TECTONIC RIFTING OF UPPER PALEOZOIC – MESOZOIC INTRA-CRATONIC BASINS IN THE SOUTHEASTERN GONDWANALAND AND ITS ECONOMIC ASPECTS: with refference to the Geology of North Sumatra and West Australia

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abstract

Lower Permian fluvio – marine glacial sediments of intracratonic basins of West Australia and these of North Sumatera, West Indonesia in addition paleomagnetic data indicate that the paleo position of all basins were probably in the Southeastern part of Gondwanaland. These are also evidence that during Permian, glaciation had been widespread occur in the part of the land. The occurence of ultrapotassic rocks comprising Permian – Triassic A-type granite (An orogenic-type granite) in north Sumatera terrain and feldspatoid bearing subvolcanics of the Canning Basin, West Australia suggests that a tectonic rifting happened during the time period in the part of that stable continental plate and give way for magmatic emplacemet from lower to upper crusts. Perhaps this rifting had also related to a convergent activity during that time in which proto Pacific Plate move westward and collided or subducted into the eastern part of proto Australia continent moving eastwards and eventually form a Permian-Triassic mobile belt along Eastern Australia known as Tasman mobile belt

Key word: tectonic rifting, intra-cratonic basin, Gondwanaland, Permian – Triassic, North Sumatra, West Australia.

Sari

Endapan glasial fluvial – laut Permian Bawah di dalam cekungan intra kraton baik yang berada di Australia Barat maupun di Sumatera Utara, Indonesia Barat berdasarkan data kemagnetan purba menunjukkan bahwa kedudukan purba cekungan tersebut berada di sebelah tenggara Gondwanaland. Hal tersebut membuktikan bahwa pada zaman Perem telah terjadi secara luas pengesan di seluruh bagian benua. Keterdapatan batuan kaya potassium yang terdiri dari batuan granit type A berumur Perm- Trias (granit tipe anorogenic) di mintakat Sumatera Utara dan batuan subvolkanik mengandung feldspatoid di Cekungan Canning, Australia Barat memberikan dugaan bahwa pada waktu itu telah terjadi tektonik bukaan di bagian lempeng benua stabil tersebut yang memungkinkan magma keluar dari kerakbumi bagian bawah ke bagian atas. Barangkali adanya tektonik bukaan ini erat hubungannya dengan adanya kegiatan konvergen pada waktu itu dimana Lempeng Pacifik purba bergerak ke arah barat dan bertabrakan atau menunjam di bawah Benua Australia Purba bagian timur yang bergerak ke arah timur dan akhirnya membentuk Jalur tektonik aktif Perm-Trias di sepanjang Australia Timur yang dikenal sebagai Jalur aktif Tasman.

Introduction

The main objective of idea is to understand paleoposition and paleotectonic generating in the southern part of Gondwanaland Super Continent during Permian to Mesozoic time, before parts of the super continent were drifted and rotated into the present day position. This idea is based on paleoposition of North Sumatra, Indonesia and the occurrences of Permian and Triassic rocks exposed in West, Central and Eastern Australia, occupying respectively as intra-cratonic basins (Palfreyman, 1984) and back basins (Amiruddin, 2009).

Paleoposition

Nishimura and Suparka (1977) reconstruct a possible Triassic position of Sumatra on the Gondwanaland of Smith and Halm (1970) (Fig. 1). It shows that Sumatra was located to the north of the eastern Gondwanaland whereas Papua is in the easternmost.

