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# HYDROCARBON POTENTIAL OF TOLO BAY MOROWALI REGENCY: QUALITATIVE ANALYSIS

## POTENSI MIGAS TELUK TOLO KABUPATEN MOROWALI: ANALISIS KWALITATIF

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**ABSTRAK**

Teluk Tolo terletak diantara Lengan Timur dengan Lengan Tenggara Sulawesi, kedalaman mencapai 3500 meter di bawah permukaan laut. Secara regional daerah ini termasuk dalam Cekungan Banggai yang terdapat beberapa lapangan migas yang telah berproduksi. Lapangan yang terdekat adalah lapangan Minyak Tiaka yang berjarak sekitar 125 km di sebelah Barat Laut daerah kajian. Kaji ulang geo-science dilakukan untuk mengetahui potensi keberadaan migas di daerah kajian. Berdasarkan data penelitian terdahulu, makalah ilmiah dan data bawah permukaan yang diperoleh dari Direktorat Minyak dan Gas Bumi, blok ini terletak pada kawasan benturan Lempeng Mikro Banggai – Sula dengan Sulawesi. Benturan ini diperkirakan terjadi pada Akhir Kapur dan Miosen Tengah. Pada fase drifting terjadi proses sedimentasi pada muka Lempeng Mikro Banggai-Sula, dengan kondisi sama dengan passive margin. Sedimen ini berpotensi sebagai batuan induk dan batuan reservoir. Sementara wilayah kajian pada fase ini diduga terletak di sisi Selatan Lempeng Mikro Banggai-Sula. Perbedaan lokasi tektonik ini akan mempengaruhi terbentuknya jenis batuan sedimen sehingga keberadaan batuan induk dan batuan reservoir di bagian ini tidak jelas. Akibat keberadaan batuan induk dan reservoir yang tidak jelas maka kegiatan eksplorasi migas di blok ini mempunyai resiko yang sangat tinggi. Dalam rangka mengurangi tingkat resiko eksplorasi maka diusulkan untuk melakukan studi geologi dan geofisika dengan menggunakan data seismik terbaru yang proses surveinya dilakukan ole PT. TGS- NOPEC dan PT ECI-PGS.

**Kata Kunci:** morowali, banggai, resiko eksplorasi, drifting, benturan

***ABSTRACT***

*Tolo Bay is located between East Arm and Southeast Arm Sulawesi, reaching a water depth of up to 3500 meters below sea level. Regionally, this block is situated within Banggai Basin where some gas and oil fields are already in production. The closest field is Tiaka Oil Field located about 125 kilometers northwest of the study area. A geo-science review has been conducted to clarify the potential existence of hydrocarbon in this block. Based on previous reports, papers, and subsurface data from the Directorate General of Oil and Gas, the study area is located within the collision area between Banggai-Sula Microcontinent and Sulawesi. This collision occurred during Late Createaceous and Middle Miocene periods. During drifting phase a sedimentation process occurred at the front of the Banggai-Sula Microcontinent. This sediment is potentially source rock and reservoir rock. Meanwhile, during the drifting phase the study area is interpreted as located at the southern part of Banggai-Sula Microcontinent. This different tectonic setting will impact on the type of sedimentary rock, hence source rock and reservoir rock occurrence in the study area is still unclear. As source rock and reservoir rock within the study area are unclear, hydrocarbon explorations*

*will be very risky. In order to reduce exploration risk, it is proposed to conduct geological and geophysical studies using the latest seismic data that was surveyed by PT. TGS – NOPEC and PT. ECI – PGS.*
***Keywords:*** *morowali, banggai, risk exploration, drifting, collision*

## I. INTRODUCTION

In Indonesia energy consumption trends increase in line with economic growth. That energy is dominated by oil and gas energy, therefore its resources and reserves must be preserved. In order to substitute oil and gas reserves, exploration activity must be conducted continuously, so production and discovery are in balance. Unfortunately during the last ten years, a reduction in available blocks has led to a reduction in oil and gas discovery. In early 2011, the oil and gas sector of the Energy and Mineral Resources Ministry held a meeting with an agenda to increase investor interest in hydrocarbon exploration in new working areas. This meeting decided on a few strategies to improve the situation. One decision was to assign LEMIGAS to conduct a geo-science review over selected available blocks.

The study area is located offshore of Southeast Sulawesi Arm, at Tolo Bay with water depth up to 3500 meters below sea level. This area is included within Banggai Basin, where some gas fields are already in production. The closest field is Tiaka Oil Field located about 125 km North West of the interest area (Figure 1).

This review will evaluate hydrocarbon occurrence within the interested area by considering petroleum system elements based on available data. Several in-house research reports from LEMIGAS and a scientific paper from the Indonesia Petroleum Association were used as the main information. Fifteen seismic lines from Petra Nusa Data can't be used as they are of poor quality. Well reports on #Dongkala-1 and #Tolo-1 show limited information. Regional maps i.e.: free air gravity, heat-flow unit, bathymetry, sedimentary thickness, seepages and field maps are considered as support data. Qualitative assessment of each petroleum system elements are a guide to the probability of hydrocarbon occurrence.

