



Oil to Source Rock Correlation of Besuki Area and its Role in Petroleum System of Banyumas Basin

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ABSTRACT - Banyumas Basin is a basin that has signs of the presence of hydrocarbons, including oil and gas seep on the surface, which indicates active petroleum systems in the subsurface. A lot of oil and gas seeps were found in Banyumas Basin, including oil seeps in Cipari and Besuki, while gas seeps were found in Mount Wetan, Karanglewas, and also Cipari. Exploration drilling wells have also been carried out, such as the Jati-1 Well, Karang Nangka-1, Karang Gedang-1, Tjipari-1, and Mount Wetan-1, but there still has been no significant evidence of this basin producing hydrocarbons. The TOC value of the outcrop samples taken in Cipari and Besuki have bad values, while the crude oil has reflected a severe biodegradation process. Both oil seep samples and one extract bitumen contained high bicadinane (R (resin) annotation) and oleanane indicating both oils and extract to have an input to Tertiary-sourced oils throughout Southeast Asia. Both oil seep samples do not exhibit similarity with the extract source rock. Based on this negative correlation there may be another source rocks in Banyumas Basin, derived from rocks that are not only from Pemali Formation. The existence of this research is expected to be able to add geological data, especially hydrocarbon geochemical data in Banyumas Basin, so that it can provide evidence of the prospect and calculation of reserves contained in this basin, and an understanding of the source rock it self.

Keywords: Source Rock, Oil Seep, Banyumas Basin, Correlation.

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INTRODUCTION

Background

The Banyumas Basin is a sedimentary basin in the South Serayu region and administratively is the southern part of Central Java. As is known in Banyumas Basin, quite a lot of oil and gas seep is found (Figure 1). The presence of a lot of oil and gas seep

indicates that the petroleum systems have been active because the source rock has matured and migrated a small part to the surface to become seepage. There are several oil seeps have been identified on the surface of Banyumas Basin, including oil seeps in Cipari and Besuki, while gas seeps are also quite a lot, such as in Mount Wetan, Karanglewas, and also Cipari. There are also seepages that arise as a result of human intervention, such as the incident in Tipar

Kidul Village, Ajibarang, where at a depth of about 90 meters it released oil, when a refueling station drilled a water well. The well was closed in 2010, to avoid unwanted things happening. Another incident occurred when a farmer drilled a water well in his rice field in Sikampuh Village, Kroya, at a depth of 20 meters spouting gas at a high enough pressure for 4 hours.

Five oil wells have been drilled for oil and gas exploration in Banyumas Basin but have not found economic reserves (Purwasatriya et al., 2019). There is no significant evidence up to now that this basin produces hydrocarbons. The exploration drilling that has failed are wells Jati-1, Karang Nangka-1, Karang Gedang-1, Tjipari-1, and Mount Wetan-1. This failure does not mean that there is no economically viable hydrocarbon in Banyumas Basin, but a new view of the geological setting is needed. Further research about this basin is needed. Setiawan et al. (2019) also stated that the Pemali Formation is assumed to be a potential source rock, while Gabon, Rambatan, and Kalipucang Formations are assumed to be hydrocarbon reservoir rocks in Banyumas Basin. The geochemical analysis does show a fair TOC value containing carbon, immature Tmax, and tends to produce gas (type III kerogen).



Figure 1
Examples of oil seepage in Cipari and gas seepage in Karanglewas, Jatilawang, Banyumas.

The source rock is one of the main problems in petroleum systems in Banyumas Basin. The problems include the content of organic material and the maturity level of the parent rock, so the level of organic material richness and maturity of the source rock needs to be investigated further. Several previous researchers, including Noeradi et al. (2006) have conducted research related to source rock for Banyumas Basin and its surroundings, namely analyzing rock samples from the Halang and Pemali Formation from Majenang and Bumiayu areas. The results of the study stated that the sample had an average TOC (Total Organic Carbon) below 0.5%. However, this is the result of surface samples that in

general have undergone leaching or biodegradation, so the results still need to be validated from other data such as data from drilling wells or outcrop data that are still in fresh condition. The existence of this research is expected to be able to add the geological data, especially hydrocarbon geochemical data in Banyumas Basin, so that it can provide evidence of the prospect and calculation of reserves contained in this basin, in addition to increasing self-confidence in understanding the source rock in Banyumas Basin.

Geological Setting

The Stratigraphy of Banyumas Basin was published by Lemigas (2005) in which the stratigraphic arrangement from oldest to youngest is as follows: The Gabon Formation is the oldest formation exposed in Banyumas Basin, which is predominantly composed of volcanic breccias, then the Kalipucang Formation in the form of reef limestones and clastic limestones that surrounded with the Pemali Formation, which consists of gray-black claystone with sandstone inserts. The Rambatan Formation consists of sandstone with claystone inserts, the Halang Formation consists of turbidite deposits with alternating sandstones with claystone and limestone, the Kumbang Formation consists of breccias with lava insertions, and the Tapak Formation consists of marl and breccia inserted sandstones (Figure 2). Lunt et al. (2008) stated that the Pemali Formation is younger than the Halang Formation, based on research in the North Serayu Basin, while Kabul et al. (2012) stated that the Pemali Formation in Banyumas Basin which is of Late Miocene age (N17-N18) is older than the Halang Formation.

