NEW PERSPECTIVE OF MESOZOIC HYDROCARBON PROSPECTIVITY WITHIN WEST TIMOR

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SUMMARY

Compared to the success of Mesozoic play in Westralian Superbasin (WASB), the lack of hydrocarbon discovery in West Timor within Timor Trough and North West Shelf Australia is still an enigma. The West Timor is still frontier petroleum province with problems in uncertainties of working petroleum system play as well as the hydrocarbon prospectivity.

This paper tries to approach this issue by integrating of fieldwork data with published well data and offshore seismic data from recent publication to re-evaluating potential hydrocarbon prospectivity in this area. Using the dataset, this study identifies structural framework across West Timor Island and offshore area, as well as potential petroleum system plays including source rock, reservoir presence and trap configuration.

The results of this study identify two potential petroleum province region including Timor deformation front and Australian passive continental margin. Within these areas, three main plays based on structural configuration were identified which are fold related fault, sub-thrust, and tilted fault block. Reservoir targets for these main plays are Jurassic sequences including sandstone of the Early-Middle Jurassic of Plover equivalent and Late Triassic Malita equivalent with seal rock including Early-Middle Jurassic shale of Wai Lui Formation and Early Cretaceous shale interval. These plays are expected to be charged from source rock interval of Triassic Formation.

The novelty of hydrocarbon prospectivity in this study will guide exploration screening of petroleum system analysis in West Timor area where current play analysis has not been tested yet.

Key words: West Timor, North West Shelf Australia; Petroleum Play, Petroleum System, Structural Framework.

INTRODUCTION

Located at the boundary of three different countries between Australia, East Timor, and Indonesian province of Nusa Tenggara Timur (West Timor), North West Shelf Australia (NWSA) can be divided into Westralian Superbasin (WASB) consisting of Northern Carnarvon, Offshore Canning, Browse and Bonaparte Basin (sensu Yeates, et al, 1987) and one orogenic belt called Timor-Banda Orogeny (Figure 1). The NWSA is a world class gas province having reserve estimation of 2.6 billion bbls of oil and 152 Tcf of gas among 233 hydrocarbon field (Longley, et al, 2003). These resource mostly found in Mesozoic play beneath Cretaceous regional seal within WASB.

In comparison with the WASB, exploration activity in the West Timor is still in frontier state with total of five wells both on onshore (Banli-1) with minor oil show and offshore well (Napoleon-1, Manta-1, Mina-1 and Belalang-1) with unsuccessful result (Figure 2). These result indicate that the petroleum system and hydrocarbon prospectivity in West Timor still possess a great uncertainties.

This study tries to approach this issue by re-evaluating potential petroleum system play of West Timor. This is achieved by integrating of fieldwork data with published subsurface data including well and offshore seismic data from recent publication. Using the dataset, this study determines structural framework across West Timor Island and offshore area, as well as potential petroleum system plays including source rock, reservoir presence, and trap configuration. The results of this study identify two potential petroleum province region including Timor deformation front and Australian passive continental margin. Within these areas, three main plays based on structural configuration were identified which are fold related fault, sub-thrust and tilted fault block.

METHOD AND RESULTS

Petroleum System Evaluation

a. Source rock development

Stratigraphy and petroleum system element of Timor and adjacent area are summarised in Figure 2. Several publications have reported that Permian lacustrine and Late Triassic sediment can be included as potential source rock in the West Timor (Charlton, 2001; Permana, et. al, 2014; Lelono, et al, 2016). The Permian lacustrine source rock has been reported containing 0.7-24.45% TOC with high maturity index (Ro>0.9) (Lelono, et al, 2016). The Permian source rock is likely can be comparable with source rock producing dry gas from the Upper Permian in Kelp Deep-1 on Sahul platform. Dry gas analysis in this well was generated from land-plant-rich source rock with Permian origin (Edwards, et al., 2000). On the other hand, Late Triassic sediment consisting bituminous shale and open marine shale facies also has been reported in this area. Late Triassic bituminous shale containing 8% TOC and 23.3% TOC with hydrogen index up to 396 indicating oil prone kerogen with good to very good source quality (Charlton, 2001). Furthermore, the Late Triassic open marine shale has been recorded 2.85-9.16% TOC with hydrogen index up to 291 indicating potential oil or gas generation (Permana, et al., 2014). These Triassic source rocks have been supported by oil seeps analysis from East Timor indicating Upper Triassic-Jurassic as the primary source (Charlton, 2001).

