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Palynology of the Permian Freshwater Deposit in West Timor

Palinologi Endapan Air Tawar Berumur Perem di Timor Barat

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Abstract - The Permian sediment is considered to be the oldest formation which occur in West Timor. It derived from Australian continent which was collided in Late Neogene with the Banda volcanic arc in the Timor Island due to northward moving of this continent. It consists of carbonate (limestone) of the Maubise Formation and clastic sediment of the Bisane Formation (equivalent to the Cribas and Atahoc Formations). This study focusses on the Bisane Formation which lithologically comprises thick calcareous sandstone (0.3 - 5 meters) with abundant marine macrofossils of Chrinoid and common mica. These facts suggest that the Bisane Formation was deposited during Permian age in the shallow marine environment. This interpretation supports the previous study to define shallow marine environment for the Permian sequence. However, this study found different lithology of the Bisane Formation in some locations which is composed of the intercalation of noncalcareous, dark gray to black shale and siltstone showing papery structure and rich of sulphur. Seven shale samples were collected randomly due to outcrop limitation. Stratigraphic range and paleoenvironment of key palynomorphs refer to some authors including Traverse (1988), Brugman *et al*. (1985), Feng *et al*. (2008), Jan (2014) and Jha *et al*. (2014). This paper reveals the result of palynological investigation performed on the noncalcareous black shales of the Bisane Formation. Palynological assemblage characterises Permo - Triassic age as indicated by the existence of striate-bisaccate pollen including *Protohaploxypinus samoilovichii, P. fuscus, P. goraiensis, Striatopodocarpidites phaleratus, Pinuspollenites globosaccus* and *Lunatisporites pellucidus*. However, the appearance of *trilete-monosaccate* spores of *Plicatipollenites malabarensis* and *Cannanoropollis janakii* defines that the mentioned shales have an age of Permian. The recovered pollen and spores are associated with the freshwater environment as supported by the disappearance of marine dinoflagellates and noncalcareous lithology. Considering tectonic event during Perm which is marked by rifting, it is possible that the analysed sediment is a product of early syn-rift sedimentation as proved by the occurrence of freshwater deposit (probably lacustrine deposit). If this is the case, the appearance of Permian black shale samples provides opportunity to discover new petroleum system in the Paleozoic sedimentary series of West Timor.

Keyword : Palynology, Permian, Freshwater Sediment, West Timor

Abstrak *- Sedimen berumur Perem merupakan endapan tertua di Timor Barat berasal dari Kontinen Australia yang bergerak ke utara menabrak busur volkanik Banda pada Pliosen Awal. Endapan ini terdiri dari batugamping Formasi Maubise dan sedimen klastik Formasi Bisane yang ekuivalen dengan Formasi Cribas dan Atahoc. Studi palinologi dilakukan pada Formasi Bisane yang dicirikan oleh batupasir gampingan tebal (0,3 – 5 meter) yang kaya kandungan fosil makro Krinoid dan ditandai juga oleh keberadaan mika. Bukti ini menunjukan bahwa Formasi Bisane diendapkan pada umur Perem di lingkungan laut dangkal, sesuai dengan hasil penelitian terdahulu. Ternyata survei geologi yang dilakukan pada studi ini menemukan litologi berbeda di beberapa lokasi, yaitu berupa perselingan antara serpih nonkarbonatan abu-abu gelap sampai hitam dan batulanau yang memperlihatkan struktur lembaran kertas dan kaya sulfur. Makalah ini menampilkan hasil analisis palinologi perconto serpih hitam nonkarbonatan Formasi Bisane. Sebanyak tujuh perconto serpih dipilih secara acak karena keterbatan kondisi singkapan. Kisaran stratigrafi dan lingkungan purba palinomorf kunci mengacu pada publikasi oleh Traverse (1988), Brugman et al. (1985), Feng et al. (2008), Jan (2014) dan Jha et al. (2014). Palinomorf yang ditemukan pada perconto ini merupakan penciri umur Perm-Trias seperti polen striate-bisaccate Protohaploxypinus samoilovichii, P. fuscus, P. goraiensis, Striatopodocarpidites phaleratus, Pinuspollenites globosaccus dan Lunatisporites pellucidus. Namun demikian, kehadiran spora trilete-monosaccate Plicatipollenites malabarensis dan Cannanoropollis janakii memastikan bahwa umur perconto serpih tersebut adalah Perem. Polen dan spora yang ditemukan berasosiasi dengan lingkungan air tawar, hal ini diperkuat oleh ketidak hadiran dinoflagelata dan batuan nonkarbonatan. Dengan pertimbangan terjadi fase rifting pada umur Perem, maka sangat mungkin bahwa sedimen yang diteliti adalah produk dari sedimentasi syn-rift awal yang berupa endapan air tawar (mungkin endapan danau). Jika benar demikian, maka penemuan serpih hitam dalam studi ini membuka peluang untuk menemukan sistem petroleum baru pada seri sedimen Paleozoikum di Timor Barat.*