In general, almost all oil and gas seeps in Banyumas Basin are in the Halang Formation (Purwasatriya and Waluyo, 2012). Other authors also argue that the oil seep sample comes from the Pemali Formation where oil has undergone secondary migration through the northwest-southeast trending joint and was found in the Halang Formation (Anil, 2021). Other researchers analyzed the relationship between source rock and oil samples (source rock to oil correlation) in four formations, namely Halang Formation, Rambatan Formation, Pemali Formation, and Karangsambung Formation (Figure 3), as well as oil samples from the Karang Nangka-1 well, Gunung Wetan -1, oil seep in Kali Panjatan, Lawen, and Karang Kobar. The results show that the Halang Formation has the most similar characteristics to the oil samples, but the authors doubt whether the

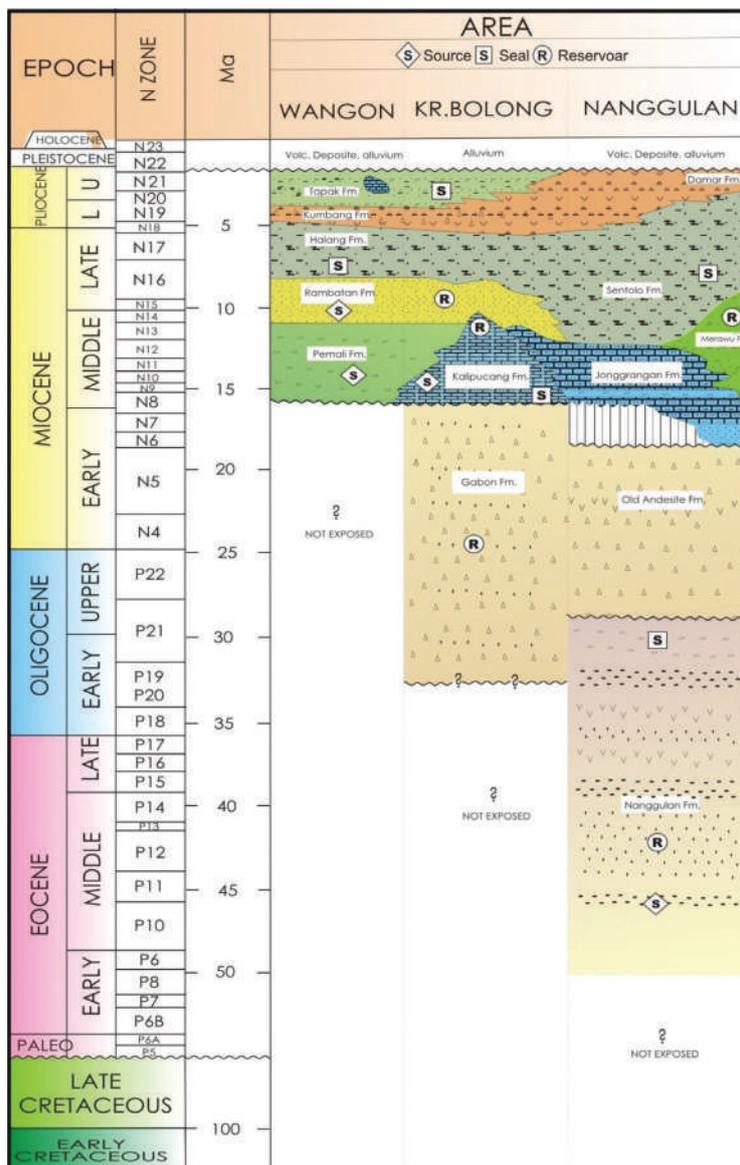


Figure 2
Regional stratigraphy of the South Serayu Basin (LEMIGAS, 2005).

relatively young Halang Formation, namely Middle Miocene – Late Miocene, has a sufficient maturity level, so it is concluded that the possibility of the Wungkal Formation which has similar characteristics to the Halang Formation but having an older age is considered to be the source rock in Banyumas Basin area (Subroto, et al., 2007). The oil-to-source correlation between oil samples from Jati-1 Well (Total Depth of 14,747 feet) and rock formations on the surface shows that the oil samples in Jati-1 Well show similar characteristics to the Eocene Karangsembung Formation with a marine environment shallow (Subroto et al., 2008). The rapid deposition of the volcanoclastic system in the magma arc will make the organic material preservation system better

and the very thick volcanoclastic sediment will make the geothermal gradient sufficient to ripen the parent rock at the bottom (Purwasatriya et al., 2018). The rapid and thick deposition of the sediment is caused by the type of volcanic arc flexure basin where the basin is limited by the presence of a volcanic arc in the middle of the sea. The implications for the source rock are mainly in the intensity of heat in the basin and thick volcanoclastic deposition, all of which affect the maturity level of hydrocarbons (Purwasatriya et al., 2019). Based on this, Banyumas Basin is estimated to have 2 (two) potential source rocks, specifically from Karangsembung Formation (Paleogene host rock) and the lower Halang Formation (Neogene source rock).

