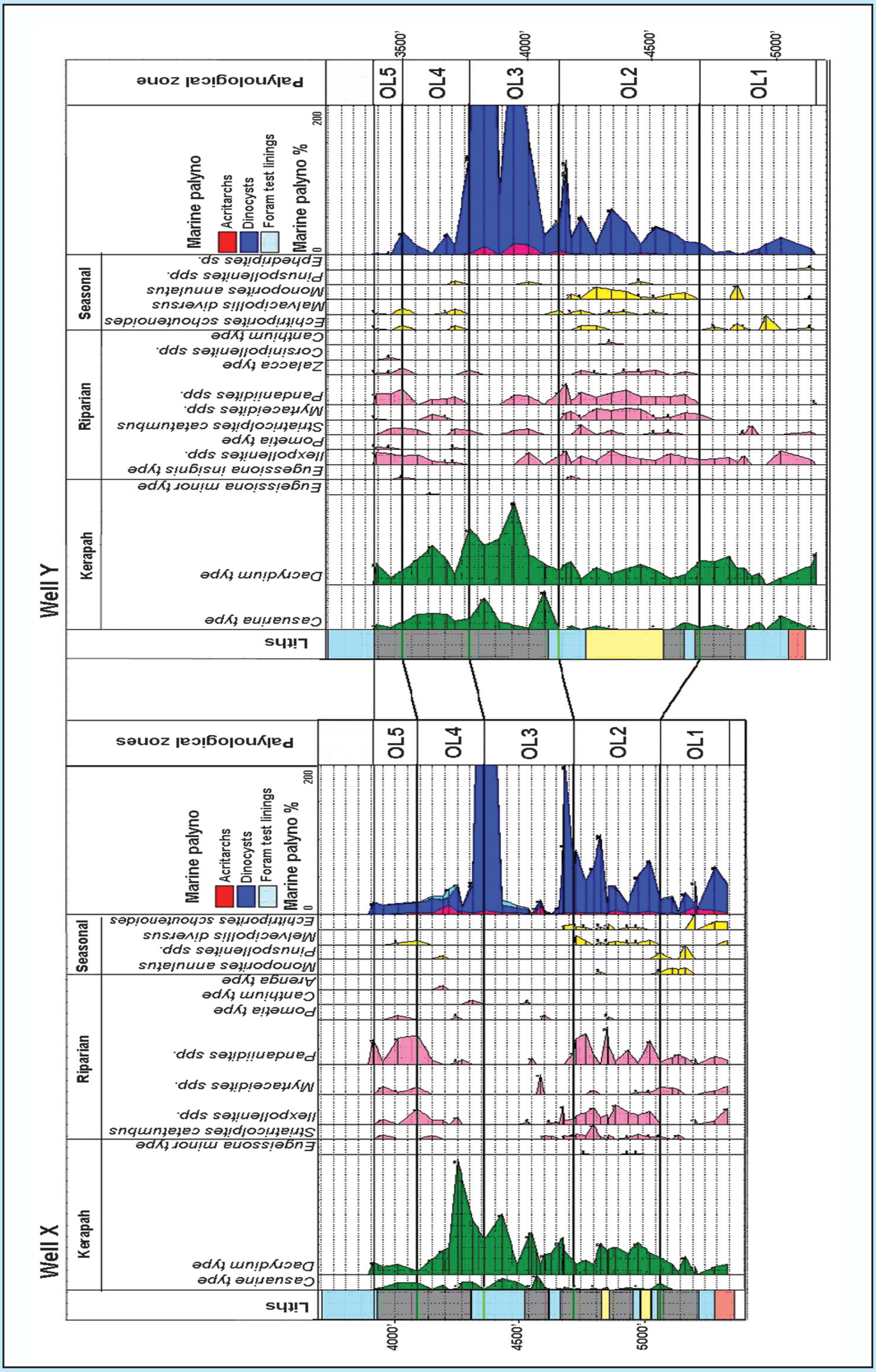

Figure 4
Algal palynomorphs from Well X and Well Y and proposed palynological zonation

SCIENTIFIC CONTRIBUTIONS OIL & GAS
VOL. 34. NO. 3, DECEMBER 2011 : 169 - 176

characterise the palynological zonation (Lelono *et al*., 2011). The palynological events are identified on the basis of assemblage change suggesting climate change (Figure 4).

