THE DISPERSAL ROUTE OF THE AUSTRALIAN ELEMENTS OF *DACRYDIUM* AND *CASUARINA* FROM ITS ORIGIN TO SE ASIA

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ABSTRACT

This paper proposes the alternative migration route of the Australian elements of Dacrydium and Casuarina from their origin to Southeast Asia. It was previously thought that these Australian affinities dispersed to Sunda region following the collision of the Australian and the Asian plates at the Oligo-Miocene boundary (Morley, 1998 and 2000).The subsequent study by Lelono (2007) extended the record of these two taxa from the Oligo-Miocene boundary to the base Oligocene. This is unlikely, since at the time of basal Oligocene, when these pollen types first appear, the Australian land mass would have been some 1000 kms south of the East Java area. Therefore, this fact led Lelono (2007) to propose the earlier arrival of the Gondwanan fragment to this area in Early Oligocene. However, recent records of Dacrydium have been reported from the Early Eocene of the Ninety East Ridge (55 Ma) and the Indian subcontinent (50 Ma) (Morley, 2009). This implies to the alternative dispersal route of this pollen. It is possible that Dacrydium dispersed into SE Asia prior to the Early Oligocene via the Ninety East Ridge and the Indian plate, and subsequently its distribution across the Sunda region and Indochina was limited by palaeoclimate, explaining why it is present in some areas of the Sunda region, but not others. Mean while, a model to explain the dispersal of Casuarina remains unresolved, since migration via India is unlikely as there is no pollen record from the Indian subcontinent. Therefore, long distance dispersal may be a possibility for this pollen.

Key word: Dispersal route, Australian elements, Dacrydium and Casuarina, SE Asia

I. BACKGROUND RESEARCH

This paper is intended to provide another possibility of dispersal route of the Australian elements of *Dacrydium* and *Casuarina* to the Southeast Asia region which may imply to the tectonic setting of this region. In addition, it is triggered by the work done by Lelono (2007) on the exploration wells of J-1 and M-1 in East Java Sea, which proposed the earlier arrival of Australian fragment in this area based on the record of these pollen in the basal Oligocene sediment. The area of study is located on the off-shore of North Madura which is a part of East Java basin (Figure 1). This basin is defined as a back-arch basin which is situated on the southern margin of the Sundaland. This basin covers an area over 54,000 km^2 with east-west direction and accommodates sediment with the thickness of more or less 6000 ft (Pusoko et al., 2005). In fact, it is well known as an important hydrocarbon province in Indonesia. The oil exploration has been started since the Dutch era which mostly concentrated on shallow structures. Recently, East Java has been an attractive area for oil exploration as new discovery continues to occur within this basin.

The Australian and Asian plates collided in the Late Oligocene as reconstructed by Hall (2002) in which, the Australian affinity continental fragments including Banggai-Sula, Tukang-Besi/ Buton, Timor or Ceram may have maintained localised emergent areas allowing some Australian taxa to be introduced directly into East Indonesia, during and after the time