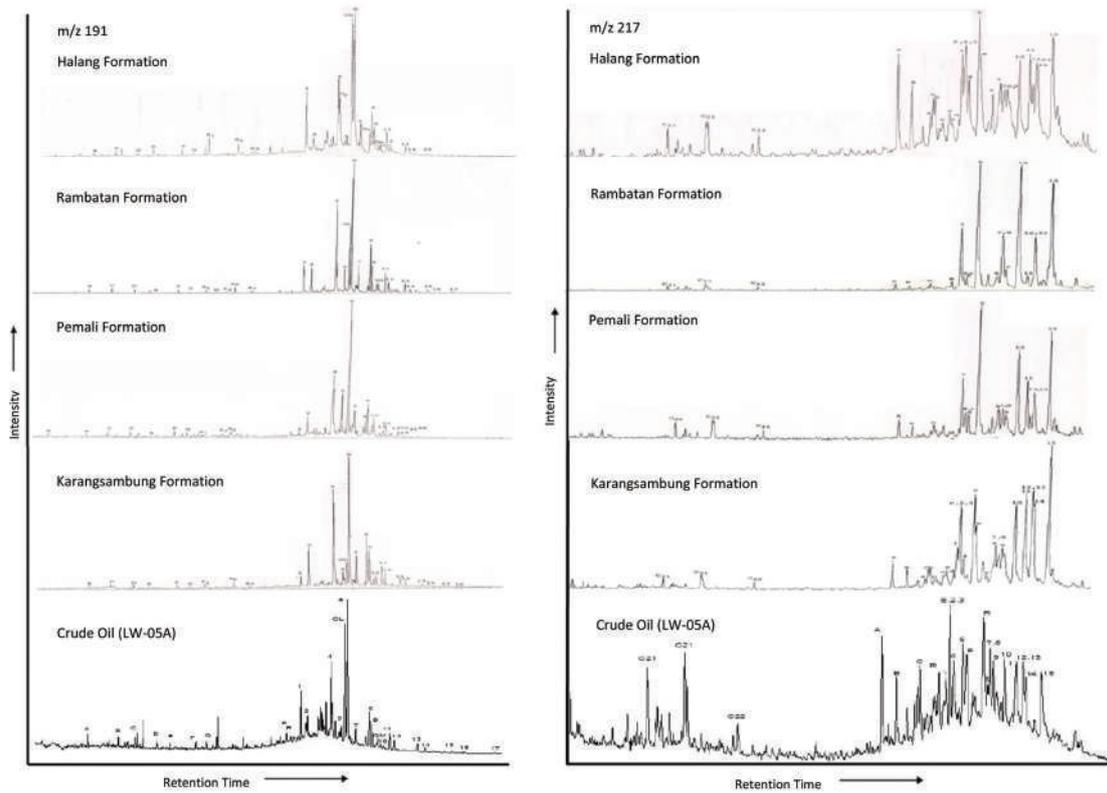


Figure 3

Analysis of partial mass chromatogram m/z-191 which shows the distribution of the hottest tricyclic and pentacyclic and partial mass chromatogram m/z-217 which shows the distribution of steranes in the sample (Subroto et al., 2007).

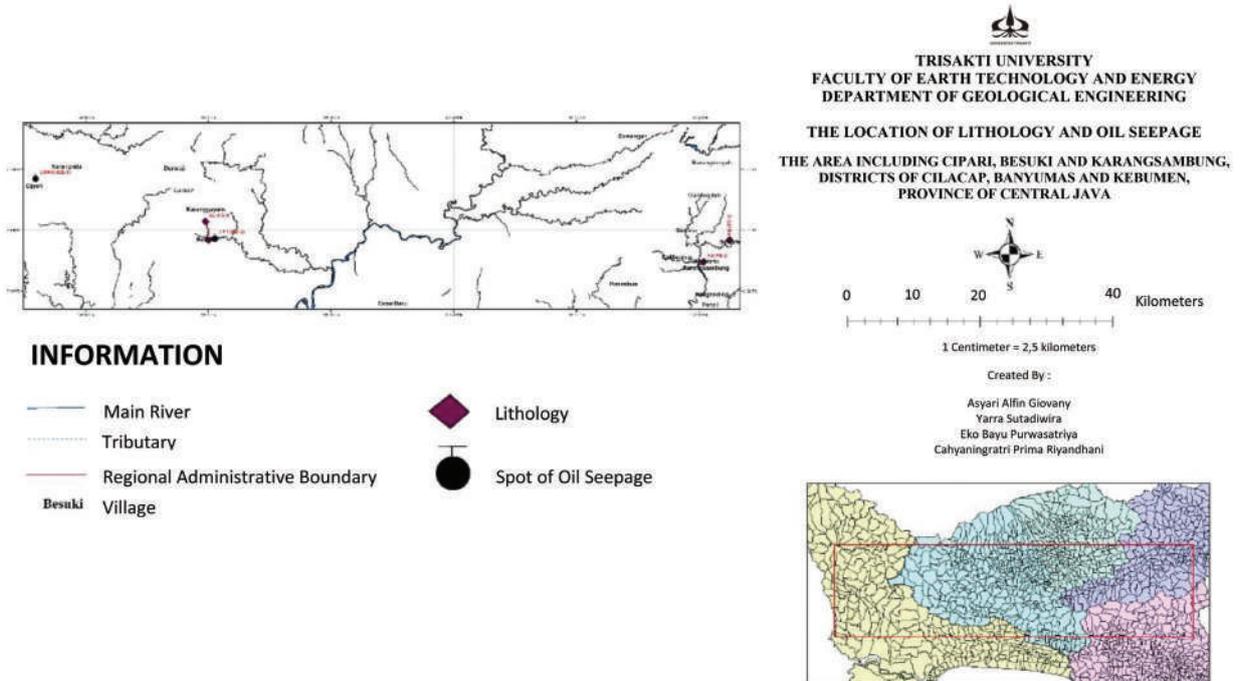


Figure 4

The map of lithology and oil seep, in Cipari, Besuki, and Karangsembung, Banyumas Basin.