Kata kunci *- Palinologi, Perm, Sedimen Air tawar, Timor Barat*

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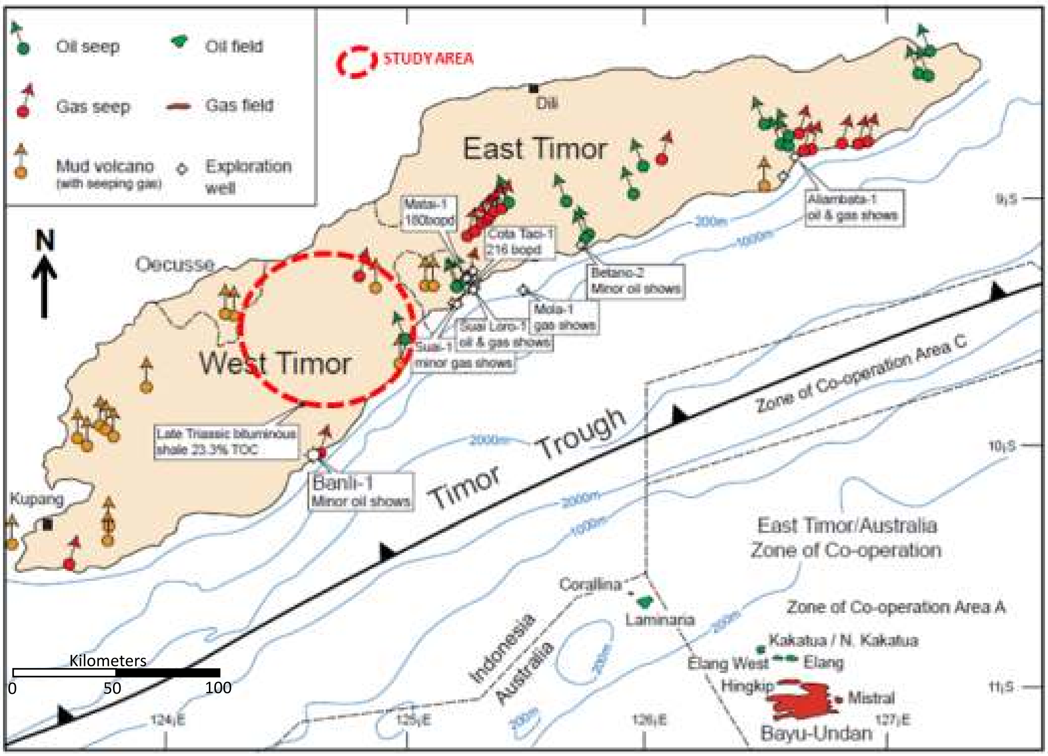
INTRODUCTION

The area of study is located in the onshore West Timor which is administravely inside Nusa Tenggara Timur Province (Figure 1). It is adjacent to the east by Republic Democratic of Timor Leste. This study is a part of geological and geophysical surveys in West Timor to evaluate hydrocarbon potential of this area. These surveys were financially supported by the Indonesian government. Data used for this publication was obtained from the surface samples which were collected during field activities.

Palynological work of the pre-Tertiary sediment is rarely performed on the onshore West Timor as indicated by limited publication regarding this subject. This is partly caused by the assumption that pre-Tertiary sediment was formed in the marine environment. In addition, it is difficult to access the data, especially those provided by the oil companies (both well and surface data). This is doubled by the fact that only one well was drilled in this area (Elnusa, 2015). This results in unsuitable material for palynological analysis. In order for responding to this situation, a field survey was conducted to collect suitable samples to allow proper palynological examination. Therefore, this paper is aimed to reveal palynological records of the Permian sediments which will contribute to an understanding of the pre-Tertiary palynology in West Timor.

West Timor is part of Timor Island which is geologicaly located in Banda arc-Australian continental collision zone, the youngest tectonic collision product in the world which created high complexity of geology. Most authors agreed that collision might occur in the Late Neogene (Hall, 2013). Tectonic situation of West Timor was explained by many researcher as overthrust (Harris, 2011), rebound (Chamalaun and Grady, 1978), imbricated (Hamilton, 1979), duplex (Harris, 1991), overthrust margin (Sawyer *et al*., 1993), and basement involved thrust (Charlton and Gandara, 2012) which developed wide exposured zone of Paleozoic-Mesozoic and Tertiary sequences. In addition, it is interpreted that Timor Island is a distal part of Australian continental plate which consist of distal marine sediment from Paleozoic (Permian) to Quaternary.

Stratigraphy of West Timor refers to that proposed by Rosidi *et al*. (1979) which is combined with those introduced by Sawyer *et al*. (1993), Charlton (2002) and Harris (2011). Generally, it can be devided into three sequences including Kekneno, Kolbano and Viqueque



