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A Review on Permian to Triassic Active or Convergent Margin in Southeasternmost Gondwanaland: Possibility of Exploration Target for Tin and Hydrocarbon Deposits in the Eastern Indonesia

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Abstract

An active convergence of continental margin is probably generated in Gondwanaland during Permian to Triassic period which is characterized by the presence of magmatic and volcanic belts and back-arc basins occupied respectively by Permian to Triassic rocks.

The magmatic belt is occupied by peraluminous granitic plutons showing characteristics of S- type granite and is considered as tin-bearing granites. The back-arc basins are occupied by the Southern Papua and Galille-Bowen-Gunnedah-Sydney Basins. Those large basins are respectivelly filled by fluvial, fluvio-deltaic to marine Permian-Triassic sediments, which are unconformably overlain by the Jurrassic-Cretaceous marine succession.

The paleomagnetic data, confirmed by flora content found in Australia and Papua, indicate that those areas initially belong to the Gondwanaland before part of them were drifted and rotated into the present day position. Tectonically, the presence of those Permian-Triassic magmatic-volcanic belts and back-arc basins in behind, indicates that at the time there were huge compressive activities: convergence of paleo-oceanic Pasific Plate moving westward, collided and subducted into the Southeastern Gondwana Continental Plate, moved relatively eastwards. This phenomenon resembles to the formation of Sumatera Tertiary tectonic zones producing back-arc basins, i.e. South Sumatera, Central, and North Sumatera Basins including the Tertiary Magmatic Arc.

Concerning the similarity of Permian-Triassic geological condition of the magmatic arc and back-arc basins in Eastern Indonesia and Eastern Australia including paleoposition, paleotectonic setting, stratigraphic succession, and lithologic composition, it is suggested to carry out an increase in a more intensive tin exploration in the Eastern Indonesia, *e.g*. Bird Head area and Banggai Sula Island, and also for hydrocarbon target (coal, coalbed methane, oil and gas, and oil shale) in the Southern Papua Basin, East Indonesia. This suggestion is confirmed by cassiterite and hydrocarbon discoveries and exploitation activity in the Eastern Australia and also a new seismic data of the Semai Basin a part of Southern Papua Basin. This seismic record shows a more complete stratigraphic sucession and a number of large structure traps of stratigraphic levels in which the Permian-Triassic units are included within the sequence.

Keywords: convergence, Permian-Triassic rocks, Gondwanaland, peraluminous granitic plutons, Eastern Indonesia

Sari

Pertemuan tepi benua aktif mungkin telah terjadi pada Zaman Perem-Trias di Gondwanaland, yang dicirikan oleh adanya jalur magmatik-gunung api dan cekungan busur-belakang yang masing-masing ditempati oleh batuan berumur Perem sampai Trias.

Jalur magmatik ditempati oleh pluton granitan peralumina yang memperlihatkan ciri-ciri granit Tipe-S yang selama ini dianggap sebagai granit pembawa timah. Cekungan busur-belakang terdiri atas Cekun-

gan Papua Selatan dan Cekungan Galille-Bowen-Gunedah, dan Sydney. Cekungan besar tersebut diisi oleh endapan fluviatil, fluviodelta, dan endapan marin berumur Perem-Trias, yang secara tidak selaras ditindih oleh runtunan endapan marin berumur Jura-Kapur.

Data paleomagnetik dan kandungan flora yang ditemukan di Papua dan Australia menunjukkan bahwa daerah pertemuan tersebut pada awalnya bersatu dengan Daratan Gondwana yaitu pada saat sebelum mengalami pemisahan dan menempati kedudukannya sekarang ini. Secara tektonis, keberadaan jalur magmatik-gunung api dan cekungan busur-belakang membuktikan bahwa pada waktu itu telah terjadi suatu gerakan kompresi yang sangat dahsyat yaitu pertemuan Lempeng Samudra Pasifik purba yang bergerak ke arah barat dan bertabrakan serta menghunjam ke bawah Lempeng Benua Gondwana sebelah tenggara yang relatif bergerak ke arah timur. Gambaran ini mirip dengan pembentukan zona tektonik Tersier Sumatera yang menghasilkan Cekungan Busur-Belakang Sumatera, juga termasuk jalur magmatiknya.

Berkaitan dengan aspek kesamaan kondisi geologi busur magmatik dan cekungan busur-belakang Perem-Trias di Indonesia Timur dan Australia Timur yang meliputi kedudukan purba, zona tektonik purba, susunan stratigrafi, dan komposisi litologi, disarankan untuk meningkatkan eksplorasi timah di Indonesia Timur (misalnya daerah Kepala Burung dan Banggai Sula), dan juga untuk target hidrokarbon (batubara, gas metan, minyak dan gas bumi, serta serpih minyak) di Cekungan Papua Selatan. Saran ini diperkuat oleh adanya penemuan dan penambangan timah dan hidrokarbon di Australia Timur dan adanya data seismik terbaru di Cekungan Semai bagian Cekungan Papua Selatan. Rekaman seismik ini memperlihatkan susunan stratigrafi yang lebih lengkap dan juga adanya beberapa jebakan struktur besar di berbagai tingkat stratigrafi tempat satuan Perem dan Trias berada di dalamnya.