METHODOLOGY

Several geochemical analyses were carried out on surface samples (outcrops) in Besuki and Karangasambung areas, including analysis of total organic carbon (TOC), rock eval pyrolysis (REP), and kerogen type. Meanwhile, analysis of gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) was carried out on surface samples and oil seep. All sample analyses were

carried out at the geochemical laboratory of PT. Geoservices. The standard method used is internationally recognized according to ISO 9001:2015. The data for all analyzed samples can be seen in Table 1, and the sample locations map is shown in Figure 4, while the peak identification of the chromatogram can be seen in Table 2. The general standard that can be used as an indication of source rock potential is the TOC value scale for sedimentary rocks from

Table 1
Sample identification

	ID Sample				Litology	Formation	TOC	HI	Tmax	GC	GCMS
	Number	Field ID	Location	Name							
Outcrops	1	KM	Cipari	FS-1	Claystone	Halang	0,4	8	-	-	-
	2	KJ	Cipari	FS-2	Scaly Clay	Karangasambung	0,19	21	-	-	-
	3	BL	Cipari	FS-3	Scaly Clay	Karangasambung	0,55	27	356	-	-
	4	11A	Besuki	FS-4	Claystone		0,66	41	408	-	-
	5	11B	Besuki	FS-5	Claystone		0,62	42	375	-	-
Oil Seep	6	Cipari	Cipari	OS-1						V	V
	7	LP-1	Besuki	OS-2						V	V
	8	LP-11	Besuki	Extract						V	V

Peters and Cassa (1994), which is then modified as in Table 3. TOC is the amount of organic carbon stored in rock expressed as a percent by weight of the dry rock. Sedimentary rock can be source rock if it has a minimum TOC value. This TOC parameter is used at an early stage to determine the potential for hydrocarbons in rock before proceeding to the next stage of analysis. TOC measurements were carried out and continued with rock eval pyrolysis (REP) if the rock contains a TOC of more than 0.5, while other analyses was the type of kerogen. Sample characteristics are shown on the GCMS profile, including organic matter content and source facies.

The quality of organic matter must also be the next determining parameter, which is a determinant of the basic properties of oil and gas products, which is referred to as kerogen. The concentration is owned by the five main elements: carbon, hydrogen, oxygen, nitrogen, and sulfur. This is a determinant to identify the type of kerogen. The method used to classify the type of kerogen is to use a graph of the value between hydrogen (HI) and oxygen (OI) known as the Van Krevelen diagram (Peters and Cassa, 1994). In the final stage of the study, the correlation was carried out between the two oil seeps (OS-1 and OS-2) and the extract samples (LP-11). One method of geochemical correlation is to compare biomarkers in source

rock and oil samples. Several types of biomarkers used include normal alkanes, sterane, and triterpane. Sterane biomarkers will indicate the source facies. Each source rock and oil sample was plotted for correlation purposes, so the results of plotting will show whether the samples are correlative or come from different sources. Triterpane tricyclic patterns can also indicate source facies. The correlation can be done by indicating the origin of organic material and source facies with the identification of tricyclic triterpane patterns from source rock and oil samples. A positive correlation may or may not indicate a relationship between samples, while a negative correlation will provide strong evidence that there is a lack of relationship between the samples (Peters et al., 2005).

RESULTS AND DISCUSSION

Based on the TOC value of the FS-1, FS-2, and FS-3 samples, the range of TOC is 0,19-0,55, which are considered bad values. The analysis did not continue to the next step based on these TOC values. The oil seeps (OS-1) from Cipari and LP-1 (OS-2), and the extract sample (LP-11) were analyzed (Table 1) using capillary gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS). The