Paleotectonic

Amiruddin (2009) also reconstructed Permian-Triassic tectonic zones, ploted on the Gondwanaland reconstruction of Smith and Halm (1970) as shown in Figure 2. These paleo tectonic zones reflect a huge compressive activity which had been generated in the east-southeasternmost margin of

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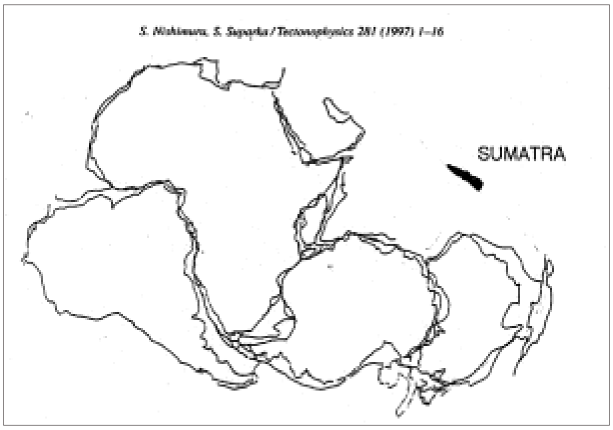

Figure 1. Possible Triassic paleogeographic position of Sumatra, Australia, and Papua (Nishimura and Suparka, 1977) on the Gonwanaland of Smith and Hallam (1970).

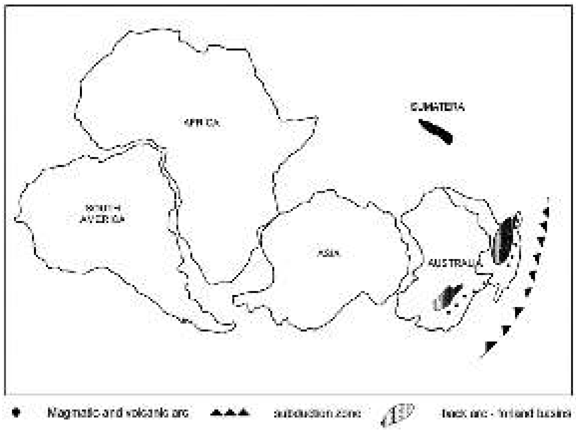

Figure 2. Posible position of Permian Triassic active margin produced magmatic arc and back arc basins in the southeasternmost Gondwanaland (Amiruddin 2009).

Gondwanaland, probably caused by Paleo West Pacific Plate moved northwest-westward and subducted or collided into the Continental Gondwana Plate, producing a granitoid and volcanic arc and back arc basins.

Kazmin (1991) described several epoch of collision and rifting which occur in Gondwanaland respectively in Late Permian, mid-Late Triassic, Late Jurassic –Early Cretaceous, end of the Early Cretaceous and Late Eocene. Audley-Charles (1983) reconstructed qualitatively eastern Gondwanaland during the Late Triassic (220 Myr) showing some of data on which the identification of the fragments rifted from the northeren Australian-central New Guinea margin has been based .

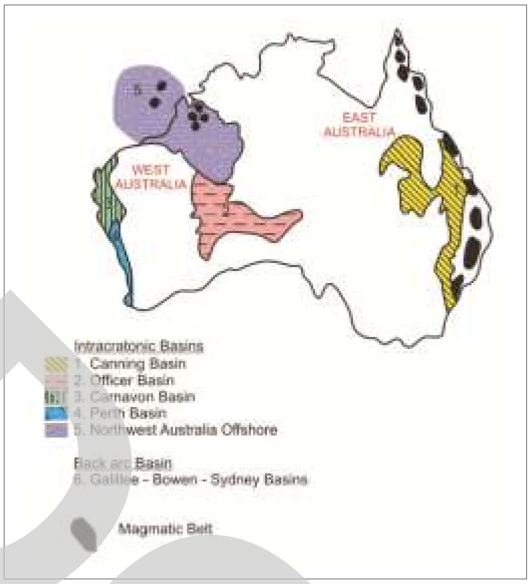

Figure 3. Distribution of Permian –Triassic intra-cratonic basins and back arc basins in Australia (Palfreyman, 1984 and Amiruddin 2009).

Permian –Triassic Geology

Permian- Triassic rocks are exposed in West and Central Australia occupying intra-cratonic basins of Canning, Officer, Carnarvon , Bonaparte and Perth Basins (Palfreyman, 1984). The Permian-Triassic rocks are also found in the Eastern part of Australia, filling Galilee, Bowen and Sidney Basins which are interpreted as back arc basins (Amiruddin 2009) (Fig.3).