***Kata kunci**: konvergen, batuan Perem-Trias, Daratan Gondwana, pluton granit peralumina, Indonesia Timur*

Introduction

Permian and Triassic granitoid plutons are widespread exposed in the Eastern Indonesia, Papua New Guinea, and Eastern Australia. They form a granitoid belt extending from Peleng and Banggai Sula Islands in the west to Papua and Papua New Guinea in the east, and then continuously bend southeasternwards to the Eastern Australia. Almost parallel to this reminder of Permian-Triassic granitoid belt in Papua, there is a large basin which is in this paper informally called as Southern Papua Basin and it was filled by Permian to Triassic sedimentary rocks. This basin occupies Bird Head Platform including Misool in the west and Arafura Platform in the east. In the Eastern Australia, the Permian to Triassic granitoid belt occupies New England Fold Belt which is parallel to the eastern coast of Australia. Again, to the west of this belt there is a large basin known as Bowen-Galille-Gunnedah-Sydney Basin which is also filled by Permian to Triassic sediments. The distribution of Permian to Triassic granitoid belt and those basins is shown in Figure 1.

The main objective of this paper is to understand and review paleotectonics of the Eastern Indonesia and the Eastern Australia during Late Paleozoic to Mesozoic period mainly in Permian to Triassic before they were drifted and rotated into the present day position. Furthermore, it is to see a posibility of tin mineralization occuring in the Eastern Indonesia, and the last to consider a possibility of various hydrocarbon discovery in that region, compared to those in the Eastern Australia and also on the basis of new seismic data obtained from the Southern Papua Basin.

Some amounts of geological data are obtained from the Geological Survey data base and published Bureau Mineral Resources reports whereas for new seismic data from Fugro Multi Client Services which carried out a new 2D seismic survey in the Semai-Gorong Basin (Searcher Seismic, Fugro and Directorate General of Oil and Gas; 2007).

Permian – Triassic Geology

Simplification of Late Paleozoic to Mesozoic lithology successions of the Eastern Indonesia, the Papua New Guinea and the Eastern Australia from various sources is shown in Figure 2.

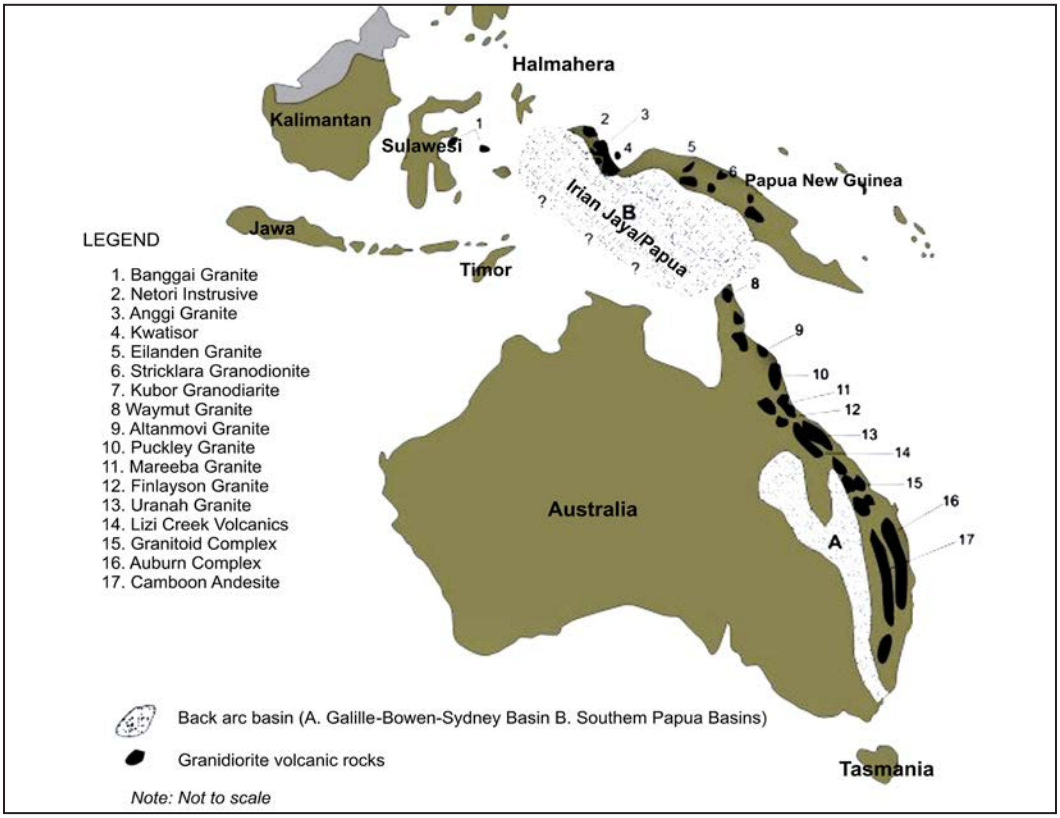

Figure 1. Distribution of Permian-Triassic granitic plutons and sedimentary basins in the Eastern Indenesia, Papua New Guinea and the Eastern Australia (Sheraton & Labonne, 1978; Amiruddin 2000).

