INDONESIAN JOURNAL ON GEOSCIENCE
Geological Agency
Ministry of Energy and Mineral Resources

Journal homepage: http://ijog.geologi.esdm.go.id
ISSN 2355-9314, e-ISSN 2355-9306

The Gondwanan Green Alga *Tasmanites* sp. in the Permian Lacustrine Deposits of West Timor

Eko Budi Lelono

Centre for Geological Survey, Geological Agency
Jln. Diponegoro No.57, Bandung

Corresponding author: ekobudilelono@gmail.com
Manuscript received: November, 13, 2017; revised: May, 23, 2018;
approved: August, 19, 2019; available online: October, 15, 2019

Abstract - This paper discusses a palynological research on the Permian lacustrine sediments of West Timor. Ten outcrop samples were collected from a 5 m high cliff. Lithologically, the outcrop mostly consists of noncalcareous black shale showing papery structures and forms part of Bisane Formation. Palynomorphs extracted from the studied samples are rich, but of a low diversity indicating a non-marine environment. More than 80% of pollen assemblages are of the green alga *Tasmanites* sp., whilst the rest are mostly represented by striate and non-striate bisaccate pollen and trilete spores which indicate a Permian age. The chromatograms of GC and GCMS (saturate) indicate that the studied samples were deposited in a lacustrine environment of an anoxic to suboxic condition. Furthermore, in term of petroleum exploration, abundant *Tasmanites* sp. is believed to be the biological source for tricyclic terpanes which are well known as the primary source of hydrocarbons. This discovery offers an excellent opportunity for establishing a new petroleum system within the Paleozoic sequences of Timor Island.

Keywords: Gondwana, Tasmanites, Permian, lacustrine sediments, West Timor

© IJOG - 2019. All right reserved

How to cite this article:
Lelono, E.B., 2019. The Gondwanan Green Alga *Tasmanites* sp. in the Permian Lacustrine Deposits of West Timor. *Indonesian Journal on Geoscience*, 6 (3), p.255-266. DOI: 10.17014/ijog.6.3.255-266

Introduction

Biostratigraphic studies of the Permian of West Timor mostly concentrate on marine fossils such as crinoids, molluscs, brachiopods, corals, and trilobites. This is mainly because many Permian sediments consist of marine facies (Van Gorsel, 2014). In addition, Timor mostly forms a distal part of the Australian continental Plate and is characterized by shallow to deep marine sediments ranging in age from Permian to Pleistocene (Charlton and Gandara, 2012). Therefore, West Timor has been well known as an area for marine biostratigraphic research of the Late Paleozoic. The value of plant fossils, such as pollen and spores, has not been previously considered. This situation changed dramatically after LEMIGAS and Elnusa teams discovered Permian outcrops during their field surveys in 2015 to evaluate the hydrocarbon potential of this area (Lelono *et al.*, 2016a). These outcrops are separated into calcareous and non-calcareous lithologies as reported by Elnusa (2015) and Lelono *et al*. (2016b). Both lithology types proved to yield moderate pollen recovery. Unfortunately, due to the poor condition of the outcrops, a systematic sampling was not possible at that time. This prevented undertaking a comprehensive palynological assessment involving systematic sampling.

The studied location is situated in West Timor of Nusa Tenggara Timur Province (Figure 1). Timor Island is located within the Banda arc-Australian continental collision zone. It is part of the youngest tectonic collision in the world that created a high complexity with respect to geology (Chamalaun and Grady, 1978; Hamilton, 1979; Harris, 1991).

The stratigraphic framework for this area, developed for mapping the Kupang-Atambua Quadrangle (Rosidi *et al.*, 1979) is shown in Figure 2. The Bisane Formation, which is the subject of this study, is of Permian age considered to be the oldest rock unit within the West Timor (Rosidi *et al.*, 1979; Sawyer *et al.*, 1993; Charlton, 2002; Harris, 2011).

During the process of detailed mapping, the team discovered good quality outcrops that were suitable for systematic sampling in which they consist of non-calcareous black shale with siltstone intercalations, rich in sulphur, and show papery structures suggestive of a lacustrine deposition (Figure 3).

Previous studies on the non-calcareous samples by Lelono *et al.* (2016a) showed the dominance of spores and bisaccate pollen. Based on the appearance of *Protohaploxypinus samoilovichi*, *Falcisporites australis*, and *Lunatisporites pellucidus*, which are restricted to the Permian and Triassic combined with the presence of *Plicatipollenites malabarensis*, and *Cannanoropollis janakii* that are restricted to the Carboniferous and Permian, the succession was therefore designated a Permian age, following Helby *et al.* (1987) and Brugman *et al.* (1985). The common appearance of striate and non-striate bisaccate glossopterid pollen and other sporomorphs combined with the non-calcareous black shale lithology may suggest a forest swamp environment possibly with peat formation, since the Glossopteris plant is thought to have grown in conditions similar to the present day Bald Cypress (Jha *et al.*, 2014; Van Gorsel, 2014). In addition, some samples yielded rare specimens of the green alga *Tasmanites* sp. This alga is recorded to occur in Precambrian to Phanerozoic deposits (Dutta *et al.*, 2006). The name of *Tasmanites* is given after the Permian oil shales of Tasmania which contain rich *Tasmanites* (Newton, 1875).

This paper aims to study the palynology of the Permian lacustrine sediments in more detail, with a view to contribute to a better understanding of the Late Paleozoic stratigraphy of West Timor.