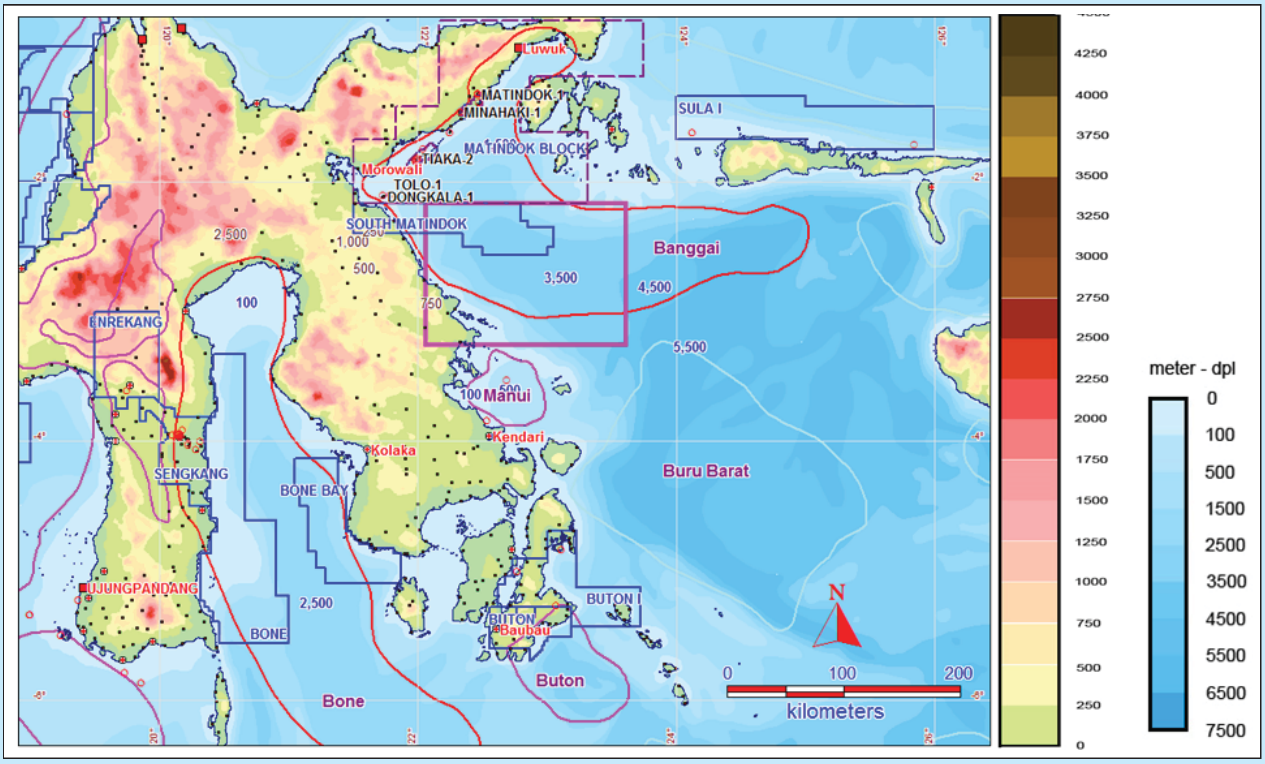



**Figure 1**
**Situation Map Showing Study Area.**

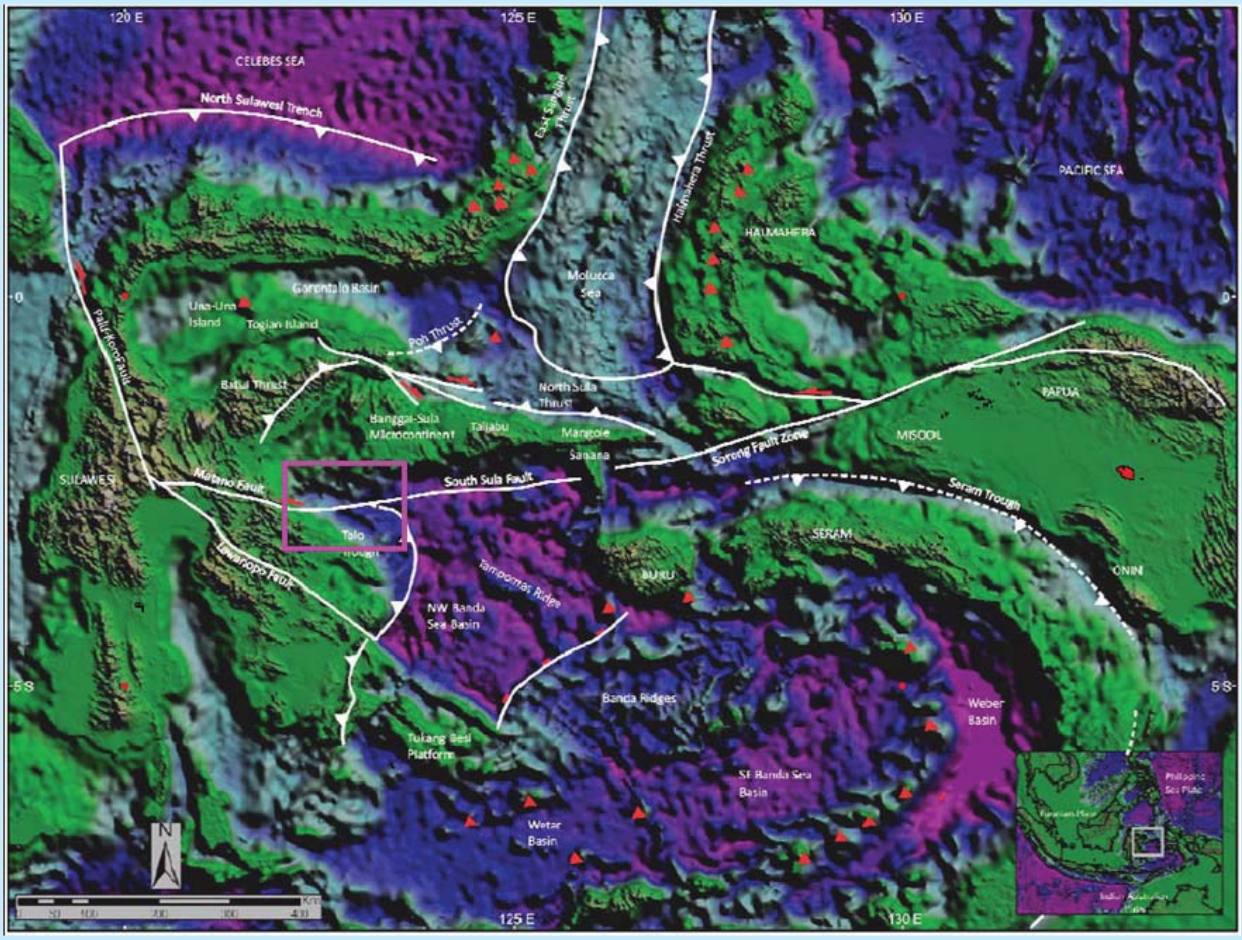



**Figure 2**
**Tectonic Elements of Banggai-Sula (Rudyawan A. & Hall R. 2012).**

## Tectonic Setting

The study area is situated within Banggai Basin where it is believed to be controlled by three major plates, i.e. western side is Eurasia, eastern side is Indo-Australia, and north-eastern side is Pacific (Figure 2).

There are some models that have been suggested by researchers. Audley-Charles *et al.* (1972) in Rudyawan and Hall (2012) linked the Banggai-Sula block with Misool Island which is located 300 km east. Hamilton (1979) and Norvick (1979) in Rudyawan and Hall (2012) suggested that Banggai-Sula sliced from the Bird's Head Papua, meanwhile Pigram *et al.* (1984) and Garrard *et al.* (1988) in Rudyawan and Hall (2012) suggested that this block had traveled from Central Papua. All interpretation is based on stratigraphic similarities.

Hall et al. (2009) and Spakman & Hall (2010) suggested that Banggai-Sula was not from New Guinea, but was part of Sula Spur which collided with the Sulawesi North Arm in Early Miocene and has fragmented by extension since the Middle Miocene due to subduction rollback into the Banda embayment.

The study area is separated by South Sula Fault into northern and southern parts. The northern part lies on the microcontinent terrain, whereas the southern part lies on an offshore extension of the microcontinent terrain. Some major structures occurred in the surrounding area i.e.: Batui-Balatak fold and thrust belt, Tolo Thrust, Palu-Koro Fault, Kolaka Fault, Lawanopo Fault, Hamilton Fault, and Matano Fault (Figure 3).