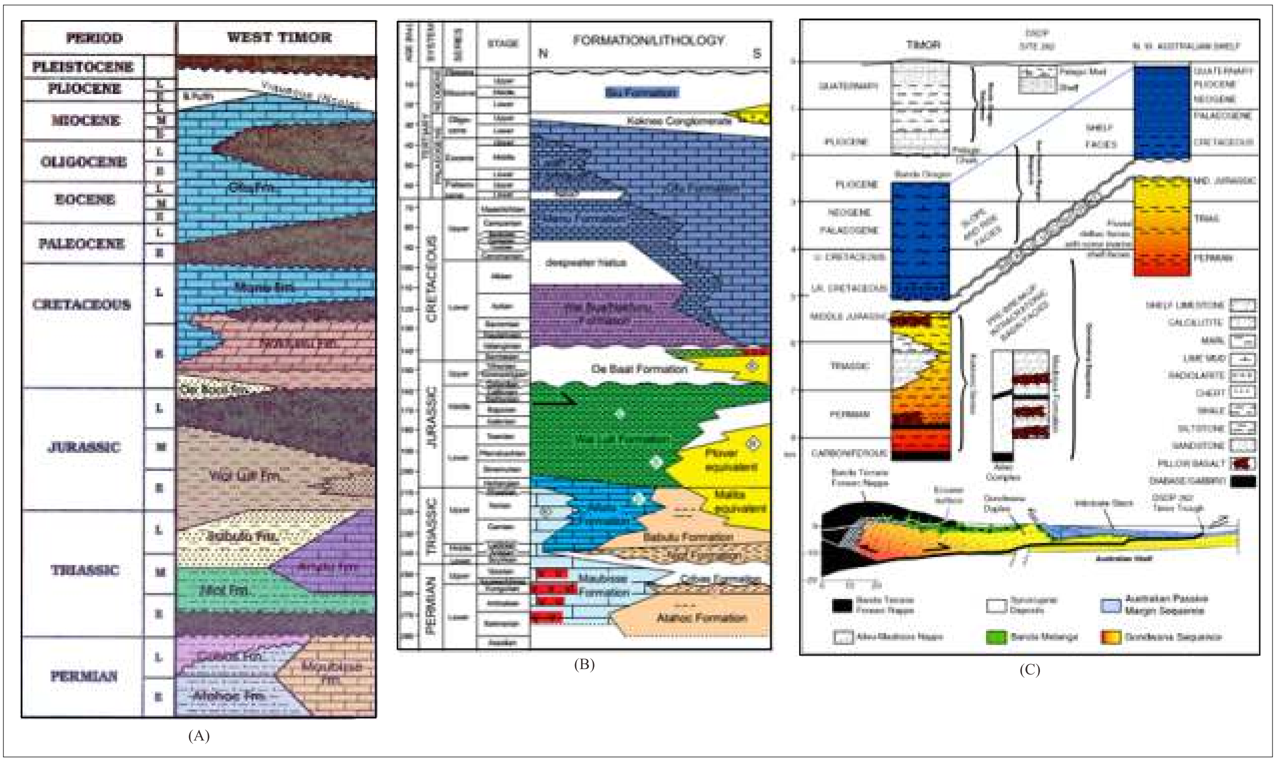
Source : Charlton, 2002

Figure 1. The Study area is situated near the border of Timor Leste (red dotted circle) with continues distribution of oil and gas seeps along this country.

sequences (Figure 2). Most sediments were deposited in the shallow to deep marine environments. The oldest formation found in West Timor is Permian age which unconformably overlays pre-Permian basement. The Kekneno sequence ranges from Early Permian to Middle Jurassic which consists of Bisane, Maubise, Niof, Aitutu, Babulu and Wailuli Formations. The Kolbano sequence is composed of Late Jurassic to Early Pliocene sedimentary succession including Oebaat, Nakfunu, Menu and Ofu Formations. The Viqueque sequence represents Plio-Pleistocene syn-orogenic sediments including the Viqueque Formation and melange. The Viquque Formation comprises Batu Putih and Nole Members, while melange consists of Bobonaro and Sonnebait Formations. Meanwhile, the youngest sediment of Quarternary formation occurs above the Viqueque sequence comprising of coral, conglomerat and gravel and alluvial.

The oldest Permian sediment generally consists of two formations including Bisane and Maubisse Formations. These two formations are separated based on their lithologies. The Bisane Formation mostly comprises of clastic sediment, whilst Maubisse Formation is dominated by limestone. This study focusses on Bisane Formation which equals to Atahoc and Cribas Formations appearing in East Timor. The Bisane Formation is characterised by thick calcareous sandstone (0.3-5 meters), yellowish grey, fine to medium grain, angular to sub-angular, fining upward, cross bedding and hummocky (Elnusa, 2015). It contains abundant mica and some marine macrofossils of Chrinoid. In addition, it is marked by the occurrence of black shale (maximum 5 meters) which has potentiality as hydrocarbon source rock. This evidence leads to the assumption that the Bisane Formation was formed during Permian in a shallow marine environment.

The Paleozoic sediment is believed to occur in Australia during syn-rift event. Therefore, palynomorphs appearing in Permian sediment are assumed to have Gondwanan affinity as indicated in the previous study done by Lelono *et al*. (2016). Van Gorsel (2014) indicated the occurrence of the tree-like seed fern *Glossopteris* typical of Gondwana (Australia-India) and *Gigantopteris* flora characteristic of low latitude chataysian terranes (South China, Indochina). *Glossopteris* itself produced striate Protohaploxypinus pollen which is a signature of Late Carboniferous-Permian (Traverse, 1988). The Late Carboniferous to Early Permian is characterised by abundant and well preserved miospore (Feng *et al*., 2008 and Jan, 2014).



Source : (A) Sawyer et al., 1993; (B) Charlton, 2002; & (C) Harris, 2011

Figure 2. West Timor stratigraphy columns whish are proposed by some selected authors.

On the other hand, Late Permian Gondwanaland palynofloras are marked by the domination of saccate forms (monosaccates and bisaccates), especially of striate bissacates showing well developed in trees of conifer or conifer-like gymnosperm (Jha *et al*., 2014). These striate bisaccate pollen persisted up to Middle Triassic.