Materials and Methods

Ten samples, numbered BSN-1 to BSN-10, were selected from the outcrop which was 5 m

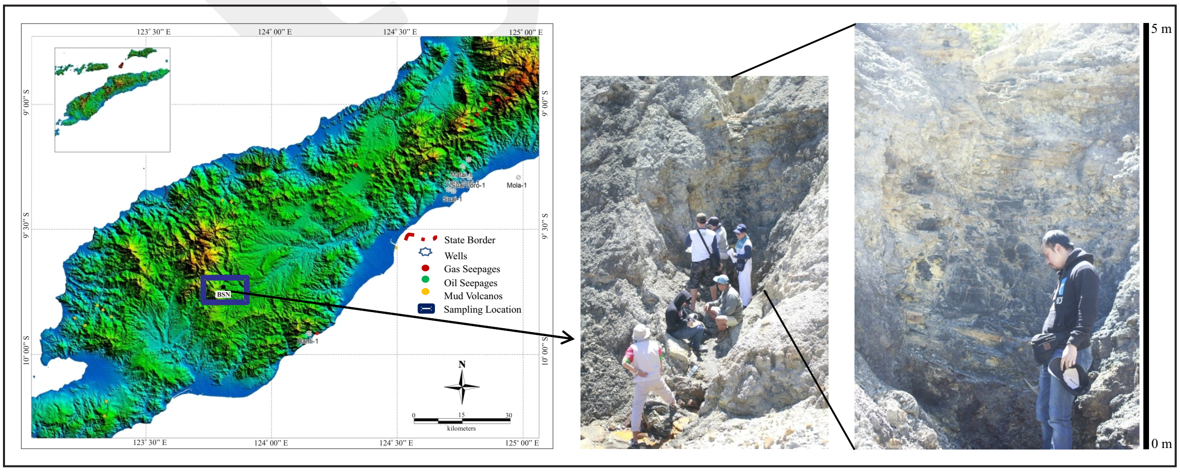

Figure 1. Sampling location shows outcrop situation which exposes on a cliff due to landslide.

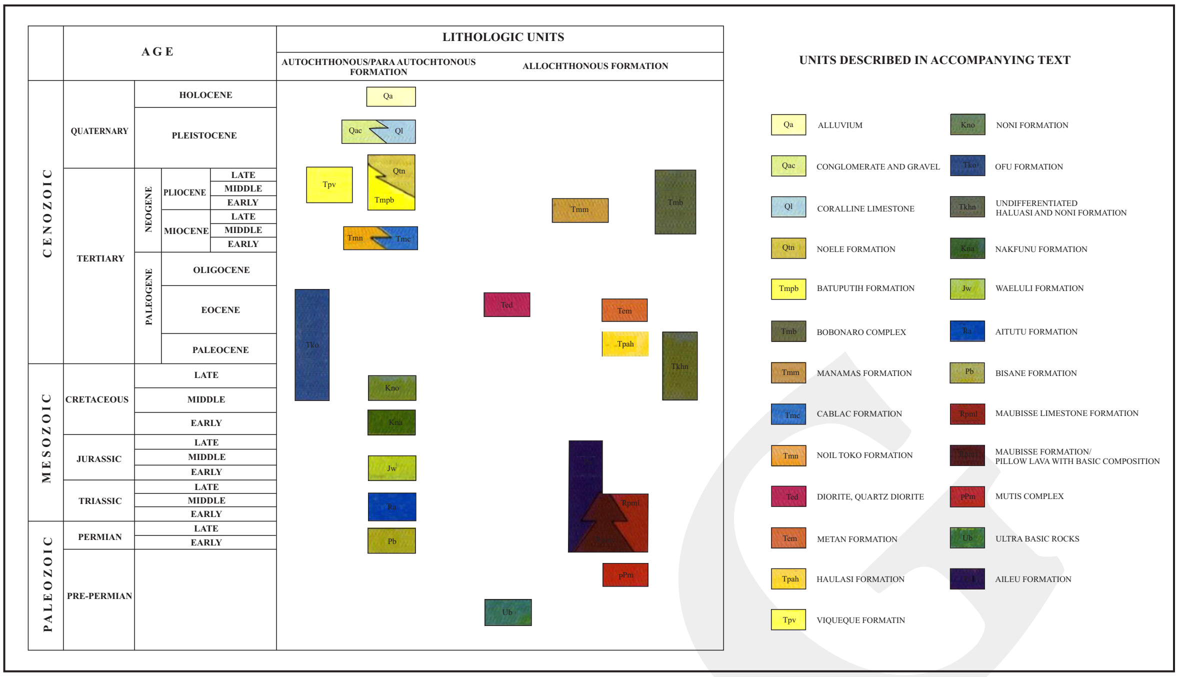

Figure 2. Stratigraphic relationship of formations occuring in the West Timor area as proposed by Rosidi *et al.* (1979).