Satyana A.H. (2006) applied the docking and post-docking tectonic escape theory in the

Banggai-Sula Area. This theory explains the effect of collision between two plates and earth lateral motion after collision. Early Cretaceous – Early Tertiary (70-50) ma, South Sulawesi is part of Sunda Platform, as island arc and melange as a result of oceanic plate subduction over the continental plate. Early Eocene – Middle Miocene (50 – 10) ma, stress from east continued and rifting occurred in Makassar Strait, Bone Gulf, Gorontalo Gulf, subduction to continent plate occurred several times and revealed magmatism and volcanic forms in West Sulawesi. During Middle Miocene – Pliocene (15 – 5) ma, significant tectonic events occurred, Banggai-Sula collided with Sulawesi East Arm, and Buton-Tukangbesi collided with Sulawesi from the southeast. This collision revealed that Sulawesi Southeast Arm rotated in an anticlockwise direction, hence wider bone basin, Sulawesi North Arm rotated clockwise, and hence produced Gorontalo Basin. Recent (0-5) ma, at the finalization stage, after collision of the Banggai-Sula and Buton-Tukangbesi to Sulawesi, tectonic escape occurred, such as the major transform fault which caused Sulawesi to become cracked and slide. In general, sliding is eastward to

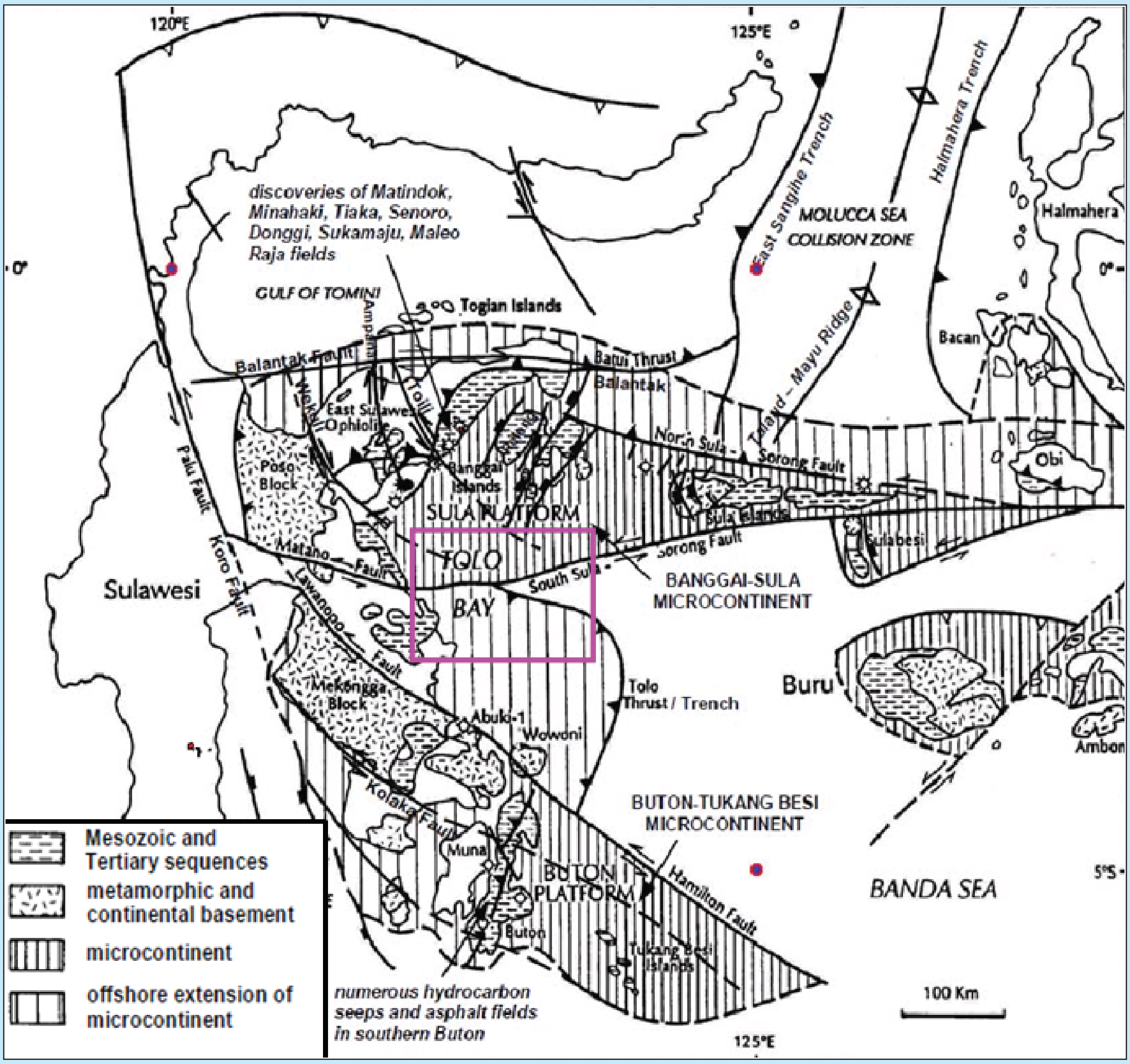
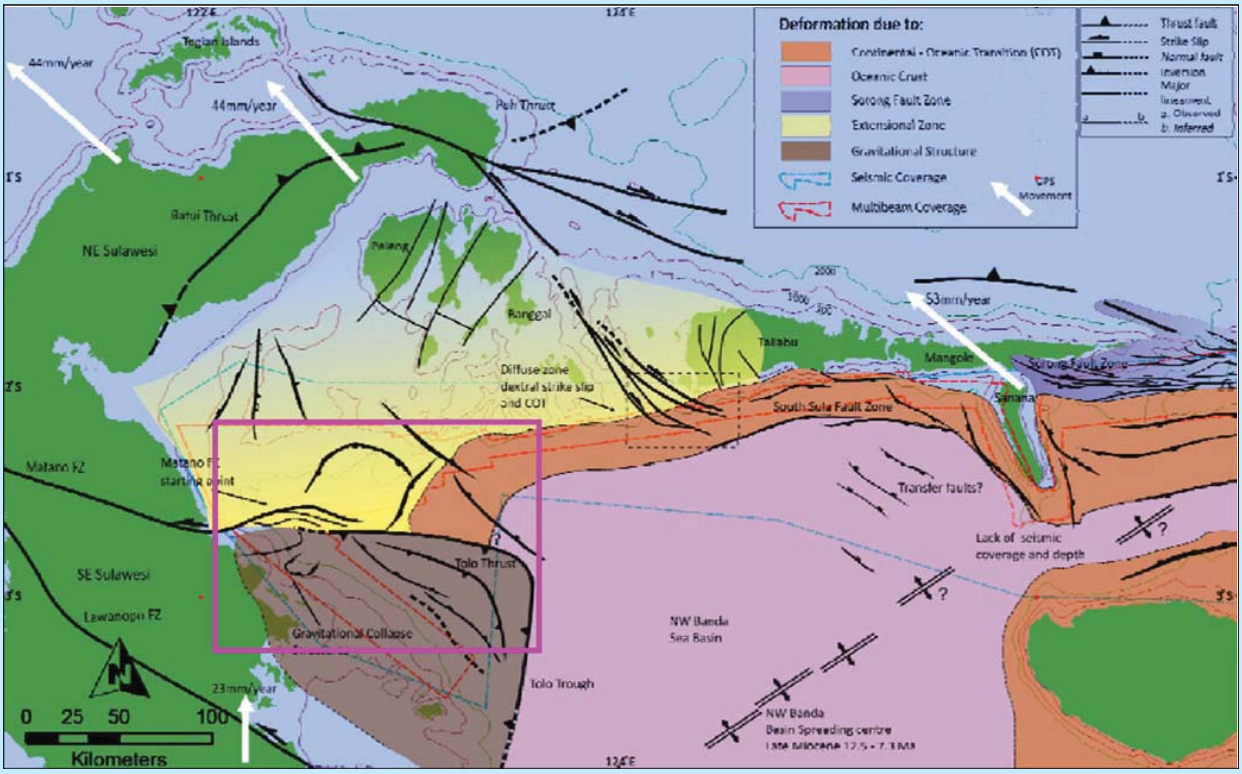



