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GUMAI SHALES OF JABUNG AREA: POTENTIAL SOURCE ROCKS IN JAMBI SUB-BASIN AND THEIR CONTRIBUTIONS TO THE NEW PETROLEUM SYSTEM

Lambok P. Marpaung[1], I Nyoman Suta[1], Awang H. Satyana[2]

[1]PetroChina International Jabung Ltd.
[2]BPMIGAS

ABSTRACT

Jabung area has been proven as prolific hydrocarbon producer. It is well known that oils and gas have been sourced from terrestrial to fluvio-deltaic shales and coals of Talang Akar Formation. In addition to this, based on geochemical and geologic data, shales of Gumai Formation display characteristics and capability of both potential and generating source rocks.

Source potential of Gumai shales is indicated by TOC value of 0.79-8.00 %, potential yield of 0.3-24.83 mg HC/g TOC and T-max of 426-445 ^{o}C. Kerogen type II and III predominate the Gumai source shales. Biomarker parameters show that the shales were deposited in anoxic to suboxic environment, indicating a good preservation of organic materials. Geologic setting determines that the Gumai shales were deposited in more marine setting than those of the Lower Talang Akar. However, inputs from higher land plants still influence the source facies. Available maturation data and modeling from well located in the kitchen area reveals that the Gumai source section is within immature to early mature window. Hence, the Gumai source from the existing data analysis is basically the potential source rocks.

However, some oils in Jabung area show close correlation to the Gumai shales, showing that the shales have been generating oils. Knowledge of Gumai as both potential and generating source rocks will create new petroleum systems of Gumai shales-Gumai sands (.) or Gumai shales-Air Benakat sands (.). These systems will make migration routes from source to reservoirs to be much simpler. The new petroleum systems will significantly influence the future exploration strategy in the Jabung area.

INTRODUCTION

Jabung area is located in Jambi province become part of northern edge of South Sumatra Basin (Figure 1). There are active 8 producing fields in the area that currently producing in average of over 60,000 BOE in a day from both oil and gas. Knowledge about petroleum system showing that hydrocarbon in this area was generated by source rocks from shales and coals of Talang Akar (Marpaung et al. 2005).

Definitely, Robinson (1987), ten Haven and Schiefelbein (1995), explained that hydrocarbon in South Sumatra was derived from lacustrine and terrigenous or fluvio-deltaic source rock. It is shown the non-marine rift-graben system acted as a kitchen and makes a trend that a main source rock was derived from non-marine or terrestrial deposit.

Looking through the rock which is organically rich and mature, it is possible to detect the presence of another potential source rock. Younger interval such as Baturaja and Gumai shales and coals have been introduced to have high potential source rock in the area (Suta, 2003).

This study focuses on the Gumai Formations represented by predominantly marine shales as a result of continuing transgression in this area. The later deposition was followed by a regression and deposition of the upper sandy member as a result of the initial Barisan compression at the end of the early Miocene to the beginning of the Middle Miocene. These Gumai shales were deposited in a low energy environment during regional post rift thermal subsidence.

In this study, TOC, Rock Eval Pyrolisis, Pyrolisis GC, gas chromatography, gas chromatography – mass spectrometry (GC-MS) and carbon isotope data are integrated to access the potential source rock of Gumai Formation.

GEOLOGIC SETTING

There were three tectonic events that controlling the structural history in South Sumatra Basin. First, major extensional event from Eocene to Early Oligocene times resulted in opening up of numerous half grabens whose geometry and orientation was influenced by basement heterogeneity. This process was followed by deposition of Lahat Formation.

Second, rifting ceased approximately 29 Ma ago and the continental crust continued to subside under South Sumatra Basin. High subsidence rates and high relative sea level resulted in a long-live transgression of the basin. This process was followed by deposition of the following syn- and post- rift of Talang Akar, Baturaja and Gumai Formations. Baturaja carbonates is not uniformly developed in the area of study to the west and east due to increased sediment input northwards of the South Sumatra Basin and more pronounced exposure of bioherms enhancing secondary porosity to the south and east (Ginger and Fielding, 2005).

The regressive distal delta front to marginal marine fluvio-deltaic facies of the Air Benakat Formation were deposited as a result of an increased sediment load from the Sunda landmass to the northeast and the emerging Barisan Mountains to the west. The regressive lower to upper delta plain Muara Enim Formation fluvio-deltaic facies were deposited in this environment, and consist of thick channel sands alternating with interdistributary shales and coals

A widespread orogenic event, the Barisan Orogeny, occurred across South Sumatra from 5 Ma to present. Numerous hydrocarbon-bearing structural traps were from at this time with northwest-southeast direction that controls oil fields in the basin at the present. The youngest Kasai Formation is essentially a continuation of the regressive fluvio-deltaic Muara Enim, except for a substantial increase in volcanic extrusives in the form of tuffs and tuffaceous sandstones.

SOURCE ROCK EVALUATION

Nineteen cutting samples have been taken from eleven wells within the Gumai Formation, generally from the lower part of the Gumai Formation. Those wells are SF-1, SF-2, JS-1, JS-2, TI-1, DV-1, SR-1, SR-5, SR-10, PC-1, PC-2. Pyrolisis data and biomarker have been taken from SF-1, SF-2, SR-5 and DV-1. (Table 1). The available data include TOC, Rock Eval Pyrolisis, carbon isotope-13, Pyrolisis GC, GC and GC-MS of saturate terpane and sterane were used to analyse the characteristic of Gumai shales in Jabung area.