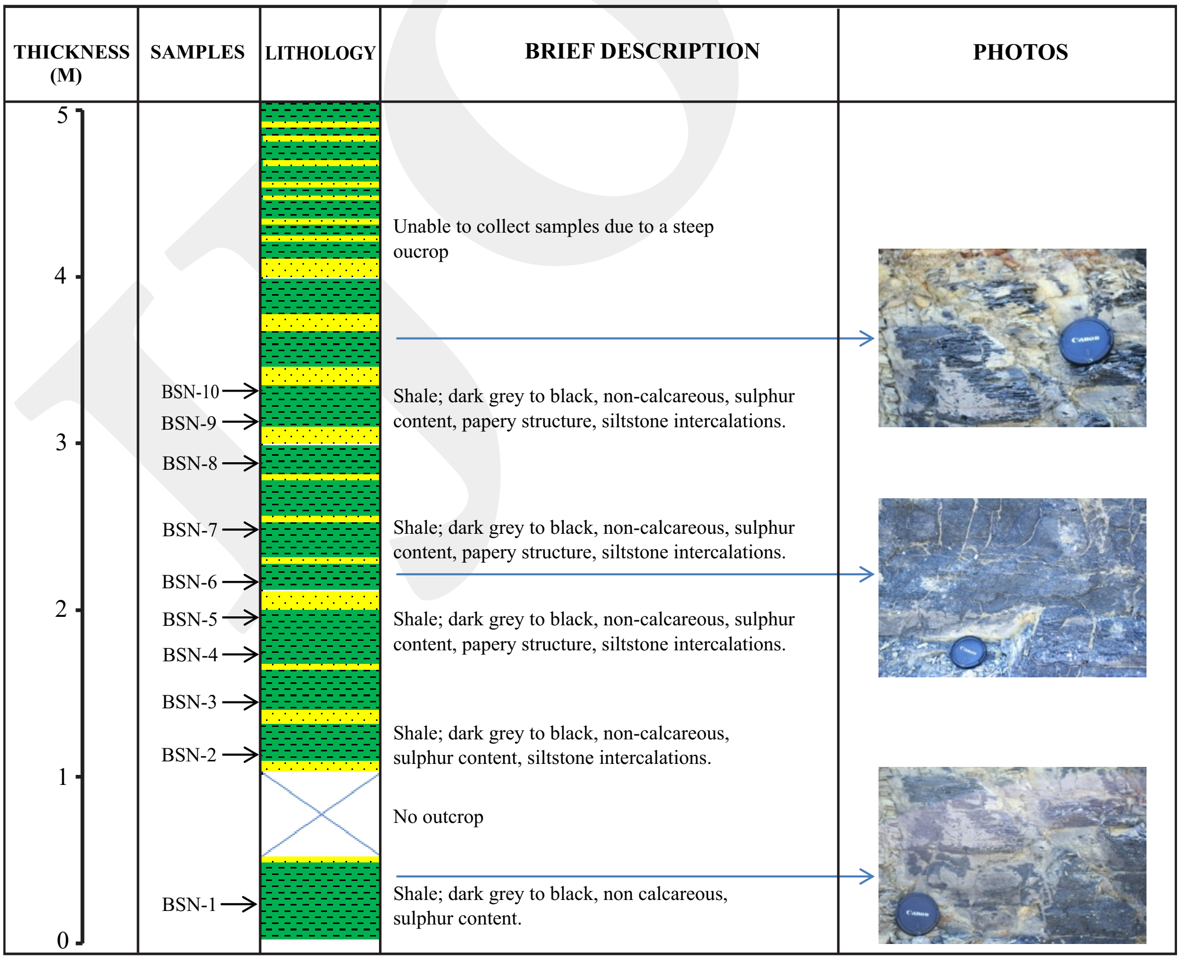

Figure 3. Samples studied are collected systematically from the outcrop applying measured section method.

in thickness. The studied outcrop is a quite steep cliff which appears to be due to a landslide (Figures 1 and 3). The outcrop is characterized by non-calcareous shales with thin siltstone intercalations, that are dark grey to black colour with a content of sulphur, and shows papery sedimentary structures. All samples for the study were selected from the black shale lithology.

Approximately 5 g of samples were weighed for laboratory preparation using the technique applied at the LEMIGAS Stratigraphy Laboratory, in Jakarta. Processing involved HCl, HF, and HNO_3 macerations. These techniques were followed by alkali treatment using 10% KOH to gain a clear residue. Sieving with a 5 μ sieve was performed to collect more palynomorphs by separating them from fine-grained debris. Finally, the residues were mounted on slides using polyvinyl alcohol and Canada Balsam (Lelono, 2001). Palynomorph examination was conducted using a transmitted light microscope with an oil immersion objective and X 12. 5 eye pieces. Each palynomorph appearing in the studied samples was counted and plotted onto a chart to show their quantitative distribution through the outcrop (Figure 4).

As palynological zonation for the Indonesian pre-Cenozoic sucessions has not been established yet, the authors refer to several publications which relate to the Permian palynology elsewhere in defining age and paleoenvironment including Brugman *et al*. (1985), Traverse (1988), Feng *et al*. (2008), Jan (2014), and Jha *et al*. (2014).

Results and Discussion

As shown in Figure 4, the studied samples generally provide an excellent pollen recovery. Only two samples (BSN-1 and 5) containing relatively poor assemblages. Pollen assemblages are quite different compared to those published by previous reseachers (Lelono *et al.*, 2016a; Lelono *et al*., 2016b). They are much richer in palynomorphs but of lower diversity. In addition, palynomorphs are dominated by *Tasmanites* sp. (green algae) and these form more than 80% of the assemblages. However, the pollen and spore taxa recorded are similar to those of the previous study, including striate bisssacates, non-striate bissacates, and monosaccate forms. Striate bisaccates are represented by *Protohaploxypinus samoilovichi* and *Lunatisporites* sp.,whilst non-striate bissacates consist of *Falcisporites australis*, *Pinuspollenites globosaccus*, *Staurosaccites quadratus*, *Platysaccus* sp., *Sulcatisporites institatus,* and some indeterminate bissacate pollen. Monosaccate forms are represented only by *Cannanoropollis janakii*. In addition to saccate pollen, spores are also well represented as indicated by the presence of *Osmundacidites senectus*, *Ceratosporites helidonensis*, *Dictyophillidites equiexinus*, *Lundbladispora willmotii*, *Ceratosporites helidonensis*, *Microbaculites tentula*, *M. australis,* and *Aequitriradiates* sp.

Age and Paleoenvironment

Key palynomorphs appear throughout the section to define the age of the studied sediments (Figure 5). The most important pollen are those indicating a Permo-Triassic age and include *Protohaploxypinus samoilovichi*, *Lunatisporites* sp. (striate bissacates), *Falcisporites australis*, and *Staurosaccites quadratus* (nonstriate bissacate). Referring to the Mesozoic pollen zonation of Australia proposed by Helby *et al*. (1987), these palynomorphs indicate the *Falcisporites* superzone which ranges from Late Permian to Late Triassic. On the other hand, another index palynomorph occurs which designates a Carboniferous-Permian age. This species is a trilete monosaccate form named *Cannanoropollis janakii* (Brugman *et al*., 1985). Considering the occurrence of the above palynomorphs, it can be concluded that the sediments studied was possibly formed during Late Permian.