Table 2
Labels used for peak identification in mass chromatograms

Peak ID	Carbon Number	Compound Name	Peak ID	Carbon Number	Compound Name
	18	Tricyclic diterpane	A	27	13β(H),17α(H)-diacholestane(20S)
B	19	Tricyclic diterpane	B	27	13β(H),17α(H)-diacholestane(20R)
C	20	Tricyclic diterpane	C	28	24-Methyl-13β,17α(H)-diacholestane(20S)
D	21	Tricyclic diterpane	D	28	24-Methyl-13β,17α(H)-diacholestane(20R)
E	22	Tricyclic diterpane	E	29	24-Ethyl-13β,17α(H)-diacholestane(20S)
F	23	Tricyclic diterpane	F	29	24-Ethyl-13β,17α(H)-diacholestane(20R)
G	24	Tricyclic diterpane	a	27	13α(H),17β(H)- diacholestane(20S)
H	25	Tricyclic diterpane	b	27	13α(H),17β(H)- diacholestane(20R)
I	26	Tricyclic diterpane	c	28	24-Methyl-13α,17β(H)-diacholestane(20S)
J	27	Tricyclic diterpane	d	28	24-Methyl-13α,17β(H)-diacholestane(20R)
K	28	Tricyclic diterpane	e	29	24-Ethyl-13α,17β(H)-diacholestane(20S)
L	29	Tricyclic diterpane	f	29	24-Ethyl-13α,17β(H)-diacholestane(20R)
1	27	18α (H),21β(H)-22,29,30-trisnorhopane (Ts)	1	27	5α(H),14α(H),17α(H)-cholestane(20S)
2	27	17α (H),21β(H)-22,29,30-trisnorhopane (Tm)	2	27	5β(H),14α(H),17α(H)-cholestane(20R)
M	30	Tricyclic diterpane	3	27	5α(H),14β(H),17β(H)-cholestane(20R)
3	28	17α (H),21β(H)-28,30-bishorhopane	4	27	5α(H),14β(H),17β(H)-cholestane(20S)
4	29	17α (H),21β(H)-30-norhopane	5	27	5α(H),14α(H),17α(H)-cholestane(20R)
5	29	17β (H),21α (H)-30-normoretane	6	28	24-Methyl-5α(H),14α(H),17α(H)-cholestane (20S)
6	30	17α (H),21β (H)-hopane	7	28	24-Methyl-5β(H),14α(H),17α(H)-cholestane (20R)
7	30	17β (H),21α (H)-moretane	8	28	24-Methyl-5α(H),14β(H),17β(H)-cholestane (20R)
8	31	17α (H),21β(H)-30-homohopane (22S)	9	28	24-Methyl-5α(H),14β(H),17β(H)-cholestane (20S)
9	31	17α (H),21β(H)-30-homohopane (22R)	10	28	24-Methyl-5α(H),14α(H),17α(H)-cholestane (20R)
10	31	17β (H),21α(H)-30-homomoretane	11	29	24-Ethyl-5α(H),14α(H),17α(H)-cholestane (20S)
11	32	17α (H),21β(H)-30,31-bishomohopane (22S)	12	29	24-Ethyl-5β(H),14α(H),17α(H)-cholestane (20R)
12	32	17α (H),21β(H)-30,31-bishomohopane (22R)	13	29	24-Ethyl-5α(H),14β(H),18β(H)-cholestane (20R)
13	33	17α (H),21β(H)-30,31,32-trishomohopane (22S)	14	29	24-Ethyl-5α(H),14β(H),17β(H)-cholestane (20S)
14	33	17α (H),21β(H)-30,31,32-trishomohopane (22R)	15	29	24-Ethyl-5α(H),14α(H),17α(H)-cholestane (20R)
15	34	17α (H),21β(H)-30,31,32,33-tetrahomohopane (22S)	R	30	Cyclic Alkane
16	34	17α (H),21β(H)-30,31,32,33-tetrahomohopane (22R)	*	30	C30-Methylated Sterane
17	35	17α(H),21β(H)-30,31,32,33,34-pentahomohopane (22S)	*	30	C30-Rearranged Methylated Sterane
18	35	17α(H),21β(H)-30,31,32,33,34-pentahomohopane (22R)	16	30	24-Ethyl-4α-Methyl-5α(H),14α(H),17α(H)-Cholestane(20S)
OL	30	18a (H)-O leanane	17	30	24-Ethyl-4α-Methyl-5α(H),14β(H),17β(H)-Cholestane(20S/20R)
Gm	30	Gammacerane	18	30	4α,23,24-Trimethyl-5α(H),14β(H),17β(H)-Cholestane(20R)
R	30	Cyclic Alkane	19	30	24-Ethyl-4α-Methyl-5α(H),14α(H),17α(H)-Cholestane(20R)
MH	30	Methylated Hopane	20	30	24-Ethyl-4β-Methyl-5α(H),14α(H),17α(H)-Cholestane(20R)
a	30	Higher-plant terpane	21	30	4α,23,24-Trimethyl-5α(H),14α(H),17α(H)-Cholestane
b	30	Higher-plant terpane	22	30	Dinosterane Isomer
c	30	Higher-plant terpane	23	30	Dinosterane Isomer
d	30	Higher-plant terpane			
MH	32	Methylated Hopane			
X	24	Tetracyclic Terpane			

Table 3
Classification of TOC, REP, and VR according to Peter and Cassa (1994)

Geochemical Parameters Describing The Petroleum Potential (Quantity) of an Immature Source Rock						
Petroleum Potential	Organic Matter					
	TOC (wt. %)	Rock-Eval Pyrolysis		Bitumen ^c		Hydrocarbons (ppm)
		S ₁ ^a	S ₂ ^b	(wt. %)	(ppm)	
Poor	0-0.5	0-0.5	0-2.5	0-0.05	0-500	0-300
Fair	0.5-1	0.5-1	2.5-5	0.05-0.10	500-1000	300-600
Good	1-2	1-2	5-10	0.10-0.20	1000-2000	600-1200
Very Good	2-4	2-4	10-20	0.20-0.40	2000-4000	1200-2400
Excellent	>4	>4	>20	>0.40	>4000	>2400

^amg HC/g dry rock distilled by pyrolysis.

^bmg HC/g dry rock cracked from kerogen by pyrolysis.

^cEvaporation of the solvent used to extract bitumen from a source rock or oil from a reservoir rock causes loss of the volatile hydrocarbons below about *n*-C₁₅. Thus, most extracts described as C₁₅₊ hydrocarbons. 'Lighter hydrocarbons can be at least partially retained by avoiding complete evaporation of the solvent (eg. C₁₀₊).