TOC and Rock Eval Pyrolisis

Gumai shales have a fair-excellent rock potential with TOC 0,71-8,00 (Figure 3) with the various hydrogen index ranging from 34-607, that showing oil and gas prone in this area. The potential yield (S1+S2) range from 0.3-24.83 indicated the various potential source rock to generate oil and gas. The highest hydrogen index occuring at SR-5 (5050-5060 ft) is evidence of an excellent oil-prone Type II source rock within this unit. Pyrolysis Tmax data (425-445) indicate the sediments have achieved the early stages of maturation will respect to oil generation i.e. marginal – early mature. Maturity was estimeated using 1D modeling software with input geochemical data such as TOC, hydrogen index, oxygen index, kerogen type, pyrolisis Tmax, and production index (PI). Burial history from well JS-1 shows that the early mature stage (Ro=0.5 %) started at 1.5 mya (million years ago) for Gumai Formation (Figure 4).

Kerogen Analysis and Pyrolisis GC

Kerogen analysis of twelve samples in four wells reveals typical Type III kerogen, with 10-95 % vitrinite, 3-86 % non-fluorescent amourphous kerogen (NFA) and only 2-5 % liptinite, consistent with entirely gas-prone organofacies (Figure 5A). Maturity in SR-5 well based on spore color index (5.4-5.6) have shown early mature condition in this unit.

A sample of the rich carbonaceous siltstones in Well SR-5 (5020-5040 ft; 6.61 % TOC, 354 HI) was subjected to pyrolisis-gas chromatography analysis. The thermal extract pyrolysate yielded an extremely light, condensate-like product, dominated by toluence. The S2 pyrolysate is non-waxy and highly paraffinic, with alkene-alkane doublets extending to about C_{30}. It displays a relatively large gas peak, with gas/oil generation index (GOGI=C_1-C_5/C_{6+}) of 1.09 and very low wax/oil generation index (WOGI=C_{23}+/C_{6+}) of 0.02, suggesting a light oil and gas-prone source. Four from Well DV-1, and one from well SF-1 yielded light, aromatic-rich thermal extract chromatograms with low wax content, and moderate pristane/phytane ratios of 2.8-4.0, suggesting a moderately oxidizing depositional environment. S2 pyrolysates were similarly light and rich in aromatic components. Gas/oil generation indices (GOGI=C_1-C_5/C_{6+}) are low to high (0.36-0.90) and wax/oil generation index (WOGI=C_{23+}/C_{6+}) neglible or zero, consistent with a gas/prone source kerogen.

The relative proportion of n-octene, meta- + para-xylenes and phenol in and Figure 5B indicates a Type II/III kerogen, suggesting a moderately high quality kerogen type.

GC and GC-MS

The Gumai Formation extract from SR-5 (5020-5040 ft) yields low concentrations of paraffins extending to c.nC_{35}. High isoprenoid/n-paraffin ratios, pristane/phytane ratio of 3.8 is consistent with mixed marine and terrestrial kerogens in anoxic to suboxic environment (Figure 6).

The terpane profile for the Gumai Formation extract from Well SR-5 (5020-5040 ft) diplays low tricyclic terpane concentration, dominated by the C_{23} “algal” form. Tm/Ts (0.76) and moretane/hopane (0.12-0.38) ratios extremely various on account. The C_{29}/C_{30} hopane ratio is relatively high (0.52-0.86), hopane/sterane relatively high except for SF-2 (6600-6700 ft) as alga influence in anoxic to suboxic environment (Figure 6), and extended hopane concentrations are strongly dominated by the C_{31} pair, as a result of extensive cleavage of the side chain under oxidizing conditions. Sterane distributions display subequal concentration of C_{27} and C_{29} forms consistent with mixed marine/terrestrial source kerogen (Figure 7). These features are all characteristic of calcareous clastic sediment containing mixed algal and terrestrial plant material, deposited under relatively oxidizing marine conditions. Based on carbon isotope-13, this formation was deposited in mixed terrestrial and algal materials with a predominance of algal (Figure 8).

Oil – Source Rock Correlation

Correlation between source rocks and crude oils was based on the distribution of biomarkers such as tricyclic terpane (m/z 191) and sterane (m/z 217). Crude oils samples have been taken from DV-1 well and PC-4 well and the sediment samples have been taken from SR-5 (5020-5040 ft) and SF-1 (5710-5720 ft). Figure 9a shows a terpane model from SR-5 (5020-5040 ft).

Figure 9b shows a comparation of both samples of crude oils and sediments that were taken from Gumai Formation. The correlation was based on tricyclic terpane that dominated by C_{23} (F) with less C_{20} (C). It is showed that deposition environment dominated by algal and terrestrial material such as higher plant. SR-5 (6300-6320 ft) is a Lower Talang Akar samples shows low C_{21} (D) and C_{23} (F) with high C_{20} (C) interpreted as a terrestrial dominated deposited in non-marine environment or fluvio-deltaic. It can discriminate the characteristics of both Gumai and Lower Talang Akar Formations. C_{27}-C_{29} sterane also used for correlation showed a mixed terrestrial and alga zones that correlate with crude oil samples in Jabung area (Figure 7).

