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Mineralogy and Rock-Eval Characteristic of Mesozoic Shale from Pedawan Formation : Implication for Shale Hydrocarbon Potential Oleh

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Abstract: ***Singkawang basin is Mesozoic basins are expected to have hydrocarbon potential of conventional and non-conventional located in West Kalimantan. This study discusses the characteristics of mineralogy and organic geochemistry of fine grained sedimentary rock of Pedawan Formationin Singkawang Basin related to non-conventional hydrocarbons. Based on XRD analysis, fine grained sedimentary rock of Pedawan Formation delicate brittle mineral content between 41-83%, clay minerals 19-49% and carbonate minerals from 1.2 to 11.6%. While the analysis of TOC, REP, and Brittleness Index (BI) showed fine grained sedimentary rock of Pedawan Formation have TOC values between 0.27 to 2.29, Hydrogen Index (HI) <100, BI between 52-99%, Based on the maturity value seen that almost all of the sample included in the level of maturity mature until over mature categories (478 - 5560 C), BI is seen almost all of the sample has a value> 50% were classified as good brittle categories for shale gas. Based on the clay minerals mostlyof the finegrained sedimentary rocks of Pedawan Formation having qualify as non-conventional hydrocarbons. Pedawan Formations shalehas potential as a non-conventional hydrocarbon.***

Keywords: TOC, West Kalimantan, shale, Mesozoic

1. Introduction

The study is located in the Singkawang Basin, where the basin is bounded by the Lupar Line in the North and Adang Flexure in the South. Administratively, the basin lies in three regency, namely Kabupaten Pontianak,Sanggau, and Sambas, West Kalimantan Province (Figure 1).

Mesozoic Rocks to date has not become the main purpose in the oil and gas exploration. The Mesozoic Rocks in Indonesia mostly are crystalline rock as a basement. One of Mesozoic Rocks which produces oil and natural gas are Beruk Northeast oil field, Suban gas field, Tanjung field, and Gunung Kemala field. It is as a result of the basement rocks with fractured technique. Jatibarang field is one of produce oil on the volcanic rocks and develop petroleum system on Mesozoic basins.

From the earlier literature study there are slightly discussing Mesozoic rocks at the Western Indonesia as a petroleum system with the rock sediment as the main purpose. Singkawang Basin is one of the Mesozoic basins that has sediments of Triassic to Cretaceous which is expected to have potential for oil and gas and has a complete petroleum system. The basins have not been much researched in more detail especially on the petroleum system (Organic Geochemistry characteristics, its potential as a source rock, reservoir, seal).

Based on the regional geology can be described that Singkawang Basin has a number of candidates as part of the petroleum system elements (hydrocarbon play) or could be able to play a role as well as non-conventional hydrocarbon resources such as oil shale, shale gas or tight sand. From some of these alternatives in this study hopefully will be able to answer some of the existing problems in the basin is mainly on the potential of source rocks.

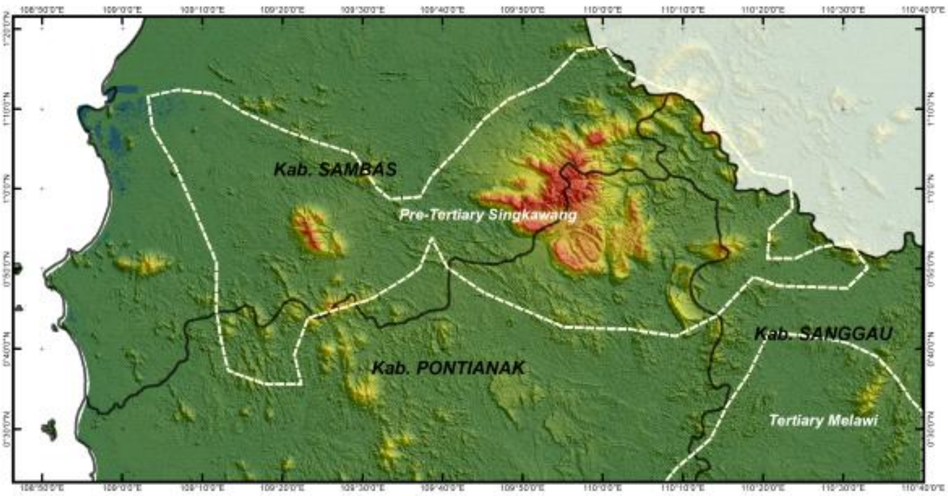

Figure 1: Location of Singkawang Basin located in the Regency of Sambas, Pontianak, and Sanggau