Geochemical Parameters Describing Kerogen Type (Quality) and the character of expelled products ^a				
Kerogen Type	HI (mg HC/g TOC)	S ₂ /S ₃	Atomic H/C	Main Expelled Product at Peak Maturity
I	>600	>15	>1.5	Oil
II	300-600	10-15	1.2-1.5	Oil
II/III ^b	200-300	5-10	1.0-1.2	Mixed oil and gas
III	50-200	1-5	0.7-1.0	Gas
IV	<50	<1	<0.7	None

^aBased on a thermally immature source rock. Ranges are approximate.

^bType II/III designates kerogens with compositions between type I and III pathways (e.g. Figure 5.1) that show intermediate HI (see Figures 5.4-5.11).

Stage of Thermal Maturity for Oil	Maturation			Generation		
	R _o (%)	T _{max} (°C)	TAI ^a	Bitumen/TOC ^b	Bitumen (mg/g rock)	PI ^c [S ₁ /(S ₁ +S ₂)]
Immature	0.2-0.6	<435	1.5-2.6	<0.05	<50	<0.10
Mature						
Early	0.6-0.65	435-445	2.6-2.7	0.05-0.10	50-100	0.10-0.15
Peak	0.65-0.9	445-450	2.7-2.9	0.15-0.25	150-250	0.25-0.40
Late	0.9-1.35	450-470	2.9-3.3	-	-	>0.40
Postmature	>1.35	>470	>3.3	-	-	-

^aTAI, thermal alteration index.

^bMature oil-prone source rocks with type I or II kerogen commonly show bitumen/TOC ratios in the range 0.05-0.25. Caution should be applied when interpreting extract yields from coals. For example, many gas-prone coals show high extract yields suggesting oil-prone character, but extract yield normalized to TOC is low (<30 mg HC/g TOC). Bitumen/TOC ratios over 0.25 can indicate contamination or migrated oil or can be artifacts caused by ratios of small. Inaccurate numbers. ^cPI, production index.

oil seep sample has been characterized and inferred as the expected source rock facies in Banyumas Basin, Centre of Java. The characterization of the oil seep sample was determined by GC-MS chromatograms to conclude the input of organic matter and its depositional environment. The oil seep sample was first analyzed using the GC technique, presented in Figures 5 and 6. Based on GC traces, it can be seen in Figures 5 and 6, that crude oil from Cipari and Besuki locations has reflected a severe biodegradation process to reach level 5 biodegradation.

This can be seen by the loss of n-alkanes and some partial removal of the isoprenoids in the GC traces. (Wenger and Isaksen, 2002). A characteristic feature of biodegraded oil is visualized by the presence of a hump in the GC traces, which indicates the presence of a complex mixture of unsolved branched/cyclic alkanes (Sutadiwiria et al., 2018). Other similar reports about crude oil indicate that the oil source contains bicadinane resin significantly, which also shows the contribution of fluvio-deltaic organic material (Sutadiwiria et al., 2017). GC and kerogen analysis were

also performed on the extract sample (LP-11). The pristane/phytane ratio is moderate (2.39), indicating that the source rock was deposited in the source facies of marine algae under suboxic conditions (Figure 7). Low Hydrogen Indices (41-42) suggest the presence of mainly gas-prone kerogen (Type III/IV, Figure 8). A more detailed analysis of the GC-MS techniques was carried out in order to evaluate the composition of the high molecular weight hydrocarbon (triterpene and sterane) biomarkers, using m/z 191 and m/z 217 mass chromatograms for triterpene and sterane biomarkers respectively. Typical m/z 191 and m/z 217 mass chromatograms of the oil seeps and the

extracted sample are shown in Figure 9 (a-f), with peak assignments in Table 2. The peak pattern of the sterane indicates the origin of the organic material is terrestrial and coupled with the presence of impurities from other compounds such as bicadinane. The abundance of these compounds in the oil seep samples indicates the presence of clay-rich sediments in the source rock. The sample is dominated by triterpane derived from higher plants. The abundance of the 18 α (H)-oleanane and bicadinane (C₃₀ resin-derived cycloalkanes annotated R) are present in relatively high amounts.

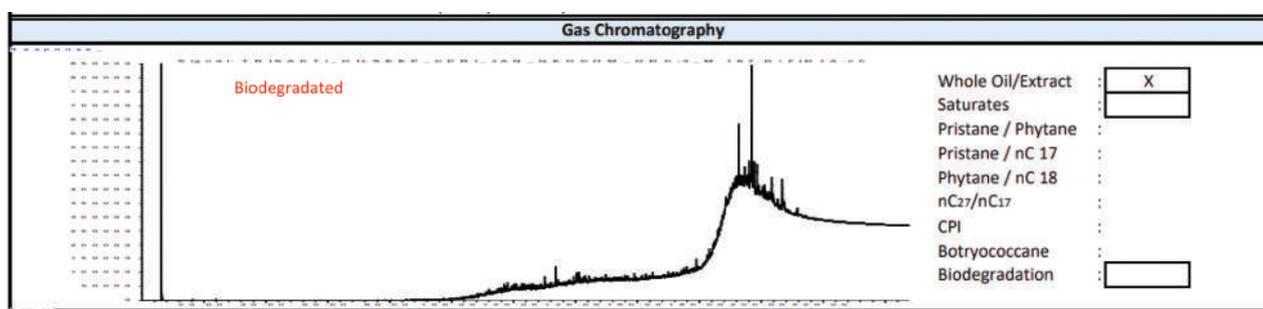


Figure 5
Whole oil chromatograms showing representative GC oil seep from OS-1, Cipari, Banyumas Basin