Oleanane/ (oleanane+hopane) ratio in oils can be used to determine a relative age from source rock (Peter et al., 1999). Oleanane was derived from Angiosperm that occurred in late Cretaceous and more abundance until Tertier. Sediment samples were taken from SF-2 showing Ol/hop ratio within Gumai (Ol/Hop = 1.08) and Lower Talang Akar Formations (Ol/Hop = 0.23) represent oleanane abundance in younger formation will be greater than older formation in Tertiery source rocks. This indicates in some samples in Jabung area can be comprised in two groups based on oleanane abundance. Figure 10 shows some oils from Talang Akar and Gumai Formations having low-medium oleanane (Ol/Hop 0.27-0.55) compared to oils in Gumai and Air Benakat

Formations having high oleanane (Ol/Hop 0.87-1.12).

This analysis followed by 17 β(H), 21α(H)-moretane to 17α (H), 21β (H)-hopane (Mor/Hop) ratio that decreased with increasing thermal maturity (Grantham, 1986). Moretane/hopane ratio in oil samples within Lower Talang Akar and Gumai Formation is 0.11-0.26 and Gumai and Air Benakat samples 0.24-0.31 (Figure 10) shows all samples derived from tertiary source rocks which younger oils can be found in Gumai and Air Benakat Formations. Based on oleanane abundance and moretane/hopane ratio, the Gumai source rock might be correlated to oils in Gumai and Air Benakat reservoirs.

CONTRIBUTION TO PETROLEUM SYSTEM IN JAMBI SUB-BASIN

Source rock evaluation shows the Gumai Formation has a potential source rock to generate oil and gas. Knowledge of Gumai as both potential and generating source rocks will create new petroleum systems of Gumai shales-Gumai sands (.) or Gumai shales-Air Benakat sands (.). The proven fields in Jabung block are also known in a younger reservoir in the Gumai and Air Benakat Formations such as in N. Geragai, Makmur and West Betara fields.

Fluid movement takes place along fault, shale fractures and local sand bodies as a barrier that fills both the Gumai and Air Benakat reservoirs. The absent / or significantly low content of CO_2 in any reservoir of Gumai and Air Benakat sands in the existing fields of the area support the conclusion that hydrocarbon might have sourced and migrated from the younger formation such as Gumai shales and coals.

The new petroleum systems will significantly influence the future exploration strategy in the Jabung area (Figure 11) and also in Jambi Sub-basin.

CONCLUSIONS

The Early Miocene Gumai Formation is also typically lean and gas-prone, with rare thin oil-prone source beds in wells in proximity to the Jabung area. Though generally immature to marginally mature, the lower part of the formation is mature in the vicinity of the North Geragai Field in the Jabung Block.

Petroleum systems of Gumai shales-Gumai sands (.) or Gumai shales-Air Benakat sands (.) can open the opportunity to explore new plays in exploration strategy. It will help the better knowledge in exploration especially in Jambi Sub-basin.

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TABLE 1: Total Organic Carbon and Rock Eval Pyrolisis of Sediment Samples in Jabung Area

Well	Sample Depth (ft)	TOC Wt %	S1 mg/g	S2 mg/g	Potential Yield mg/g	HI mg/gC	Tmax ^{o}C
SF-1	5714	1.52	0.24	2.19	2.43	144	437
SF-2	6600-6700	1.06	0.4	4.3	4.70	406	444
JS-1	4461	1.23	0.19	1.2	1.39	98	436
JS-1	4789	1.49	0.28	1.99	2.27	134	442
JS-1	4986	2.22	0.26	2.08	2.34	94	441
JS-1	5379	1.65	0.20	1.70	1.90	103	445
JS-1	5510	1.26	0.20	1.02	1.22	81	442
JS-2	5643	1.47		*2.54*		173	441
TI-1	4231	0.75	0.11	0.53	0.64	71	436
TI-1	4330	0.71	0.06	0.24	0.30	34	432
DV-1	4010-4020	1.36	0.56	2.01	2.57	148	428
DV-1	4360-4370	0.98	0.29	1.41	1.70	144	426
SR-1	3855	1.23	0.28	2.07	2.07	168	434
SR-5	5020-5040	6.61	1.45	23.38	24.83	354	429
SR-5	5040-5050	8.00	0.58	14.4	14.98	180	426
SR-5	5050-5060	3.69	1.04	22.38	23.42	607	430
SR-10	4450-4460	0.79	0.08	1.40	1.48	177	430
PC-1	4240-4260	1.27	0.09	1.12	1.21	88	425
PC-2	4100-4120	1.44	0.1	1.66	1.76	115	426

