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Characteristics of the Triassic Source Rocks of the Aitutu Formation in the (West) Timor Basin

ASEP KURNIA PERMANA¹, ARIS KUSWORO¹, and ANDI HERI PRASTIAN²

¹Center for Geological Survey, Geological Agency, Ministry of Energy and Mineral Resources
Jln. Diponegoro No.57 Bandung, Jawa Barat, Indonesia

²School of Geology, Faculty of Engineering, Diponegoro University
Jln. Prof. H. Soedarto, S.H, Tembalang, Semarang, Jawa Tengah, Indonesia

Corresponding author: permana_ak@yahoo.com or permana@grdc.esdm.go.id

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Abstract - The Triassic rocks of the (West) Timor Basin mainly deposited in the marine environment have been identified. The fine-grained clastic and carbonate rocks of this Triassic marine facies are considered to be the most promising source rocks potential in this basin. Geochemical and petrographic data from outcrop samples of the Triassic carbonate of Aitutu Formation are presented in this paper, in terms of the organic maturation, kerogen type, and the origin of the organic matter. Some representative selected samples were subjected to Rock-Eval Pyrolysis, vitrinite reflectance measurement, and thermal alteration index determination as well as bitumen extraction. The extracts were then analyzed by the GC-MS (Gas Chromatography-Mass Spectrometry). The samples were collected from a marine deposit of the Triassic sequence. The TOC (Total Organic Carbon) values of the analyzed samples range between fair and rich level (0.51% - 9.16%, wt.%, TOC), whilst the kerogen is dominated by Type II with minor Type III. The organic matter was considered to be predominantly oil/gas prone with lesser gas prone potential. The thermal maturity assessed from T_{max} , TAI, and vitrinite reflectance shows an immature to early peak mature stage. The biomarkers indicate mainly that the organic matter was derived from mixed source rocks facies containing alga debris and higher plant terrestrial origin.

Keyword: source rock potential, Triassic Aitutu Formation, (West) Timor Basin

INTRODUCTION

Several surface seepages of oil and gas occur in the Timor area, and have been mapped and described by Audley-Charles (1968) and Charlton (2001). These seepages are mainly distributed within the East Timor, and only two seepages in West Timor. The source of these seepages is believed to be derived from the Late Triassic-Jurassic source rocks. Price *et al.* (1987) and Peters *et al.* (1999) interpreted a similar aged source rocks at Seram Island, in the northern Banda Arc. They stated that biomarkers for Seram oils suggest a Late Triassic or Early Jurassic micritic limestone source, deposited under highly reducing or anoxic conditions.

The source rock potential of the autochthonous rocks in the Timor are considered to have close affinities to the northern Australian shelf. Jurassic shales of the Elang and Plover Formations are interpreted as the primary source rocks on the Australian North West Shelf. The Late Permian to Cretaceous sedimentary section of the shelf is generally considered to have a good source rock potential, with the Cretaceous being considered to be sufficiently mature at the northern parts of the shelf, in the surrounding areas of the Timor trough (Kraus and Parker, 1979).

Triassic sedimentary rocks are well exposed in the Fatu and Toeheum or Meto Sections, Kolbano Area (Permana, 2012). Bird (1987) and

Cook (1986) comprehensively described the sedimentological characteristics of this Triassic sequence. The Triassic Aitutu Formation that mainly comprises well-bedded limestone of open marine environment indicates a better source rock potential (Permana, 2012). A similar range of lithofacies characteristics is found in the Triassic sequence of the East Timor, and these have been suggested as potential source rock sequences by Audley-Charles and Carter (1972) and Charlton (2001). Thus, the Triassic sedimentary rocks of Aitutu Formation in this area may also have a similar source rock potential with the Triassic sequence in the East Timor.

The aim of this paper is to present the geochemical and petrographic characteristics of the organic rich shales and marl from the Triassic Aitutu Formation, including organic maturation,

kerogen type of the organic matter, and the origin of the organic matter for evaluating source rock potential.

METHODS

The study was carried out based on outcrops of the Triassic Aitutu Formation, mainly along the Noil Fatu and Toeheum, Kolbano Area (Figure 1). Selected rock samples were collected from the outcrops and used for several analytical techniques. Sixteen thin sections from those samples were also analyzed under transmitted light microscopy to identify the microfacies of the rocks.