This study reveals rich green algae of *Tasmanites* sp. for the first time in pre-Cenozoic sediments of eastern Indonesia. Revill *et al*. (1994) reported the enrichment of *Tasmanites* in the

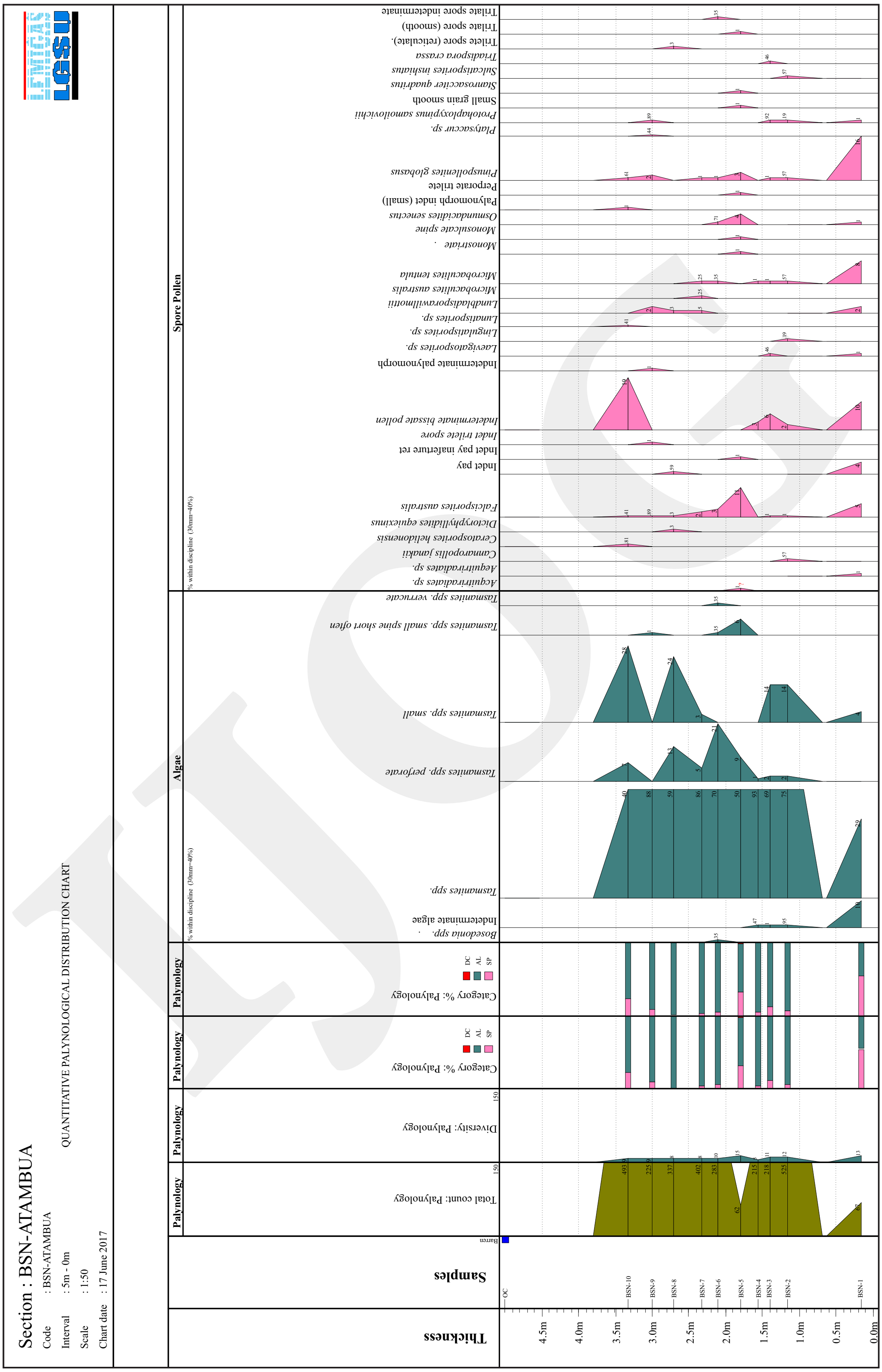

Figure 4. Pollen assemblages appearing in the Late Permian lacustrine sediments are characterized by a high abundance but low diversity of palynomorphs. More than 80% of these assemblages are represented by green algae of *Tasmanites* .

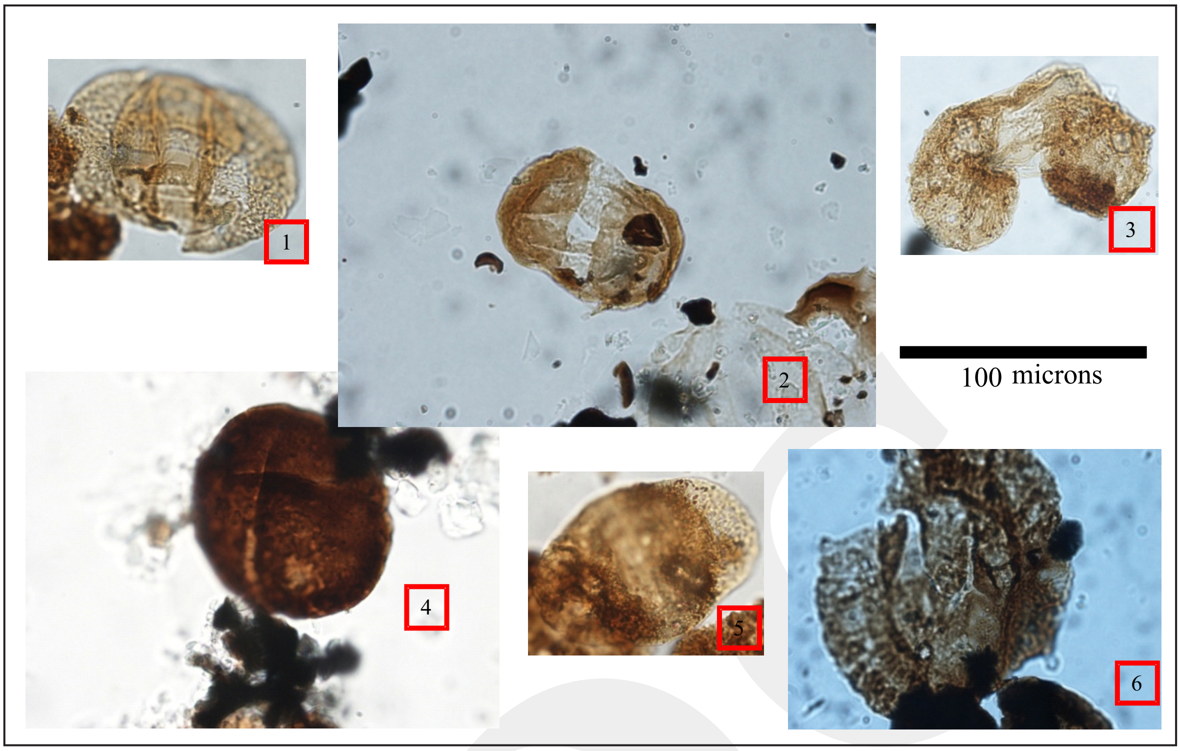

Figure 5. Key palynomorphs from Permian West Timor: (1) *Protohaploxypinus samoilovichi*, (2) *Lunatisporites* sp., (3) *Pinuspollenites globosaccus*, (4) *Staurosaccites quadrifidus*, (5) *Falcisporites australis*, (6) *Cannanoropolllis janakii*.