FIGURE 1: Location map of Jabung area in Jambi Province, Sumatra

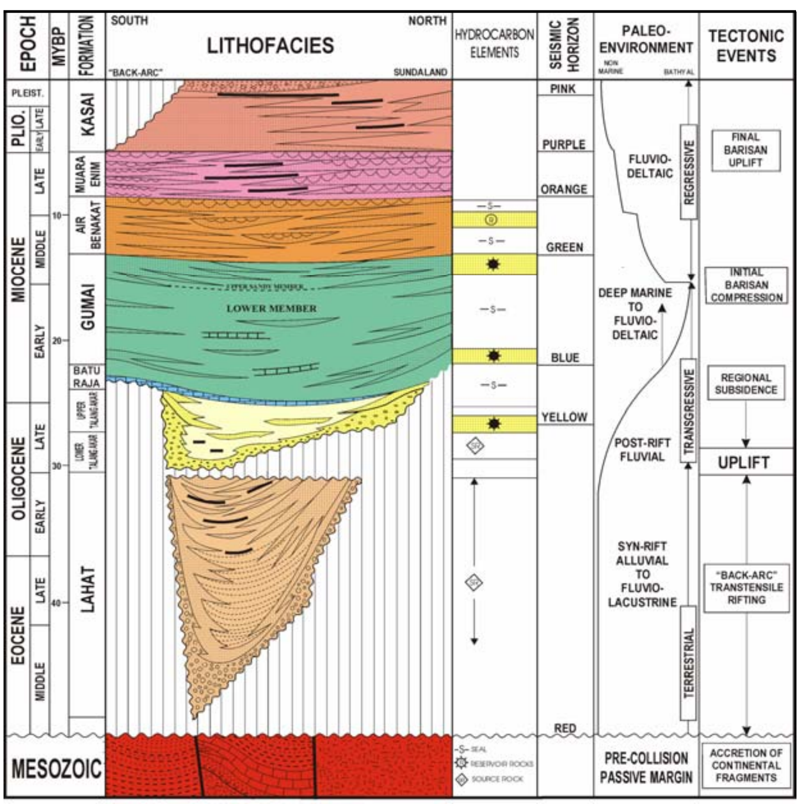

FIGURE 2 : General stratigraphy of Jabung area in Jambi Sub-basin

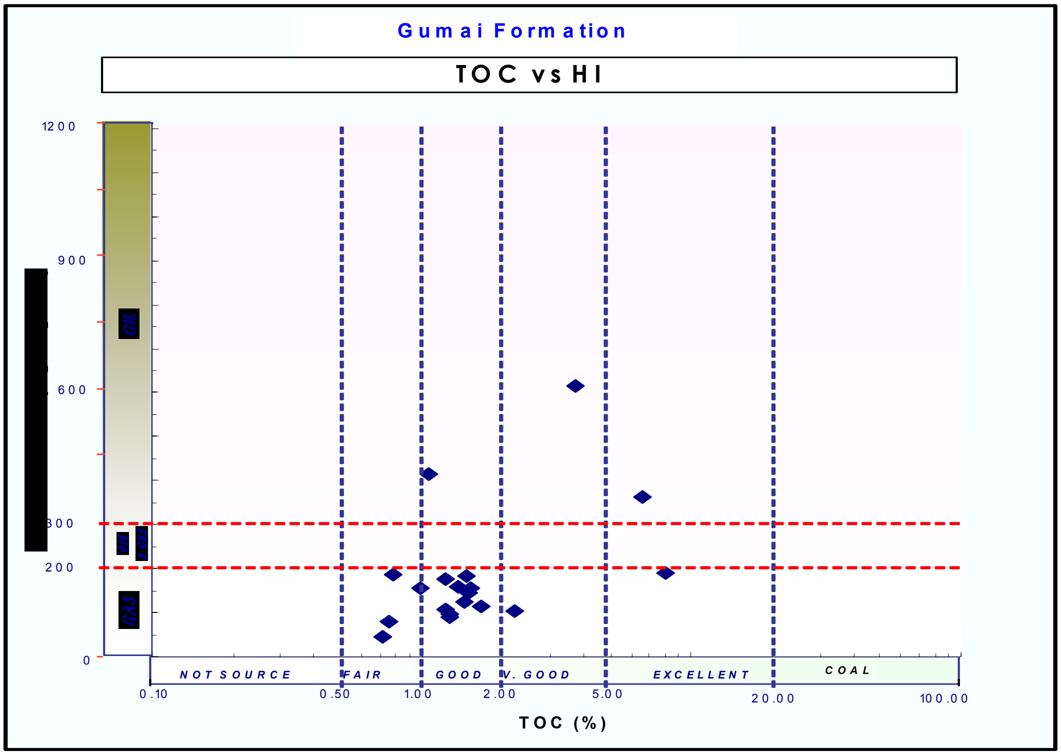

FIGURE 3 : TOC versus hidrogen index crossplot shows fair to excellent rock potential in Gumai Formation