Zone OL-1 probably reflects a period with moderately wet climates since rain forest and peat swamp pollen dominate assemblages, Zone OL-2, on the other hand probably reflects a period of marginally seasonal climates. The assemblages through OL-2 are in fact 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.

It is because the palynological zones are characterized by elements suggesting regional climate change that the zones are thought to be of potentially wide correlatable significance.

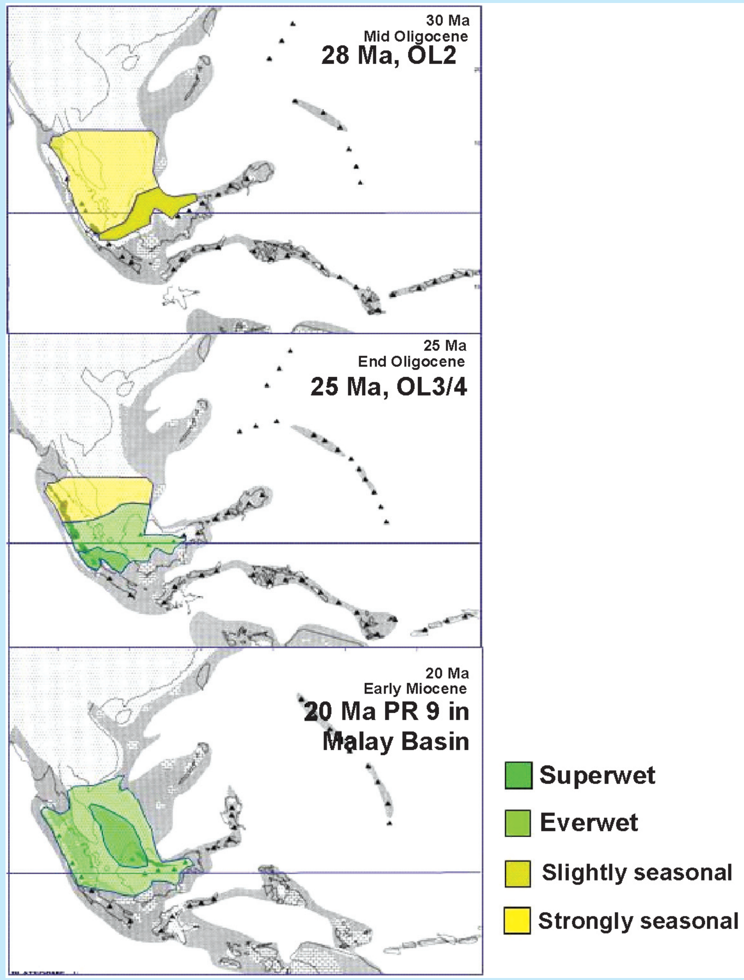

Figure 5
Climate sketches for zones OL-2, 3 and 4.

IV. EAST JAVA WET CLIMATE PROVINCE

For most of the Oligocene in Southeast Asia, seasonal climate assemblages are the rule (e.g. Morley 2000; Morley *at al.*, 2003; Morley and Shamsuddin, 2006), although essentially everwet climates have recently been interpreted for the Udang Formation in Block B, West Natuna (southernmost part of Natuna) by Morley et. al. (2006). The wettest climates recorded for the Oligocene, however, 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. Possible palaeoclimate sketches for zones OL-2, and OL-3/4 are shown in Figure 5.

V. CONCLUSION

Although Southeast Asia was dominated by seasonal climate during Oligocene, this study proves that Java experienced everwet climates. The Early Oligocene is characterized by common rain forest elements, suggesting an everwet rain forest climate at that time. The early part of the Late Oligocene,

SCIENTIFIC CONTRIBUTIONS OIL & GAS
VOL. 34. NO. 3, DECEMBER 2011 : 169 - 176

however, contains much reduced rain forest elements, and the presence of regular Gramineae pollen, suggesting a more seasonal climate, whereas for the latest Late Oligocene, rain forest (and peat swamp) elements return in abundance, suggesting a very wet rain forest climate.

In addition, previous study indicated that West Natuna experienced everwet climate during Oligocene. However, Java region experienced the wettest climate 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.

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