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2. Methodology

2.1 Laboratory Analysis

Laboratory analysis used in this study are: X ray Difraction (XRD), and Geochemical analysis of Organics (TOC and Rock-EvalPyrolysis(REP) to know mineralogy and organic content, the quality of the source rock, maturity, characteristics and hydrocarbon potential.

2.2 Geology

2.2.1 Stratigraphic Research Area

The research area is a basin that genetically is part of Sundaland in the past (Figure 2).

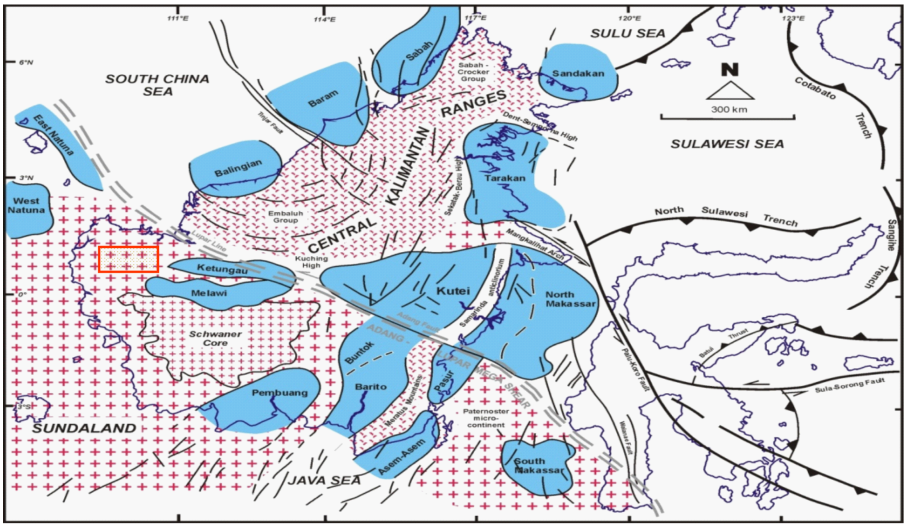

Figure 2: Areas of research is a part of Sundaland (BPPKA, Pertamina, 1997)

The research areas covered in the Geologic Map scale of 1:250,000 Singkawang Sheet (Suwarna and Langford, 1993), Sanggau Sheet (Supriatna, et al, 1993), and Sambas Sheets (Rusmana and Pieters, 1993).

In stratigraphic sedimentary rocks that became the target of research in Singkawang Basins are formations that are geologically potential candidates as part of petroleum system elements which are:

2.2.2 Kayan Sandstones

The sandstones consist of quartz – feldspathic sandstone, shale, silstone with minor conglomerate, coal, locally silicified wood. Age of this sandstone is Late Cretaceous to Late Eocene.

2.2.3 Pedawan Formation

Shale, carbonaceous mudstone, silstone and sandstone with locally calcareous, limestone, tufa but also fossiliferous. Age of Pedawan Formation is aproximately Cretaceous.
Brandung Formation
Calcareous mudstone alternating with mudstone, shale slatty, and fossiliferous fine grained sandtone. This formation is around Late of Jurrasicr.

2.2.4 Bengkayang Group

Bengkayang group consists of two formations:

- ***Sungaibetung Formation***: consists of alternating mudstone, silstone, fine to medium sandstones grey young – black. This formation was deposited in the early Jurassic and conformable above the formation of Banan.
- ***Banan Formation***: composed of sandstones and rare of conglomerates at the top, sandstone and shale in the Middle, sandstones and sandstones with inset of tuffaceous acidic Tuff composition in the bottom. This formation was the Late of Triassic.