b. Reservoir Potential

In term of reservoir potential, the Late Triassic "Malita equivalent' and Early-Middle Jurassic "Plover equivalent" sandstone are the best reservoir potential in West Timor. These sediment was penetrated by Banli-1 in southern Western Timor (Sani, et al., 1996; Charlton, 2001). While there is no porosity data that has been reported in these two potential reservoirs, Late Triassic "Malita equivalent" and "Plover equivalent" sandstone are identified to be shallow marine sandstone based on Banli-1 (Sani, et al., 1996). Furthermore, these potential reservoirs has been suggested to be distributed in marine environment especially in the southern part of Timor Island based on paleogeographic reconstruction between Late Triassic to Middle Jurassic age (Charlton, 2012). The "Malita equivalent" sandstone in this area has been suggested can be comparable with Middle-Upper Triassic marginal marine reservoir in the Challis fields. In this field, the reservoir sand has quality with average porosity 29% and permeability between 500-7000 mD (Charlton, 2001). On the other hand, the Jurassic sandstone has analogue from Coralina-1, Chudith-1 and Flamingo-1 that has been producing hydrocarbon on Laminaria- Flamingo High. In these wells, the Plover sandstone has reservoir quality with average porosity between 13.9%-15.7% and permeability between 21-597 mD (Cadman and Temple, 2003).

c. Seal Potential

Middle-Late Jurassic shales of the Wai Luli formation is expected to act as seal for reservoir potential beneath it within West Timor. This shale has been reported to have thickness about 100 m in Banli-1 with the overpressure within it representing sealing quality (Sani, et al., 1995; Charlton, 2001; Jacobs, et al., 2011). Another possible seal potential especially within West Timor offshore is Cretaceous shale. This Cretaceous shale (Frigate, Flamingo and Echuaca Shoal formation) is interpreted to be in deepening continental shelf depositional environment act as seal in Laminaria High (Ciftci, and Langhi, 2012).

d. Post-Exploration Well and Existing Play in West Timor

With total of five wells that has been drilled in West Timor, only onshore well (Banli-1) that has been published in public domain. The Banli-1 target anticlinal crest of Kolbano structure supported by positive Bouguer gravity anomaly data (Sani, et al., 1996). However, structural model as the basis for well location is debatable because of an assumption of its location as paleogeography high. It is in contrast with equivalent thickness between 275 m of Plover Formation in Banli 1 and 200 m – 672 m in Australian shelf which does not suggest stratigraphic thinning in Jurassic level. On the other hand, the well also has been suggested only intersected the southern flank of the sub-thrust anticline (Charlton, 2001).

In term of offshore wells, these wells located on southern part closer to Nancar Trough and Laminaria High (Figure 1). While these wells information has not been published in public domain, several previous studies has indication that Belalang-1, Manta-1 and Napoleon-1 have horst block targets. While the Belalang-1 has Jurassic sediments as reservoir target with no result, both Manta-1 and Napoleon-1 are missing the Jurassic sediments due to tectonic uplift in Ashamore platform causing non-deposition within area of these wells (Jones, et al., 2011; Baille, et al., 2013).

