Geological Aspect and Hydrocarbon Potential in West Timor

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Abstract. Geological condition of the West Timor is originated from the Australian Continent Terrane, Banda Arc Terrane and local deposited rocks. The geology of the study area specifically is divided into Banda Terrane units, Australian Passive Margin Sequence, Gondwana Sequence, Post-Orogenic Sequence, Syn-Orogenic Sequences and Bobonaro Clay Complex. This study aims to analyze the geology and hydrocarbon potential includes the source rock, reservoir rock and seal rock in the West Timor area. The Oligocene-Miocene Mutis Complex beginning the collision between the Asian Continent and the Australian Continent. In this study, it was shown that the highest collision activity occurred at the end of the Miocene - Early Pliocene and continued to recent. Outcrop samples were collected and GC-MS analyses performed in the laboratory for source rocks. The result shows that the main source rocks found was shale of the Aitutu Formation (Triassic) and shale from the Wailuli Formation (Early Jurassic) with Ro>0.7, they are indicating mature source rocks. The source rocks are thought to be generated in a shallow marine environment and low energy condition with a mixture of terrestrial material. Halobia fossil was found out on the outcrop, which is play as marker fossil of the Triassic age. A reservoir rock is the sandstone from Oebaat Formation. Oebaat Formation consists of interbedded grainstone-wackestone. Belemnite fossil was found on the outcrops, which is marker as a fossil from Jurassic age. The secondary reservoir is a limestone of the Nakfunu Formation (Lower Cretaceous). The reservoir is thought to be generated in a high-density turbidity condition in shallow marine environment. Shale from Wailuli Formation (Early Jurassic) can be a potential seal rock.

1. Introduction
Timor Island is one of the most complex geological features in Indonesia archipelago. West Timor is originated from the Australian Continent Terrane, Banda Arc Terrane and local deposited rocks. The geology of the study area specifically is divided into Banda Terrane units, Australian Passive Margin Sequence, Gondwana Sequence, Post-Orogenic Sequence, Syn-Orogenic Sequences and Bobonaro Clay Complex..

Kolbano area is located on the Southeast coast of Timor. Here several rocks of the Mesozoic and Cenozoic ages are exposed.

2. Data and Method
Geological fieldwork has been carried out in Kolbano area and it surroundings. Some rock samples were taken for analyses of Total Organic Carbon (TOC) and Gas Chromatography – Mass Spectrometry (GC – MS) for gases[1].

Structural geology measurements like bedding plane, fold, faults and veins were measured for further structural analyses.
2.1. Regional Geology
Regional geology of the Timor Island reflects a collision zone between Banda Arc and Australian Passive Margin (Figure 1). This Island has been explored for petroleum since the early 20th century.

The existence of Timor has a good correlation to Banda Arc which have two belts in “U” shape that under influence of the interaction between three main crusts in the word namely Indo-Australia, Pacific and Eurasian [2]. Banda Arc can be recognized as Banda Suture because three crusts has been converge there [3]. In general, Timor Island can be divided into:
1. Inner belt of the volcanic composed of volcanic rocks, calc-alkaline, with volcanic elastic sediment and carbonate.
2. Outer arc of the Banda composed of igneous, sediment and metamorphic.

![Figure 1. (A) Regional Tectonic Map of the Eastern Indonesia and Northern Australia (B) Geological map of the Kolbanu area.](image)

2.2. Structural Geology
The most dominant structure of the area are fold and thrust fold trends to east northeast – west southwest [6]. There are some strike-slip dextral with northwest – southeast trending and also some sinistral fault directed northeast – southwest. Normal fault are available in the field but they are minor only.

2.3. Stratigraphy
Rocks of the Timor Island can be divided into Mesozoic, Cenozoic, and Quaternary (Figure 1 (B) and Figure 3).

Commence from the oldest to the youngest the formations will be provided here. Maubisse Formation is mainly composed of Early–Late Permian limestone and extrusive rocks member [7,8] Aitutu Formation is dominantly composed of white mudstone, pink and intercalated by mudstone, which colour grey until black. Babulu Formation contain intercalation of the shale and mud, thinly bedded sandstone dan massive sandstone. Wailuli Formation is dominated by dark grey claystone and shale intercalated by limestone rich of organics material and calsilutite. This formation is mainly composed of the massive sandstone with belemnite fossils, interbedded marl and sandy marl and shale. Nakfunu Formation contain radiolarite, claystone, calsilutite, shale and calcarenite, wackestone and packstone. Ofu Formation is dominantly by a very hard and massive limestone, conoidal. Viqueque Formation shows a succession of the coarsening upward of the chalk and calcilutite to sandstone and is covered by conglomerate of the Quaternary and some limestone.
3. Result and Discussion

A brief result of this research shows in the Table 1 and Table 2. In Table 1 shows the result analyses of the Total Organic Carbon samples. The samples analyses result show that samples of the Aitutu Formation are immature, late mature until over mature. Table 2 shows the influence of non hydrocarbon gas. These need a further analyses like carbon – isotop to make sure about the composition of the gas samples.