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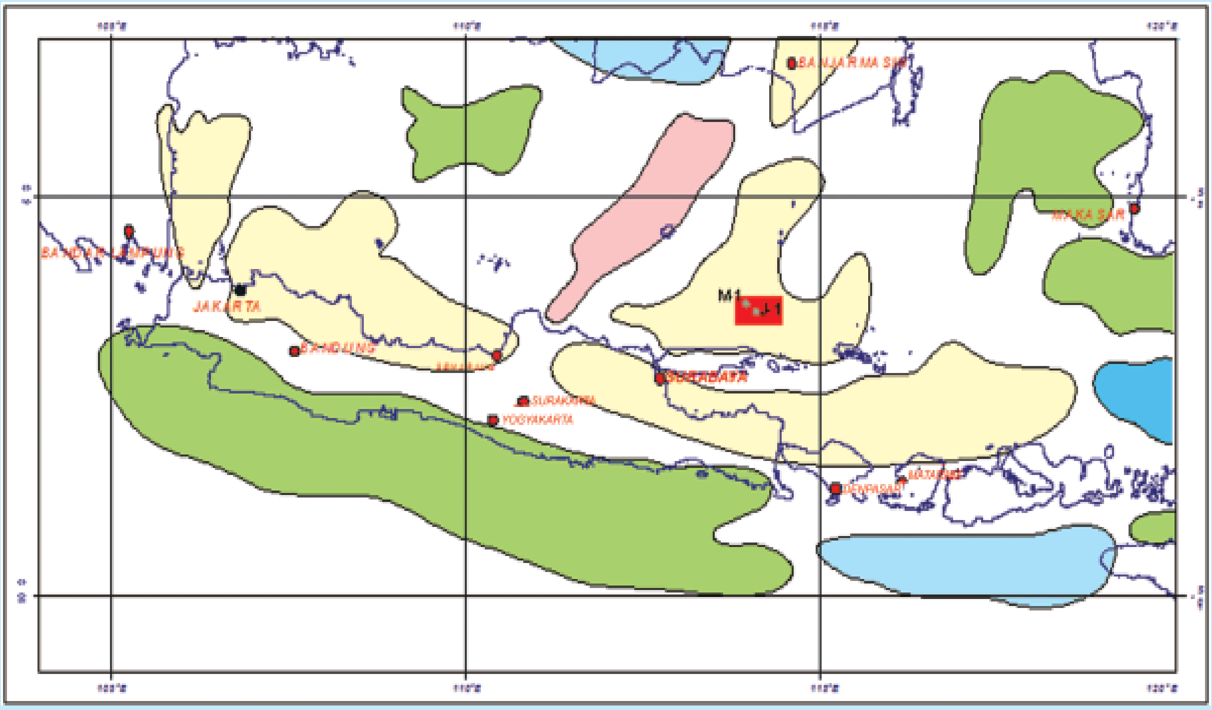

Figure 1
Location of the study area

of collision (Figure 2). Possible candidates to be considered are *Eucalyptus deglupta* (Myrtaceae) and other *Eucalyptus* spp. in the Maluku and *Casuarina junghuhniana* in Nusa Tenggara and East Java (Morley, 2000). In fact, these pollen are recorded in Early Miocene successions of West Indonesia. Mean while, in order to investigate the occurrence of the Gondwanan/ Australian taxa in the Paleogene sediments of East Java, a study by Lelono (2007) focused on some selected pollen including *Dacrydium* and *Casuarina* as they occurred commonly and regularly along the studied wells including J-1 and M-1. According to the previous researchers, both pollen were assumed to migrate to western Indonesia following the latest Oligocene collision between Australian plate and Sundaland (Morley, 1998 and 2000). In fact, *Dacrydium* and *Casuarina* were firstly recorded in the basal Early Miocene as seen in the North west Java Basin and West Natuna Basin (Morley, 2000). Therefore, many palynologists often refer to the first appearance of these pollen for separating Early Miocene from Oligocene succession (Figure 3). This situation raises question of the existence of the pathway which allows dispersal of these pollen from their origin in the Australian plate into the Sundaland. It is possible that the collision of Australia and Sundaland occurred earlier in East Java compared to that in other areas of Indonesia. On the other hand, current data published by Morley (2009) recorded that *Dacrydium* was found in the older sediment of Ninety East Ridge and India which suggests different route of migration from Australia to Southeast Asia via Ninety East Ridge and India.