The similar Permian and Triassic rock facies are also exposed in Central-North Sumatra Terrain which at the time was located to the north west Australia (Fig. 1). Distribution of those Permian-Triassic rocks in the north-central Sumatera Terrain is shown in Figure 4.

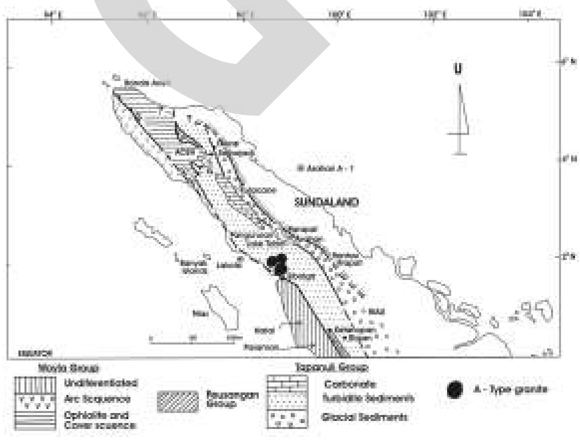

Figure 4. Distribution of Permian –Triassic intra-cratonic basins and back arc basins in Australia ((Palfreyman, 1984 and Amiruddin 2009).

Comparation among Paleozoic – Mesozoic lithology sequences and facies of the North – Central Sumatra and intracratonic basins of West Australia are simplified in Table 1 and described bellows.

Table 1. Simplified upper Paleozoic to Mesozoic lithofacies in Northern Sumatra and Western Australia (Aspdent *et.al*., 1982; Suwarna *et.al*., 1987; Silitonga, P.H. and Katowo, 1975., Cameron *et.al*., 1980; Surono *et.al*., 1989, Subandrio and Suparka, 1994, Condont *et.al*., 1953, Coleman, 1957).

AGE	NORTH SUMATRA	CENTRAL SUMATRA	CANNING BASIN	CARNARVON BASIN *)	PERTH BASIN	OFFICER BASIN
CRETACEOUS	Ultrabasic emplacement	No deposition	Subareal sediments	Coastal to marine	Marine sediments	Shallow marine sediments
JURASSIC	Meta sediments and volcanic	No deposition	Sub areal sediments	Coastal to marine sediments	Subareal sediments	No deposition
TRIASSIC	A-type Granite	Granite Deep marine Carbonate sediments	Feldspatoid rocks	Fluviatile, coastal to marine sediments, accompanied by intrusion and extrusions	Marine sediments	No deposition
UPPER PERMIAN	Carbonate sediments	Carbonate sediments	Silisiclastic and Carbonate sediments	Shallow marine sediments	Silisiclastic marine sediments	No deposition
LOWER PERMIAN	Glacial and marine sediments	Fluvioglacial and glacio-marine	Glacial and aqueo-glacial sediments	Fluvio Glacial and marine sediments	Glacial and shallow sediments	Fluvio Glacial and sediments
Pre-PERMIAN	Meta sediments	Meta sediments	Shallow marine and subaerial sediments	Subaerial and marine sediments	Subaerial sediments	Glacial, shallow marine, subaerial, basalt lava

*Onshore and Offshore West Australia

Stratigraphy of the intra-cratonic basins, Western Australia

These large cratonic basins are in west and northwest Australia comprising Carnarvon, Canning, Perth, Officer and Bonaparte Gulf basins (Fig. 1). The basins are mainly filled by Mid Paleozoics sediments, containing Devonian to lower Carboniferous marine sandstone, shale and limestone. These were folowed by glacial deposits in Permian times which overlying in and outside the basins. After this glaciation period, the sedimentation was then folllowed by thick Jurassic and Cretaceous sequences.