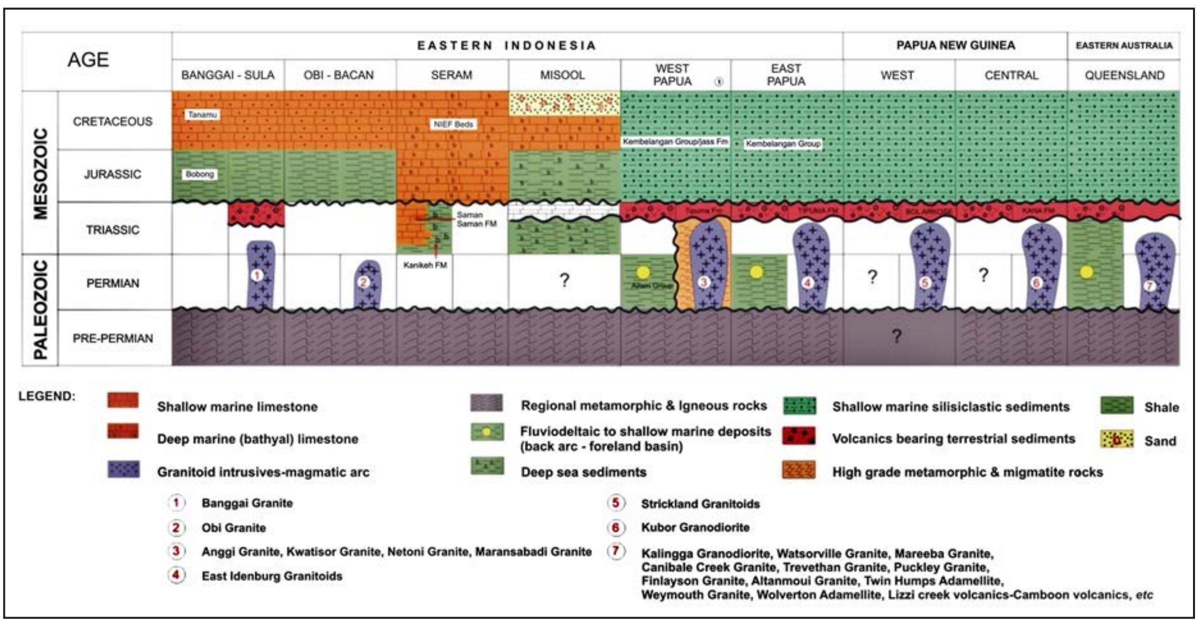

Figure 2. Simplified Late Paleozoic to Mesozoic rock units in Eastern Indonesia, Papua New Guinea, and Eastern Australia (Bain *et al*., 1975; Jensen *et al*., Pigram & Panggabean, 1983; Amiruddin, 2000).

Characteristics of Permian - Triassic Granitoid Plutons

Permian to Triassic magmatic activities produced granitoid intrusive and extrusive rocks. The characteristics of those granitoid rocks are briefly described below and shown in Table 1.

Eastern Indonesia

The granitoid rocks exposed in Eastern Indonesia belong to I- and S-type granites. These two types are distinguished by their mineralogy content and geochemical composition. The S-type granite is represented by the Banggai, Anggi, and Kwatisor Granites whereas the I-type granites comprises the Netoni Intrusive and Maransabadi Granite. The co-magmatic volcanic rock consists of the Mangole Volcanics and pyroclastic-bearing Tipuma Formation. The S-type granite is characterized by the presence of more aluminous minerals (biotite, muscovite, garnet, and cordierite). It has peraluminous and more alkalic to alkalic-calcalkalic and more felsic compositions. In the field, it is intim-atelly associated with migmatic rock with a regional aureole contact. In places, Sn is much more often found in stream sediment and pan concentrates.

The I-type granite is represented by the presence of less aluminous minerals such as hornblende and

Table 1. Late Paleozoic-Early Mesozoic Granitic Rocks of Eastern Indonesia, Papua New Guinea, and Northeast Queensland (Sheraton and Labonne, 1978; Amiruddin, 2000)

Granitic Plutons	Approximate Age	Geochemical Composition	Associated Mineralization
EASTERN INDONESIA			
Banggai Granite	Permian-Triassic	Peraluminous	-?Sn
Anggi Granite	Permian-Triassic	Peraluminous	-Sn. Cu, Pb,Zn
Netoni Granite	?Permian-Triassic	Metaluminous	-?Cu,Pb.Zn,?Sn
Maransabadi Granite	?Permian-Triassic	-	-
Kwatisor Granite	?Permian-Triassic	-	-
Idenburg Granite	Permian-Triassic	-	-
PAPUA NEW GUINEA			
Strickland Granite	Permian-Triassic	-	-
Kubor Granite	Permian-Triassic	-	-
EASTERN AUSTRALIA			
Elizabeth Creek Granite	Carboniferous to Permo-Carboniferous	Peraluminous	Sn, Mo,W,Pb,Cu, F (Au,Bi, Ag, Sb)
Hammonds Creek Granodiorite	Permo-Carboniferous *	-	-
Bakerville Granodiorite	Permo-Carboniferous	-	-
Herbert River Granite	Permo-Carboniferous	Peraluminous	Cu, Pb, W
Almaden Granite	Permo-Carboniferous	Metaluminous	Cu, Pb,Ag,Zn (Bi)
Unnamed Granitic Rocks of Ingham and Innisfail Sheet Areas	Permo-Carboniferous	Peraluminous	Sn,W,(Bi,Mo,Pb,,Zn,Au,Ag)
Hales Siding Granite	-	-	-
Atlanta Granite	-	-	-
Tully Granite Complex	Permo-Carboniferous to Early Permian	Peraluminous	Au (Sn)
Kalunga Granodiorite	Early Permian	-	-
Watsonvile Granite	Early Permian	-	-
Mareeba Granite	Early Permian	Peraluminous	Sn.W,Cu,Au (Mo, Zn,Bi)
Canibal Creek Granite	Early Permian	Peraluminous	?Sn
Pukley Granite	Early Permian	Peraluminous	?(Au,Sn,Cu.W)
Trevethan Granite	Late Permian-Triassic	-	-
Finlayson Granite	Late Permian	Peraluminous	Sn (W,Mo, Pb,Cu)
Altanmoui Granite	Late Permian	Peraluminous	Au,Sn,W,Sb,Cu

*) Approximately the Permo-Carboniferous boundary

more mafics: pyroxene which consistent to metaluminous and calcalkalic and more basic composition. In the field, it associates with copper, zinc and lead and shows a contact aureole granite producing hornfelsic rocks (Amiruddin, 2000). The geochemical composition of those granites is shown in Figures 3 and 4. Radiometric dating result of those granitoids is Permian to Triassic in age.

