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Characteristics Of Source Rock In Salawati Basin, West Papua

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ABSTRACT : Three formations namely the Kais Formation, the Klasafet Formation, and the Klasaman Formation, which are located in the Salawati Basin, West Papua have proven to have produced hydrocarbons. However, stratigraphically there are two other formations, namely the Faumai Formation and the Sirga Formation which can potentially act as source rocks as well. To prove that these two formations can be source rocks and produce hydrocarbons, it is necessary to conduct a geochemical analysis of the YB-01, YB-04, and YB-05 exploration well samples, in the form of an analysis of total organic carbon, kerogen type, and evaluation of maturity, with parameters on total organic carbon, rock-eval pyrolysis, vitrinite reflectance, and Tmax. It is hoped that the results of this geochemical laboratory analysis can prove that these two formations can indeed become source rock prospects and produce hydrocarbons.

KEYWORDS: Geochemistry, Salawati Basin, Faumai Formation, Sirga Formation

I. INTRODUCTION

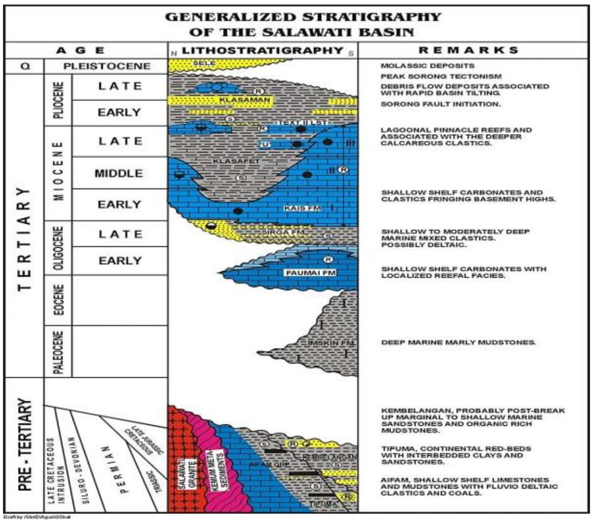
Oil reserves found in Salawati Basin, West Papua of 0.5 BBO and 0.1 TCFG of gas, are assumed to come from source rock of Tertiary and Pre-Tertiary source rock. The source rock that is considered to be able to produce oil hydrocarbons in Salawati Basin is claystone from the Klasafet Formation which was deposited in a shallow marine environment of the Middle Miocene age. The coal contained in the limestone which is thought to function as source rock and is of Early Miocene age is the limestone of the Kais Formation (Pireno G.E., 2008). The Klasafet Formation is still in the early mature phase which is not yet effective for forming hydrocarbons, this is assumed based on the hydrocarbon

maturation models made at several model locations in the basin.The source rock must reach a certain maturity, quantity, and quality conditions to obtain economical hydrocarbons. The results of the analysis in the form of the total value of organic carbon and kerogen type were obtained from rock eval pyrolysis, while the maturation value was obtained from optical observations, such as the reflection of vitrinite (Ro). The physical and chemical parameters of organic materials due to thermal evolution cause the maturity of source rock to turn into hydrocarbon compounds. Based on this, it is necessary to conduct an analytical study of the characteristics of the source rock from the Sirga and Fuaumai Formation, to determine the potential in terms of quantity, quality, and maturity level of the source rock.The oldest rock formations in Salawati Basin started from the Paleozoic, in the form of metamorphic rocks, namely the Kemum Formation, acting as the basement. Above Kemum Formation deposited Aifam Formation, which consists of conglomeratic sandstone and shale, graded upwards to sandy claystone and slightly argillite limestones, with sandy claystones and sandstones with an insertion of a coal seam at the top (Figure 1) As a result of the uplift, the Mesozoic deposits did not develop well in this basin, only in the southern part of the basin with the formation of the Kembelangan Formation consisting of non-marine facies, transitional to deep water facies during the Jurassic–Cretaceous period. The Imskin Formation in the southern part is a Paleocene sedimentary with marly mudstone deposits from the deep water. At the end of the Eocene to the beginning of the Oligocene, there was sea inundation and shallow marine carbonates were deposited in the form of limestone, dolomite, marl and evaporite rock in several places, called the Faumai Formation. The Sirga Formation was deposited during the Oligocene which consists of sandstone and shale with the presence of limestone. Furthermore, at the beginning of the Miocene, the limestone layer developed accompanied by the widespread formation of limestone exposures. Above the Sirga Formation there is the Kais Formation which was deposited from the Early Miocene to Late Miocene in harmony, where the rock forming this formation is reef limestone which thins out at the center of the basin (depocenter).