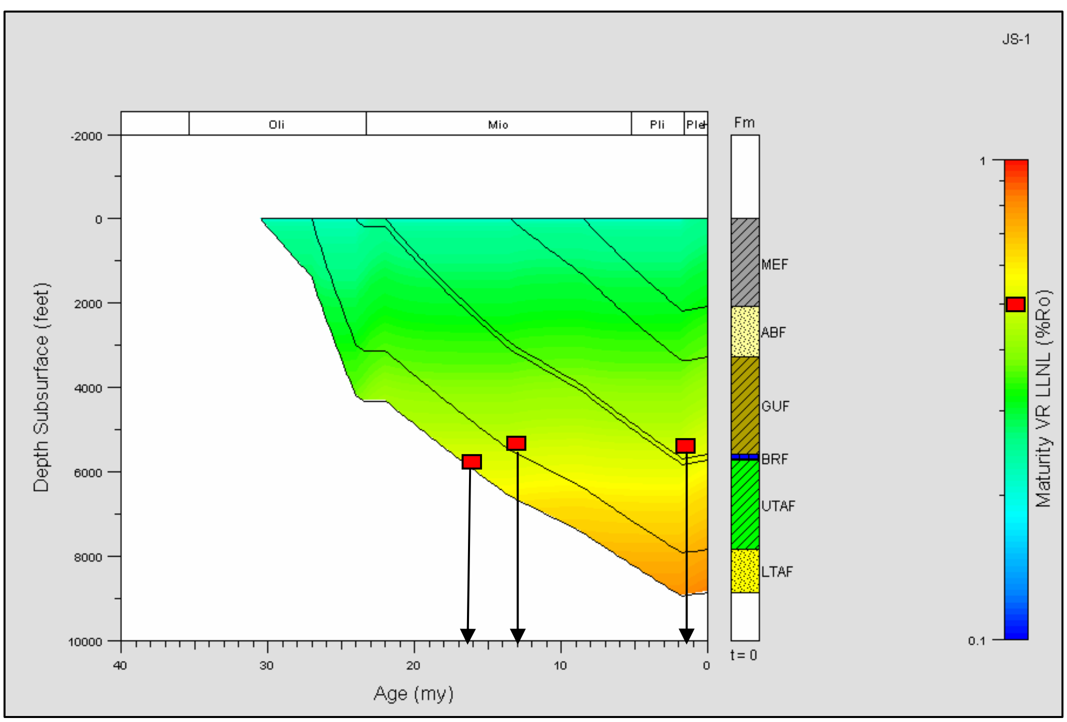

FIGURE 4 : Burial History model of well JS-1, showing an early mature stage (Ro=0.5 %) started at 16.5 mya for Lower Talang Akar Formation, 13 mya for Upper Talang Akar Formation and 1.5 mya for Gumai Formation

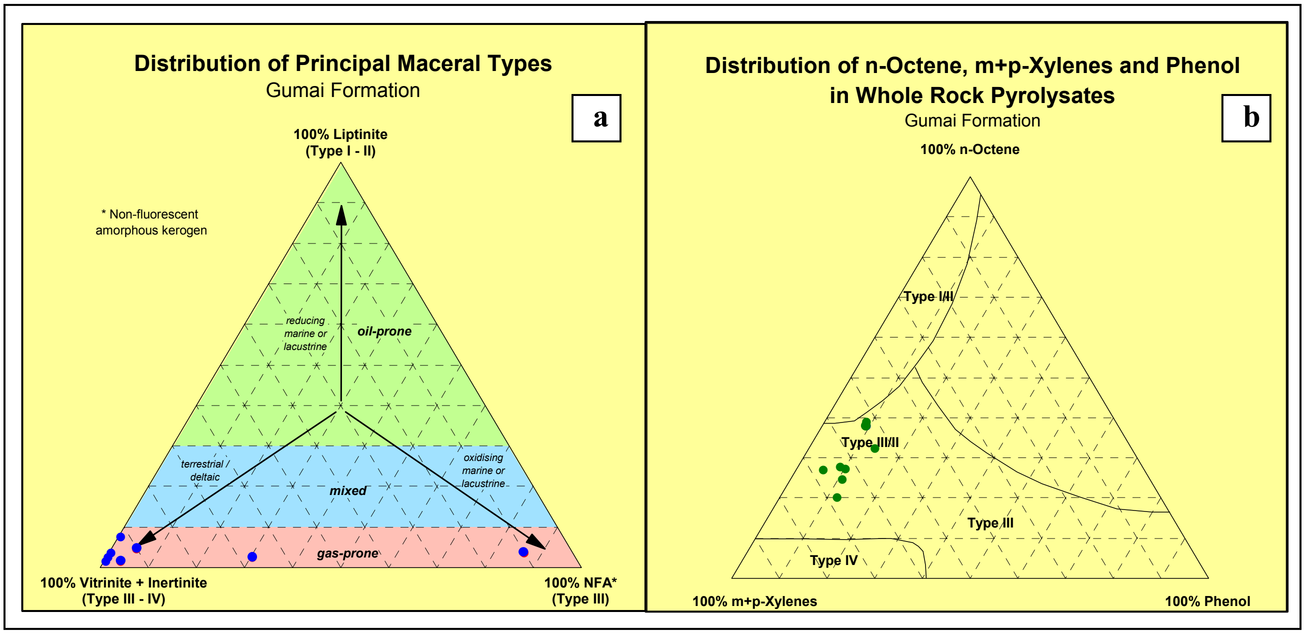

FIGURE 5 : (a) Kerogen analysis reveals typical Type III kerogen, consistent with entirely gas-prone organofacies (b) The relative proportion of n-octene, meta- + para- xylenes and phenol indicates a type II/III kerogen