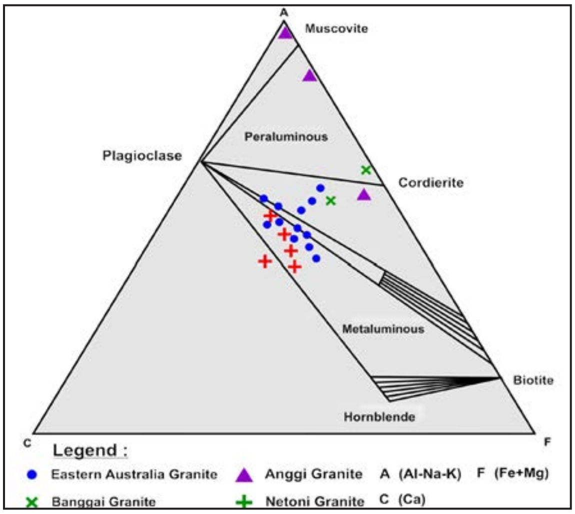

Figure 3. The ACF diagram of Permian-Triassic granitoid rocks of the Eastern Indonesia and Eastern Australia showing metaluminous and peraluminous composition (Amiruddin, 2000).

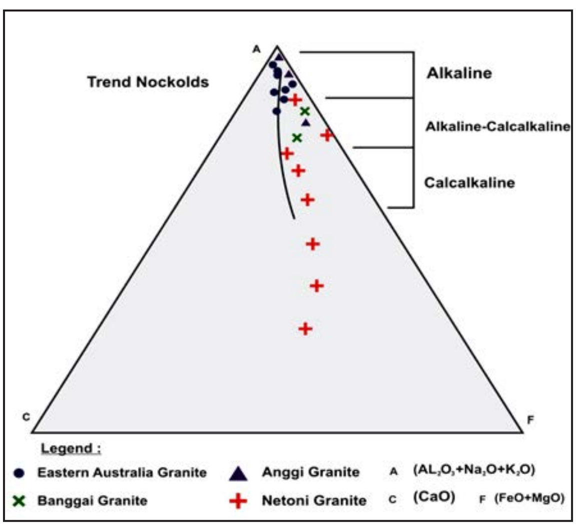

Figure 4. The ACF Diagram showing alkalinity of the Permian-Triassic Eastern Indonesia and the Eastern Australia granitoid plutons (Amiruddin, 2000).

Papua New Guinea

Magmatic activities generated during Triassic in New Guinea are represented by the presence of granitoid intrusion comprising Strickland Granite and Kubor Granodiorite, described and determined by Page (1976). The Kubor Granodiorite comprises granodiorite, tonalite minor gabbro, diorite, and adamelite plutons, including dykes and pegmatites.

The rocks probably belong to the I- and S-type granites characterized by the presence of hornblende bearing granites and muscovite granitoids respectively. No geochemical data is obtained from this rock. Radiometric dating by K-Ar and Rb-Sr indicates that the rocks are Triassic in age.

The Strickland Granite is exposed at the headwaters of the Strickland River, in the northwest Papua New Guinea closed to the boundary between Indonesia and Papua New Guinea. Only one sample of the pluton has been dated on biotite mineral producing a calculated age of 222 ± 4 m.y. or Late Triassic. It can be correlated to the Kubor Granodiorite.

Eastern Australia

Distribution of granitoid plutons exposed in the Eastern Australia extends from Cape York Peninsula and Torres Strait in the north to New South Wales in the south. Those granitoid rocks are partly considered as tin-bearing granites on the basis of associated mineralizations found around them as shown in Table 1. These granites comprise the Pukley, Trevethan, Finlayson, Mareeba, Canibal Creek, and Altanmoui Granites (Sheraton and Labonne, 1978).

Permian To Triassic Basins

Southern Papua Basin

In this paper, it is informally indicated the name of Southern Papua Basin for a large basin filled with Permian to Triassic sediments. It occupies a large platform, and also part of a high range extending from Bird Head and Arafura Platforms, Papua including Misool in the west to the New Guinea Platform in the east (Papua New Guinea) as shown in Figure 1. This basin was filled with Permian to Triassic successions, which are unconformably underlain by older Paleozoic metamorphic rock basements. These rock units are unconformably overlain by Jurassic to Cretaceous sediments having a hiatus or non deposition boundary during Early Jurassic.

This is consistent to the stratigraphic succession interpreted from 2 D seismic data in the Semai Gorong Basin (Figures 5 and 6). To the north, this basin is bordered by remainders of magmatic arc forming a belt comprising Permian-Triassic Anggi Granite, Netoni Intrusives, Kwatisor Granite, Maransabadi Granite, and Idenburg Granodiorite, which are exposed in the Papua region and also Strickland Granite to the north of New Guinea Platform.