Structural Framework of West Timor

a. West Timor Onshore

In constructing structural framework of West Timor onshore, fieldwork data within Kolbano and Kekneno area from previous study (Sapiie, et al., 2017) has been used. Within Kolbano area, the fieldwork data observed NE-SW strike of thrust and/or reverse fault, NE-SW of fold axis with north dipping and NNW-SSE to NNE-SSW strike of wrench fault with north dipping. Through the north of this area, the strike orientation of the thrust fault change both on the western part into NNE-SSW and eastern part into NNW-SSE. This fieldwork data also supported by contrast change of topographic profile in this area. Charlton (2001) has suggested the topographic contrast can be possibly interpreted as an antiform resulted by subthrust basement-involved deformation. In term of Kekneno area, the fieldwork data observe NE-SW and NW-SE strike of thrust sheet package with north dipping orientation and syncline and anticline folding on Triassic to Permian sequence.

b. West Timor Offshore

In understanding the structural geometry within West Timor offshore, four seismic lines from previous studies (Jones, et al., 2011; Baille, et al., 2013) were discussed in this paper (Figure 1). Three NW-SE dip sections represent structure and stratigraphy between accretionary complex in the north and part of the Australian Continental margin in the south. The other one is a strike section represent structure and stratigraphy on NE-SW trend.

Seismic dip section show that beneath southern part of the offshore area, the sequence between Permian to Pliocene age has been deformed into normal tilted fault block developing horst and graben feature and inversion with dip around 60^{o} (Figure 3). These normal fault system is dominant element of deformation pattern in the Timor Sea bounded by Timor trough in the north forming by two different phase of extension both in Jurassic and Mio-Pliocene (Ciftci, and Langhi, 2012). On the other hand, closer to the trough area, decollement has been observed around 4s TWT (Figure 4). This study interpreted that this decollement is related to sub late-Jurassic post-rift decollement that has been suggested by Audley-Charles (2011). Beneath this decollement, Permian to Late Jurassic sequence is interpreted was deformed by sub-thrust basement-involved inversion. Regarding of seismic strike section, it represent normal tilted fault block in the center of West Timor offshore. The normal fault system mostly deform Permian to Triassic sequence developing horst and graben through the north-eastern. Jones, et al (2011) suggested that the structural geometry in top of Triassic within West Timor offshore area has NE-SW trend. This reflect regional structural trend of NWSA in Carboniferous-Permian and Mesozoic rifting (Etheridge & O 'Brien, 1994; Harrowfield, et. al., 2003).

Hydrocarbon Prospectivity Implication

According to structural framework analysis in West Timor, this paper infers that there are two potential petroleum regions consisting of Timor deformation front and Australian passive continental margin. Within these areas, three main Mesozoic plays based on structural configuration were identified which are fold related fault, sub-thrust and tilted fault block.

a. Timor deformation front area (sub-thrust and fold-related fault play)

Analysis of structural framework across of West Timor indicates thrust fault and inversion system mostly present in Kolbano area and Timor trough. These systems develop trap configuration such as sub-thrust play and fold-related fault play. The sub-thrust play may also exist in onshore area where the fieldwork data observe thrust sheet package in Kolbano area. The Plover and Malita equivalent that can form as the reservoir potential target in this area is deformed with this geometry of trap configuration. In addition, Charlton (2001) has suggested that overpressured shales of the Wai Luli Formation in this area can act as a seal, while Permian-Triassic formation likely to be the source rock in the northward part of Timor Island.

In term of West Timor offshore, this trap configuration also can be observed on seismic dip section deforming Permian-Late Jurassic sequence in the Timor trough (Figure 4). On the other hand, fold-related-fault play also can be observed deforming between Permian to Cretaceous sequence on the centre part of Timor Trough (Figure 3). This system can be a potential play where the thrust acts as a trap configuration is presence on Middle Jurassic of Plover formation. The Plover Formation act as reservoir interval in this area is covered by 0.5 TWT of seal which is the Middle-Late Jurassic sequence of Wai Luli Formation. The source rock are likely to be a restricted marine sequence of Triassic formation. The restricted marine sequence could be present and accumulated in adjacent graben (Charlton, 2012).

b. Australia passive continental margin area (tilted fault block play)

Within southern part of West Timor offshore, several tilted fault block has been observed in seismic section. This structural framework has implication for trap configuration in hydrocarbon prospectivity. In this trap configuration, Triassic of Malita equivalent sandstone deposited in shallow marine depositional environment can act as reservoir. On the other hand, Cretaceous sequence has possibility to be a seal in this play and interpreted to be consisted of fine sediment. This interpretation based on regional tectonic event of transgression state in Early Cretaceous where shale of continental shelf (Frigate, Flamingo and Echuaca Shoal Formation) is deposited in Laminaria high. This play is also expected to be charged by restricted marine sequence of Triassic formation deposited in adjacent graben.