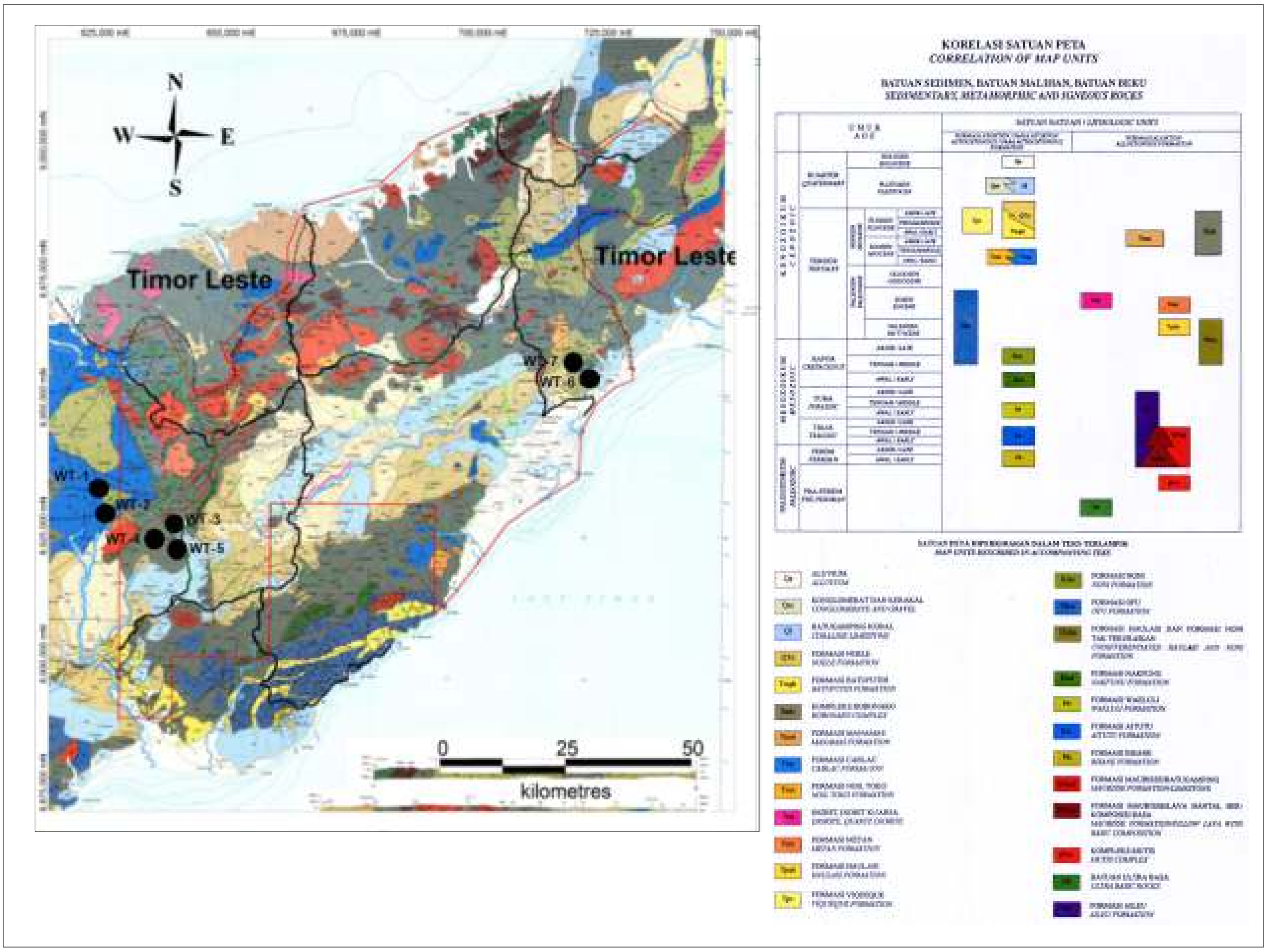
MATERIAL AND METHOD

Materials used in this study are surface samples which were collected during field campaign. Due to outcrop limitation, samples collected in this study are spot samples (Figure 3). Seven samples with noncalcareous shale lithology are available for this study. These samples are WT-1, WT-2, WT-3, WT-4, WT-5, WT-6 and WT-7 which are assumed to have an age of Permian. Lithologically, these samples show the intercalation of shale and siltstone, dark grey to black colour, rich of sulphur and they are characterised by papery sedimentary structure (Figure 4).

The analysed samples were processed in the LEMIGAS Stratigraphy Laboratory using the standard methods including HCl, HF and HNO_3 macerations, which were utilised to get sufficient recovery of plant microfossils 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 (Lelono, 2001).