In the Bird Head and Arafura Platforms, the basin was filled with the shallow marine to fluvio-deltaic Aifam Group and the terrestrial Tipuma Formation. However, the Permian sediments were not developed to the easternmost of the basin. The Aifam Group exposed in the Charles Louis Mountain Central Range was renamed by Pigram and Panggabean (1983) as the Aiduna Formation. This formation consists of well bedded feldsphatic and/or micaceous lithic sandstone interbedded with black carbonaceous shale and siltstone with minor highly fossiliferous grey to black biocalcarenite, polimictic conglomerate, and coal. This formation contains Gondwana flora. The Aiduna Formation or its equivalent is very carbonaceous. It may have a good potential as petroleum source rocks and also contains some coal seams having a thickness up to 1.50 m, indicating that this formation may have an economic prospect in the future.

The Tipuma Formation consists of well bedded maroon and locally green mudstone and lithic sandstone, and pebbly conglomerate which may be micaceous, feldspathic or tuffaceous. A minor bedded tuff and micritic limestones are also present in places. This formation was deposited in a terrestrial, fluvial environment (Pigram and Panggabean, 1983) indicating that the micritic limestone was a product of evaporitic deposition.

Pigram and Panggabean (1983) also indicated that a volcanic-detrital source of the Tipuma Formation was derived from Late Permian to Early Triassic granitoids exposed to the north of the Waghete Sheet on the Enarotali and Kaimana Sheet areas. A Late Triassic volcanism is also known in Papua New Guinea as the Kana Volcanics.

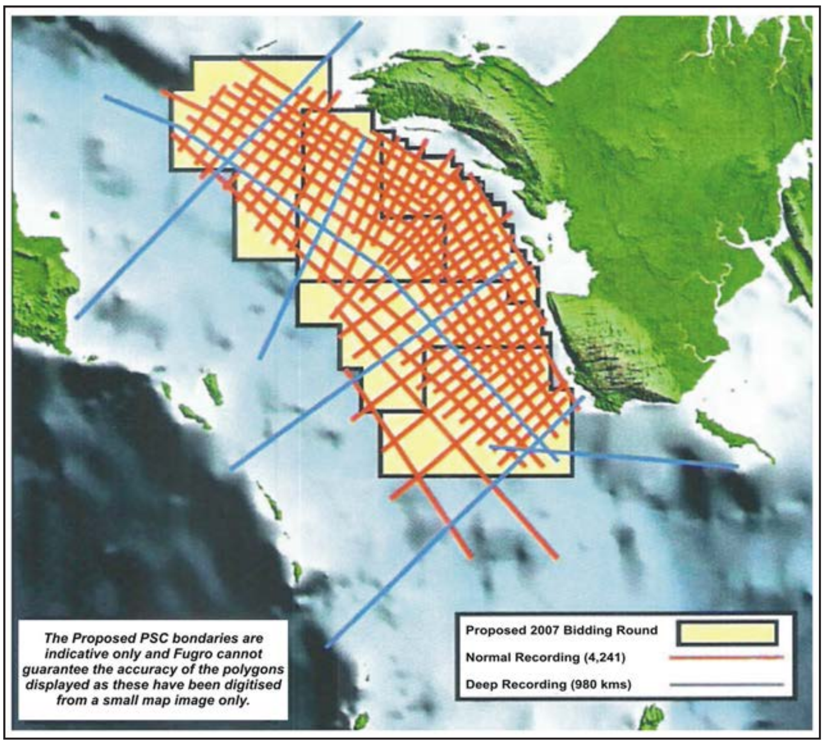

Figure 5. Location of 2D Seismic Survey in the Semai Gorong Basin Southern Papua Basin (From Seacher Seismic *et al*., 2007).

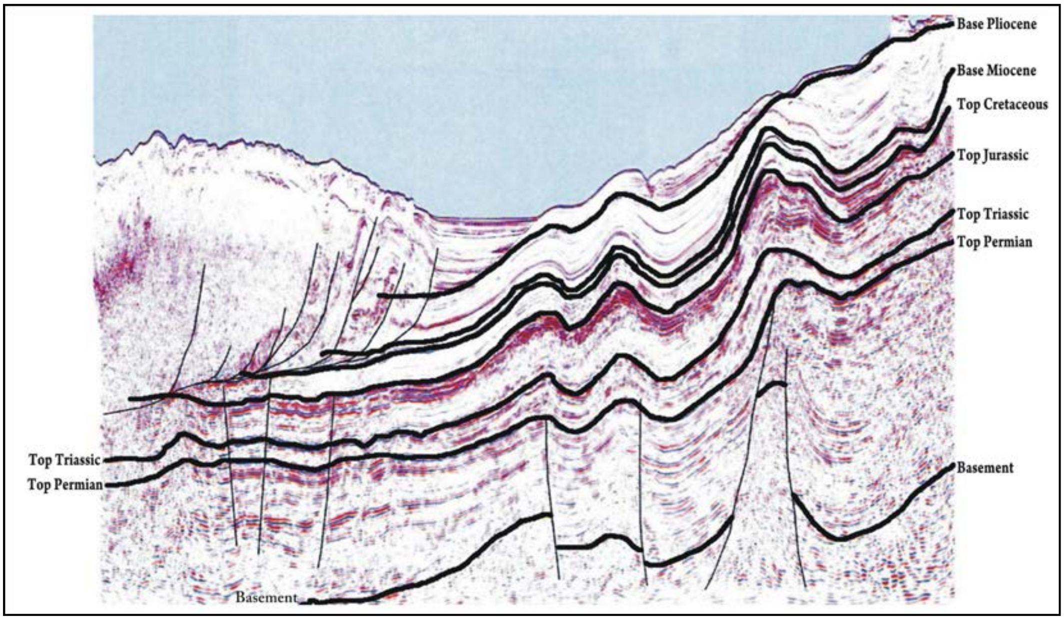

Figure 6. 2D seismic interpretation of the Semai-Gorong Basin belonging to the South Papua Basin. To make it clearer, base and top stratigraphic lines have been redrawn (Seacher Seismic *et al.*, 2007).