**Figure 3**
**Regional Structure Banggai-Sula Based on Stratigraphic Similarity (modified from Satyana 2006).**




**Gambar 4**
**Regional Structure of Banggai-Sula Based on Seismic and Multy-Beam Data (modified from Rudyawan & Hall 2012).**

free oceanic edge. These faults include Palu-Koro, Matano, Lawanopo, Kolaka, and Balatak. This tectonic activity also manifested in Banggai-Sula and in the Buton-Tukangbesi area.

According to Rudyawan and Hall (2012), the Banggai-Sula area is divided into five zones, Continental-Oceanic Transition, Oceanic Crust, Sorong Fault, Extensional, and Gravitational Structure. The northern part of the study area is included within Extensional and Continent-Oceanic Transition; meanwhile the southern part of this block is a part of Gravitational – Structure (Figure 4).

## Stratigraphy

Ferdian (2010) defined stratigraphic of the Banggai-Sula Island from older to younger as follows: Metamorphic/basement, Mangole Volcanic, Banggai Granit, Bobong Formation, Buya Formation, Tanamu Formation, Salodik Formation, Pancoran Formation, and Peleng Formation. (Figure 5).

The oldest rock is metamorphic rock of Carbonaceous or greater age, intruded by Permo-Triassic granites associated with acid volcanic rock of similar age. This rock unit is equal with “A” seismic unit. Bobong Formation is equivalent with Kabauw Formation (Triassic – Middle Jura), unconformity above basement, and it is suggested it consists of continental canalized red bed and coarse sedimentary rocks. This rock unit is interpreted as equal with “B1” seismic unit. Buya Formation (Middle Jura – Lower Cretaceous), unconformity above Bobong Formation/Kabauw Formation, consists of marine sediments including quartz-rich sandstones, shales and limestone. This rock unit is considered equivalent to “B2” seismic unit.

Tanamu Formation (Upper Createaceous – Paleocene) was unconformably deposited above Buya Formation, and this rock unit is interpreted to be deposited at a deeper marine environment, and interpreted as equal with “B3” seismic unit. Salodik Formation (Eocene – Miocene), which is unconformity above Tanamu Formation, consists of carbonate platform, marls, and locally reef that are based by siliciclastic rocks. Salodik Formation