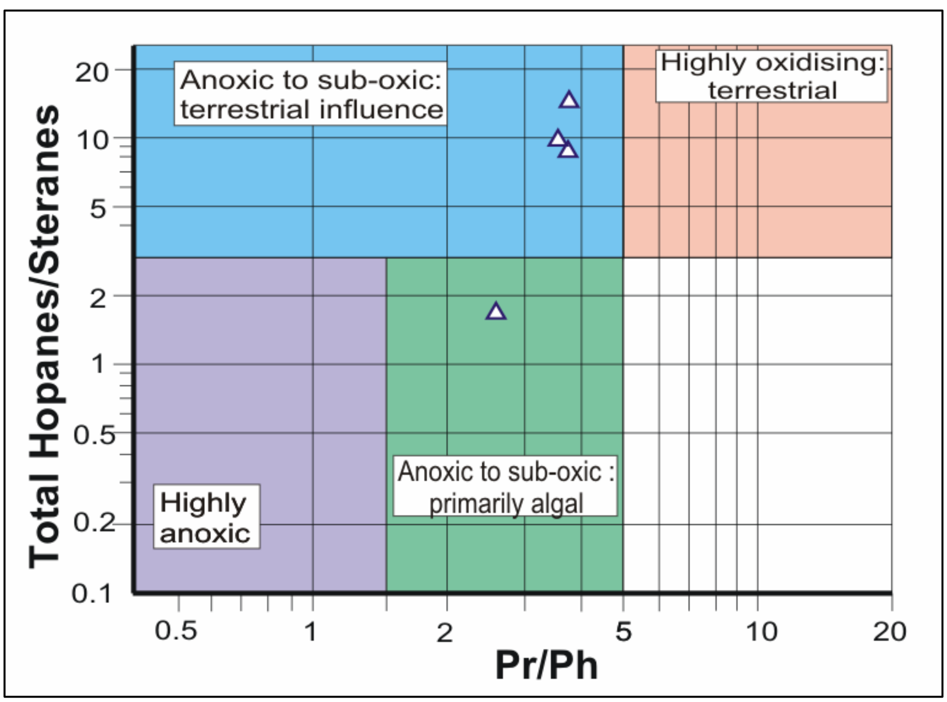

FIGURE 6 : Pr/Ph versus total hopanes/steranes shows an anoxic to suboxic environment with algal and terrestrial influence

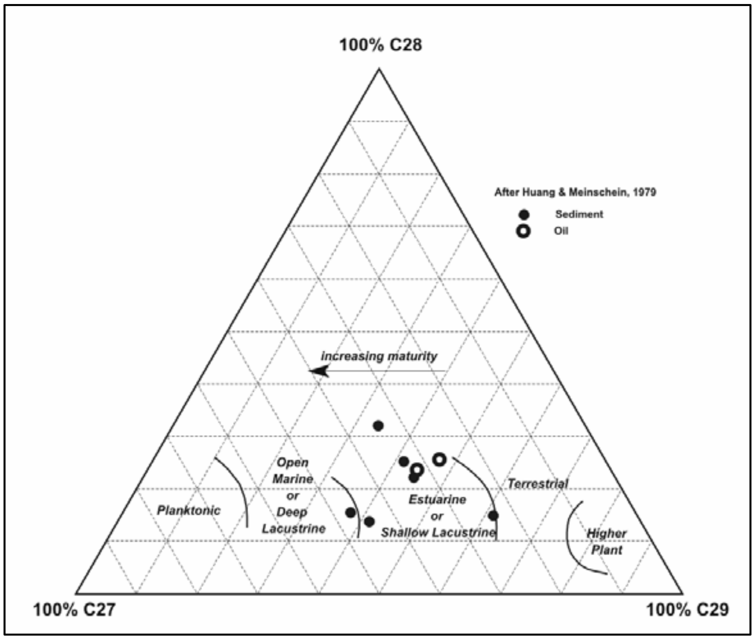

FIGURE 7 : Sterane distributions display concentration of C_{27}-C_{29} forms consistent with mixed marine/terrestrial source kerogen