II. REVIEW ON PREVIOUS WORKS

The arrival of Australian plate in the Southeast Asia is predicted to occur in Oligo-Miocene following the collision of both plates (Hall, 2002). In addition, this collision facilitating gateway for the Australian flora to migrate to Indonesian region as proved by the occurrence of the Australian affinity of *Dacrydium* and *Casuarina* in the basal Miocene (Morley, 2000). Some areas of West Indonesia provide evidence of their occurrence within Early Miocene sediments including Northwest Java and Natuna Basins. Mean while, Lelono (2007), in his study on the Oligocene sediment collected from East Java Sea, extended the stratigraphic range of these palynomorphs from the Oligo-Miocene boundary to the base Oligocene. Based on this fact, he proposed the earlier arrival of the Australian fragments to East Java area in Early Oligocene. Moreover, The regional tectonic study of East Java carried out by Sribudiyani et al. (2003) indicated that from the end of Cretaceous to Early Eocene (70-35 Ma), a continental fragment, possibly detached from the Gondwana super-continent to the south, drifted northeastward approaching the Late Cretaceous to early Tertiary subduction complex (Lok Ulo-Meratus belt). The collision of this micro-continent with the eastern margin of the Sunda Microplate caused the Eocene magmatic activity to cease and uplifted the subduction complex, creating the Meratus Mountains in the eastern part of Kalimantan and The Lok Ulo mélange complex in the central Java (Sribudiyani et al., 2003). During this period, the contemporaneous northeastward movement of the Australian plate resulted in its subduction under the Sunda Microplate along Java-Meratus suture (Figure 4). Furthermore, dating analysis of the intrusive rocks using a method of SHRIMP U-Pb zircon done by Smyth et al. (2003) indicated the possible occurrence of the Australian origin of this mineral. This would imply transport of the sediment far to the north onto the Indian plate during the Paleogene. These works suggest that East Java was a continental fragment deriving from Gonwana which collided with the eastern part of the Sundaland during the end of Cretaceous to Early Eocene. This collision facilitated gateway for the Australian flora especially *Casuarina* and *Dacrydium* to disperse to East Java in Early Oligocene and extended through the Late Neogene.

III. NEW RECORD OF *DACRYDIUM* AND *CASUARINA*

The Australian affinities of *Dacrydium* and *Casuarina* were previously known to firstly appear in basal Miocene in Western Indonesia (Morley, 2000). It was thought that these two taxa dispersed into the Sunda region following the collision of the Australian

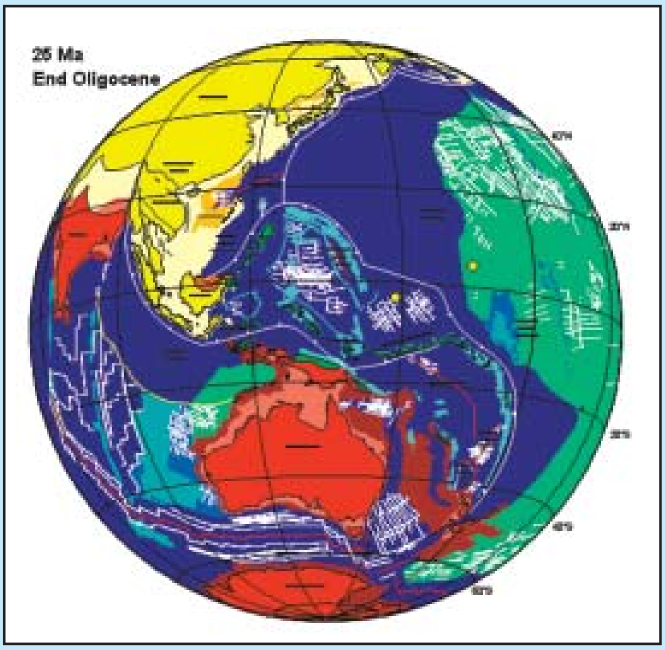

Figure 2
The plate reconstruction of SE Asia and SW Pacific regions at about 25Ma or end Oligocene, showing the first contact of Australian continental crust with SE Asia (taken from Hall, 2002)