Seminis Formation

Slate, Phyliite, meta-sandstone, This formation was carbon-Permian age.

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Figure 6: Stratigraphic column of the Pedawan Formation in the area of Ledo.

2.3 The Organic Material Content

Based on the results of the analysis of the TOC and the REP (Table 1) the content of organic material is an indicator of the ability of a sedimentary rock to form hydrocarbons. The content of organic material in the sedimentary rocks is stated as Total Organic Carbon (TOC) with units of percent of rocks indry state. TOC analysis will give you an early idea in a study of source rocks whether sedimentary rocks can act as source rocks or not.

Based on the results of the analysis of the TOC (Figure …) on 26 sample fromfinesedimentary rocks of PedawanFormationhas a rich organic material 0.42 – 2.29, indicating likely into the category of poor to very good and have the ability as a fair to good source rocks.

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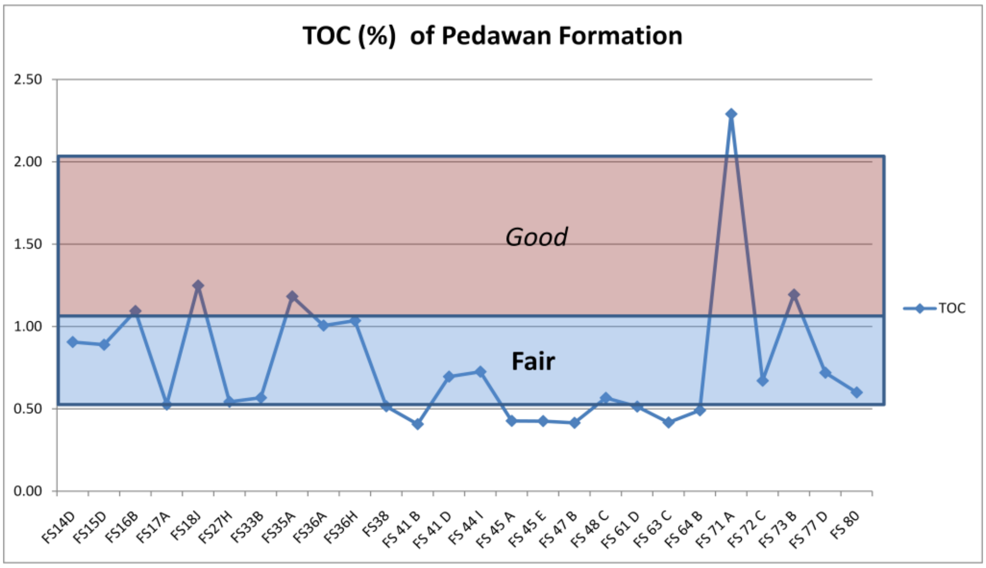

Figure . TOC of Pedawan Formation (shale, siltstone, claystone).

Table 1: Result of TC and Rock EvalPyrolisis Analysis from Sedimentary Rock of Pedawan Formation