Five polished sections of the fine-grained clastic rock (shale and marl) samples were examined

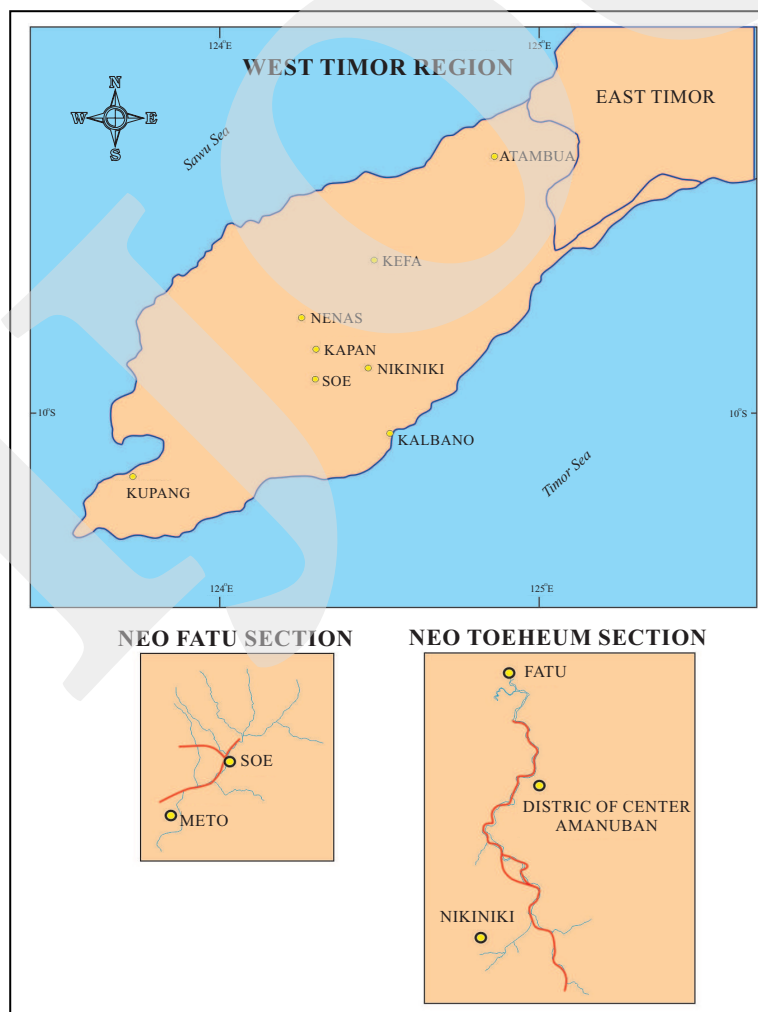


Figure 1. Locality map of the studied area (Noe Fatu and Toeheum Sections).

by using combined techniques of petrological or-
ganic microscopy (transmitted light microscopy)
and palynofacies techniques, including vitrinite
reflectance measurement, maceral identification,
and thermal alteration index determination. Five
hand picked samples from the outcrops were also
subjected to geochemical analysis, such as rock-
eval pyrolysis (TOC, T_{max} , HI, OI, PI, S1, S2,
and S3 parameters). Bitumen extraction, liquid
chromatography, and GC-MS were conducted
on two of them.

RESULTS

Lithofacies

The most representative outcrops of the Trias-
sic Aitutu Formation are exposed in the Noe Fatu,
Niki-Niki area and Noe Toeheum or Meto, near
Soe. This formation mainly consists of well bed-
ded, white or pink limestone and light grey limy
sandstones with interbedded grey to dark grey or
black of shales and marls, with sharp and planar
contact, some are highly folded (Figures 2a,b).