Galille-Bowen-Gunnedah-Sydney Basin

The Galille-Bowen-Gunnedah-Sydney Basin is a large, elongate Permo-Triassic sedimentary basin extending from North Queensland to Sydney in New South Wales, Australia. To the east the basin is bounded by an intermittently active magmatic and volcanic arc, whereas to the west it is bounded by cratonized Precambrian and older Palezoic. The basin is considered to be a back-arc extensional to foreland basin that developed landwards of an intermittently active continental magmatic and volcanic arc associated with the convergence of the paleo-Australian and paleo Pacific Plates (Baker *et al.*, 1993).

It contains variably deformed, marine and non-marine siliciclastic sedimentary rocks which, in the south, is unconformably overlain by relatively flat-lying Jurassic and Cretaceous sedimentary rocks of the Surat Basin. The Bowen and Sydney Basins are the most intensively explored sedimentary basins in Australia due to have an economic aspect for accumulation of coal, natural gas, and precious metals (Baker *et al*.,1993). Stratigraphically, the filling sediment units of the basin resemble to this in the Southern Papua Basin.

In relation to the possibility of oil generation basins, the study of source and maturity for Permian and Triassic rocks in the Sydney and Gunnedah Basins had been done indicating that the coal measures are gas prone, whereas within and underlying the marine unit, the coal measures are probably oil prone. Potential terrestrial reservoir rocks including fluvial-fluviodeltaic sandstones are found at many levels in the Sydney Basin with porosities up to 20% and methane gas flow achieved as 1 million cubic meter per day recorded. Oil seepage have also been reported to come out from these rocks. Seal rocks are also found in this basin consisting of green claystones.

Oil shale is found in many places, occurring in the upper part of the Late Permian sediments and it has been exploited, such as torbanite in New South Wales which was mined between 1860 and 1952, generally produced kerosene. During World War 2, petrol was refined from shale exploited at Glen Davis producing 220-550 crude oil (http://www. dpi.nsw.gov.au/sedimentary basins., 2007).

Permian Coal deposits in the Bowen and Galille Basins are the most important commodity, which have been exploited. Coal seams in the Bowen Basin show a major variation in rank and quality ranging from low to high rank, *e.g.* medium to high volatile bituminous and including best coking coals (http:// w.w.w. bowen basin.cqu.edu.au/basin data, 2007).

Coal seam methane is also found in many areas in the Sydney Basin. The majority of the coal seams are sufficiently thermally mature for gas generation (http://www. dpi.nsw.gov.au/sedimentary basins., 2007).

Subsurface Geology

In 2006, Fugro Multi Client Services and Patra Nusa Data carried out a regional 2D Seismic Survey covering the Semai-Gorong Basin, which has never been explored up to the deepest portions. The basin is situated between Seram Island and Bird Foot of Papua. In this paper, the basin belongs to the part of the South Papua Basin (Figure 5) .

Interpretation of that Seismic Data has a explained more complete lithology succession consisting of Early Paleozoic basement, Permian, Triassic, Jurassic, Cretaceous to Tertiary units. This recording has also revealed a number of large structure which is capable of keeping significant volumes of hydrocarbon at a variety of stratigraphic levels as shown in Figure 6. This sequence corresponds with this of Paleozoic, Mesozoic, and Tertiary units exposed in the southern part of Papua, *e.g*. Modio Dolomite, Aiduna Formation, Tipuma Formation, Kembelangan Group and Tertiary units. These seismic data also indicate that the Semai-Gorong Basin has a similar depositional history to hydrocarbon-rich Bintuni-Salawati Basin (Searcher Seismic *et al*., 2007).

Flora of Gondwana

The Gondwana flora found in the Papua Basin is derived from the Permian Aiduna Formation consisting of *Iriana hartonoae gen*. et sp., Nov., *Trizygia speciosa*, *Fascipteris sp*. Nov., *Cladophlebis roylei* sp., *Glossopteris* sp. 20, *Glossopteris* sp. 22, *Glossopteris* sp. 51, *Glossopteris* sp. 85, *Glossopteris elongate* sp., and *Vertebraria indica*. According to Rigby (1983; in Pigram and Panggabean, 1983) the flora plants were also found in the Bowen Basin, Eastern Australia, derived from the New Castle Coal Measures that are usually assigned a Late Permian (Tartarian) age.

After revising the previous observation and identifiying new collections from the Aiduna Formation in 1997, Rigby (1998) concluded the Permian floras from Papua (western New Guinea) are predominantly Gondwana but with the addition of two Cathaysian genera each with one endemic species, viz. *Fascipteris aidunae* and *Gigantonocleaqirani.*

Prasad (1981; in Rigby ,1998) collected wood, *Planoxylon stopesii* from the Aimau Formation of Vogelkop, Papua, showing characters of araucarian and abietinian wood, which are common wood types from the Late Paleozoic of Gondwanaland.