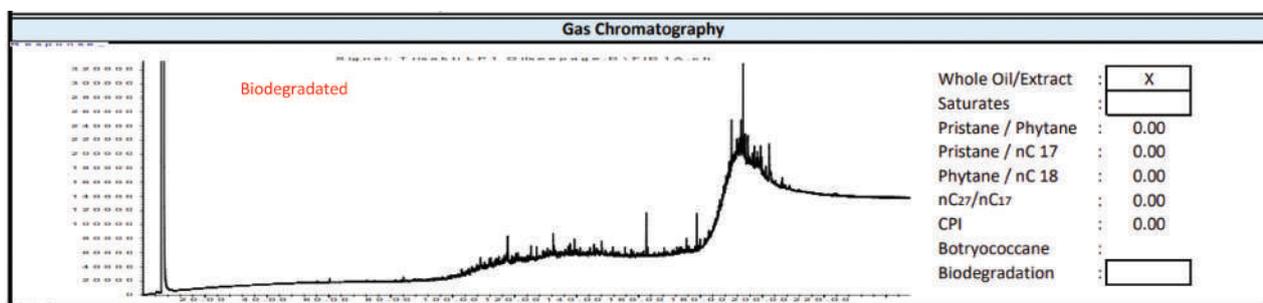


Figure 6
Whole oil chromatograms showing representative GC oil seep from OS-2, Besuki, Banyumas Basin

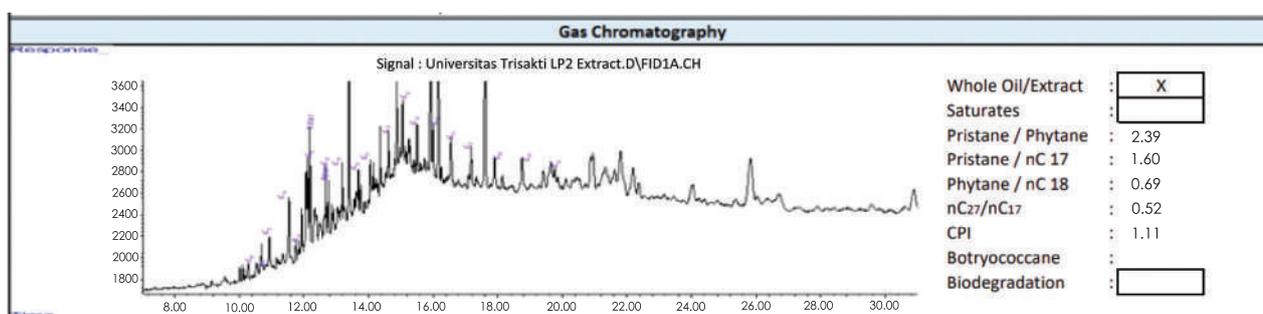


Figure 7
Whole oil chromatograms showing representative GC oil seep from extract sample LP-11, Besuki, Banyumas Basin