CONCLUSIONS

Existing play in West Timor has identified both sub-thrust anticline on onshore area and tilted fault block in offshore area. However structural framework of West Timor based on integration between fieldwork data and recent published seismic data enhance our insight in determining hydrocarbon prospectivity in this area. Based on the analysis of the structural framework, two potential petroleum regions can be determined consisting of Timor deformation front and Australia passive continental margin area. Within these region, sub-thrust play is also existed in offshore area while tilted fault block play has not been tested in Triassic sequence. Moreover, fold-related fault play is also existed in offshore area closer to Timor trough. The petroleum system element in these plays consist of Early-Middle Jurassic of Plover and Late Triassic Malita equivalent act as the reservoir, and Jurassic shale of Wai Lui Formation and Early Cretaceous shale interval act as the seal. These plays are expected to be charged from source rock interval of Triassic Formation.

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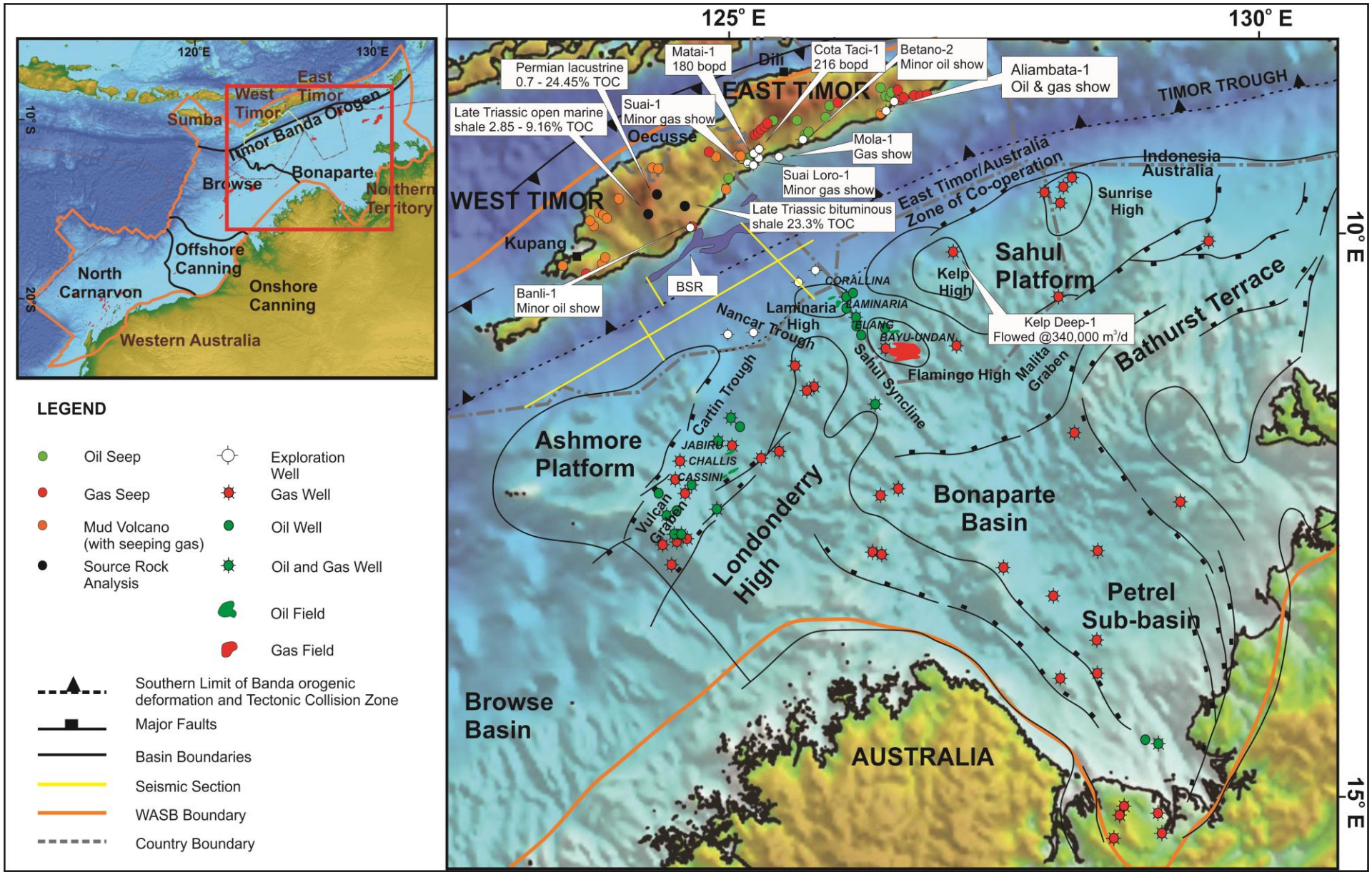