**Table 1. Result of the Total Organic Carbon analyses**

| No. | Sample Id | General Lithology Description | TOC (%) | Formation | Maturity (Peter and Cassa, 1994) |
|-----|-----------|-------------------------------|---------|-----------|----------------------------------|
| 1   | 18JW01A   | Meta-shale (?), redish light grey, calcareous | 0.16    | Aitutu    | Immature                         |
| 2   | 18JW01C   | Shale, dark grey, calcareous   | 1.07    | Aitutu    | Late Mature                      |
| 3   | 18JW01D   | Shale, dark grey-black, calcareous | 7.97    | Aitutu    | Over Mature                      |
| 4   | 18JW01E   | Shale, rose-colored, calcareous | 0.16    | Aitutu    | Immature                         |
| 5   | 18JW014   | Shale, light grey, calcareous  | 0.15    | Aitutu    | Immature                         |

**Table 2. Result of the gas analyses using GC-MS**

| No. | Component | Samples | 18 NV 02 | 18NV04 |
|-----|-----------|---------|----------|--------|
| 1   | Carbon dioxide | CO₂ | 0.56 | 0.09 |
| 2   | Oxygen     | O₂     | 23.01   | 22.12  |
| 3   | Nitrogen   | N₂     | 61.21   | 75.47  |
| 4   | Methane    | C₁     | 15.22   | 2.31   |
Figure 3. Halobia fossil of Aitutu Formation in Toeheum River: (a) 18JW006; (b) 18JW007

Aitutu Formation consist of shale that looks compact, and thinly bedded (Figure 4). Some beds appear to fining upward from fine sand to clay. The abundance of halobia fossil in this formation as indicator for Triassic age (Figure 3). Marl of this formation has vitrinite reflectance (Rv) ranges from 0.67 to 0.73% which maturity early peak mature for oil generation at catagenesis stage. On the other hands, black shale vitrinite reflectance (Rv) ranging from 0.43 to 0.57% indicates an immature to early mature for dry gas generation at diagenesis stage [9].

Figure 4. Lithological log of the Aitutu Formation which exposed in Toeheum River.

Oebaat Formation is well exposed in Oebaat area. It is characterized by brownish grey sandstone, very fine in grain size, carbonaceous and the present of *Belemnopsis sp* (Figure 7). It is well remark for Late Jurassic age. Quartz sandstone of the Oebaat Formation is characterized by its highly porosity. The lower part of Oebaat formation shows the present of quartz sandstone with abundance of *Belemnopsis sp.*, with some siltstone intercalations (Figure 5). The upper part of this formation are dominated by interbedded of the wackestone and grainstone (Figure 6).
Figure 5. Lithological log lower part of the Oebaat Formation which is dominated by quartz sandstone with huge of belemnite.

Figure 6. Lithological log of the upper part Oebaat Formation contain interbedded between wackestone and grainstone.

Figure 7. (a) Grey limy sandstone interbedded with shale; (b) Belemnopsis sp. of Oebaat Formation.
Figure 8. Lithological column of the Wailuli Formation in the Lakat area.

Wailuli Formation is dominated by intercalation of the grey shale and red/brown shale. Shale are interbedded by mudstone lenses and some manganese nodul (Figure 8).

Geochemical analysis result showed in Table 3 which is evaluated using Rock-Eval Pyrolisis and important for determine source rock potential. Samples with HI values from 300 to 600 mg HC/g TOC represent a type II kerogen, whereas HI values from 50 to 200 mg HC/g TOC represent a type III kerogen. Shale samples was taken from 16 outcrop samples of Aitutu Formation and 10 shale samples from Banli-1 well of Wailuli interval formation. The analyzed shale samples for Aitutu Formation have HI values between 20 to 500 mg HC/g TOC (Table 3), and are mostly represent Type II kerogen and these kerogen type is in agree with modified van Krevelen diagram in Figure 11, whereas the Wailuli Formation shale samples from Banli-1 well have HI values between 100 to 150 mg HC/g TOC which means represent type III kerogen. Cross-plots of Total Organic Carbon (TOC) versus potential yield (PY) of Aitutu Formation showed good to very good source rock potential and Wailuli Formation showed poor to excellent source rock potential (Figure 10). Thermal maturity from Tmax value of Aitutu Formation between 405 to 434 °C and Wailuli Formation between 426 to 434 °C both are in immature stage.