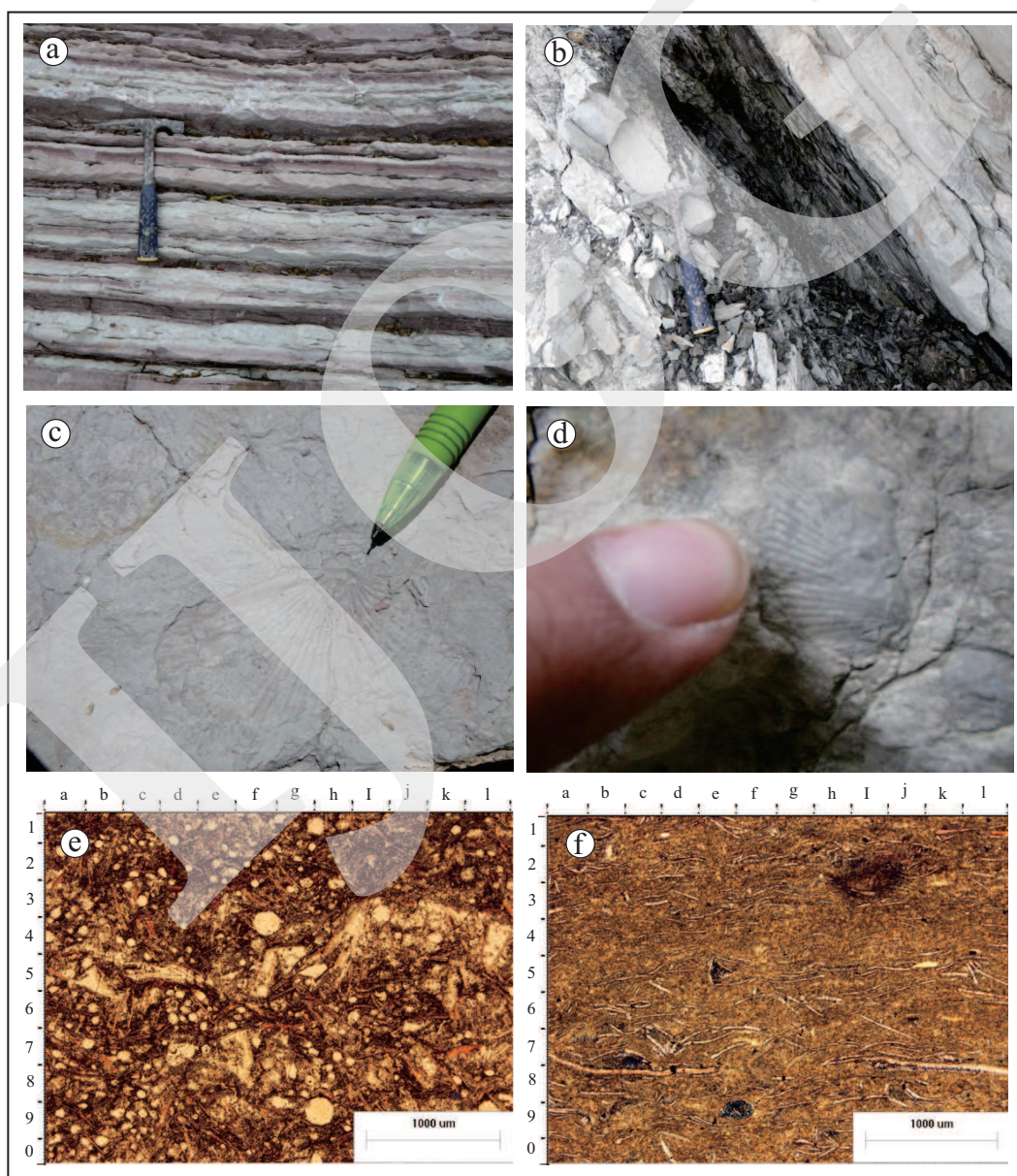


Figure 2. (a and b) white or pink limestone and light grey limy sandstones with interbedded grey to dark grey or black of shales and marls, with sharp and planar contact; (c) *Halobia spp.*; (d) *Monotis sp.*; (e) Radiolarian Wackstone; (f) Wackstone with green algae content.

Macrofossil and other fossil fragments are commonly found in the bedding plane, such as *Monotis* sp. (Middle Norian-Rhaetian) and *Halobia* spp. (Carnia-Norian), as shown in Figures 2c,d.

Petrographic examination of 16 samples shows that this formation is composed of bioclastic, radiolarian, algal, and foraminiferal mudstone, wackstone, and grainstone (Figures 2e and f). Permana (2012) indicates that the algal limestone was mainly deposited in a bay or pond at the platform interior restricted to open marine. However, the foraminiferal and radiolarian limestone were deposited at the deep shelf margin to basin margin environment, based on the standard facies zone of the modified Wilson (1975; Figure 3).

Maceral-Vitrinite Reflectance-TAI

The platform interior restricted to open marine samples (AP 36-H, AP 36-I, and KW 45-E) contains moderate to good content of organic matter. The organic matter predominantly consists of lamalginite and sporinite (Figure 4A), with less amount of liptodetrinite and minor framboidal pyrite (Figure 4b) content. The vitrinite reflectance values (R_o) ranging from 0.65 – 0.74% indicate that the organic matter is early peak mature for oil generation. The thermal alteration index (TAI) varying from 2 (yellow) to 3 (dull orange) reveals that the thermal maturation of organic matter of these sediments is early mature at catagenesis stage.

The deep shelf margin to basin margin shale samples (KW 39-A and KW 42-B) contain poor organic matter content. The organic matter predominantly comprises vitrinite and inertinite, with lower sporinite and liptodetrinite and minor iron oxides content. The vitrinite reflectance values (R_o) varying from 0.43 – 0.57% indicate that the organic matter is immature to early mature for dry gas generation. TAI ranging from 1 (yellow) to 2 (amber yellow) shows that these sediments are thermally immature at diagenesis stage.