Figure 1: Petroleum highlight of Timor and Bonaparte Basin. Based map based on Gebco from British Oceanographic Data Centre and Baille et al. (2013); Offshore structural framework and Australian petroleum highlight based on Cadman and Temple (2003); Timor petroleum highlight is modified after Jones, et al. (2011).

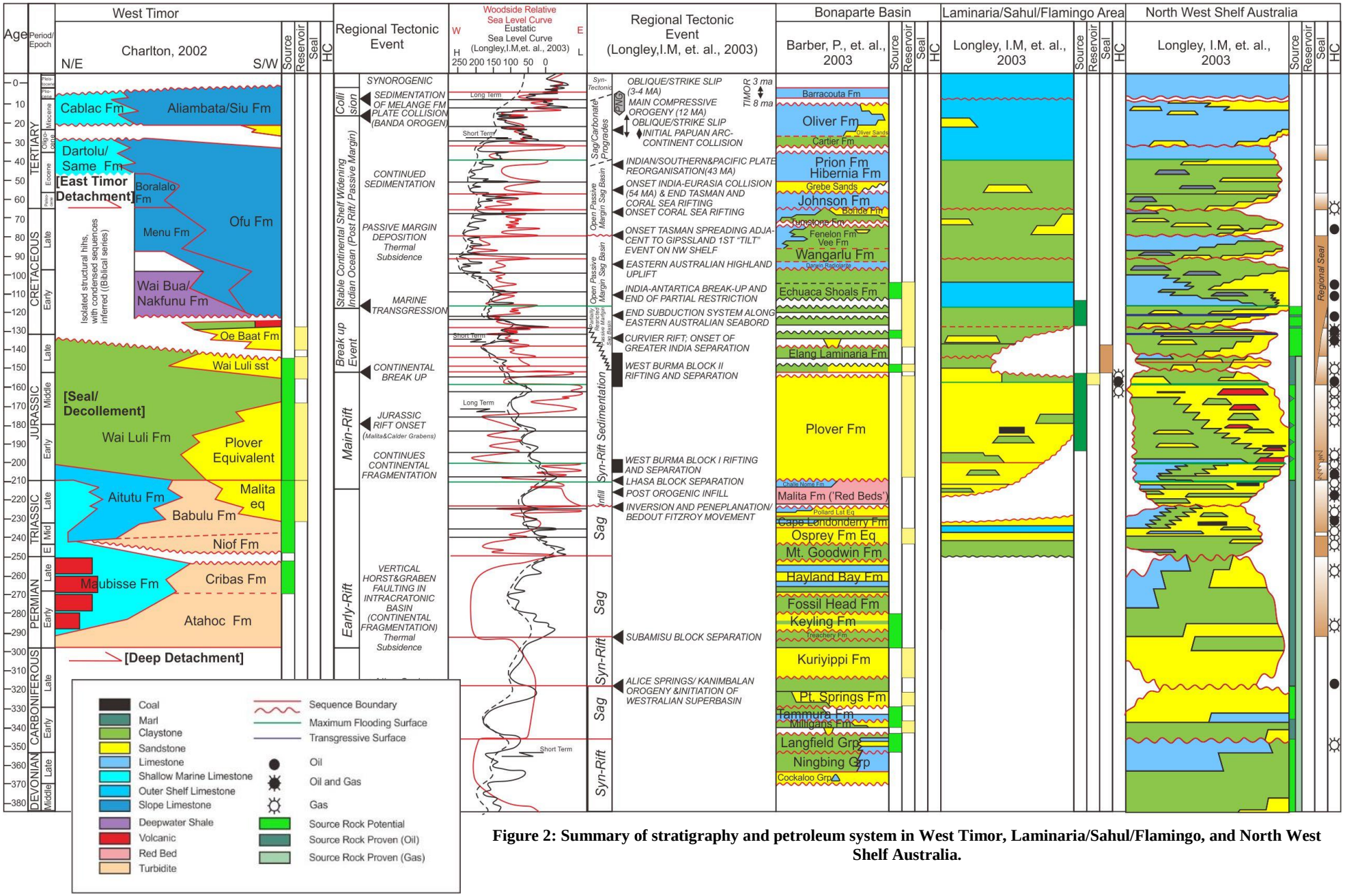

Figure 2: Summary of stratigraphy and petroleum system in West Timor, Laminaria/Sahul/Flamingo, and North West Shelf Australia.