Carnarvon Basin

The Carnarvon Basin was filled-up by Silurian to Tertiary sediments. These comprise basal continental Silurian sediments, unconformably overlain by Devonian deltaic and carboniferous shallow marine sediments; unconformably overlain by *Permian glacial, fluvioglacial* and shallow marine sediments; these overlain by alternating sequences of marine and continental sediments extending through the Triassic, Jurassic, Cretaceous and Tertiary. The igneous activity is minor, comprising acid volcanics.

Perth Basin

The Perth Basin was filled-up by Silurian to Tertiary sediments. These sediments consist of basal continental Silurian deposit, unconformably overlain by *Permian glacial* and shallow marine sediments; overlain by marine Triassic sediments, continental and marine Jurassic and Cretaceous sediments, and Tertiary carbonates. Minor Cretaceous dolerite intrusions are present.

Canning Basin

The Canning Basin was filled-up by Ordovician to Cretaceous sediments. The oldest sediments is Ordovician marine sediments. It was unconformably overlain by Devonian evaporate and continental sediments; unconformably overlain in the northeast by Late Devonian carbonate and by Carboniferous fluviatile, estuarine and marine sediments; unconformably overlain by marine sedimens of Permian, Triassic and Jurassic age with unconformities at the end of the Permian and Triassic; onshore sedimentation ceased after the deposition of continental sediments in the Cretaceous. Triassic igneous activities are present.

Officer Basin

The Officer Basin was filled-up by Proterozoic shallow-marine evaporitic and glacial sediments, and is unconformably overlain by Paleozoic sediments including *Permian fluvio-glacial* sediments, and Cretaceous shallow marine sediments. Igneous activity comprises Cambrian tholeiitic basalt.

Exmouth – Wombat Plateau area of Indian Ocean

The Exmouth – Wombat Plateau area is in Indian Ocean, in Australian Northwest shelf (Figure 5).

This area have been drilled for the Oceanic Drilling Program comprising Leg 122 and 123. The lithological sequence recovered in the area comprises Permian, Mesozoic and Tertiary Sediments, including igneous intrusion and extrusion accompanied pre- Norian and post-Rhatetian or upper Triassic deposition. The Triassic sediments comprise 30% carbonates, and the remainder of paralic to fluviodeltaic facies. The Cretaceous and Cenozoic sediments comprises hemipelagic to eupelagic marls, chalk and oozes (Haq *et.al.,* 1990).

Stratigraphy of the cratonic terrain, North-Central Sumatera

The terrain occupies a large area extending from North to Central Sumatera in which Upper Paleozoic and Triassic sediments are exposed. This terrain is bordered by faults (Cameron *et.al*., 1980.) as shown in Figure 3.Furthermore in this paper, this terrain is called as the Bohorok – Mentulu Basin

Bohorok - Mentulu Basin

In the northern part of the basin, it was dominantly filled-up by upper Paleozoic flysh type-marine sediments which underwent a low grade metamorphosed, process, forming meta-sediments; It was unconformably overlain by Permian Glacial sediments of Bohorok (*Suwarna, Andimangga, personal com. 2009)*. These sediments were intruded by Permian – Triassic Alkaline Granitoid Rocks (Subandrio and Suparka, 1994).

In the southern part of basin (Central Sumatera), it was also filled-up by Lower Permian glacio-marine and fluvioglacial sediments of Mentulu Fm. (Surono *et. al.,* 1990); and it was underlain by pre Permian meta marine sediments. These glacial sediments were conformably overlain by Upper Permian shallow marine carbonate sediments which is overlain by deep marine (slope) carbonates. The igneous activities comprise granitoid intrusive of Triassic to Jurassic in Age.

Ultrapotassic Rocks West Australia.

Feldspatoid bearing rocks

The ultrapotassic rocks found in west Australia were located in the northwestern part. They occupy a valley extending northwestward along Fitzrroy River. The valley was bound by faults. There are twenty intrusives ultrapotassic rocks occur in the valley, intruded Paleozoic and Lower Triassic sediments, so the age of the ultrapossic rocks was estimated Uper Triassic or ?younger. A few small craters were also found (Guppy *et al*., 1958).