Flora of Sumatera

Serra (1989; in Fontaine and Gafoer, 1989) documented the Lower Permian Continental Flora of Sumatera in the Jambi Province collected and described by Jongmans and Gothan from 1925 to 1937. He had concluded that the Permian Jambi Flora belongs to Cathaysian elements, such as *Gigantopteris, Lobatannularia, Tingia, Protoblechnum,* etc. This Sumatera flora is regarded as an intermediate between the oldest Korean and Chinese floras and the typical Cathaysian assemblage.

Fossil woods found comprise *Cordaitophytaceae* and *Coniferophytaceae* growing under a tropical to subtropical condition.

They have been also reported from the other areas of Cathaysia.

Paleolatitude

Mubroto *et al*. (1993) measured paleomagnetics of Late Paleozoic to Early Mesozoic formations filling the South Papua Basin in Bird Head, Papua region, namely from Late Carboniferous Aimau, Early Permian Aifat, Late Permian Ainim, and Late Triassic-Jurassic Tipuma Formations. The result indicates that the Aimau Formation was probably derived from paleolatitude of 47˚ S, the Aifat Formation from 46˚ S, the Ainim Formation from 35˚S, and the Tipuma Formation from 42˚ S.

Metcalfe (1993) reconstructed paleogeographic position of the Tethyan region including the Papua and Australia Terrains during Early Carboniferous, Early Permian, Late Permian, Late Triassic, and Late Jurassic as shown in Figure 7. In Early Carboniferous, the paleo position of Papua was in equator region. In Early Permian it moved southwards up to about 40-45 ˚S. In Middle to Late Permian, it moved again northwards up to about 30˚ S. Then, in Late Triassic, it moved more northwards up to 20˚to 30˚S with slightly clockwise rotated about 30˚.

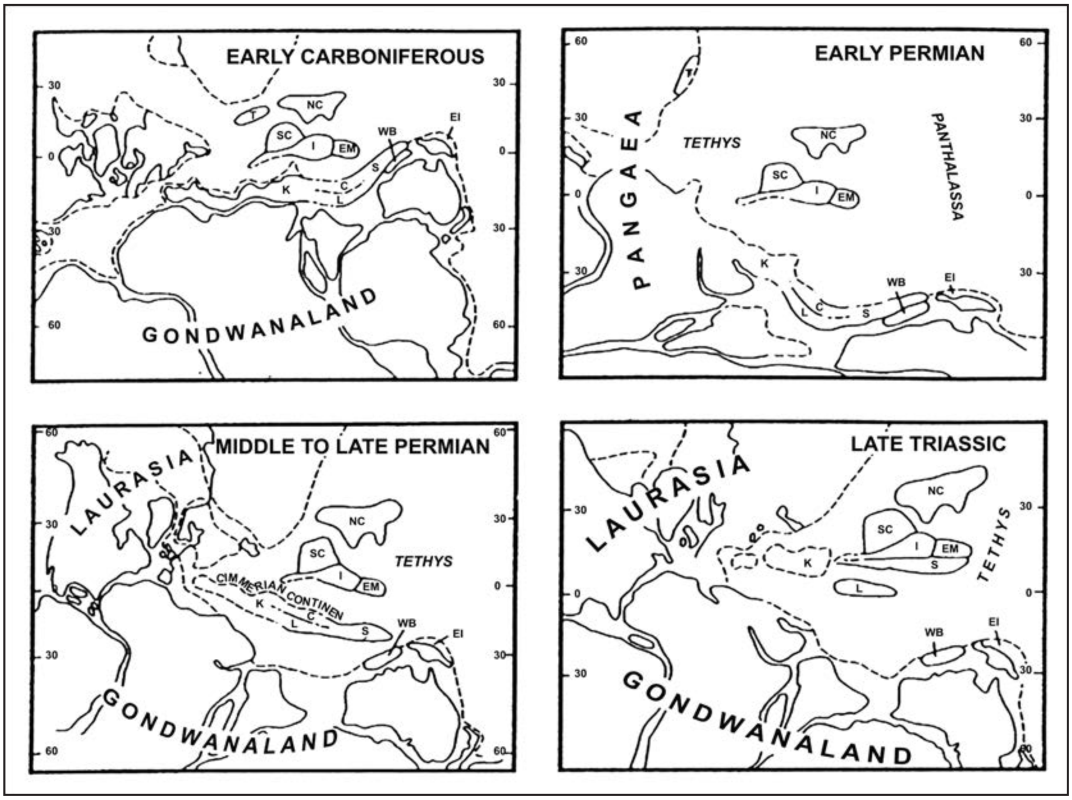

Figure 7. Paleogeographic reconstruction of Tethyan region for Early Carboniferous, Early Permian, Middle – Late Permian and Late Triassic (Metcalfe, 1993). NC: North China; SC: South China; I: Indo China; T: Tarim; WC: Western Cimmerian Continent; S: Sibumasu; L: Lhasa; Q: Qaidam.

Nishimura and Suparka (1997) reconstructed a possible Triassic position of Sumatera as located on the Gondwanaland reconstruction of Smith and Hallam (1970) as shown in Figure 8. They assumed that the Sumatera belongs to the Gondwanaland rather than part of Cathaysia. The reconstruction shows that the position of Papua is in the westernmost part of Australia, where as the Sumatera is to the north of Australia. Embleton and Schmidt (1977; in Nishimura and Suparka, 1997) also reconstructed the Triassic position of Australia at 47˚ and 176˚E.