No.	Sample ID	Sample Type	General Lithology Description	Formation	Age	TOC (%)	S1	S2	S3	PY	Tmax (°C)	PI	PC	HI	OI	S2/S3	Production	Ro (%) (Jarvie, et.all, 2001)	TR S1/(S1+S2)	HIo	TR S1/(S1+S2)
							mg/g														
1	FS14D	OC	Shale, dk grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.91	0.03	0.17	0.03	0.20	535	0.15	0.02	19	3	5.67	Oil Prone	2.48	0.15		0.15
2	FS15D	OC	Sandstone, lgt grey, hard, brittle, oxidated, Non Calc	Pedawan	Cretaceous	0.89	0.02	0.14	0.05	0.16	540	0.13	0.01	16	6	2.80	Gas prone	2.56	0.13		0.13
3	FS16B	OC	Claystone, dk grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	1.09	0.02	0.09	0.03	0.11	556	0.18	0.01	8	3	3.00	Mixed	2.84	0.18		0.18
4	FS17A	OC	Claystone, lt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.53	0.03	0.08	0.06	0.11	555	0.27	0.01	15	11	1.33	Gas prone	2.82	0.27		0.27
5	FS18J	OC	Shale, black, soft, oxidated, Non Calc	Pedawan	Cretaceous	1.25	0.03	0.16	0.05	0.19	543	0.16	0.02	13	4	3.20	Mixed	2.61	0.16		0.16
6	FS27H	OC	Claystone, lt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.54	0.05	0.08	0.03	0.13	532	0.38	0.01	15	6	2.67	Gas prone	2.41	0.38		0.38
7	FS33B	OC	Siltstone, lt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.57	0.03	0.07	0.05	0.10	546	0.30	0.01	12	9	1.40	Gas prone	2.67	0.30		0.30
8	FS35A	OC	Siltstone, lt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	1.18	0.07	0.17	0.14	0.24	541	0.29	0.02	14	12	1.21	Gas prone	2.57	0.29		0.29
9	FS36A	OC	Siltstone, lt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	1.01	0.05	0.11	0.07	0.16	550	0.31	0.01	11	7	1.57	Gas prone	2.74	0.31		0.31
10	FS36H	OC	Claystone, lt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	1.04	0.04	0.11	0.05	0.15	556	0.27	0.01	11	5	2.20	Gas prone	2.85	0.27		0.27
11	FS38	OC	Claystone, lt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.52	0.06	0.09	0.44	0.15	511	0.40	0.01	17	85	0.20	Gas prone	2.03	0.40		0.40
12	FS 41 B	OC	Claystone, lgt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.41	0.05	0.12	0.10	0.17	481	0.29	0.01	29	25	1.20	Gas prone	1.50	0.29		0.29
13	FS 41 D	OC	Shale, lt grey, soft, Non Calc	Pedawan	Cretaceous	0.70	0.05	0.34	0.06	0.39	447	0.13	0.03	49	9	5.67	Oil Prone	0.88	0.13		0.13
14	FS 44 I	OC	Siltstone, dk grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.73	0.08	0.19	0.08	0.27	449	0.30	0.02	26	11	2.38	Gas prone	0.91	0.30		0.30
15	FS 45 A	OC	Shale, lgt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.43	0.04	0.18	0.04	0.22	489	0.18	0.02	42	9	4.50	Mixed	1.65	0.18		0.18
16	FS 45 E	OC	Shale, black, soft, Non Calc	Pedawan	Cretaceous	0.43	0.03	0.15	0.06	0.18	466	0.17	0.01	35	14	2.50	Gas prone	1.23	0.17		0.17
17	FS 47 B	OC	Shale, black, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.42	0.07	0.08	0.15	0.15	528	0.47	0.01	19	36	0.53	Gas prone	2.35	0.47		0.47
18	FS 48 C	OC	Shale, lgt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.57	0.04	0.21	0.09	0.25	456	0.16	0.02	37	16	2.33	Gas prone	1.04	0.16		0.16
19	FS 61 D	OC	Siltstone, lgt grey, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.51	0.03	0.13	0.06	0.16	468	0.19	0.01	25	12	2.17	Gas prone	1.27	0.19		0.19
20	FS 63 C	OC	claystone, lgt grey, soft, brittle, oxidated, Non Calc	Pedawan	Cretaceous	0.42	0.04	0.17	0.07	0.21	491	0.19	0.02	41	17	2.43	Gas prone	1.69	0.19		0.19
21	FS 64 B	OC	claystone, lgt grey, soft, brittle, oxidated, Non Calc	Pedawan	Cretaceous	0.49	0.03	0.12	0.08	0.15	509	0.20	0.01	24	16	1.50	Gas prone	1.99	0.20		0.20
22	FS 71 A	OC	Shale, black, soft, oxidated, Non Calc	Pedawan	Cretaceous	2.29	0.05	0.11	0.33	0.16	405	0.31	0.01	5	14	0.33	Gas prone	0.12	0.31		0.31
23	FS 72 C	OC	Shale, black, soft, oxidated, Non Calc	Pedawan	Cretaceous	0.67	0.03	0.10	0.21	0.13	493	0.23	0.01	15	31	0.48	Gas prone	1.71	0.23		0.23
24	FS 73 B	OC	Siltstone, lgt grey, massive, hard, Non Calc	Pedawan	Cretaceous	1.19	0.06	0.48	0.11	0.54	435	0.11	0.04	40	9	4.36	Mixed	0.68	0.11		0.11
25	FS 77 D	OC	claystone, lgt grey, soft, brittle, oxidated, Non Calc	Pedawan	Cretaceous	0.72	0.03	0.11	0.18	0.14	541	0.21	0.01	15	25	0.61	Gas prone	2.59	0.21		0.21
26	FS 80	OC	Shale, lgt grey, soft, oxidated, Calc	Pedawan	Cretaceous	0.60	0.06	0.12	0.15	0.18	534	0.33	0.01	20	25	0.80	Gas prone	2.44	0.33		0.33