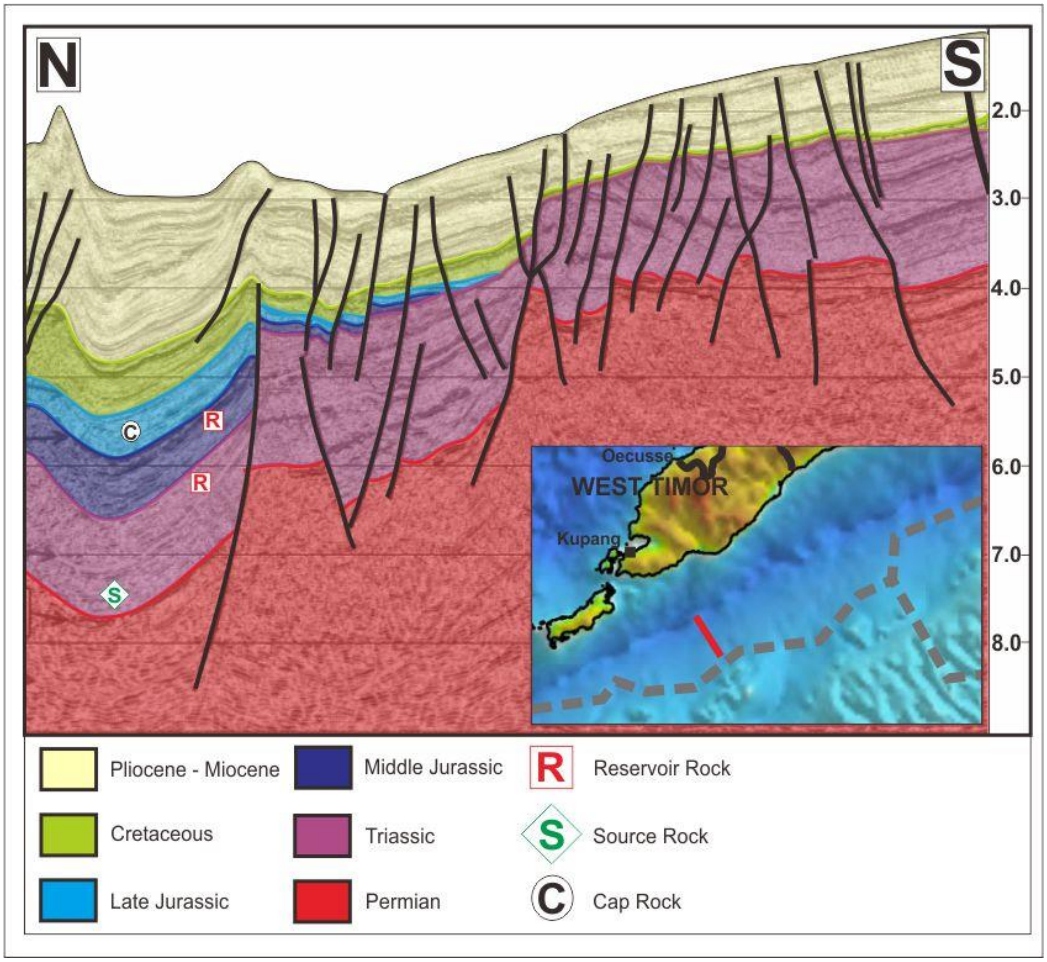

Figure 3: NW-SE regional offshore seismic line in West Timor (modified from Jacobs, et. al., 2011). It represent part of Australian continental margin where normal tilted fault block developing horst and graben feature and inversion in this area.