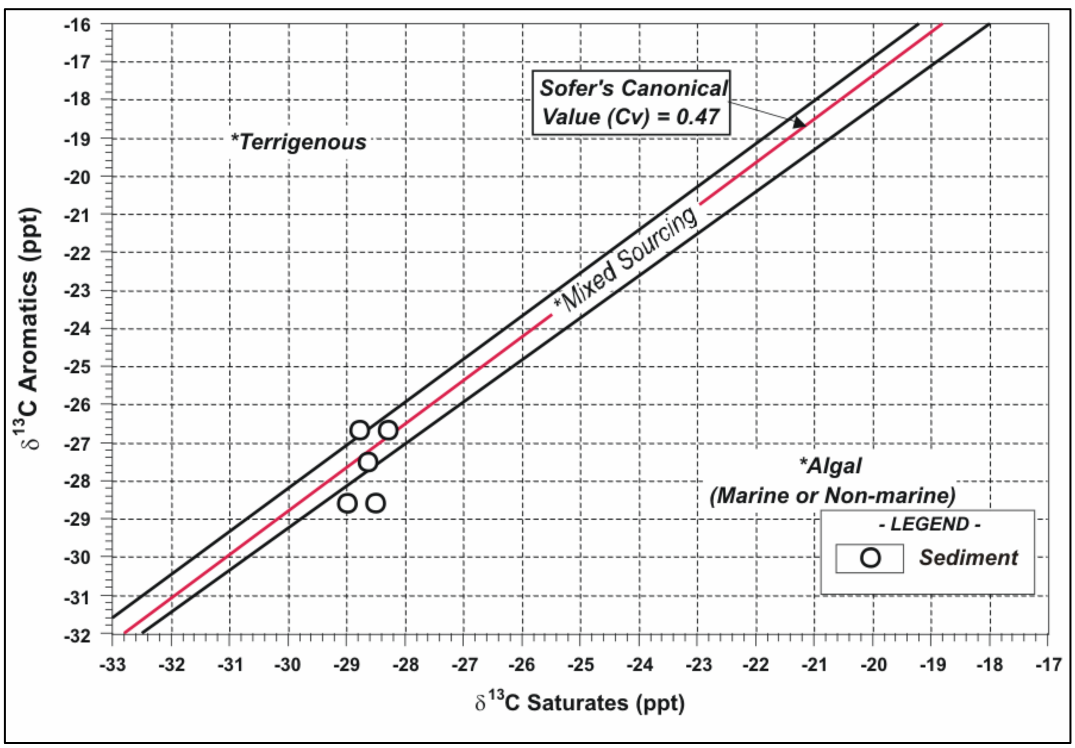

FIGURE 8 : Saturate and aromatic of carbon isotope-13 shows a mixed terrestrial and algal material, dominated with algal

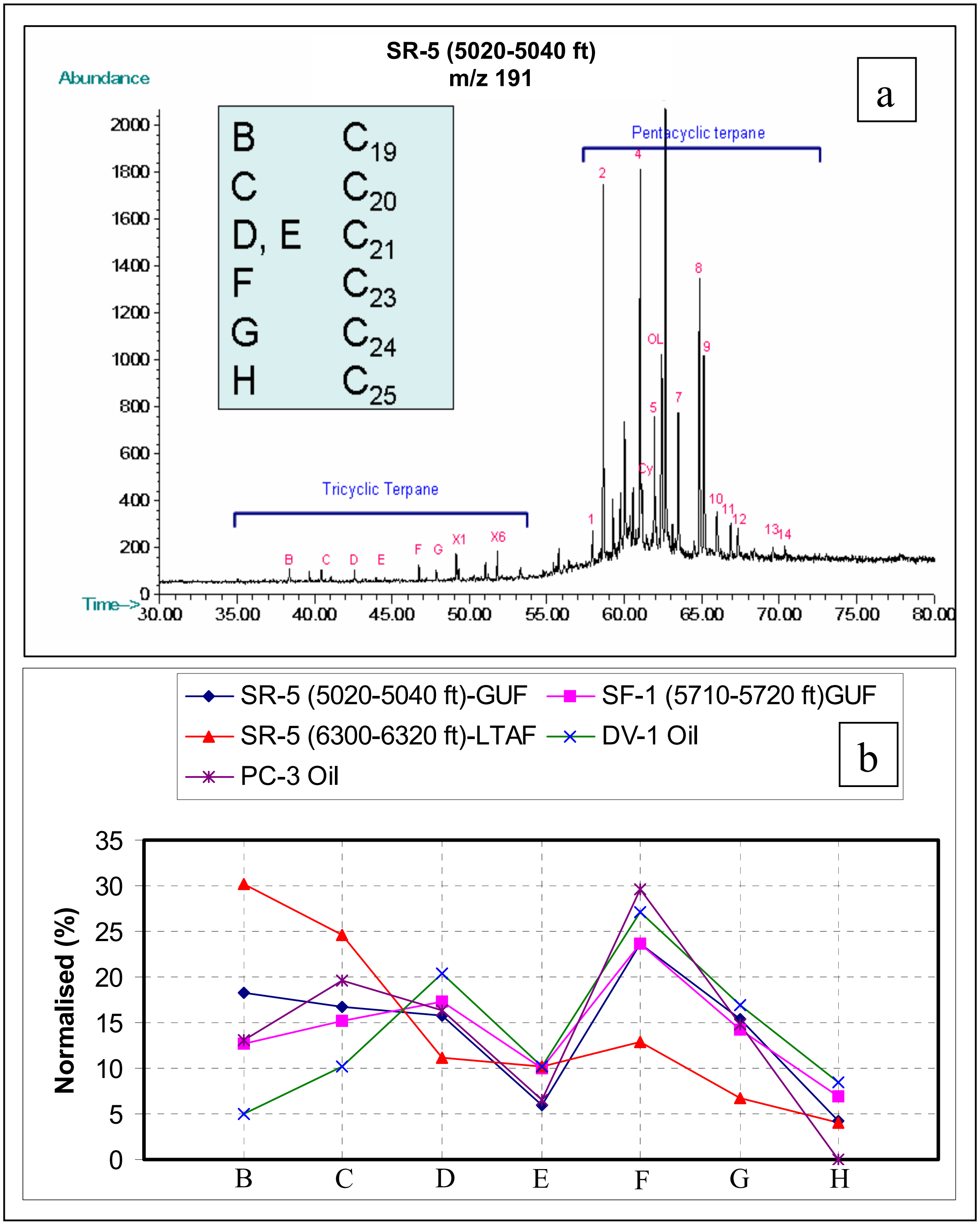

FIGURE 9 : (a) Saturate and aromatic carbon isotope-13 shows a mixed terrestrial and algal material, dominated with algal, (b) Distribution of tricyclic terpanes show a correlation between oil and sediment from Gumai Formation and compare to Lower Talang Akar sediment