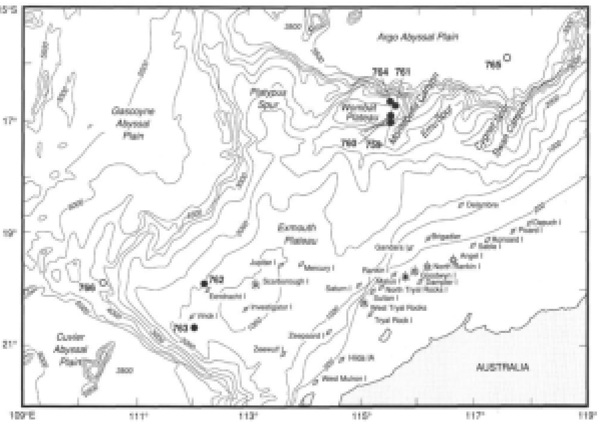

Figure 5. Location of the Exmouth and Wombat Plateaus in Indian Ocean. In Australian Northwest shelf.

The ultrapotassic rocks predominantly comprise leucite bearing intrusives and a few lamproites.

Ultrapotassic Rocks of North Sumatera

A-type granitoid rocks

The ultrapotassic rocks of North Sumatera are represented by Sibolga -granitoid Complex including meta-felsic volcanic rocks i.e rhyolites – rhyodacites. Radiometric dating of the granitois are of 257 ± 24 Ma and 217.4 ±4.4 Ma (Subandrio and Suparka, 1994) producing age range from Upper Permian to Triassic. On the basis of mineralogical and geochemical contents suggest that the granitoid rocks belong to A-type granite.

The tectonic setting of this A-type granites were in Within Plate Granite as is of A-type granite from other regions, indicating that the granitoid rocks occur along riftzones and whitin a stable continental blocks (Subandrio and Suparka, 1994). Nishimura and suparka (1997) described the intrusions of the Sibolga granite complex were more often bounded by WSW-ENE-ENE or E-W striking faults.

About Ultrapotassic Rocks (Potassium Richest Rocks)

Ultrapotassic rocks are defined by molar K_2O/Na_2O >3. To produce that molar ratio up to three or more, the rocks must be produced by: High depth of melting which in turn pavors; low degrees of partial melting, which provides: enrichment of lithophile element (K, Ba, Cs, Rb), high potassium contents and silica undersaturation (no free silica). The melting must favor liberating as opposed to sodium; generally this may be achieved by partial melting of plagioclase-poor source rocks, or by melting of a potassium-enriched source rocks. Ultrapotassic granites are uncommon but are usually produced by melting of the continental crust above upwelling mafic magmas, such as at rift zones. Types of ultrapotassic rocks comprise lamprophyres and mellitic rocks, kimberlite, lamproit, orangeit, feldspatoid bearing rocks *e.g*. Nepheline-bearing monzonites and leucite bearing granites, leucitites, nepheline syaenits; K. feldspar enriched leucogranites and phonolites and ultrapossic A-type intracontinental granites. The economic aspects usually related to ultrapotassic rocks is varied, for examples: Leucite, nepheline and other feldpathoids make excellent refractories. They are good for manufacture of kiln glasses and furnace tiles. Kimberlite, lamproites and perhaps even lamprophyres are known to contain diamond. These rocks are all produced at depths more than 120 km, so that it can bring diamond to the surface as xenocrysts. Ultrapotassic granites are often host rock for gold mineralization. Significant porphyry-style mineralization is often obtained from highly potassic to ultrapotassic granites. Ultrapotassic A-type intracontinental granites may be associated with fluorite, niobium and tantalite (Foley and Peccerillo, 1992)