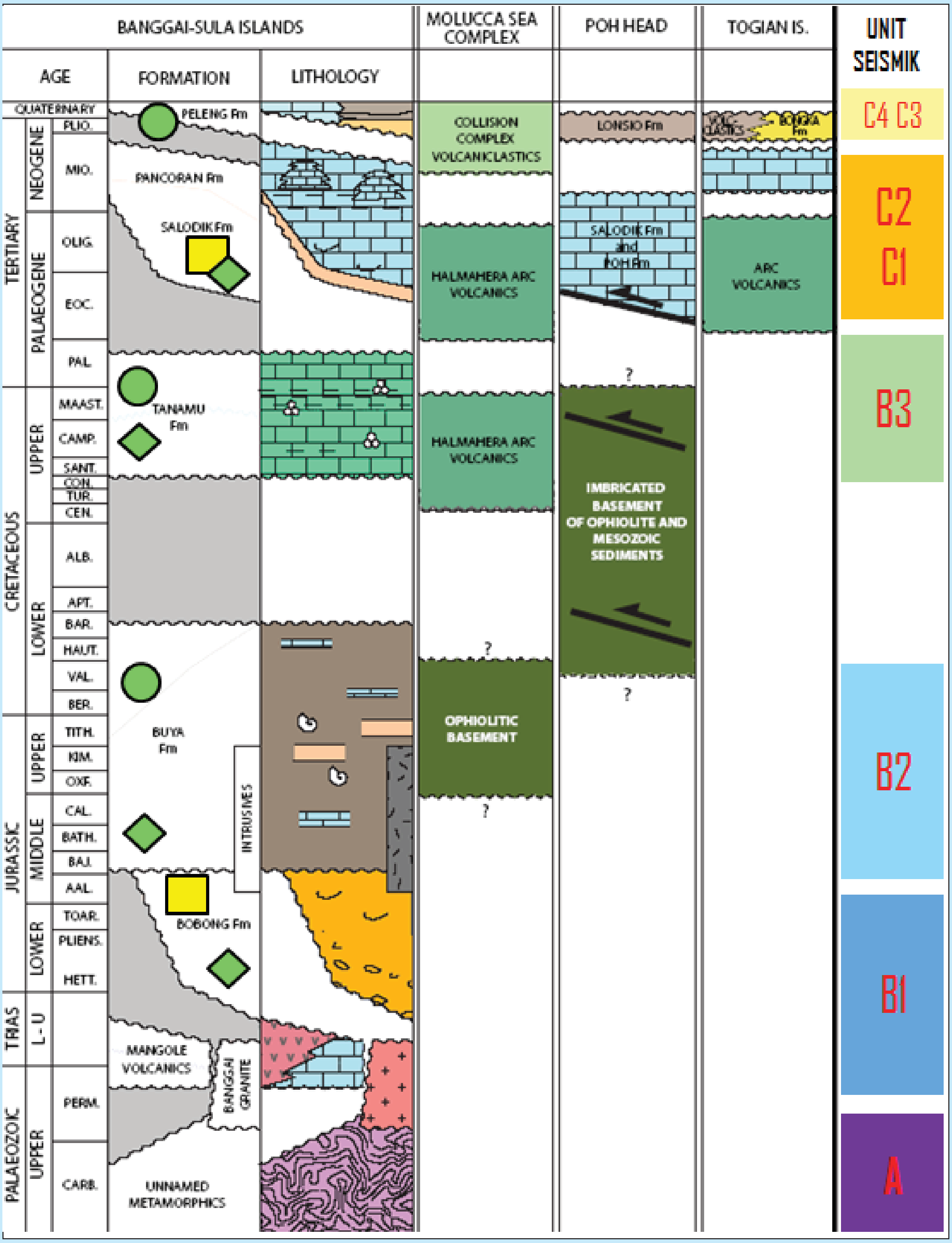



**Figure 5**
**Regional Stratigraphy of Banggai Basin (modified from Ferdian *et al.* 2010).**

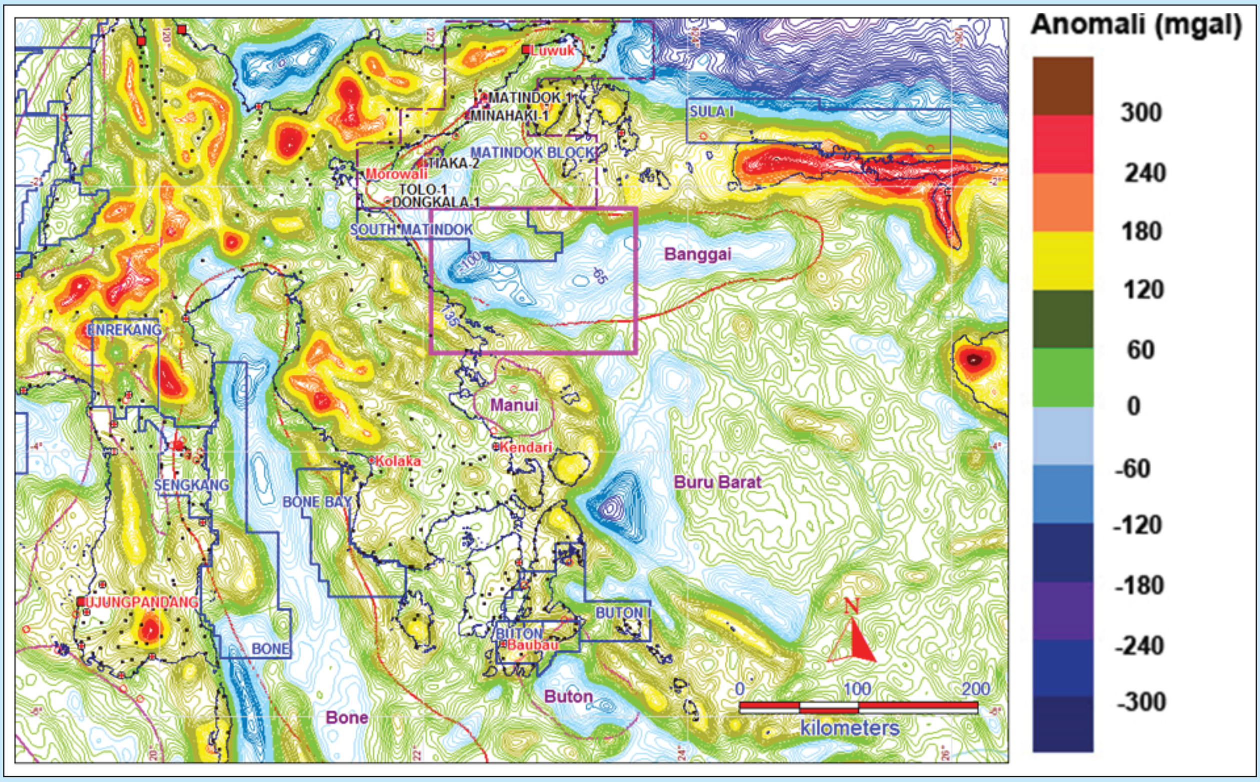



**Figure 6**
**Free Air Gravity Map of Sulawesi and Surrounding Area.**

is considered equal with "C1" and C2" seismic units. Pancoran (Middle Miocene – Pliocene), is interfingered with Salodik Formation and lithologically similar. Pancoran Formation is suggested to be equal with "C2" seimic unit. Peleng Formation/Luwuk Formation(Pliocene – Recent), is unconformity above Pancoran/Salodik Formation, consists of conglomerate with coral fragments, molluscs, algae, and foraminifera.

### Petroleum System

In Banggai Basin it is suggested that potential source rock occur in several stratigraphy intervals, such as coal and marine clay of Triassic and Jurrasic age; claystone and limestone of Paleogene age; and limestone, coal, and marine clay of Early to Middle Miocene age. Geochemical analyses from seepages and wells show high sulfur percentage and biomarker related with Miocene age (LEMIGAS, 2007). Reservoir rock also suggested they come from several stratigraphic levels, such as clastic sediment and reef limestone of Middle Jurassic to Upper Jurassic age and limestone and sandstone of Eocene to Miocene age. Cap rock suggested at fine grained sedimentary rock of Middle Jurassic – Upper Jurassic, fine sedimentary rock of Late Cretaceous age, and sedimentary rock of Pliocene age. Trapping, it is suggested, occurred as stratigraphic traps (pinch-out and reef) and structure trap (anticline), and migration through fault plane that connected source rock to reservoir rock.

## II. METHODOLOGY

These qualitative analyses for hydrocarbon potential in Tolo Trough applied several data sources, such as bathymetry, air gravity anomaly, heat-flow map, seismic section, well data, scientific papers, and reports from previous study. According to Smith and Sandwell (1977), the bathymetry map is created based on satellite remote sensing data of Geosat and ERS-1 (http://marine.csiro.au/). The air gravity anomaly can be downloaded at http://topex.ucsd.edu/cgi-nin/get. The cgi data is recorded by remote sensing satellite of Geosat (http://marine.csiro.au/). The Heat-Flow map sources are from PPPTMGB LEMIGAS Database, and seismic data and well data source are from Petra Nusa Data and the Directorate of Oil and Gas. Because the processed seismic data is not able to show a layer of rock, the subsurface mapping cannot be conducted. Interpretation is conducted based on the published information in scientific publications.

Data processing of the bathymetry shows sea depth within the study area, hence support to identified technical risk during drilling. The air gravity anomaly processing shows the depth of the basement rock, hence sedimentary thickness can be interpreted for identification of the potential source rock location. Processing of the Heat-Flow shows heat-flow distribution trend, and it can be a guide to identify statues of hydrocarbon maturity.

A comprehensive analysis is conducted simultaneously over the gathered data and supported by petroleum geology knowledge hence reveal petroleum system statues of the study area.

## IV. DISCUSSION

The study area on the Topography and Bathymetry map is located at offshore area with water depth of up to 3500 meters below sea level, the deepest located in the eastern area. The air gravity anomaly value varies between (-100) mgal to (+100) mgal, hence a low area is located in the western area. A low area is usually potentially a kitchen area (Figure 6).

Based on a regional Heat-Flow map, the study area located on the Q HFU value varies from 1.0 to 2.0, where the high value lies on the western part (figure 7). This medium Q HFU value shows a source rock likely to be mature for hydrocarbon generation. According to Pertamina and Unocal (1977), sedimentary thickness in Banggai Basin is up to 4000 meters. Sedimentary thickness and its distribution is shown at figure 8. Hydrocarbon seepages are not identified within the Study area, but along eastern Sulawesi located about 50 kilometer west of study area some gas and seepages have been already mapped (Figure 9).

Overlying analyses over gravity map, heat-flow map, and sedimentary thickness map shows the western part of the study area as low area, thick sedimentary up to 4000 meters, and high Q HFU value up to 2.0. That condition supports hydrocarbon generation from existing source rock.