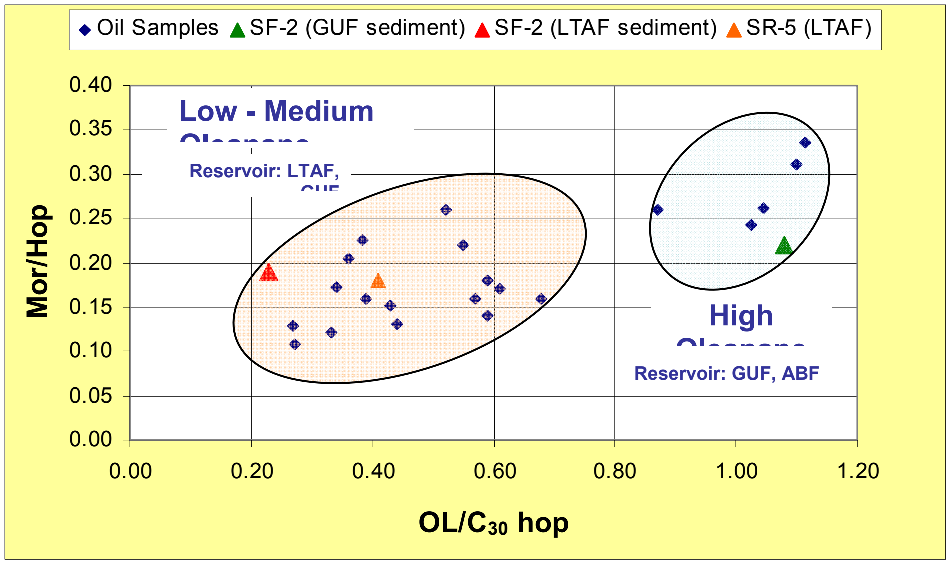

FIGURE 10 : Crossplot of source rocks and oils based on oleanane and moretane abundance showing correlation between Gumai sediment and oils in Gumai and Air Benakat reservoirs

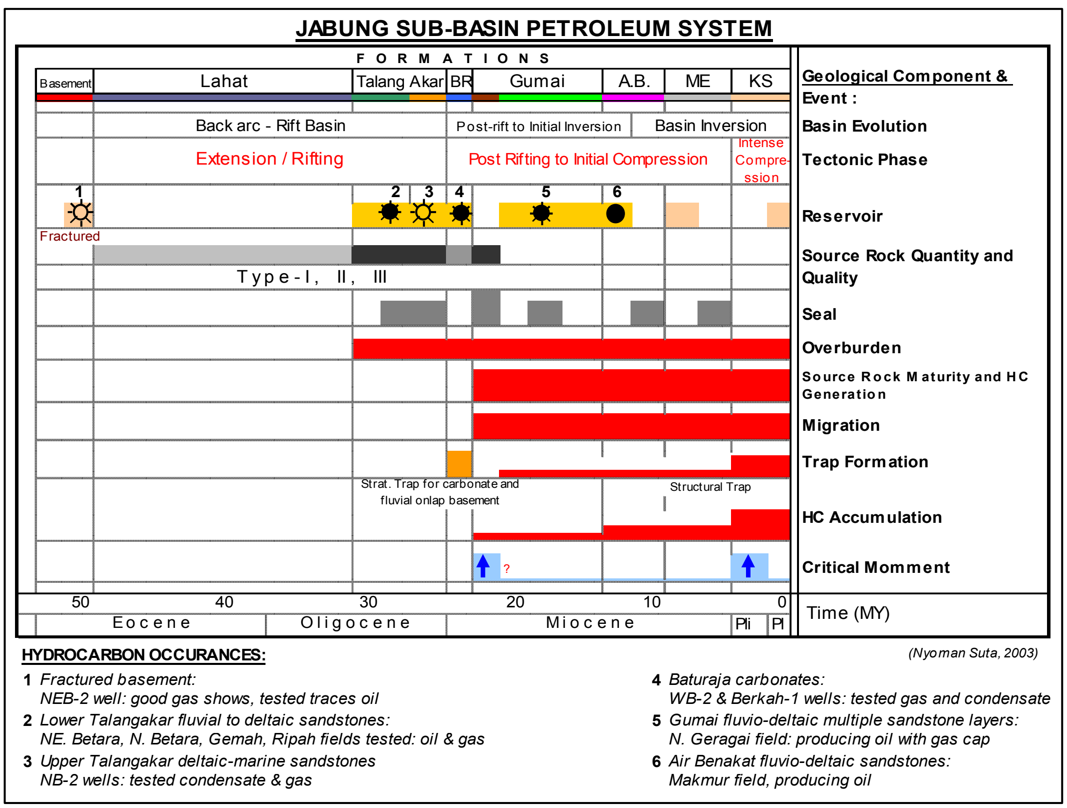

FIGURE 11 : Petroleum system of the area showing base Gumai source rock potential in relation to other geologic element / events.