Rock-Eval Pyrolysis

The TOC contents of two samples of the platform interior restricted to open marine marl from the Noe Fatu section are 2.85% (AP 36-H)

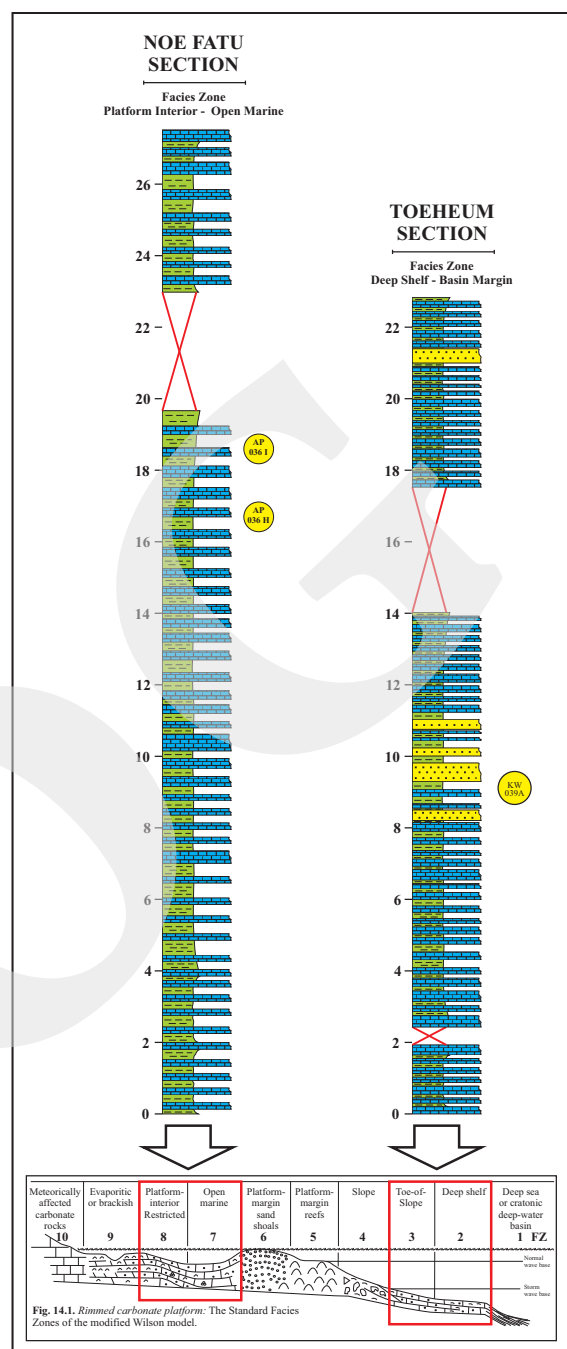


Figure 3. Lithological succession of the platform interior restricted to open marine and deep shelf margin to basin margin facies zone.

and 9.16% (AP 36-I) respectively. The genetic hydrocarbon potential (S_1+S_2) or PY of those two samples are 8.40 and 42.35 mg HC/gm rock, indicating a potential for oil/gas generation (Table 1).

Kerogen type analysis from the respective Hydrogen Index (HI) vs. Oxygen Index (OI) plotted on van Krevelen diagram, indicates the

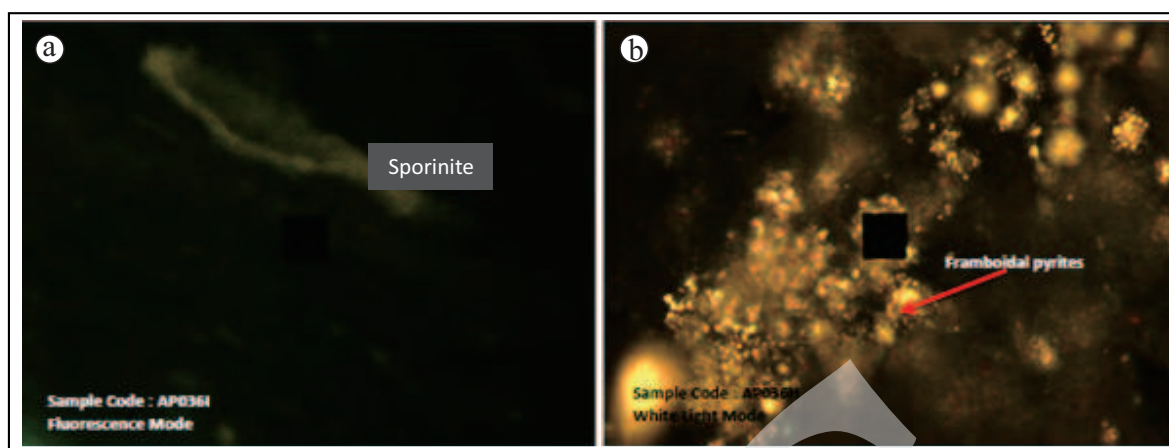


Figure 4. Maceral composition of the organic rich sediments, showing (a) sporinite maceral, and (b) mineral matter of framboidal pyrite.