The Klasafet Formation was formed in harmony above the Kais Formation in the Early Miocene to Early Pliocene, consisting of shale and shale limestones that are thickening towards the west of the basin. The Klasaman Formation was unconformably deposited above the Klasafet Formation, which consists of calcareous clastic rocks. The Sele Formation is the last formation, which is unconformably formed above the Klasaman Formation and consists of conglomerate deposits and sandstone eroded from the deformation zone of the Sorong Fault.

II. RESEARCH METHOD

Figure 1. Stratigraphy of Salawati Basin (Satyana, 2001)



The characteristics of the source rock in the Sirga Formation and the Faumai Formation were carried out using secondary data, from 18 well-cutting samples and 11 core samples from three exploration drilling wells, namely YB-1, YB-4, and YB-5, with a depth of YB-1= 8022 feet; YB-4 = 6646,982 feet and YB-5 = 12325 feet (deepest). In general, the lithological types of rock samples are siltstone, claystone, and shale.The position of the YB-01 well is in the east, while the YB-04 and YB-05 wells are in the west and southwest (Figure 2). The target of analysis in this study is the Tertiary source rock represented by the Sirga Formation and the Faumai Formation, which were found in two wells of the three existing wells.

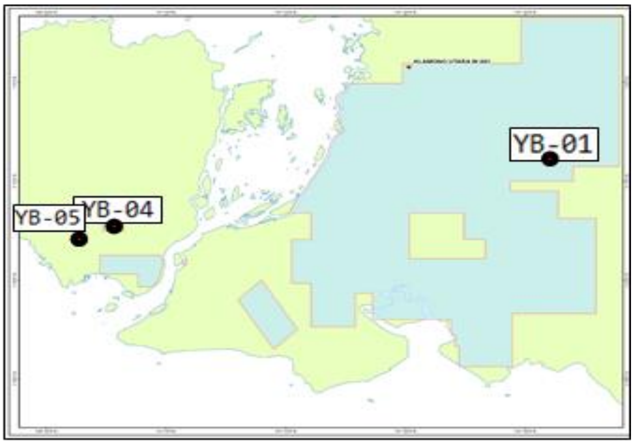


Figure 2. Location map of exploration wells in Salawati Basin, West Papua (Muhartanto et al., 2016)

This study was conducted quantitatively and qualitatively.

According to Sutadiwiria et al. (2020), geochemical data used in this study include data on total organic carbon (TOC), rock-eval pyrolysis (REP), vitrinite reflectance, kerogen type, gas chromatography (GC), and gas chromatography/mass spectrometry (GC/MS). Quantitatively it is done by taking data reflectance vitrinite, TOC (Total Organic Carbon), rock eval pyrolysis (S1, S2, and S3), Tmax, OPI (Optimization Potential Index), potential yield (S1+S2), Hydrogen Index (HI), and Oxygen Index (OI). Qualitative research is carried out by interpreting and analyzing the results of quantitative research, such as the level of organic richness, kerogen type, and maturity level of the source rock sample. The final result obtained is to know the geochemical characteristics of the source rock of the Sirga Formation and the Faumai Formation, so that it can be proven whether these two formations have the potential to become effective source rocks in producing hydrocarbons.The analytical classification used is for TOC and rock-eval pyrolysis (Peter and Cassa, 1994, Figure 3), and for vitrinite reflectance (Dow,1977) dan Senftle and Landis et al (1991), Table 1.

Petroleum Potential	Organic Matter: TOC (wt. %)	Rock-Eval Pyrolysis: S_1[a]	S_2[b]
Poor	0–0.5	0–0.5	0–2.5
Fair	0.5–1	0.5–1	2.5–5
Good	1–2	1–2	5–10
Very Good	2–4	2–4	10–20
Excellent	>4	>4	>20

Bitumen[c] (wt. %)	(ppm)	Hydrocarbons (ppm)
0–0.05	0–500	0–300
0.05–0.10	500–1000	300–600
0.10–0.20	1000–2000	600–1200
0.20–0.40	2000–4000	1200–2400
>0.40	>4000	>2400

Peters and Cassa (1994)

Figure 3. TOC classification (Peters and Cassa, 1994)

Tabel 1. Vitrinite reflectance (Dow ,1977), and Senftle and Landis (1991)

Oil-Prone Generation		Gas-Prone Generation	
Generation Stage	R_o(%)	Generation Stage	R_o(%)
Immature	<0.6	Immature	<0.8
Early oil	0.6–0.8	Early gas	0.8–1.2
Peak oil	0.8–1.0	Peak gas	1.2–2.0
Late oil	1.0–1.35	Late gas	>2.0
Wet gas	1.35–2.0		
Dry gas	>2.0		

II. RESULTS AND DISCUSSION

The core samples or cuttings of the YB-1 well could not be analyzed, because the availability of data representing the Sirga Formation and Faumai Formation samples did not exist (Table 2), while Tables 3 and 4 show sample data from the Sirga Formation and Faumai Formation analyzed in the YB-well 04 and YB-05. Table 5-7 shows the results of the geochemical laboratory analysis.