2.4 The Type of Organic Material

The type of organic material is affected by the composition of the maseral that is in the sedimentary rocks. In kerogen typeinterpretation, type of maseral in general are divided into maserals which produces oil, gas, and does not produce anything. Kerogen Type is divided into type I, II, and III. According to Waples (1985), kerogen type I mainly derived from algae lacustrine and has a high capacity to produce hydrocarbons. Kerogen type I is generally composed of maseralliptinit like alginit. Most type II kerogen found in marine sediment deposits under the condition of reduction (backmangrove). This type has the capacity to form hydrocarbons and a little gas. Kerogen type II consists of the upperresinit, kutinit, and sporinit, whereas the type III kerogenis composed by organic land material that lacked an element of grease and wax. This type generally produces gas. Vitrinit is the dominant maseral as framers of the kerogen type III. Type IV Kerogen is kerogen-containing alteration material from various sources and under the condition of high oxidation. Kerogen type will not produce oil. Maseralinertinit is a constituent of type IV kerogen (Table 4.5). The wealth of organic material on the shale not only deposited on marine environment but also non-marineor even transition, but even the most is the environment fasies lacustrine (Zhang, et al., 2008; Zou, et al., 2011 in Ju, et al., 2001).

Based on the composition of chemical elements, i.e., C, H and O, initially the kerogen is distinguished into three main types i.e. kerogen types I, type II, and type III (Tissot and Welte, 1984; in Killops and Killops, 2005).

Table 4: Type of kerogen, maseral content, and origin of organic material(Waples, 1985)

Maseral	Kerogen Type	Origin Of Organic Material
Alginit	I	Freshwater algae
Liptinit	II	Pollen, spores
Kutinit	II	Wax Coating plants
Resinit	II	Resin plants
Liptinit	II	Fat plants , sea algae
Vitrinit	III	High plant material (wood, cellulose)
Inertinit	IV	Charcoal, re-arranged material that oxidized

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Kerogen type determines the quality of the source rock. The greater the value of the hydrogen index (HI) then the quality is also good. The four basic types of kerogen found in sedimentary rock. A source rock may contain one or a mixture of several types of kerogen. The following Table 4.6 defines four types of kerogen according to Law (1999).

Table 5: The four basic types of kerogen according to Law (1999)

Kerogen Type	The Main Hydrocarbon Producer	Type The Environment Of Deposition
I	Oil-producing	Lake
II	Oil and gas producers	Sea
III	Gas generator	Landline
IV	Does not produce any	Landline

Based on the results of pyrolysis of Rock-Eval can be known the price of S1, S2,and S3 which is expressed in units of milligrams of hydrocarbons. The parameter S1 shows the first existing hydrocarbons in the rocks, and the equivalent of bitumen that can be extracted by using solvent.