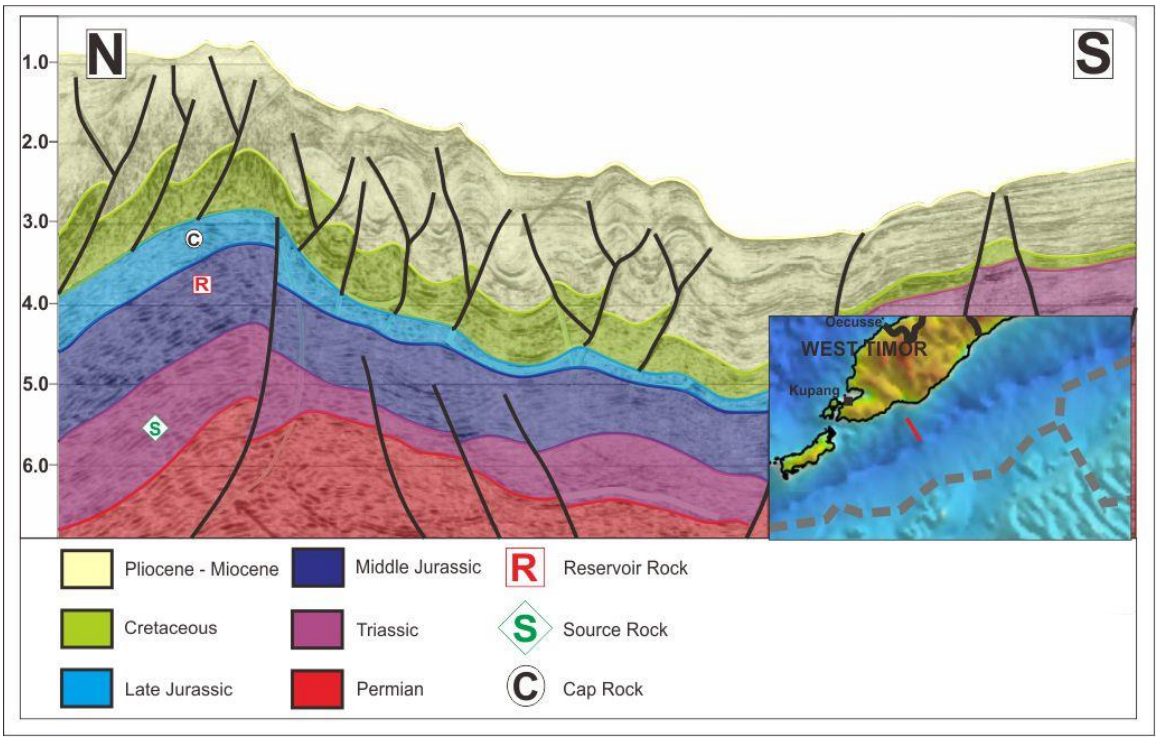

Figure 4: NW-SE regional offshore seismic line in West Timor (modified from Jacobs, et. al., 2011). It represent Timor trough area which decollement has been observed around 4s TWT. The decollement is related to sub late-Jurassic post-rift decollement.