Gondwanan Palaeozoic deposits from Tasmania which were interpreted as a reflection of algal blooms in areas supplied with meltwater from surrounding glaciers. Such a setting would be consistent with Timor Island being geographically situated far south in the temperate region during the Permian. The dominance of *Tasmanites* may indicate a closed or restricted lacustrine environment. On the other hand, the presence of various bisaccate pollen of both striate and non-striate forms as discussed above may be attributed to a Glossopterid flora which represent swamp forest development in the hinterland (Van Gorsel, 2014). Meanwhile, the regular appearance of spores in the studied samples indicates that their source taxa might have grown as herbaceous understorey plants in a flood plain environment (Jha *et al.*, 2014). The studied samples are lithologically non-calcareous black shale with a distinct sulphur content and papery structure. The integration of palynological and lithological data leads to the interpretation that the depositional environment of the sediments strongly relates to peat formation. Therefore, it is interpreted that the sampled succession was deposited in a lacustrine setting bordered by swamps, possibly with peatlands. Throughout geological time, peat formation has occurred in three broad latitudinal belts, one within the tropical zone, the second within the northern temperate zone, and the third at southern temperate latitudes (Ziegler *et al.*, 2003). The Permian succession studied here would have occurred in the southern temperate zone.

The Occurrence of Tasmanites Green Algae

The genus *Tasmanites* was firstly described by Hooker (1852) and was considered to be lycopod seed cases (Mendelson, 1933). However, the name of *Tasmanites* was formally proposed by Newton (1875) based on specimens that occurred abundantly in the Permian oil shale of Tasmania. It was initially thought to be some kind of spore, but it is currently thought to be algal in origin (Schopf *et al.*, 1944; Eisenack, 1958). Today, *Tasmanites* is generally regarded as phycomata of prasinophyte algae (Tappan,

1980) which may originate as very small motile cells (10 mm in diameter). Prasinophyte algae currently occurs in abundance within marine environments such as in the Mediterranean sea and in the Bay of Biscay, and algal blooms regularly occur in the English Channel (Parke, 1966; Parke *et al*., 1978). The cells passively float on these oceans and move vertically from about 10 m down to 100 m in depth daily (*i.e.* below the photic zone). The presence of these algae in the water column is limited by high water temperatures (Parke and den Hartog-Adams, 1965). It is interpreted that the blooms of prasinophycean algae were related to the enrichment of the water by nitrogen and phosphates (Ackmann *et al*., 1970). Prasinophyte green algae occur from Early Paleozoic to recent and has species resident in fresh to marine water (Traverse, 1988). In the Middle Triassic successions of Svalbard and the Barents Shelf of Norway, *Tasmanites* algae abundantly appeared in the marine dark shales which are a hydrocarbon source rock (Vigran *et al*., 2008). On the contrary, in the Early Devonian sediments of Rhynie Village in Scotland, prasinophytes fossils were extracted from the lacustrine shales which might have played important roles in the functioning of early non-marine ecosystems, perhaps as primary producers in food webs (Kustatcher *et al.*, 2014).

The occurrence of abundant *Tasmanites* within the Permian of West Timor is described here for the first time. Generally, these green algae are described as more or less comprising a spherical body with a thick wall, psilate sculpture, and various sizes from 30 to 90 μ (Figure 6). The importance of an algal component in the sediments is confirmed by gas chromatography-mass spectrometry analysis (GCMS saturate chromatogram m/z 191) on four selected samples which proves the absence of a higher plant contribution to the contained organic matter. In addition, the high ratio of sterane and hopane is typical of organic matter with a planktonic or benthic algal contribution (Moldowan *et al*., 1985). Abundant gamacerane combined with the low ratio of pristane and phytane (Pr/Ph) indicates lacustrine bitumen. On the other hand, a ternary diagram of sterane composition shows that organic material of the analyzed samples was derived from the same source. The organic materials are a mixture of higher plant matter and algae which accumulated in a lacustrine environment (Figure 7).

Analysis of gas chromatography (GC chromatogram) shows higher values of pristane compared to that of phytane (the ratio of Pr/Ph ranges from 1.32 to 1.70) indicating that organic material forming source rock was deposited in an anoxic to suboxic setting (Figure 8).

A chromatogram m/z 191 of the analyzed samples exhibits a similar trend in which source rock indicator of tricyclic terpanes can be clearly observed (Figure 9). The relationship between rich *Tasmanites* and the occurrence of tricyclic terpane compounds has been proven by previous authors who analyzed pre-Cenozoic oil shale elsewhere. *Tasmanites* is assumed as a biological source of the tricyclic terpenoids which is typi-

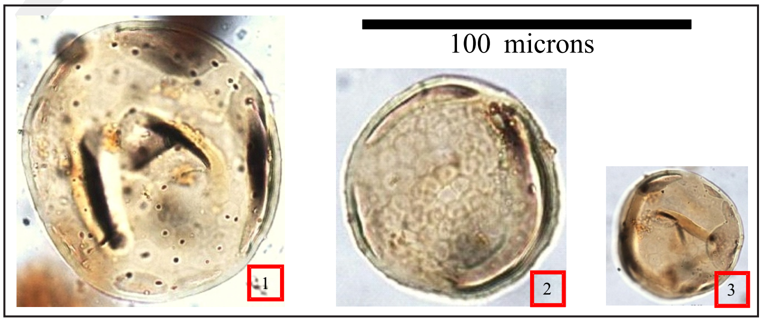

Figure 6. Green algae of *Tasmanites* sp. appears in various sizes: (1) Large *Tasmanites* sp., (2) Medium *Tasmanites* sp., (3) Small *Tasmanites* sp.