The second Hydrocarbon prices shown with S2, and is the hydrocarbons formed from kerogen in the process of pyrolysisRock-Evaldue to the decomposition of kerogenis by thermal. The price of the S2 is considered an important indicator of the ability of the kerogen produces hydrocarbons at the moment. S3 is the amount of oxygen content in kerogen. The price of hydrogen index (HI) and the oxygen index (OI) is an indicator in the determination of the type of kerogen source rocks. Hydrogenindex is obtained by dividing the price of the S2 with a TOC, whereas the oxygen index is the result of the Division of the TOC content with S3.

According to Waples (1985), hidrogenindex< 150 mg hydrocarbons/g TOC indicates the absence of a number of fat that produce oil and including kerogen type III and IV that will only generate a little amount of gas. HI over 150 shows the increase in the amount of material rich in fats, which come from the Mainland (kutinit, resinit, liptinit) or from sea algae material and lacustrine algae (alginit). HI between 150 and 300 contains more type III kerogen than type II, so that it has the medium ability to produce oil. Kerogen with HI > 300 are generally made up of type II maseral that have a tendency to produce liquid hydrocarbons, while 600 > HI value is kerogen which consists overTipe I and II are capable of excellent produce liquid hydrocarbons. Peters and Cassa (1994). The hydrogen index divides into five grades namely HI < 50 does not produce hydrocarbons including kerogen type IV, HI between 50 – 200 are generally capable of producing gas and pertained to in kerogen type III (table 4.8).

Table6.Geochemical kerogen Type Parameters and resulting product
(Peters and Cassa, 1994).

Kerogen Type	Hydrogen Index (mg HC/g TOC)	S2/S3	Atom H/C	Main Products
I	> 600	> 15	> 1.5	Oil
II	300 – 600	10-15	1.2 – 1.5	Oil
Ii/IIIb	200 – 300	5-10	1.0 – 1.2	Oil and Gas
III	50 – 2 00	1-5	0.7 – 1.0	Gas
IV	< 50	< 1	< 0.7	There is no

HI which had values between 200 – 300 in kerogen type II/IIIb who have the ability to produce oil and gas, HI between 300 – 600 generally produce oils and kerogen type included in II, while 600 > HI can be classified into type I kerogen which can produce oil.

Based on the results of the analysis of the TOC and the REP (table 4) show that all sample have the value of the hydrogen Index (HI) < 150 and comparisons of S2/S3 value is minor (dominant < 3). Figure7. shows most of the fine sedimentary rocks in the Pratersier Singkawang Basin has a tendency belong to the type of kerogen that produces dry gas and pertained to lean organicmeans organic has limitations that are very small. Some of the sample included in the sedimentary rocks that could produce a dry gas, it can be interpreted that gas production results from the source rock in Singkawang Basins has entered a stage of very mature (over mature).