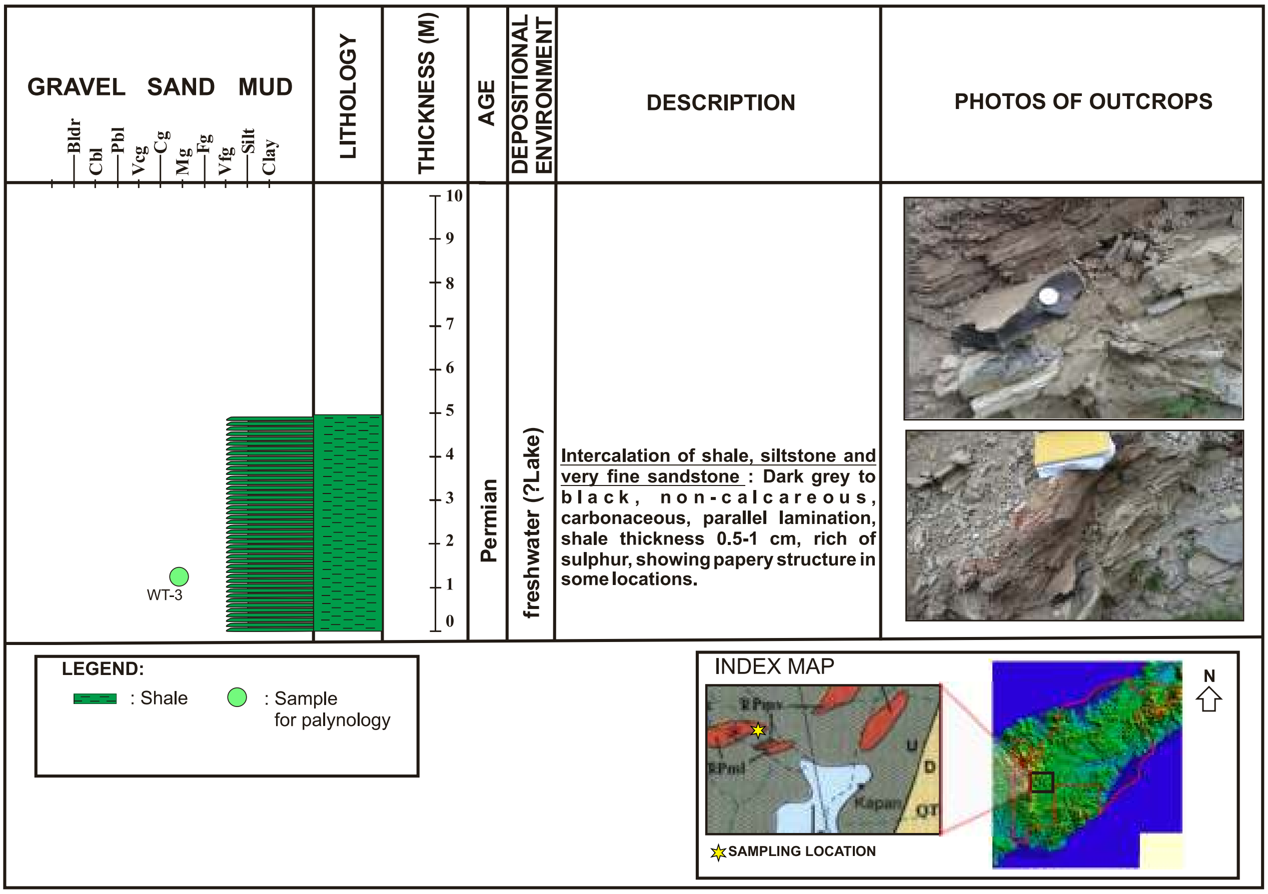
Data & Analysis

Data and analysis of this work proved the occurrence of noncalcareous sediment within the Permian Bisane Formation. It shows the intercalation of shale and siltstone, dark grey to black, rich of sulphur and characterised by papery sedimentary structure. It associates with gas seep. This data suggest that the noncalcareous Bisane Formation was pressumably formed in the freshwater environtment (?lacustrine) during early syn rift phase.



Sources : Rosidi et al., 1979; Lelono et al., 2016 with modification

Figure 3. Geology map of the study area shows the position of spot samples as marked by black circles (●)



Sources : Lelono et al., 2016

Figure 4. Lithological column of sample WT-3.

Palynomorph 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. In addition, index palynomorphs appearing within the studied samples were photographed for pre-Tertiary pollen collection.

Age interpretation and palaeoenvironmental analysis refers to the classic book of Traverse (1988) combined with those of Brugman *et al*. (1985) and recent publications introduced by several authors including Feng *et al*. (2008), Jan (2014) and Jha *et al*. (2014).

RESULTS AND DISCUSSION

Palynomorphs found in the studied samples show moderate abundance and diversity. About thirty distinct palynomorphs were recorded within this study. They are mostly miospores and bisaccate pollen as listed in Table 1. Palynomorphs occurring in this study were also found in Australia, Africa and India as reported by the previous authors. In addition, key palynomorphs for zonal construction and age analysis occur in these samples. Interestingly, no marine dinoflagellates were found in these samples.

Palynological Assemblage

Palynological analysis demonstrated well preserved pollen and spores showing the domination of miospores and striate bisaccate forms. Miospores are reperesented by *Plicatipollenites malabarensis, Cannanoropollis janakii* and *Osmundacidites senectus*. Trilete spores with monosaccate including *P malabarensis* and *C janakii* designate Late Carbonaceous to Early Permian. Meanwhile, striate bisaccate pollen consist of *Protohaploxypinus samoilovichi, P fuscus, Lunatisporites pellucidus, L. noviaulensis* and *Distriatiles insolitus*. The nonstriate bisaccate is also commonly recorded as shown by *Falcisporites australis, Alisporites spp*. and *Pinuspollentis globasaccus*. The domination of these pollen especially those of *Protohaploxypinus samoilovichi* and *Falcisporites australis* may indicate late Paleozoic (Brugman *et al*., 1985). Selected miospore and pollen mentioned above are the key elements to determine the age of the studied sediment which will be discussed at the next sub-chapter.