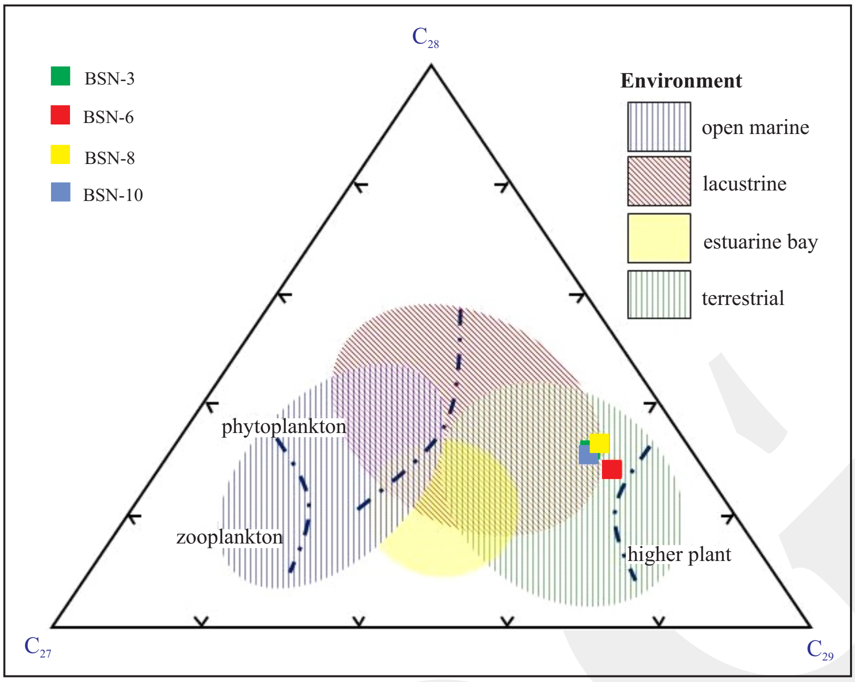

Figure 7. Sterane composition diagram of four analyzed samples indicating the origin of their organic materials in a lacustrine environment.

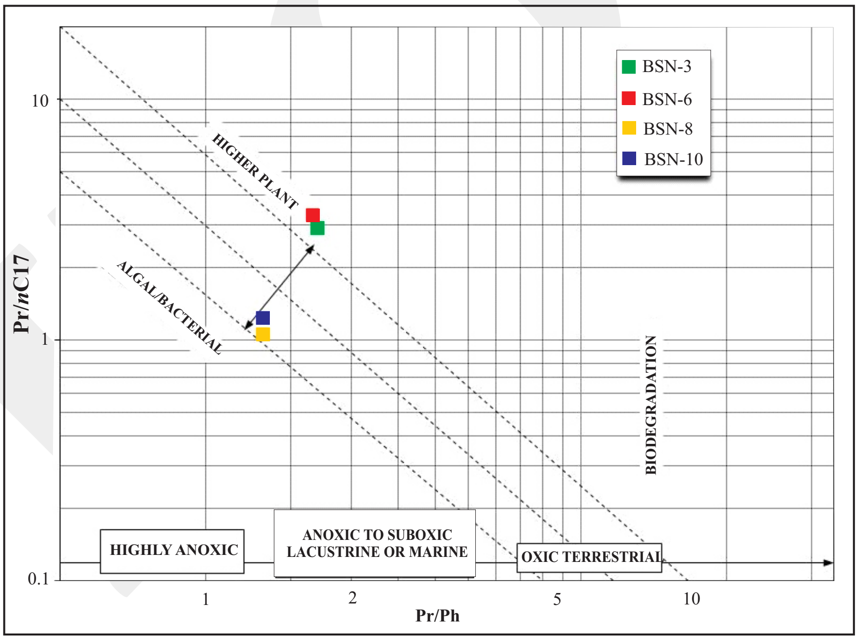

Figure 8. Plotting of Pr/Ph ratio *versus* Pr/nC 17 ratio obtained from fingerprint chromatogram of GC analysis.

cally recorded in a high abundance in the host of oil shales (Greenwood *et al*., 2000; Dutta *et al*., 2006). Meanwhile, all analyzed samples show low maturity (immature) as indicated by the low ratio of Ts/Tm combined with the high index of homohopane. Having all data provided above, the discovery of abundant *Tasmanites* is a significant finding as this alga is a major contributor to the formation of hydrocarbon source rocks. Therefore, this offers an excellent opportunity for the establishment of a new petroleum system within the Paleozoic sequences of Timor.