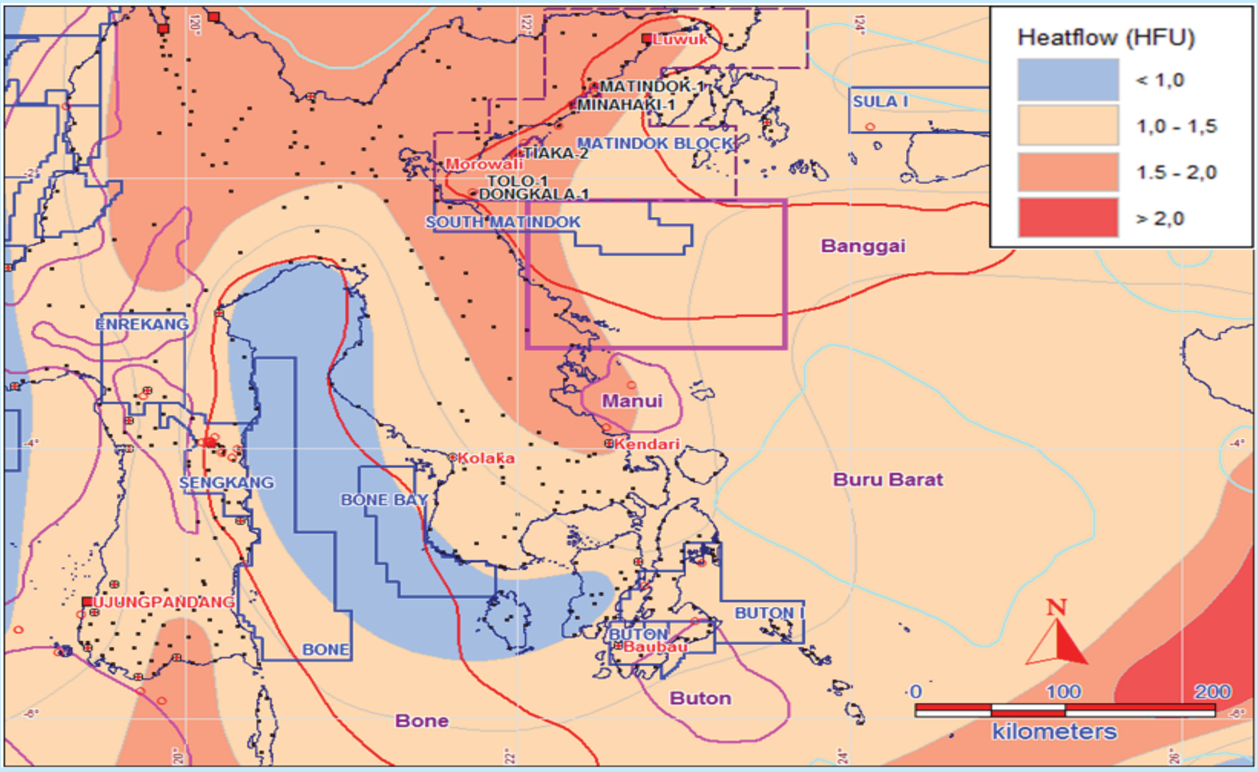



**Figure 7**
**Heat-Flow Unit Map of Sulawesi and Surrounding Area.**

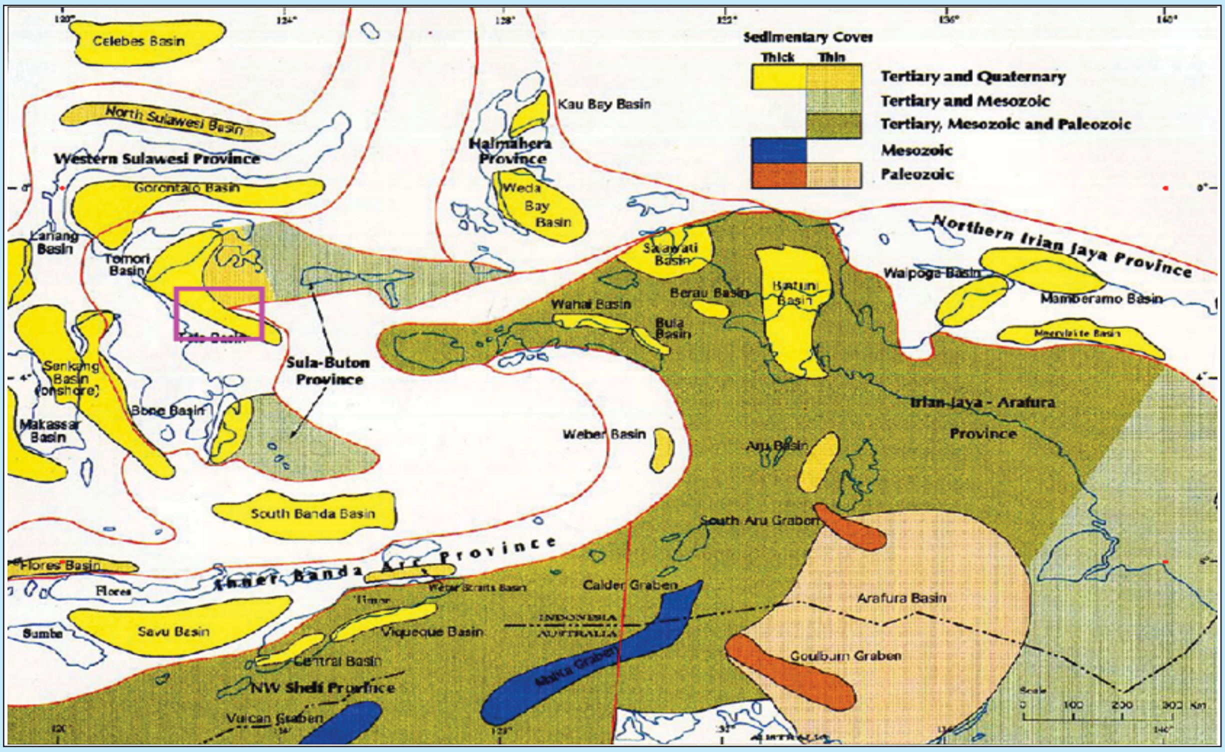



**Figure 8**
**Sedimentary Rock Map of Eastern Indonesia (modified from Livsey *et al*. 1992).**

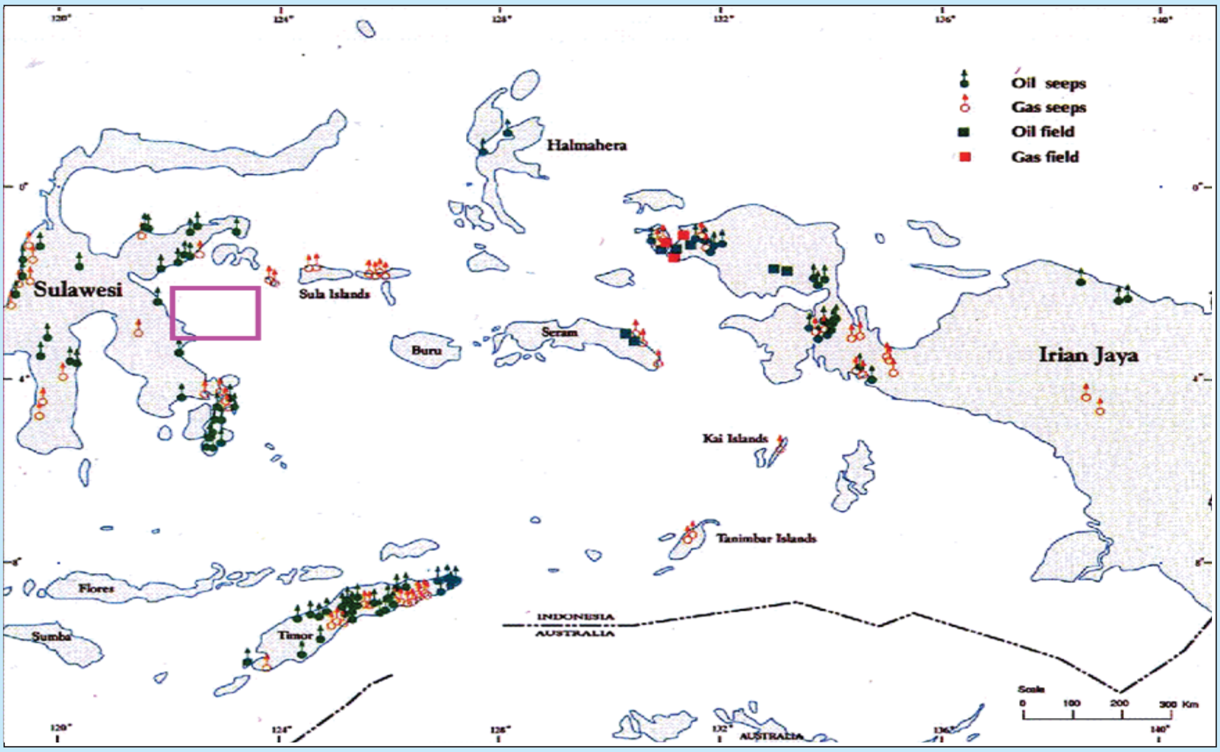



**Figure 9**
**Existing Hydrocarbon Field and Seepages of Eastern Indonesia (modified Livsey *et al.* 1992).**

The study area is located within the collision between Banggai-Sula and Sulawesi, hence exploration will refer to existing oil and gas field within the collision area (figure 10). Sedimentary rock that was deposited in front of the microcontinent possibly act as source and reservoir rock, and subduction of source rock will improve rock maturity and then be covered by molasses sediment (figure 11). During the drifting phase, environmentally in front of the microcontinent equivalent with passive margin, hence sedimentation produce intercalation coarse grain and fine grain.

The northern part of the study area is included within Extensional and Continent-Oceanic Transition, meanwhile the southern part is included within Gravitational – Structure. A thrust fault seen on the east edge, with basement rock overlaid oceanic plate and sediment thickness around 1.5 second only. There is a gravitational collapse structure identified within basement and between “A” and “B” (Figure 12). Hence, considering the sediment thickness