Table 1. Rock-eval pyrolysis and TOC Content of the Organic rich Sediments from the Aitutu Formation

No	Sample ID	Lithology	TOC	Mg/gm rock			Tmax (°C)	Production Index	Potential Yield	Hydrogen	Oxygen
			(wt.%)	S1	S2	S3			S1+S2	Index	Index
1	AP 36-H	Marl	2.85	0.11	8.29	0.82	429	0.01	8.4	291	29
2	AP 36-I	Marl	9.16	0.31	42.04	4.16	418	0.01	42.35	459	45
3	KW 039-A	Shale	1.5	0.05	0.15	0.42	428	0.25	0.2	10	28
4	KW 042-B	Shale	0.23	0.12	0.03	0.08	359	0.8	0.15	13	34
5	KW 045-B	Marl	8.07	0.36	44.59	3.37	414	0.01	44.95	552	46

predominance of organic matter of Type II (Figure 5). Thermal maturity from the T_{max} values indicates that this type of organic matter is in immature stage, with T_{max} values of 429° and 418° (Figure 6).

Two samples of the deep shelf margin to basin margin shale from the Toeheim or Meto section show a relatively lower TOC value of 1.50% (KW 39-A) and 0.23% (KW 42- B). On the other hand, the open marine marl facies from the same location has a higher TOC value of around 8.07% (KW 45-E). The first two samples also reveal a low hydrocarbon potential (PY) that are around 0.20 and 0.15 mg HC/gm rock, compared to the latter facies showing a high value of PY 44.95 mgHC/gm rock. This may indicate that the two samples from the deep shelf margin to basin margin environment tend to be more gas prone potential (kerogen type III) than the open marine facies (Figure 5). The T_{max} values ranging from 359° to 428° indicate that the organic matter of those sediments is thermally immature (Figure 6).

Eom, Lc, Gc-Gcms

Extraction analysis (EOM) was carried out on two samples from the platform interior restricted to open marine marl (AP 36-H and AP 36-I). Characteristic bitumen of those samples exhibits moderate to very good levels of soluble of organic matter (EOM 1439 ppm to 6026 ppm). Corresponding hydrocarbon yields (262 ppm and 553) suggest poor to good liquid hydrocarbon source potential. The ratios of extractable bitumen to total organic carbon (EOM/TOC) in these samples of 5.05% and 6.58% (Table 2) indicate the presence of indigenous hydrocarbon only.

Liquid chromatography (LC) data show low levels of saturate hydrocarbons (3.13% and 9.30%) and low concentration of aromatic hydrocarbons (6.05% and 9.30%). The concentration of polar compounds (NSO's) plus asphaltene that are relatively high (total 81.78% and 90.82%), suggests that they are typically moderate maturity-generated hydrocarbon (Figure 7). The

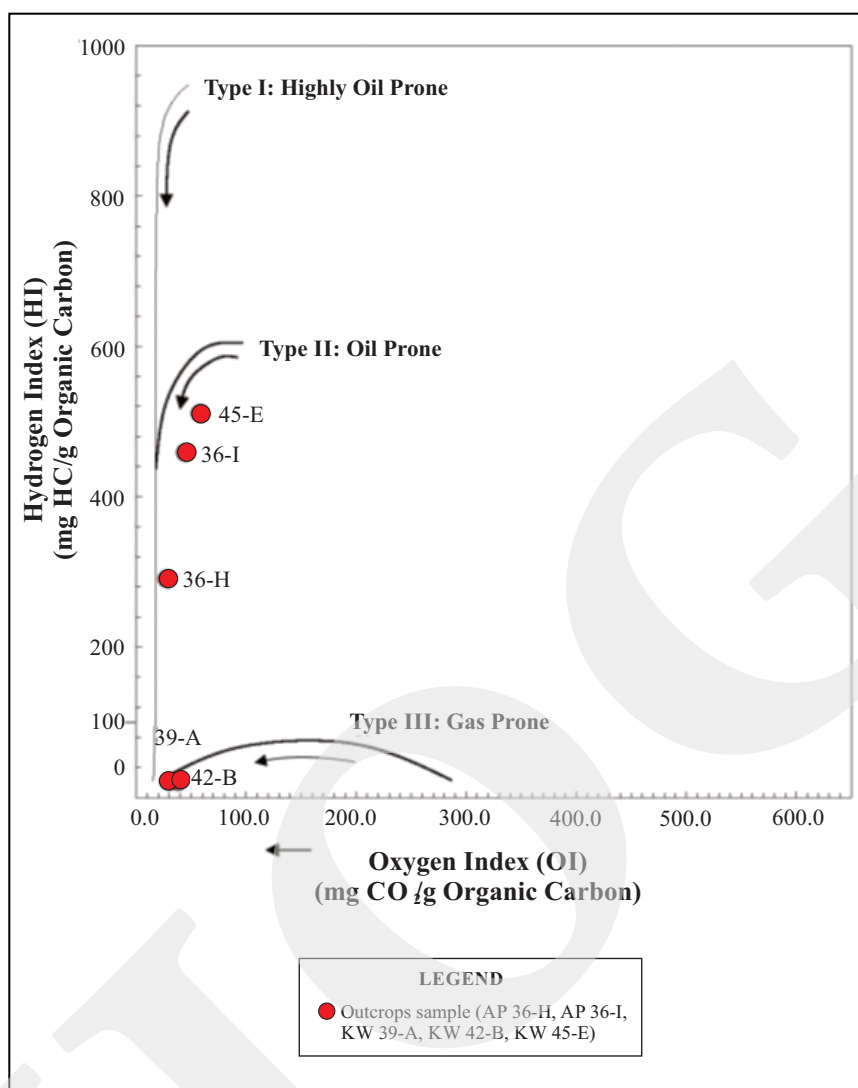


Figure 5. Van Krevelen diagram of the organic rich sediments of the Triassic Aitututu Formation, showing kerogen type and oil-gas prone category.