Figure 9. Cross-plots of Total Organic Carbon (TOC) versus potential yield (PY) of Aitutu Formation and Wailuli Formation (after [10]).
**Figure 10.** Hydrogen Index versus Tmax diagram (modified van Krevelen diagram) of Aitutu Formation and Wailuli Formation

**Table 3.** Geochemical results of the shale samples of Aitutu Formation from Outcrops samples and Wailuli samples of Banli-1 well

| Sample ID | TOC (wt %) | Rock-Eval Pyrolysis data | S1 (mg/g) | S2 (mg/g) | PY (mg/g) | Tmax | PI (mg/g) | HI | OI |
|-----------|------------|---------------------------|-----------|-----------|-----------|------|----------|----|----|
| AP 036 H  | 2.85       |                           | 0.11      | 8.29      | 8.4       | 429  | 0.0130952 | 291| 29 |
| AP 036 I  | 9.16       |                           | 0.31      | 42.04     | 42.35     | 418  | 0.00732  | 459| 45 |
| AP 037 C  | 0.33       |                           | 0.03      | 0.08      | 0.11      | 405  | 0.2727273 | 24 | 69 |
| AP 039 B  | 2.47       |                           | 0.09      | 4.22      | 4.31      | 434  | 0.0208817 | 171| 88 |
| AP 057 C  | 0.19       |                           |           |           |           |      |          |    |    |
| KW 039-A  | 1.5        |                           |           |           |           |      |          |    |    |
| KW 042-B  | 0.23       |                           |           |           |           |      |          |    |    |
| KW 045-B  | 8.07       |                           |           |           |           |      |          |    |    |
| KW 071 A  | 0.11       |                           |           |           |           |      |          |    |    |
| KW 071 B  | 0.21       |                           |           |           |           |      |          |    |    |
| KW 078 B  | 0.43       |                           |           |           |           |      |          |    |    |
| DNS 005   | 0.8        |                           |           |           |           |      |          |    |    |
| DNS 006 A | 0.51       |                           | 0.09      | 0.15      | 0.24      | 432  | 0.375    | 29 | 33 |
| DNS 007 A | 0.17       |                           |           |           |           |      |          |    |    |
| DNS 007 B | 0.14       |                           |           |           |           |      |          |    |    |
| DNS 008 A | 0.17       |                           |           |           |           |      |          |    |    |
| 3630-3660 ft | 1.18 |                           | 0.28      | 1.26      | 1.54      | 427  | 0.1818182 | 107|    |
| 3660 ft    | 2.49       |                           | 0.22      | 3.44      | 3.66      | 434  | 0.0601093 | 138|    |
| 3660-3690 ft | 2.68 |                           | 0.26      | 3.3       | 3.56      | 433  | 0.0730337 | 123|    |
| 3678 ft    | 1.86       |                           | 0.33      | 2.52      | 2.85      | 430  | 0.1157895 | 135|    |
| 3700 ft    | 2.46       |                           | 0.33      | 2.84      | 3.17      | 430  | 0.1041009 | 116|    |
| 3810-3840 ft | 2.47 |                           | 0.45      | 2.82      | 3.27      | 426  | 0.1376147 | 114|    |
| 3840-3870 ft | 1.84 |                           | 0.31      | 2        | 2.31      | 426  | 0.1341991 | 109|    |
| 3870-3900 ft | 2.64 |                           | 0.46      | 3.66      | 4.12      | 430  | 0.1116505 | 139|    |
| 3900-3930 ft | 2.34 |                           | 0.56      | 3.48      | 4.04      | 427  | 0.1386139 | 148|    |
| 3930-3960 ft | 1.64 |                           | 0.2       | 1.62      | 1.82      | 429  | 0.1098901 | 99 |    |
4. Conclusion
This research still on going until current time. As preliminary conclusions, there are several important notice: Source rocks on Kolbano area definitely shale of the Aitutu Formation and Wailuli Formation, Reservoir of the research area should be quartz sandstone of the Oebaat Formation and conglomeratic rocks of the Quaternary alluvium deposits, Seal rocks must be shale of the Wailuli Formation and clay within alluvium, There are two proposed trapping mechanisms i.e. structural trap within Mesozoic Play and stratigraphic trap for Quaternary Play.

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