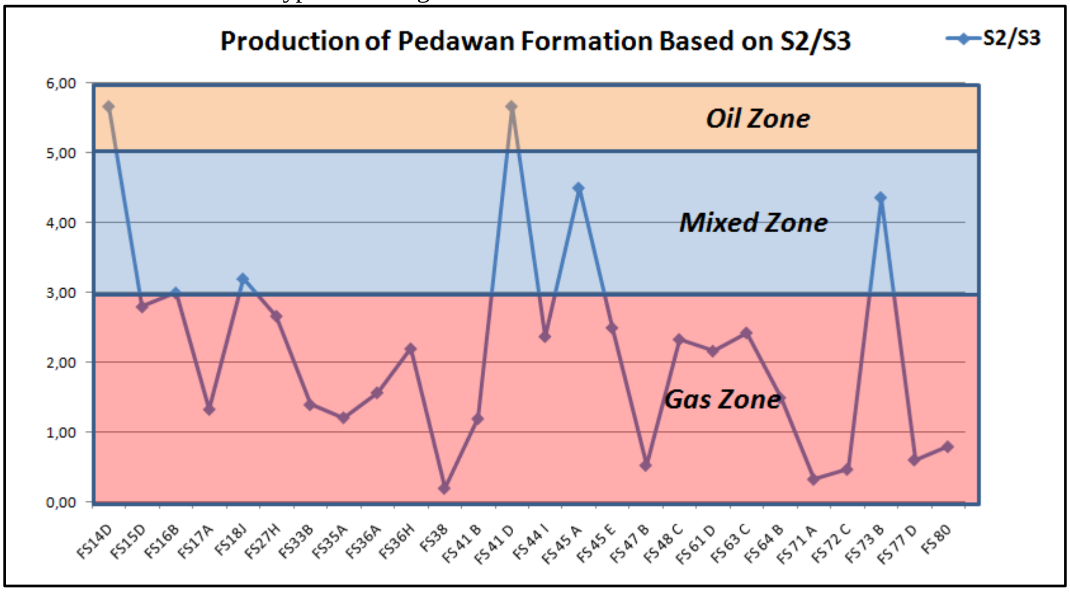

Figure: Hydrocarbon potential of Pedawan Formation based on S2/S3

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Brittleness indeks (BI)

BI serpih adalah sifat kerapuhan dari serpih yang merupakan informasi yang sangat penting untuk menunjang dalam penentuan kelayakan suatu serpih dapat berperan sebagai sumber gas serpih. Dalam menghitung nilai tingkat kerapuhan atau brittleness index (BI) suatu batuan dihitung berdasarkan rumus yang diajukan oleh Wang dan Gale (2009) sebagai berikut :

BI = (kuarsa + karbonat) / (kuarsa + karbonat + lempung + material organik)

Nilai BI dihubungkan dengan potensi gas serpih dapat digolongkan menjadi tiga atau empat tingkatan (Wang dan gale, 2009; Perez dan Marfurt, 2014 ; Gambar 3) yaitu :

- < 30% (<16%) = rendah/ductile
- 30 – 50 (16 - 32%) = sedang/ Less ductile dan less brittle
- > 50% (>48%) = tinggi/baik/ brittle

No.	Sample Code	Lithology	Formation	Composition (%)				Brittlesness Index (BI) (%)
				Brittle mineral	Clay Mineral	Carbonate	TOC /Organic material	
1	FS 01 B	siltstone	Pedawan	41	31.4	9.6	1.18	60.83
2	FS 01 K	siltstone	Pedawan	55.9	40.8	3.2	1.18	58.47
3	FS 01 V	shale	Pedawan	58.1	41.8	0	1.18	57.48
4	FS 06 A	siltstone	Pedawan	51	49.1	0	1	50.45
5	FS 06 AO	shale	Pedawan	73.5	23.7	2.7	1	75.52
6	FS 06 R	shale	Pedawan	83.5	13.6	2.8	1	85.53
7	FS 07 C	shale	Pedawan	60.4	35.2	0	0.63	62.77
8	FS 07 L	shale	Pedawan	64.3	34.3	1.4	0.63	65.29
9	FS 14 B	shale	Pedawan	61.6	36.5	1.8	0.91	62.89
10	FS 15 A	siltstone	Pedawan	66.1	19	11.6	0.89	79.62
11	FS 16 B	siltstone	Pedawan	57.5	41.3	1.3	1.09	58.11
12	FS 17 C	shale	Pedawan	51.6	47.6	0.9	0.53	52.17
13	FS 17 I	shale	Pedawan	72.3	12.8	1.2	0.39	84.78
14	FS 18 C	siltstone	Pedawan	55	35.2	5.2	1.25	62.29
15	FS 18 H	siltstone	Pedawan	69	21.6	2.9	1.25	75.88
17	FS 27 A	claystone	Pedawan	56.8	30.5	8.2	0.54	67.68
18	FS 27 I	claystone	Pedawan	63.3	0	0	0.54	99.15
19	FS 28 B	shale	Pedawan	45.6	47.9	6.4	0.37	51.86
20	FS 33 A	shale	Pedawan	59.8	37.3	3	0.57	62.38
21	FS 36 E	shale	Pedawan	45.6	44.3	1.4	1.04	50.90

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