chromatograms (from the GC-MS analysis) are characterized by very limited normal alkenes distribution from nC_{15} to nC_{25+} (Figure 8). These GC features are commonly seen in low to moderate maturity indigenous hydrocarbons. The gas chromatography (GC) chromatograms are characterized by very limited normal alkenes distribution from nC_{15} to nC_{25+} (Figure 8). These GC features are commonly seen in low to moderate maturity indigenous hydrocarbons.

Biomarker analysis of these extracts has been performed by computerized Gas Chromatography-Mass Spectrometry, which was undertaken on the saturated fractions. The m/z 191 fragmentograms for two extracts (AP 36-H and AP

36-I) display a relatively simple distribution of bacterial-derived $17\alpha\beta(H)$ -hopanes which are dominated by the C_{30} $\alpha\beta(H)$ -hopanes (C_{30} hopanes > C_{29} hopanes). It tends to indicate that the extracts are much more clastic origins than the carbonate material, however the petrography analysis of those sample shows as carbonate rich sediments.

The high abundance of C_{23} tricyclic compound (F) relatively C_{19} and C_{20} tricyclic compound (A and B, respectively) is indicative of an algal origins. The regular steranes for the extracts show full suite of sterane with the $C_{29}\alpha\alpha\alpha$ (R) forms more abundance (47.79% and 44.99%) compared to the $C_{27}\alpha\alpha\alpha$ (R) sterane (40.36% and 41.52%). This points to a significance contribution from

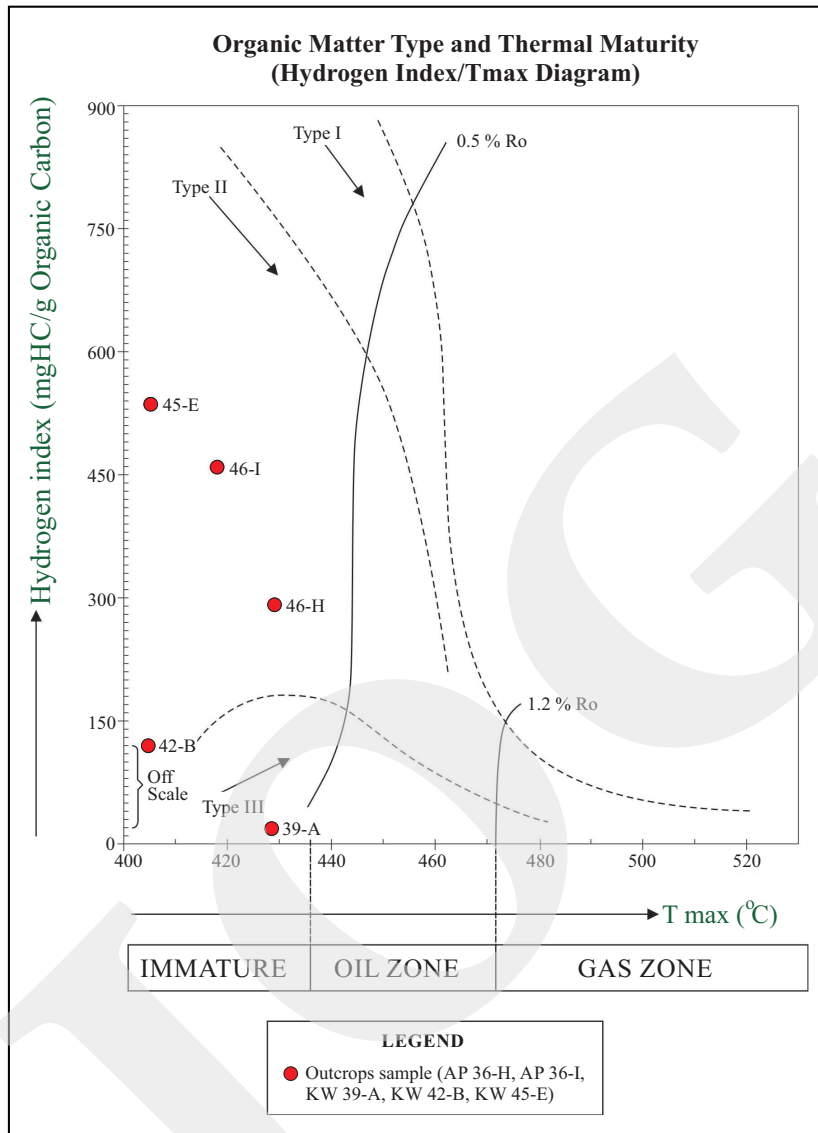


Figure 6. Hydrogen Index (HI) vs. Tmax diagram (modified van Krevelen diagram), showing kerogen type and thermal maturity of organic rich sediments from the Triassic Aitutu Formation.