Table 1. The occurrence of pollen and spores in the studied samples

PALYNOMORPHS	SAMPLES						
	WT-1	WT-2	WT-3	WT-4	WT-5	WT-6	WT-7
					8		
STRIATE BISACCATES							
Protohaploxypinus samoilovichi	6	6	23	5			
Protohaploxypinus fuscus		3					
Lunatisporites noviauliensis	2	1	1				
Lunatisporites pellucidus		3					1
Lunatisporites sp.							2
Distriatites insculptus			1				
Distriatiles insolitus	1	1	1				
Stratersporites indicus		7					
NON-STRIATE BISSACTES							
Vitreisporites pallidus	2						5
Ashmoripollis reducta	1	2					
Pinuspollentis globosaccus		5		1			15
Pityosporites spp.		1		4			
Falcisporites australis	1	2	11	3		5	20
Limitisporites elongatus		2					
Triadispora plicata	1						
Triadispora crassa	1						
Sulcatisporites instilatus	1	2					
Alisporites spp.		1					10
Callialasporites pallidus		2					
Staurosaccites quadrifidus		5	2				6
Corisaccites alutas		1					
Ruqubiversiculites sp.							11
Samaropollenites speciosus							4
Platysaccus spp.							3
Sulcatisporites institatus							7
Triadisporites plicata							3
Callialasporites spp.			1				
bisaccate pollen indeterminate						4	
MONOSACCATE							
Cannanoropollis janakii	14	2	1				
Plicatipollenites malabarensis		3					
OTHER POLLEN							
Vittatina simplex	1	2					
Inaperturopollenites sp.		2					
Cycadophytes stonei	2	3		1			4
Araucariates fissus	7						
SPORES							
Osmundacidites senectus	1		4	1		1	
Osmundacidites wellmani	1						
Cadargasporites senectus		1					
Dictyophyllidites mortonii	8	1					3
Zebrasporites sp.	3						
Baculatisporites comaumensis	2						
Staplinisporites telatus	9						
Ceratosporites helidonensis	2						
Semiretisporis denmeadi	2						
Antulsporites saevus	4						
Laevigatosporites belfordii	2		1				
Polycingulatisporites crenulatus	5	1					
Apiculatisporites carnarvonensis	1						
Aratisporites parvispinosus	1						
Lundbladispora willmotii							2
Concavissimisporites variverrucatus			1				
Cicatricosisporites australis		1					
Microbaculisporites trisina							2
Ceratosporites sp.			1				

Sources : Lelono et al., 2016 (with some additional data)

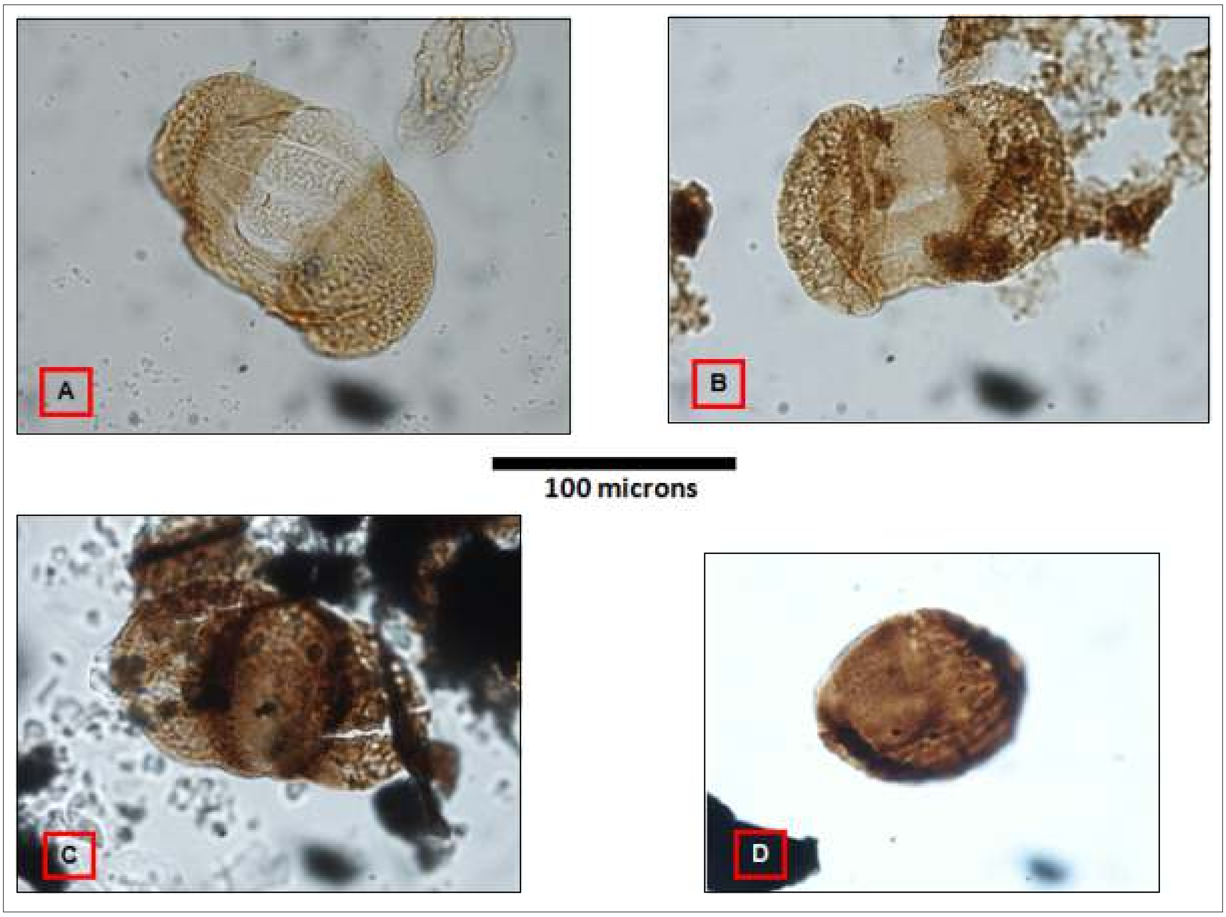
Other palynomorphs appear in the studied samples are nonsaccate pollen and spore as well as nonstriate bisaccates which suggest Permo-Triassic age. The nonsaccate pollen include *Vittatina simplex, Cycadopites stonei* and *Inaperturopollenites* sp. Meanwhile, the nonsaccate spores are represented by *Aratisporites parvispinosus, Apiculatisporites carnarvonensis, Laevigatosporites belfordii* and *Lundbladispora willmotii*. *Nonstriate bissacates* include *Limitisporites elongatus, Samaropollenites speciosus, Pityosporites* spp., and *Platysaccus* spp.