Table 2. Data sample of well YB-1

No	Well name	Formation	Depth (ftbpl)	Sample cutting depth interval (10 or 15 *feet*)	Depth of Samples taken for Geochemical Analysis
1	YB-1	Klasafet	*surface*	–	data is not available
2		Klasaman	-5561	(-5360) – (-5375) feet etc to (-7110) – (-7120) feet	
3		Kais	-7181.6	(-7190) – (-7200) feet	
4		**Sirga**	-7840.5	–	
5		TD	-8022	–	

note: KB = 28.04 m; TD = *total depth*

Table 3. Data sample of well YB-04

No	Well name	Formation	Depth *(feet)*	Sample cutting depth interval (2 or 5 meter)	Depth of Samples taken for Geochemical Analysis
1	YB-04	Klasaman	surface	–	-
2		Klasafet	-282.15	(-278.87) – (-295.27) feet etc to	-
				(-853.01) – (-869.42) feet	-
3		Kais	-869.42	(-902.231) – (-918.63) feet etc to	-
				(-1494) – (-1496) feet	-
4		**Sirga**	-4917.97	(-4901.57) – (-4927.82) feet etc to (-5052.49) – (-5059.05) feet	(-4921.26) – (-4927.82) (-4954.06) – (-4960.63) (-4986.87) – (-4993.43) (-5013.12) – (-5019.68) (-5019.68) – (-5026.24) (-5039.37) – (-5045.93) (-5052.49) – (-5059.05)
5		**Faumai**	-5055.77	(-5085.30)– (5091.86) feet etc up	-
				(-5905.51) – (-5912.07) feet	-
6			-6020.34	(-6023.62) – (-6030.18) feet etc to (-6640.42) – (-6646.98) feet	(-6023.62) – (-6030.184) (-6069.55) – (-6076.11) (-6338.58) – (-6345.14) (-6561.68) – (-6568.24) (-6633.85) – (-6640.42) **(-6640.42) – (-6646.982)**
7		TD	-6646.98	–	-

Table 4. Data sample of well YB-05

No	Well name	Formation	Depth (feet)	Sample cutting depth interval (2 or 5 meter)	Depth of Samples taken for Geochemical Analysis
1	YB-05	Kais	-9833	(-420 ft) – (-2790 ft) dst s/d (-9270 ft) – (-10480 ft)	-
		Sirga	-10880	(-9660 ft) – (-10480 ft) dst s/d (-11052 ft) – (-11055 ft)	(-9660) – (-12300); (-9830) – (-12320); (-9890) – (-11010); (-9900) – (-11010); (-9900) – (-12120); (-11012) – (-11039) *; (-11019) – (-11022) *; (-11020) –(-11055) *; (-11022) – (-11025) *; (-11024) – (-11058) *; (-11025) – (-11028) *; (-11028) – (-11031) *; (-11031) – (-11034) *; (-11034) – (-11037) *; (-11037) – (-11040) *; (-11040) – (-11043) *; (-11040) – (-11058) *; (-11043) – (-11046) *; (-11049) – (-11052) *;
2		**Faumai**	-11300	-	-
3			?	(-11590 ft) – (-12300 ft) dst s/d (-11590 ft) – (-12320 ft)	-
4		*Basement* (Granit)	-12325	-	-

* core sample

Table 5. Laboratory Analysis Results (*Vitrinite Reflectance* (VR/R_o)

No	Sample depth			Sample type	Median R_o (%)	*Minimal Vitrinite Reflectance (%)*	Minimal Vitrinite Reflectance (%) *minimum*
Well : YB-01							
1	(data is not available)						
Well : YB-04							
2	6633	-	6640 *feet*	*cuttings*	0.63	0.46	0.78
3	6640	-	6646 *feet*	*cuttings*	0.64	0.48	0.80
Well : YB-05							
4	11020	-	11055 *feet*	*core*	0.64	0.51	0.77
5	11024	-	11058 *feet*	*core*	0.65	0.52	0.79
6	11025	-	11028 *feet*	*core*	0.58	0.51	0.68
7	11028	-	11031 *feet*	*core*	0.60	0.52	0.69
8	11031	-	11034 *feet*	*core*	0.62	0.53	0.72
9	11034	-	11037 *feet*	*core*	0.64	0.55	0.73
10	11040	-	11043 *feet*	*core*	0.62	0.55	0.74
11	11040	-	11058 *feet*	*core*	0.64	0.56	0.72
12	11043	-	11046 *feet*	*core*	0.56	0.47	0.65