Table 2. C₁₅₊ Extractable of Organic Matter (EOM) Analysis

No	Sample ID	Lithology	TOC (wt.%)	EOM S1	HC S2	Composition of C 15 + Extractable Organic Matter (Normalised Percent)				Percent			SAT/ Aro
						Sat	Aro	NS O	Asph	EOM/ TOC	HC/ TOC	HC/ EOM	
1	AP 36-H	Marl	2.85	1439	262	9.3	8.91	46.51	35.27	5.05	0.92	18.2	1.04
2	AP 36-I	Marl	9.16	6062	553	3.13	6.05	39.73	51.09	6.58	0.6	9.2	0.52

herbaceous organic material within the pregnitor source rock facies.

Based on the biomarker distribution, it is suggested that the extracts were derived from mixed source rock facies containing algal debris and higher plant terrestrial organic matter. A plot

of the sterane distribution on Huang and Mein-schein's (1979, *in* Waples and Machihara, 1991), paleoenvironment diagram shows that the extracts are situated within a region assigned bitumens derived from a source facies deposited within an estuarine environment (Figure 9).

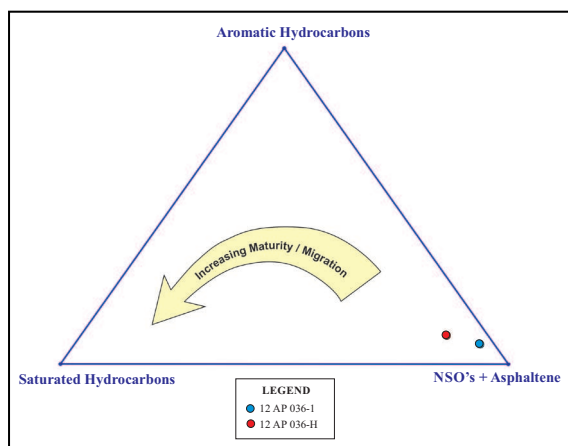


Figure 7. Extract composition plot show moderate maturity-generated hydrocarbon (from totsl, NSO's + Asphaltene).

DISCUSSION

Organic rich sediments (marls and shales) of the Triassic Aitututu Formation indicate a fluctuation of the organic matter content from low to very rich (TOC: 0.23% - 8.07%). The different features are possibly related to the preservation

condition of the organic matter. Pedersen and Calvert (1990) shows that the preservation and productivity of organic material control the formation of organic-carbon rich sediments.

The difference of maturation stage (diagenesis-catagenesis) of the samples are closely controlled by maceral composition and thermal maturation index. Thus, it assumes that the difference of organic material composition would transforms the organic matter into kerogen in different stages of maturation during burial process.

As figure out above, the organic rich sediments of the Aitututu Formation also have different sources of organic material (Kerogen Type II and III). This is related to sedimentary environment setting. Kerogen type II is mainly generated in a reducing environment found in moderately deep marine setting. However, the kerogen type III is primarily derived from terrigenous plant debris, which has been deposited into a deep marine environment.