Age Analysis

This research proves the occurrence of index taxa for Permo-Triassic age such as *Protohaploxypinus samoilovichi, P. fuscus, Falcisporites australis, Lunatisporites pellucidus* and *Vittatina simplex* as shown in Figure 5. Referring to Mesozoic zones proposed by Helby *et al.* (1987), the appearance of these palynomorphs indicates Falcisporites superzone which ranges from Late Permian to Late Triassic (Figure 6). As the palynomorph assemblages derive from spot samples, the vertical distribution of each index taxa is hardly observed. This causes the difficulty in defining pollen zone within the Falcisporites superzone. Therefore, based on the appearance of *Protohaploxypinus samoilovichi, P. fuscus, Falcisporites australis, Lunatisporites pellucidus* and *Staurosaccites quadrifidus*, the studied samples are designated to Permian – Triassic age.

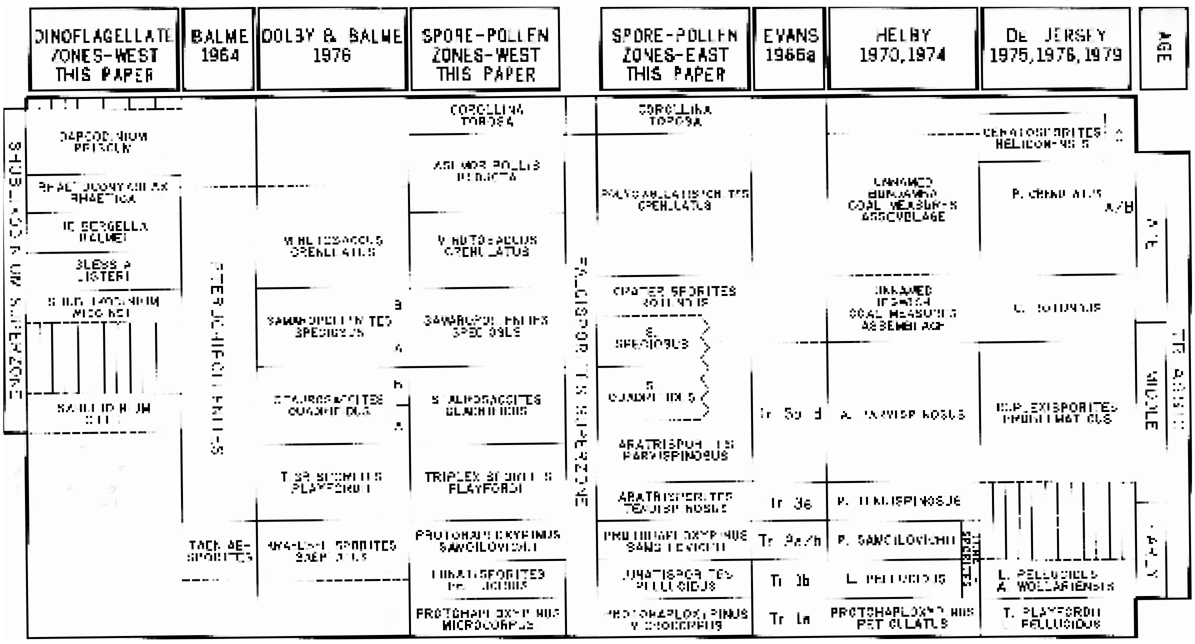
On the other hand, the studied samples contain moderate trilete spores with saccate marking Carboniferous - Permian age. These miospores are reperesented by *Plicatipollenites malabarensis* and *Cannanoropollis janakii* (Figure 7). On the basis of the occurrence of these spores, it is inferred that the studied samples were formed during Carboniferous - Permian (Brugman *et al.*, 1985).

After all, it can be inferred that the studied samples are attributed to Permian age.