and heat-flow unit, the probability of hydrocarbon occurrence in northern parts is higher compared to the southern parts. These seismic sections show thick Mesozoic sedimentary rock, therefore these sections can be an s exploration target for the near future.

Tectonic setting between the Study area with existing oil and gas field, such as Tiaka Oil Field, Mentawa Gas Field, Minahaki Gas Field, and Senoro Field is deferent. All existing oil and gas fields located in front of Banggai-Sula Microcontinent during drifting and collision phases, while the study area is located at the southern area. Hence, source rock and reservoir rock occurrence is unclear. Structure trap and cap rock from Sulawesi molasses may have  occurred in the study area. Since two element petroleum system in this block at unclear statues, hence exploration will be risky. Before deposited Salodik Formation a regional unconformity is identified, it means uplift occurred,

| LEGEND | PLAY TYPES | DISCOVERY / ANALOG |
|---|---|---|
| A | MIOCENE REEFAL BUILD-UP | SENORO, DONGGI, MINAHAKI |
| B | MIOCENE CARBONATES ON WRENCH-RELATED STRUCTURE | MATINDOK-1 |
| C | MIOCENE CARBONATES ON IMBRICATED STRUCTURES | TIAKA, KALOMBA |
| D | OPHIOLITE BELT (BASAL SAND OR FRACTURED RESERVOIR) | DONGKALA-1 (SHOWS) |
| E | MESOZOIC SECTION ON IMBRICATED STRUCTURE | OSEIL-1 OF SERAM (ANALOG) |
| F | MESOZOIC SECTION IN GRABEN STRUCTURE | LOKU-1 OF SULA (ANALOG) |