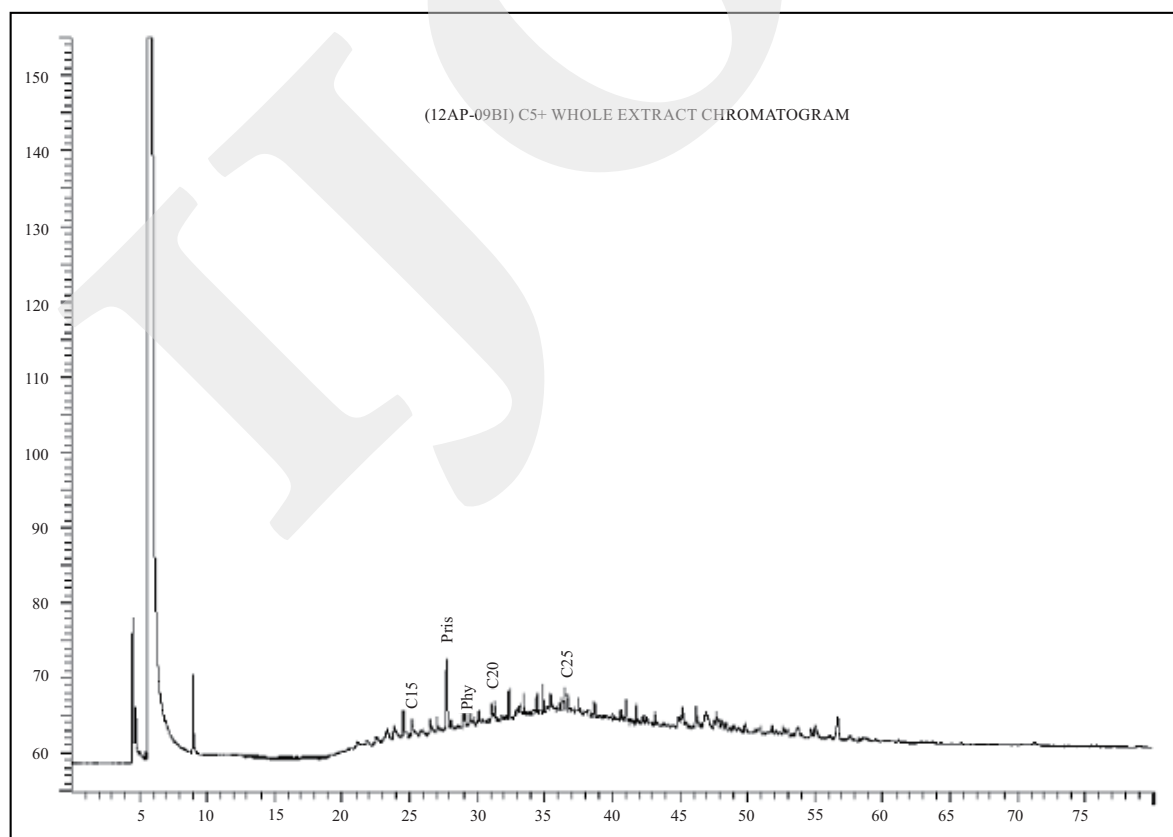


Figure 8. Chromatograms (AP 36-I), showing very limited normal alkenes distribution from nC_{15} to nC_{25+} .

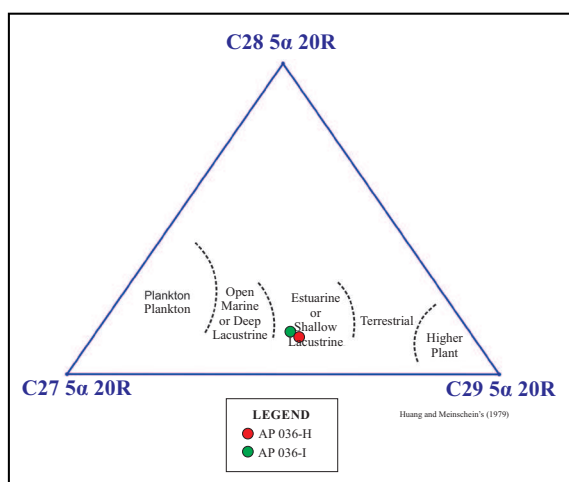


Figure 9. Triangle diagram of C27, C28, and C29 steranes according to Huang and Meinschein (1979, in Waples and Machihara, 1991), showing the source rock environment.

Biomarker analysis of two samples from the platform interior restricted to open marine marl (AP 36-H and AP 36-I) shows a mixed source rock facies containing algal debris and higher plant terrestrial organic matter. Thus, it reveals that terrestrial plant debris was transported into estuarine environment and mixed with alga debris, both of them were then well preserved in this environment setting as organic rich sediments.

Therefore, the formation of source rocks of the organic rich sediments of the Aitutu Formation, not only depends on favourable preservation condition of organic matter, but also the environment setting during the formation of source rock.

CONCLUSIONS

Based on the standard facies zone of the rimmed carbonate platform (Wilson, 1975), the Triassic Aitutu Formation consists of at least two facies zones, those are platform interior restricted to open marine marl and deep shelf margin to basin margin shale.

Marl from the platform interior restricted to open marine facies zone predominantly consists of lamalginate, sporinite, and minor pyrite content, with (Rv) ranges from 0.67 – 0.73%, falling under early peak mature for oil generation at catagenesis stage. On the other hand, black

shale of the deep shelf margin to basin margin, predominantly consists of vitrinite and inertinite, with lower sporinite and liptodetrinite, and minor iron oxide content, whilst vitrinite reflectance (Rv) ranging from 0.43 – 0.57%, indicates an immature to early mature level for dry gas generation at diagenesis stage.

Extraction analysis of two samples from the platform interior restricted to open marine indicates that bitumen of those samples exhibits a moderate to very good level of soluble of organic matter, poor to good liquid hydrocarbon source potential.

Biomarker analysis of two samples from the platform interior restricted to open marine, shows the extracts were derived from mixed source rock facies containing algal debris and higher plant terrestrial organic matter originated from a source of shallow lacustrine environment.

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