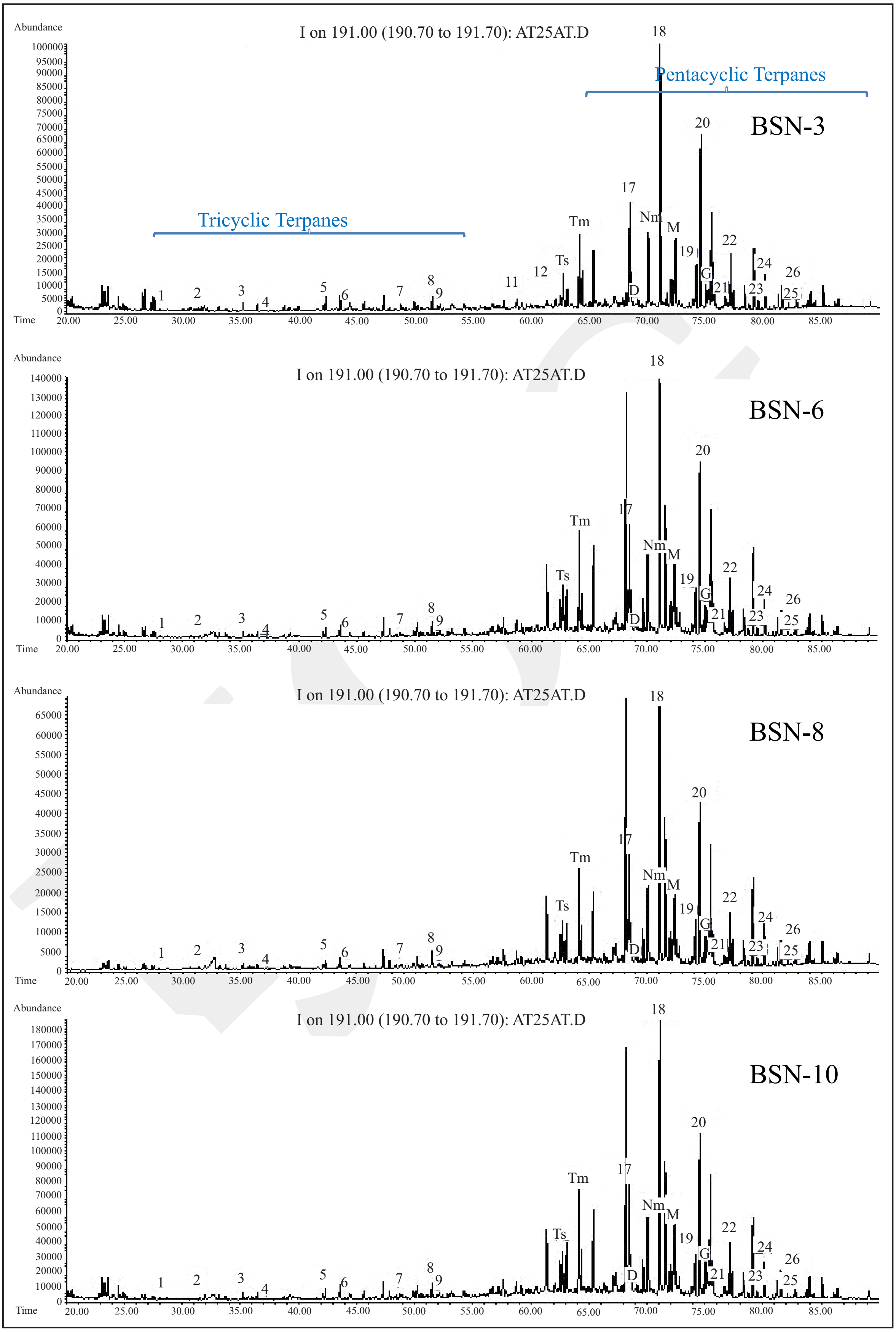

Figure 9. Chromatogram m/z 191 of the selected samples which are generated using GCMS saturate fraction.

Conclusions

A 5 m thick outcrop of black shale from West Timor is shown to be of Permian age and was deposited in a lacustrine environment. The lithologies are dark grey to black in colour, non-calcareous with sulphur content, and papery. The presence of the index taxa *Protohaploxypinus samoilovichi*, *Falcisporites australis*, *Lunatisporites* sp., and *Cannanoropollis janakii* suggests the age to be Late Permian.

This study shows the presence of abundant green algae of *Tasmanites* which dominates more than 80% of pollen assemblages. This is the first time to discover rich *Tasmanites* in the Late Paleozoic sediments in Indonesia. The GC chromatogram and GCMS saturate chromatogram also indicate that the organic material accumulated in a lacustrine environment in an anoxic to suboxic setting. The abundant *Tasmanites* is believed to be the biological source for tricyclic terpanes which is well known as a primary hydrocarbon source. This is a significant finding for discovering potential source rocks within the Late Paleozoic of Timor.

Acknowledgment

The author thanks the management of the project for providing permission to publish this research result which is part of LEMIGAS exploration activity in West Timor. This study is following up the previous work to obtain palynology information of the Late Permian lacustrine sediments.

References

Ackmann, R.G., Addison, R.F., and Hooper, S.N., 1970. Halosphaera Virides: Fatty Acid Composition and Taxonomical Relationships. *Journal of the Fisheries Resources Board Canada,* 27, p. 251-255. DOI: 10.1139/f70-032

Brugman, W. A., Eggink, J. W., Loboziak, S., and Visscher, H., 1985. Late Carboniferous-Early Permian (Ghazelian-Artinskian) Palynomorphs. *Micropalaeontology,* 4 (1), p. 93-106. DOI: 10.1144/jm.4.1.93

Chamalaun, F. H. and Grady, A. E., 1978. The Tectonic Development of Timor. A New Model and its Implications for Petroleum Geology. *APEA Journal,* 18, p.102-108. DOI: 10.1071/aj77012

Charlton, T.R., 2002. The Petroleum Potential of West Timor. *Proceedings of the Indonesian Petroleum Accosiation,* 30.

Charlton, T. R. and Gandara, D., 2012. Structural-Stratigraphy Relationships at the Boundary of the Lolotoi Metamorphic Complex, Timor Leste: Field Evidence Againts an Allochtonous Origin. *1st International Geology Congress of Geology of Timor Leste*, Dili.

Dutta, S., Greenwood, P. F., Brocke, R., Schaefer, R. G., and Mann, U., 2006. New Insights into the Relationship Between Tasmanites and Tricyclic Terpenoids. *Organic Geochemistry,* 37, p.117-127. DOI: 10.1016/j.orggeochem.2005.08.010

Eisenack, A., 1958. Tasmanites Newton 1875 und Leiosphaeridia n. g. als Gattungen den Hystrichosphaeridia. *Palaeontographica, Abteilung A. Palaozoologie',* 110, p.1-19.

Elnusa, 2015. Survey, Processing and Interpretation of Geological and Geophysical Data of the Atambua Area and its Vicinity, West Timor. *Lemigas Internal Report*.

Feng, L., Huaicheng, Z., and Shu, O., 2008. Late Carboniferous - Early Permian Palynology of Baode (Pao-Te-Chou) in Shanxi Province, North China. *Geological Journal,* 43, p.487-510. DOI: 10.1002/gj.1121

Greenwood, P. F., Arouri, K. R., and George, S. C., 2000. Tricyclic Terpenoid Composition of Tasmanites Kerogen as Determined by Pyrolysis GC-MS. *Geochimica et Cosmochimica Acta,* 64 (7), p.1249-1263. DOI: 10.1016/s0016-7037(99)00326-9

Hamilton, W., 1979. *Tectonics of the Indonesian Region*. U.S. Geological Survey Professional Paper*,* 1078.