Table 6. Rock-Eval Pyrolysis and TOC (total organic carbon) result

No	Sample depth			TOC	sample (mg/gm)			T_{max} (°C)	OPI	Potentialr result (S_1+S_2)	Hydrogen index	Oxygen index
					S_1	S_2	S_3					
1	6633.8	-	6640.4	1.49	0.03	0.61	0.51	447	0.54	1.12	218	34
2	6640.4	-	6646.9	1.33	0.05	0.53	0.43	445	0.55	0.96	204	32
3	4311	-	4317.5	0.50	0.21	1.26	0.29	430	0.22	0.27	252	58
4	4475	-	4481.6	0.78	0.37	2.05	0.71	432	0.15	2.42	263	91
5	5131.2	-	5137.7	0.26	0.06	0.21	0.24	419	0.22	0.27	81	92
6	5170.6	-	5177.1	0.27	0.05	0.26	0.25	413	0.16	0.31	96	93
7	6417.3	-	6423.8	0.65	0.30	0.78	0.27	409	0.28	1.08	120	42
8	6509.1	-	6515.7	0.53	0.01	0.08	0.17	353	0.11	0.09	15	32
9	6561.6	-	6568.24	0.28	0.01	0.06	0.22	377	0.14	0.07	21	79
10	6594.4	-	6601	0.68	0.02	0.08	0.14	384	0.20	0.15	12	21
11	6653.5	-	6660.1	1.10	0.02	0.07	0.17	428	0.22	0.09	6	15
12	6686.3	-	6692.9	0.19	0.00	0.06	0.23	323	0.00	0.06	32	121
13	6751.9	-	6758.5	0.22	0.05	0.27	0.19	414	0.16	0.32	123	86
14	11020	-	11055	2.19	0.54	9.36	0.35	447	0.05	9.90	334	25
15	11024	-	11058	1.61	0.42	5.64	0.37	443	0.07	6.06	267	29
16	11025	-	11028	2.66	0.83	10.06	0.45	442	0.08	10.89	321	16
17	11028	-	11031	1.26	0.26	4.11	0.25	440	0.06	4.37	329	28
18	11031	-	11034	3.20	0.97	11.51	0.85	448	0.08	12.48	363	36
19	11034	-	11037	1.19	0.30	6.44	0.30	441	0.04	6.74	268	38
20	11037	-	11040	0.91	0.21	1.46	0.12	440	0.13	1.67	273	25
21	11040	-	11043	1.01	0.28	6.14	0.29	439	0.04	6.42	304	32
22	11040	-	11058	2.93	0.85	10.78	0.55	445	0.07	11.63	351	36
23	11043	-	11046	3.02	0.82	10.98	0.45	446	0.07	11.80	354	41
24	11049	-	11052	0.65	0.15	1.38	0.17	437	0.10	1.53	253	15

Table 7. Laboratory analysis result of kerogen data

No	Sampel depth (ftMD)			Amorphinite (Type I-III/IV)		Exinite (Type I/II)						OPK %	Vitrinite Type III %	Semi Fusinite Type IV %	Inertinite Type IV %	Pre-serv.	Rec. of Organic Matter	Mean R_o %	TAS	Fluorescence Colour		Srt	Ang
				NFA %	F.A %	A %	C %	S %	R %	SR %	L %									F. A	Herb		
	Well : YB-01																						
1	data is not available)																						
												Well : YB-04											
2	6633	-	6640 ft	65.5	-	-	0.5	1	-	-	-	1.5	20	8	5	P	G	0.63	4	-	-	M	SA-SR
3	6640	-	6646 ft	74	-	-	1	1	-	-	-	1	20	-	5	P	G	0.00	4	-	-	M	SA-SR
												Well : YB-05											
4	11020	-	11055	84.5	-	-	1	1	-	-	-	1.5	12	2	-	P	G	0.54	4	-	-	M	SA-SR
5	11024	-	11058	92.5	-	-	1	-	-	-	-	0.5	7	-	-	P	G	0.55		-	-	G	SR
6	11025	-	11028	88.5	-	-	1	1	-	-	-	1.5	8	2	-	P-M	G	0.38	3/4	-	-	M	SA-SR
7	11028	-	11031	87.5	-	-	1	1	-	-	-	1.5	10	1	-	P-G	G	0.40	3/4	-	-	M	SA-SR
8	11031	-	11034	87	-	-	-	-	-	-	-	-	12	1	-	P	G	0.42		-	-	M	SA-SR
9	11034	-	11037	87	-	-	-	1	-	-	-	1	12	-	-	P	G	0.44	3/4	-	-	M	SR
10	11040	-	11043	81.5	-	-	1	1	-	-	-	1.5	15	2	-	P-M	G	0.42	3/4	-	-	M	SA-SR
11	11040	-	11058	89.5	-	-	-	1	-	-	-	0.5	10	-	-	P	G	0.54	4	-	-	M	SR
12	11043	-	11046	89	-	-	-	1	-	-	-	1	10	-	-	P	G	0.46	4	-	-	M	SR