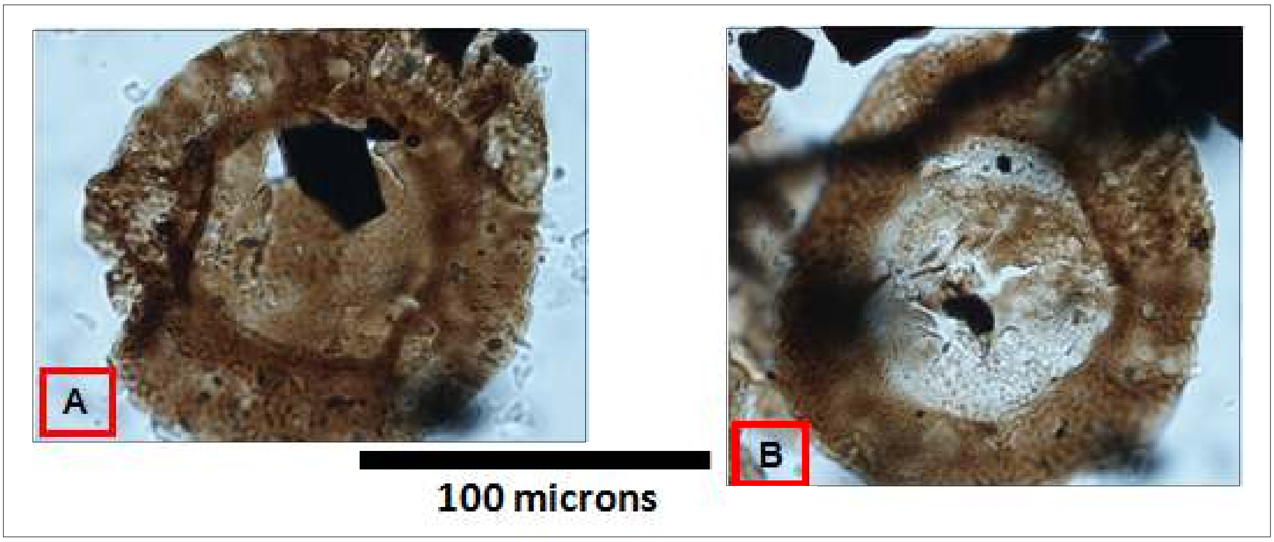
Lelono et. al., 2016 with some additional photos

Figure 5. Some index pollen appear to indicate Permian-Triassic age. (A) Protohaploxypinus samoilovichii (Jansonius, 1962) Hart, 1964. (B) Lunatisporites pellucidus Goubin. (C) Falcisporites australis (Gould, 1975). (D) Vittatina simplex (Jansonius, 1962). All specimens are X 1000.



Sources : Helby et al., 1987

Figure 6. The Falcisporites superzone ranges from Late Permian to Late Triassic.



Sumber : Lelono et al., 2016

Figure 7. Indicators of the Late Carboniferous-Permian age. (A) Plicatipollenites malabarensis (Potonie and Sah, 1958) Foster, 1975. (B) Cannanoropollis janakii (Potonie and Sah, 1958). All specimens are X 1000.

Paleoenvironmental Analysis

Generally, the studied samples are characterised by common occurrence of spores and bisaccate of gymnosperm pollen. Some bisaccate polens of both striate and non-striate forms may be attributed to Glossopterid which represent forest development in the hinterland. These bisaccates are represented by *Protohaploxypinus samoilovichi, P. fuscus, Lunatisporites pellucidus, Staurosaccites quadrifidus* (striate forms) and *Falcisporites australis* (non-striate form). Meanwhile, spores commonly appear to indicate wet environment. They are *Osmundacidites senectus, Polycingulatisporites crenulatus, Apiculatisporites carnarvonensis* and *Aratisporites parvispinosus*. These spores might have grown as herbaceous understorey plants in the flooding environment (Jha *et al*., 2014).

Lithologically, the studied samples are black shale indicating high organic materials. In addition, they are noncalcareous suggesting lack of marine influence as supported by the absence of marine dinoflagellates. The studied samples are considered to have different facies to those collected from the Permian shallow marine sequences with macrofossils of Chrinoid as defined in the previous report (Elnusa, 2015). These facts lead to the assumption that the depositional environment of the studied samples may relate to the freshwater condition.

Based on the above discussion, it can be concluded that the studied samples might have been formed in the freshwater environments, especially those of forest swamp environment. In addition, paleoclimate occurring during the deposition of the samples is assumed to be cool and wet.

CONCLUSION

This study is for the first time to access palynomorph assemblage of the Permian sediment cropping out in West Timor. Seven spot samples were processed to extract palynomorph content which were dominated by spores and bisaccate forms. Based on the appearance of index pollen of *Protohaploxypinus samoilovichi, Falcisporites australis, Lunatisporites pellucidus* (Permian - Triassic) combined with index spores of *Plicatipollenites malabarensis, Cannanoropollis janakii* (Carboniferous - Permian), it can be interpreted that the studied samples have an age of Permian. On the other hand, common appearance of striate and *non-striate bisaccates* (*glossopterid*) and miospores combined with noncalcareous black shale lithology may suggest forest swamp environment.

Correlating this palynological study with the rifting phase during Permian, it can be inferred that the studied sediment is a product of early syn-rift which was formed in the freshwater environment (probably lacustrine). The presence of freshwater (lacustrine) sediment is a new finding in the Permian sediment which was initially defined as a shallow to deep marine deposits. If this is the case, the appearance of Permian black shale provides opportunity to discover new petroleum system in the Paleozoic series of West Timor. However, it is required geochemical analysis to prove sorce rock quality of the samples.

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