About Rift

Rift is a place where the earth crust and lithosphere are being pulled part or expanding. Typical features tend to be a downdropped graben between a pair of faults (normall or oblique extentional (transtensional), forming a rift valley. Allong this valley or graben is commonly occupied by shallow intrusives and occasionally volcanic extrussives Rifts are differ from Mid-ocean ridges, where new oceanic crust and lithosphere is created by seafloor spreading. In rifts, no crust or lithosphere is produced, but if rifting continues eventually a mid-ocean ridge like may form, marking a divergent boundary between two tectonic plates. Rifts are commonly occur in continental crust, they do not commonly develope to become spreading because the continental rifting fail to continue. Examples of rifts include : Great Rift Valley in Africa, Red Sea, Lake Baikal, where the bottom of the lake is the deepest continental rift on the earth. *etc*. (Anonym, in Wikipedia).

Paleoposition Sumatra In Gondawanaland

Nishimura and Suparka (1997) measured paleomagnetic for Triassic sediments of Sumatera Mountain Range (Figure 6, Table 2) to reconstruct paleolatitude of Sumatra during that time. They then have compared and evaluated virtual geomagnetic poles (VGP) of Sumatra to those of other regions such as the Russian Platform and to aspects of sea floor spreading in the Indian Ocean and also to the Triassic position of Australia (originally part of Gondwanaland) at 47º S and 176ºE (Embleton and Schmidt, 1977 in Nishimura and Suparka, 1977) . On the basis of the patterns of sea floor spreading between Antarctica and Australia (accompanied by Sumatra), eventually the Triassic position of Sumatera can be placed on reconstructed map of

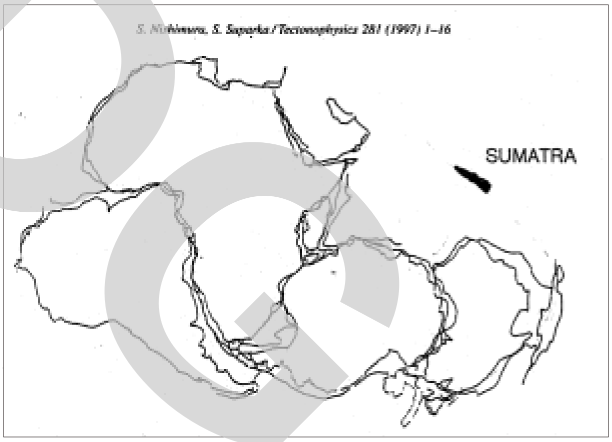

Figure 6. Possible position of Sumatera in Gondwanaland (Nishimura and Suparka (1997).

Table 2. Paleomagnetic data of Triassic sediments from Sumatera mountain range (Nishimura and Suparka (1997)

Site	Rock Type	N	D (o)	I (0)	Alpha 95	VGP	
						Long (ºW)	Lat (ºN)
ID 166	black shale	10	-2.6	-41.9	9.6	73.7	66.8
D 133	black sahle	7	5.0	-34.3	19.1	93.7	68.0
ID 161	limestone	7	199.9	28.0	11.7	130.9	65/0
ID 162	limestone	14	241,3	31.2	8.2	151.0	27.6

Gondwanaland by Smith and Hallam (1970). Thus, it tends reasonable to assume that the Sumatera was part of Gondwanaland during the Triassic.

Wahyono, (1997 in Surono *et al*. 1999) analysed paleomagnetic on sample of glacial pebbly mudstone of Mentulu Formation and stated that the rock was deposited in basin located in S 41º and underwent rotated anticlockwise of 115º.

Discussion and Conclussion

As mentioned before, many authors have reconstructed paleoposition of east Gondwanaland during Paleozoic to Mesozoic period based on paleomagnetic data combined to geological and biological data (i.e Audley-Charles, 1983; Kazmin,1951, Metcalfe (1993), Embleton and Schmidt, 1977 *etc*.), moreover on the basis of new and more paleomagnetic data measured from Sumatera, Nishimura and Suparka (1997) also reconstructed paleoposition of the Sumatera terrain in accordance with the Permian – Triassic position drawn by Smith and Hallam (1970). Their recontruction is more suitable with the result of their calculation and evaluation.