One of the most important factors in a source rock is the level of maturity, so that the sample can generate hydrocarbons. The chemical properties of organic materials in sedimentary rocks will change over time, reflecting temperature and loading history. Data on the quality and richness of organic matter can be measured and combined with potency and maturity, to estimate the number of hydrocarbons produced. In well YB-04, according to the TOC classification (Peters and Cassa, 1994), we found samples of source rock classified as poor (6 samples), fair (4 samples), and good (3 samples). Meanwhile, the YB-05 well found samples were classified as fair (1 sample), good (4 samples), and very good (5 samples). Thus, the YB-05 well sample has more total organic carbon levels, good (4) and very good (5), than the YB-04 well sample.

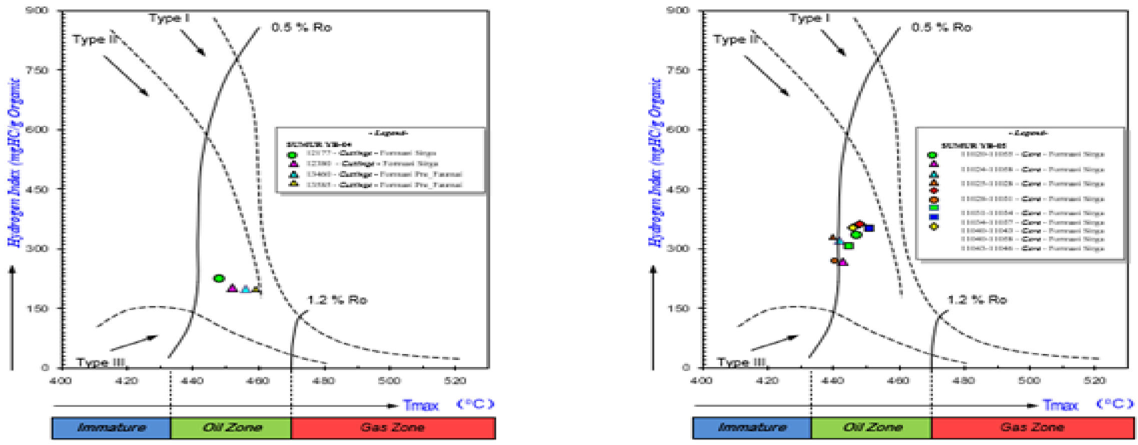


Figure 4. Diagram Hydrogen Index dan Tmax of well YB-04 (left) dan YB-05 (right) *revised by* Mukhopadhyay (1990)

The results of kerogen analysis (Table 7 and Figure 4) obtained from two wells (YB-04 and YB-05) indicate that the Faumai Formation found in Well YB-04 shows the dominance of Type II, namely the exinite type which when it reaches maturity tends to produce oil (oil-prone) which is located in the oil zone. Meanwhile, the Sirga Formation sample found in the YB-05 well shows content with a dominant Type II, namely the exinite type which when it reaches maturity tends to produce oil (oil-prone) which is located in the oil zone. The maturity level of source rock can also be obtained from the results of the Vitrinite Reflectance (%Ro) obtained from the two wells studied (Table 4). According to the Dow classification (1977), Senftle and Landis et al. (1991, Table

1), the Faumai Formation shows a percentage of 0.63% - 0.64%, which means that this sample is in an early mature condition with %Ro 0.60% – 0.65%. Well YB-05, the level of thermal maturity based on the %Ro value in Sirga Formation shows a value of 0.56% - 0.64% which indicates the sample is in an early mature condition with %Ro 0.60% - 0.65%.

V. CONCLUSION

With the description of the source rock characteristics above, it can be concluded that the Faumai Formation and Sirga Formation have the potential as source rocks and can produce hydrocarbons in the Salawati Basin, West Papua, in addition to Kais Formation, Klasafet Formation, and Klasaman Formation which have been proven in previous studies.

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