Harris, R. A., 1991. Temporal Distribution of Strain in the Active Banda Orogen: A Reconciliation of Rival Hypotheses. *Journal of Southeast Asian Earth Sciences,* 6, p.373-386. DOI: 10.1016/0743-9547(91)90082-9

Harris, R. A., 2011. *The Nature of the Banda Arc-Continent Collision in the Timor Region. In*: Brown, D. and Ryan, P.D. (Ed.), Arc-Continent Collision, Frontiers in Earth Sciences, DOI 10.1007/978-3-540-88558-0_7, Springer-Verlag Berlin Heidelberg, p.163-211. DOI: 10.1007/978-3-540-88558-0_7

Helby, R., Morgan, R., and Partridge, A. D., 1987. A Palynological Zonation of the Australian Mesozoic. *In*: Jell, P. A. (Ed.), *Studies in Australian Mesozoic Palynology*. The Association of Australian Paleontologists, Sydney, p.1-94.

Hooker, J., 1852. On the spheroidal bodies, resembling seeds, from the Ludlow Bone Bed. *Quarterly Journal of the Geological Society of London*, 9 (1), p.12.

Jan, I., 2014. Progress in the Gondwanan Carboniferous-Permian Palynology and Correlation of the Nilawahan Group of the Salt Range, Pakistan: A Brief Review. *Journal of Earth System Science,* 123 (1), p.21-32. DOI: 10.1007/s12040-013-0391-y

Jha, N., Aggarwal, N., and Shivanna, M. 2014. Late Permian Palynology and Depositional Environment Chintalapudi Sub-basin, Pranhita - Godavari Basin, Andhra Pradesh, India. *Journal of Asian earth Sciences,* 79, p. 382-399. DOI:10.1016/j.jseaes.2013.10.010

Kustatscher, E., Dotzler, N., Taylor, T. N., and Krings, M., 2014. Microalgae from the Lower Devonian Rhynie Chert: A New Cymatiosphaera. *Zitteliana A,* 54, p.165-169. DOI:10.2478/acpa-2014-0010

Lelono, E. B., 2001. Obtaining the Suitable Techniques for Palynological Preparation. *Lemigas Scientific Contribution*, 2, p. 2-6.

Lelono, E. B., Nugrahaningsih, L., Kurniadi, D., Suandhi, P. A., and Utomo, B. H., 2016a. Palynological Investigation of the Permian Sediment in the On-shore West Timor. *Proceedings of the 14th Geosea and the 45th Indonesian Geologist Accosiation Annual Convention*, p. 401-404.

Lelono, E. B., Nugrahaningsih, L., and Kurniadi, D., 2016b. Permo-Triassic Palynology of the West Timor. *Scientific Contribution Oil and Gas,* 39(1), p.1-13.

Mendelson, C. V., 1993. Acritarchs and Prasinophytes. *In*: Lipps, J. H. (ed.), *Fossil Prokaryotes and Protists*. Blackwell, Boston, p.77-104.

Moldowan, J. M., Seifert, W. K., and Gallegos, E .J., 1985, Relationship Between Petroleum Composition and Depositional Environment of Petroleum Source Rock. *AAPG Bulletin,* 69, p.1255-1268. DOI:10.1306/ad462bc8-16f7-11d7-8645000102c1865d

Newton, E. T., 1875. On 'Tasmanite' and Australian 'White Coal'. *Geological Magazine,* 12, p.337-342. DOI:10.1017/s001675680016008x

Parke, M., 1966. The genus Pachysphaera (Prasinophyceae). *In*: Barnes, H. (ed.): *Some contemporary studies in marine science*, p.555-563. London: Allen and Unwin.

Parke, M., Boalch G. T., Jowett, R., and Harbour, D. S., 1978. The genus Pterosperma (Prasinophyceae): Species with a Single Equatorial Ala. *Journal of the Marine Biological Association of the United Kingdom,* 58, p.239-276. DOI:10.1017/s0025315400024528

Parke M. and den Hartog-Adams, I., 1965. Three species of Halosphaera. *Journal of the Marine Biological Association United Kingdom,* 45, p. 537-557. DOI:10.1017/s0025315400054990

Revill A.T., Volkman J.K., O'Leary T., Summons R.E., Boreham C.J., Banks M.R., and Denwer K., 1994. Hydrocarbon Biomarkers, Thermal Maturity, and Depositional Setting of Tasmanite Oil Shales from Tasmania, Australia. *Geochimica et Cosmochimica Acta,* 58, p.3803-3822. DOI:10.1016/0016-7037(94)90365-4

Rosidi, H. M. O., Suwitodirjo, K., and Tjokrosapoetro, S., 1979. *Geological map Kupang - Atambua Quadrangle, Timor 1:250.000*. Geological Research and Development Centre, Bandung, Indonesia.

Sawyer, R. K., Sani, K., and Brown, S., 1993. Stratigraphy and Sedimentology of West Timor, Indonesia. *Proceedings of the 22nd Indonesian Petroleum Accosiation Annual Convention*, p.1-20.

Schopf, J. M., Wilson, L. R., and Bental, R., 1994. An Annotated Synopsis of Paleozoic Fossil Spores and the Definition of Generic Groups. *Illinois State Geological Survey Report of Investigations,* 91, p.1-72. DOI:10.5962/bhl.title.61674

Tappan, H., 1980. *The Paleobiology of Plant Protists*. Freeman, San Francisco, CA.

Traverse, A., 1988. *Paleopalynology*. Unwin Hynman, Boston, 600 pp.

Van Gorsel, J. T., 2014. An Introduction to Paleozoic Faunas and Floras of Indonesia. *Berita Sedimentologi,* 31, p.6-26.

Vigran, J. O., Mork, A., Forsberg, A. W., Weiss, H. M., and Weitschat, W., 2008. *Tasmanites* algae—contributors to the Middle Triassic hydrocarbon source rocks of Svalbard and the Barents Shelf. *Polar Research,* 27, p. 360-371. DOI:10.3402/polar.v27i3.6196

Ziegler, A.M., Eshel, G., Rees, P.M., 2003. Tracing the tropics across land and sea: Permian to present. *Lethaia*, 36, p.227-254. DOI:10.1080/00241160310004657

IJOG