Amiruddin (2009) plotted possible position of Permian-Triassic magmatic arc and back basins developed in East Australia and East Indonesia on the Nishimura and Suparka's recontstruction diagram. He suggested that the Upper Paleozoic to Mesozoic magmatic arc and back basin were produced by huge compressive activity between the southeastern most Gondwanaland continent moved eastward and collided with or subducted into proto Pacific plate moved westward and formed Tasman mobile belt. In this paper, the paleomagnetic data and ultrapotassic rocks found far away from the subduction zone or an active margin suggest that in the part of more stable continent had probably been also generated a rifting activities created rifting zones and formed intracontinental basins, accompanied by ultrapotassic intrusive and volcanism activities (Fig. 7). Furthermore, the rifting seems to be continous up to Upper Mesozoic and cause basin subsidence, so that eventually, the basins were filled-up by very thick sediments.

These intracraton basins were filled by very thick sediments during rifting accompanied by magmatic activity during Upper Paleozoic to Mesozoic. These basins give advantages in economic aspect for Australia and Indonesia, namely for energy reources such as oil and gas discovery in West –Northwest Australia offshore basins including Timor, Seram and Abadi Field in Tanimbar Basin in the present day position after they underwent drifting from the original place (Fig. 8). Another benefit is the occurences of mineral resources as diamond bearing ultrapotassic rocks as lamproites found in Fitzroy Basin, West Australia and also the presence of A-Type Granite in Sibolga North Sumatera considered as base metal-Au bearing granite including rare erth minerals i.e fluorite, niobium and tantalite in the present day position after the granite bearing terrain

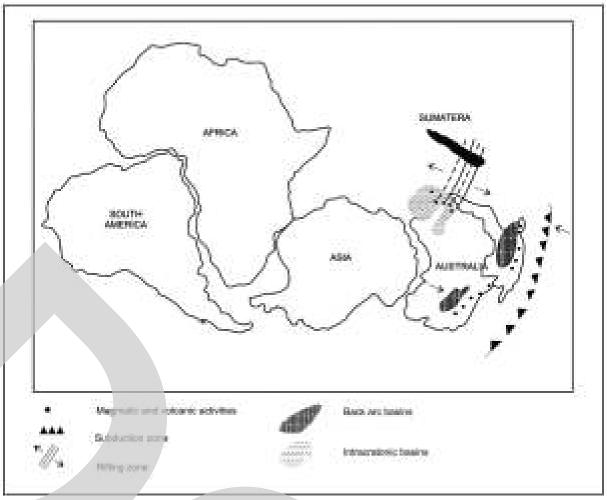

Figure 7. Possible position of Permian-Triassic compressive and rifting which respectively produce back arc basins and intracraton basins, accompanied by magmatic and volcanic activity.

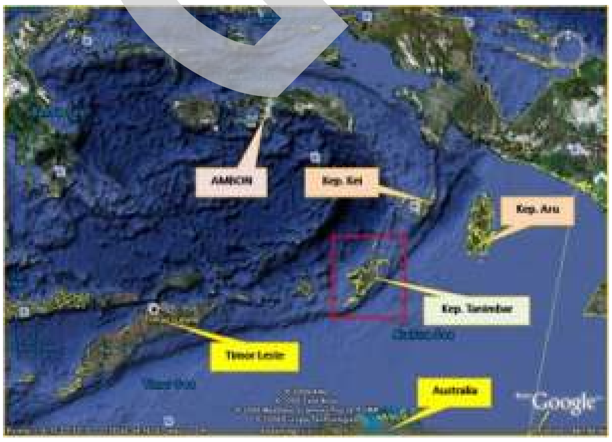

Figure 8. Location of Timor, Tanimbar, Seram and North West Australia. offshore present day.

had been drifted and transported far away from original position in southeastern Gondwanaland.

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