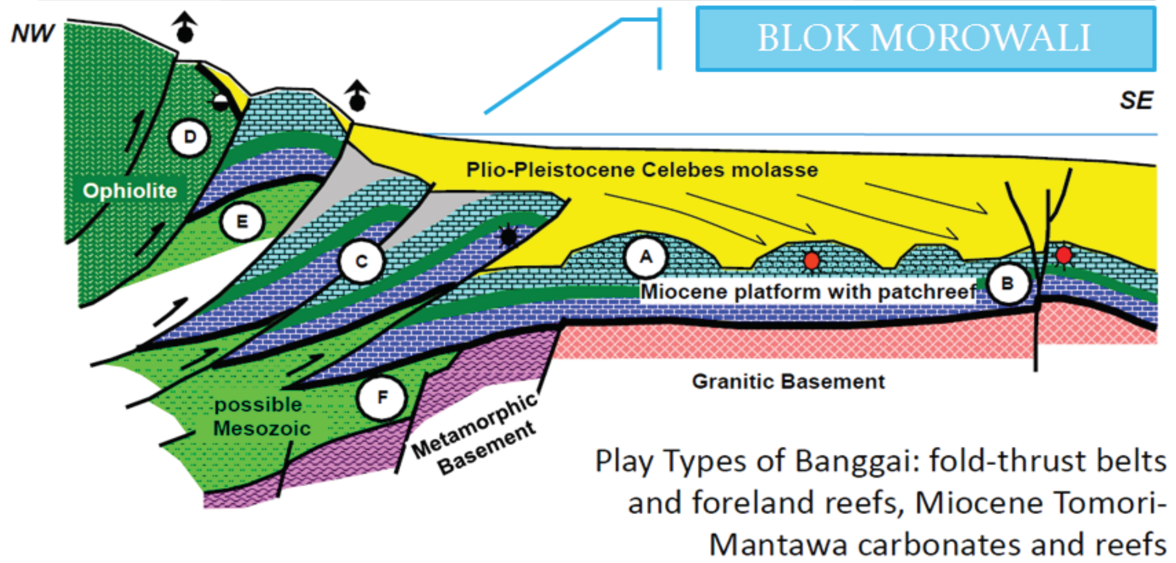



**Figure 10**
**Play Model at Collision Area**

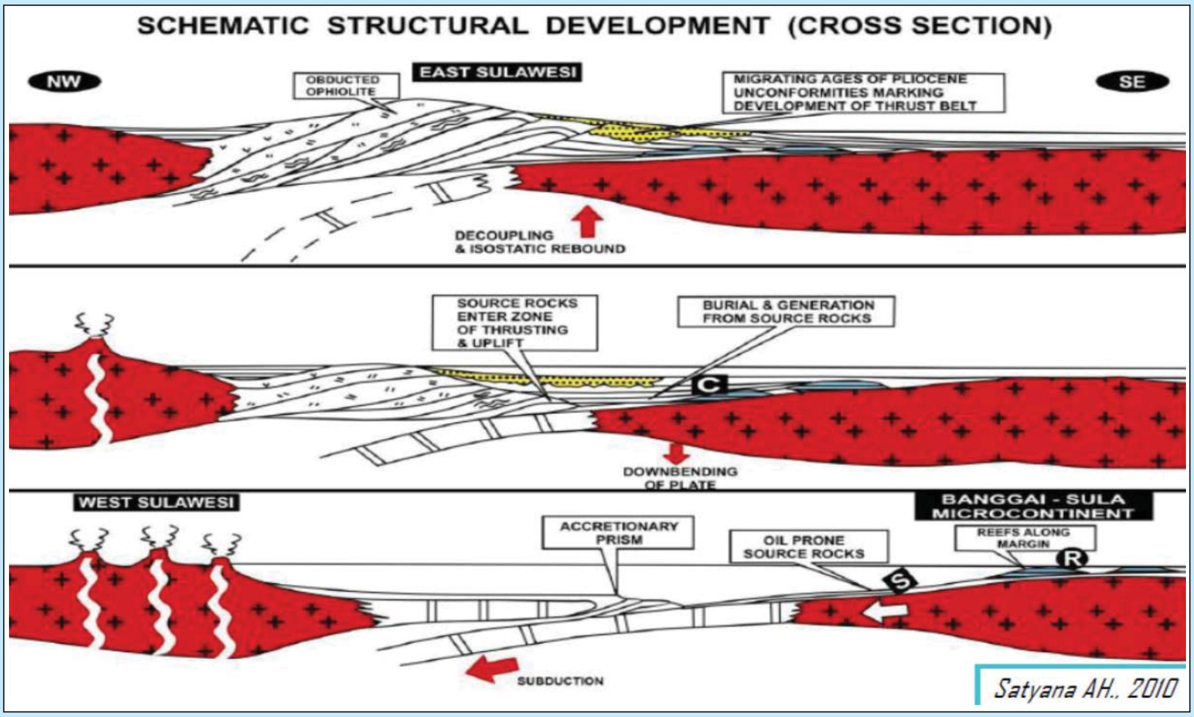



**Figure 11**
**Collision Model in East Sulawesi (Satyana 2010)**

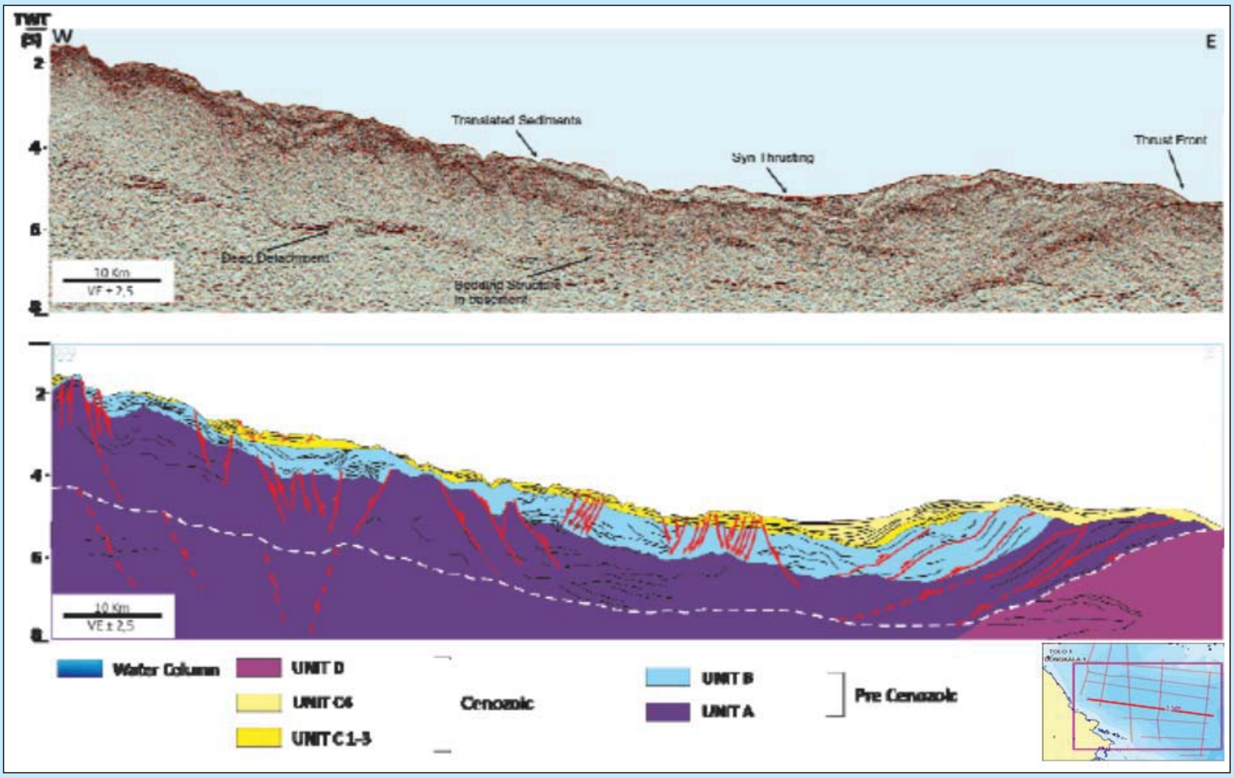



**Figure 12**
**Seismic line and its interpretation (modifield from Rudyawan & Hall 2012)**

so if hydrocarbons already mature at this time will migrate and no hydrocarbon is trapped. This condition increases exploration risk.

## V. CONCLUSIONS

The hydrocarbon potential analyses of the study area that were conducted are based on scientific publications, LEMIGAS internal studies, and seismic and wells data from the Directorate General of Oil and Gas. Based on references studied, the study area is located within the collision area between Banggai-Sula Microcontinent and Sulawesi at Late Cretaceous and Middle Miocene. Regionally the study area is an interesting area for exploration, as some oil and gas fields are already productive and some oil seepages are found just west of this block. Unfortunately, this area during collision and drifting is on the south side of the microcontinent, different to the Matindok, Minahaki, and Tiaka areas that are located in front of the Banggai-Sula Microcontinent. Therefore, source rock and reservoir rock within the study area are still unclear. New seismic data shows better quality compared to the old data. These data penetrate more than 6 seconds and show sediment rock that is interpreted as from the Mesozoic age. Hence, the Mesozoic sedimentary rock may be an exploration target in this study area. In order to re-evaluate the petroleum system element of the study area, it is suggested that a geology and geophysical study be conducted by applying the latest seismic data that was surveyed by PT. TGS - NOPEC and by PT. ECI – PGS.

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