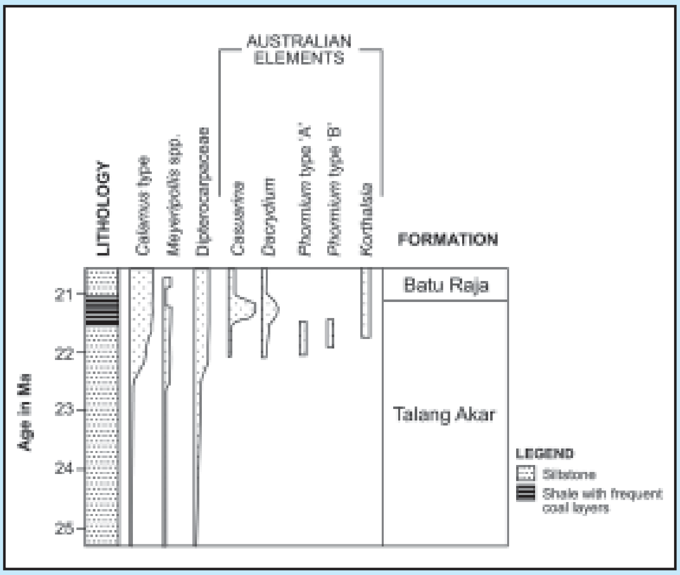

Figure 3
Some distinctive pollen types from the Early Miocene of the Java Sea, showing abundance of dipterocarp pollen, immigrants from Australia and the representation of Meyeripollis (taken from Morley, 2000 page 194)

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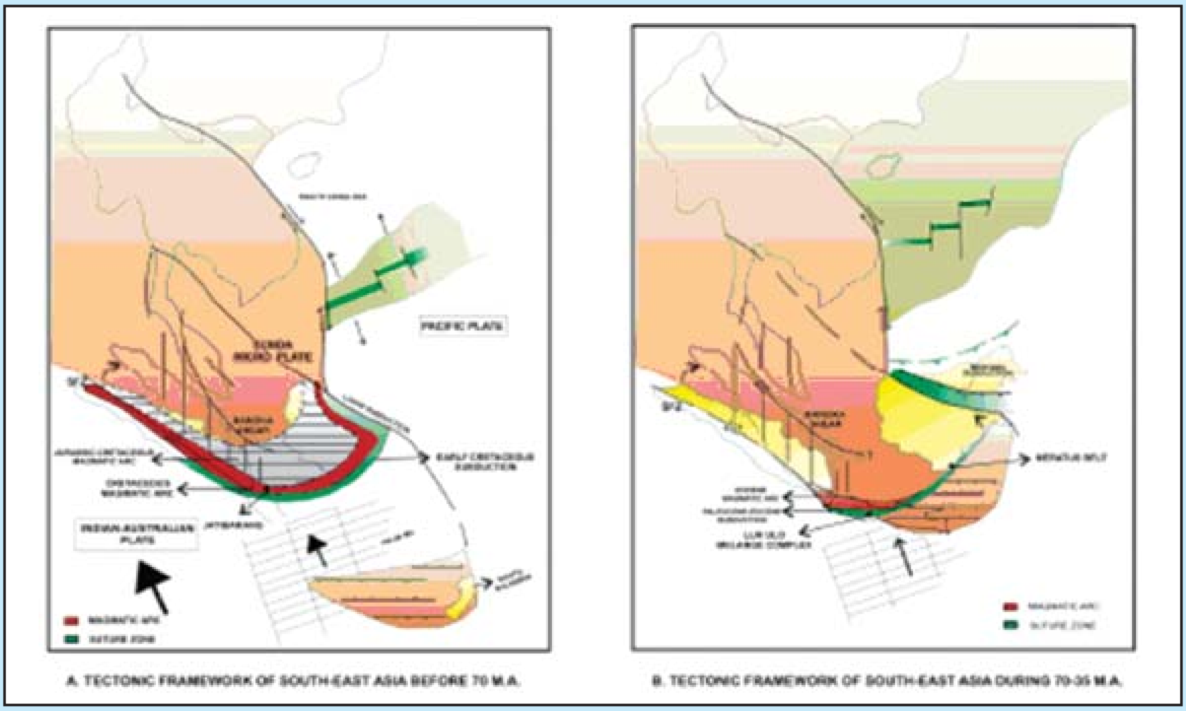

Figure 4
Tectonic setting of Western Indonesia during Late Cretaceous-Early Tertiary (taken from Sribudiyani et al., 2003)

and Asian plates, at the Oligo-Miocene boundary (Morley 1998 and 2000). Mean while, later investigation by Lelono (2007) discovered the occurrence of these pollen in the basal Oligocene sediment of East Java Sea which implies to the possibility of earlier arrival of Gondwanan fragment within this region.