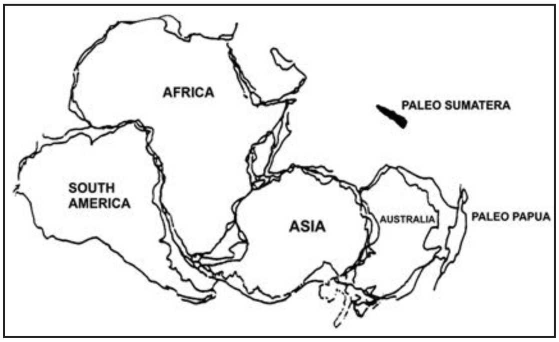

Figure 8. Possible Triassic paleographic position of Sumatera, Australia, and Papua as located on the Gondwanaland reconstruction of Smith and Hallam (1970; in Nishimira and Suparka, 1997).

Paleotectonics

On the basis of those paleomagnetic data measured and paleographic reconstruction done by the above authors combined to the distribution of magmatic and volcanic belt, and also back-arc basins occupying the Eastern Indonesia (Papua) and the Eastern Australia, it indicates that during Permian to Triassic there was a huge compressive activity producing an active margin in the southeasternmost of the Gondwanaland, probably caused by the Paleo-West Pacific Plate moved northwest-westwards and subducted or collided into the Continental Gondwana Plate, producing a granitoid and volcanic arc and back-arc basins as shown in Figure 9.

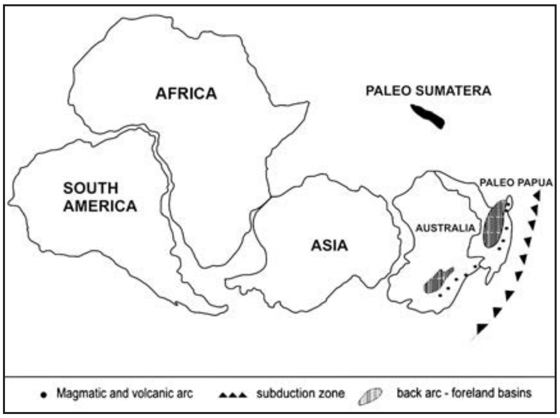

Figure 9. Possible position of Permian-Triassic active margin produced magmatic arc and back-arc basins. Those tectonic zones are ploted in the Gondwanaland reconstruction of Smith and Hallam (1970).

Discussion

On the basis of the paleomagnetic data, the Papua Island during Late Paleozoic to Early Mesozoic especially during the Triassic time, was still a unified land with Australia forming a continental margin in the southeasternmost Gondwanaland. It is confirmed by the presence of the floras of Gondwanaland found both in the Southeastern Papua Basin of Eastern Indonesia and also in the Galille-Bowen Basin, Eastern Australia. The paleo-position of Sumatera Island which was to the northwest Paleo-Papua indicates that the presence of the additional Permian Cathaysia flora genera in Papua might be related to this paleo-position of Sumatera, which was relatively closer to the Paleo-Australia. This means that the Cathaysia flora might be derived from the same island that was transported and deposited in the paleo-South Papua Basin at least during the Triassic time.

The plotting position of tectonic zones in the paleo reconstruction on Permian-Triassic Gondwanaland of Smith and Hallam (1970), shows that the paleo-position of the Galille-Bowen-Gunnedah and Sydney Basins (Eastern Australia Basin) and Southern Papua Basins was in the southeasternmost part of Gonwanaland, extending from southwest to northeastward, and then, it was more to the eastern, parallel to those basins having a magmatic and volcanic belt as shown in Figure 9. Thus, this evidence interprets that in the Permian to Triassic periods there had occurred a huge compressive activity between Gondwanaland Plate moving eastwards and Paleo-Pacific Plate relatively moved westwards.

The similar Permian-Triassic granitic rocks found both in Eastern Indonesia and Eastern Australia have a peraluminous composition which is tin-bearing granite. On the basis of that similarity then in the Eastern Indonesia the tin deposit may also be generated. It is confirmed by a discovery of a tin deposit both as primary and secondary cassiterite, associated with those peraluminous granitoid rocks in the Eastern Australia (See Table 1). In addition, the regional geochemical data of stream sediment and pan concentrates collected during the geological mapping in the Ransiki Sheet, Papua, produced a high content of Sn.

The similar stratigraphic and lithology sequences from Paleozoic to Tertiary ages indicate that both basins seem to own a similar geological history such as basin dynamics including mechanism of deposition, and tectonic and burial history related to the various fossil fuel generation including coal, coalbed methane, oil shale, oil, and gas. Therefore, on the basis of various hydrocarbon discovery from Permian to Triassic sediments in Eastern Australia basins, it indicates that fossil fuel in Papua, East Indonesia could be also found. This is supported by the new seismic result showing a more complete succession and a large structure that may hold a significant hydrocarbon volume at various stratigraphic levels. The presence of coal and carbonaceous pelitic and psamitic rocks of the Aiduna Formation in Papua and also oil discovery of Permian-Triassic sediments in Seram Basin tend to suggest an increase of more intensive oil exploration within the succession should be performed.

Conclusions

A similarity of Permian and Triassic paleotectonics and the geological condition between Eastern Indonesia and Eastern Austrlia related to the tin mineralization and fossil fuel generation followed by their evidences has been found in Eastern Australia. In the future, tin is probably not only found in the Western Indonesia but also in Eastern Indonesia (Papua). Hydrocarbon is not only from Tertiary rocks but also from Permian-Triassic sediments.

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