Recent works done by Morley (2009) prove new stratigraphic record of the Australian element of *Dacrydium*. Palynological study on broad region reported the occurrence of this pollen in the Early Eocene sediments of Ninety East Ridge and Indian Subcontinent. Apparently, this record is older than that found in East Java Sea as brought to attention by Lelono (2007). It was previously interpreted that *Dacrydium* and *Casuarina* migrated into the Sundaland following the collision of the Australian and Asian plates, at the Oligo-Miocene boundary (Morley 1998 and 2000), but this study suggests that this is unlikely, since at the time of the basal Oli-

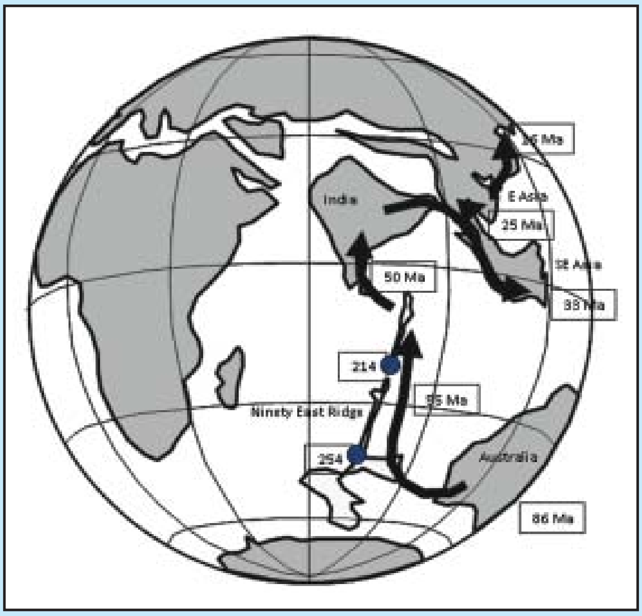

Figure 5
The dispersal route of the Australian element of *Dacrydium* to Southeast and East Asia through Ninety East Ridge and India (Morley, 2009)

gocene, when these pollen types first appear, the Australian land mass would have been some 1000 km south of the East Java area.

Recently, *Dacrydium* has been reported from the sediment with an age of 55 Ma (Early Eocene) in the Ninety East Ridge (Morley, 2009). Moreover, this pollen is also found in the sediment with 50 Ma age (Early Eocene) in the Indian subcontinent (Morley, 2009). Therefore, it is now believed that *Dacrydium* dispersed into SE Asia prior to the Early Oligocene via the Ninety East Ridge and the Indian plate (Figure 5). In addition, it is interpreted that its distribution across the Sunda region and Indochina was limited by palaeoclimate, explaining why it is present in some areas of the Sunda region, but not others (Lelono et al., 2009). On the other hand, a model to explain the dispersal of *Casuarina* remains unresolved, since dispersal via India is unlikely as there is no pollen record from the Indian subcontinent. In this case, long distance dispersal may be a possibility.

IV. CONCLUSION

Previously, the appearance of *Dacrydium* and *Casuarina* in basal Oligocene of East Java Sea was interpreted to indicate earlier arrival of the Gondwanan/ Australian fragment in this area compared to that in other areas of Indonesia. However, the latest records show that the Gondwanan palynomorph of *Dacrydium* is found in the older sediments of the Ninety East Ridge (55 Ma ~ Early Eocene) and the Indian Subcontinent (50 Ma ~ Early Eocene) compared to those of East Java Sea (Early Oligocene age). Based on this discovery, it is suggested different dispersal route of this pollen from its origin in Australia to Southeast Asia via the Ninety East Ridge and the Indian Subcontinent, and that subsequently its distribution across the Sunda region and Indochina was limited by palaeoclimate, which explain limited occurrence of this pollen in some areas of these regions.

Mean while, a model to explain the dispersal route of *Casuarina* remains unresolved, since migration route via India is unlikely as there is no pollen record from the Indian Subcontinent. It is possible that this pollen migrated to Southeast Asia through long distance dispersal.

V. ACKNOWLEDGMENT

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