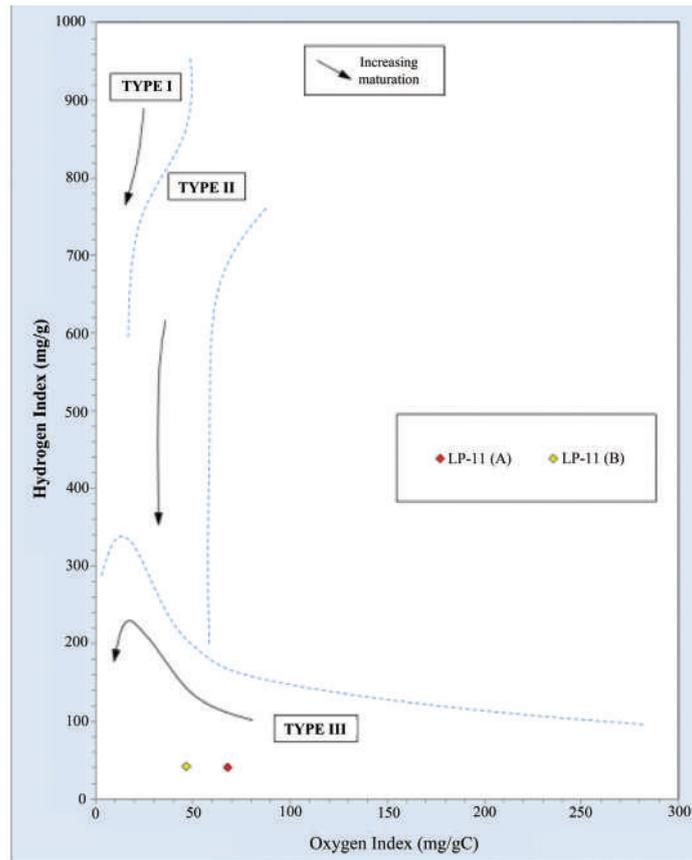


Figure 8
Modified Van Krevelen Diagram of Hydrogen Index Vs. Oxygen Index

Ion 191.00(190.70 to 191.70):Univ Trisakti LP1 Oilseep SAT.D\data.ms

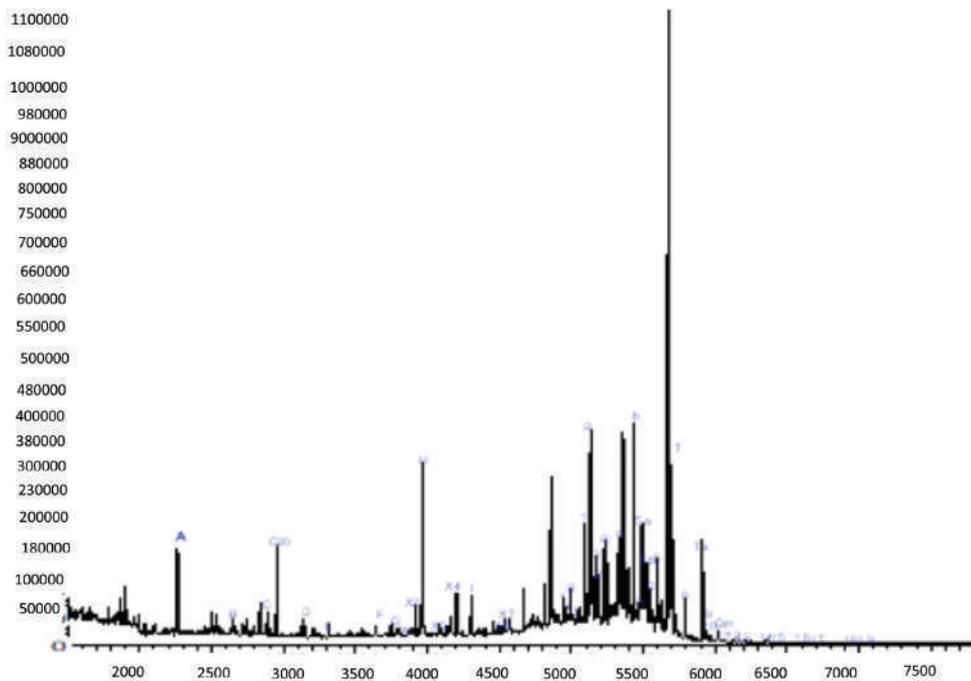


Figure 9a
GCMS results in the form of m/z 191 showing the distribution of oil seep Cipari (OS-1), Banyumas Basin. See Table 2 for the key to labels.

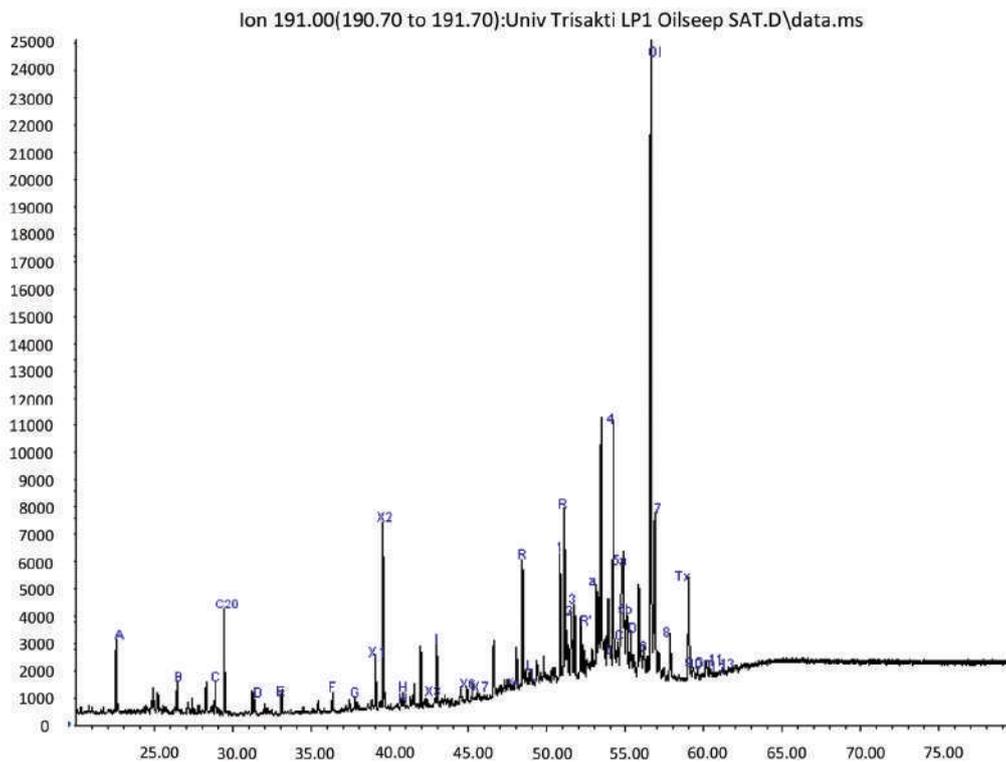


Figure 9b
GCMS results in the form of m/z 191 showing the distribution of oil seep LP-1 (OS-2), Banyumas Basin. See Table 2 for the key to labels.

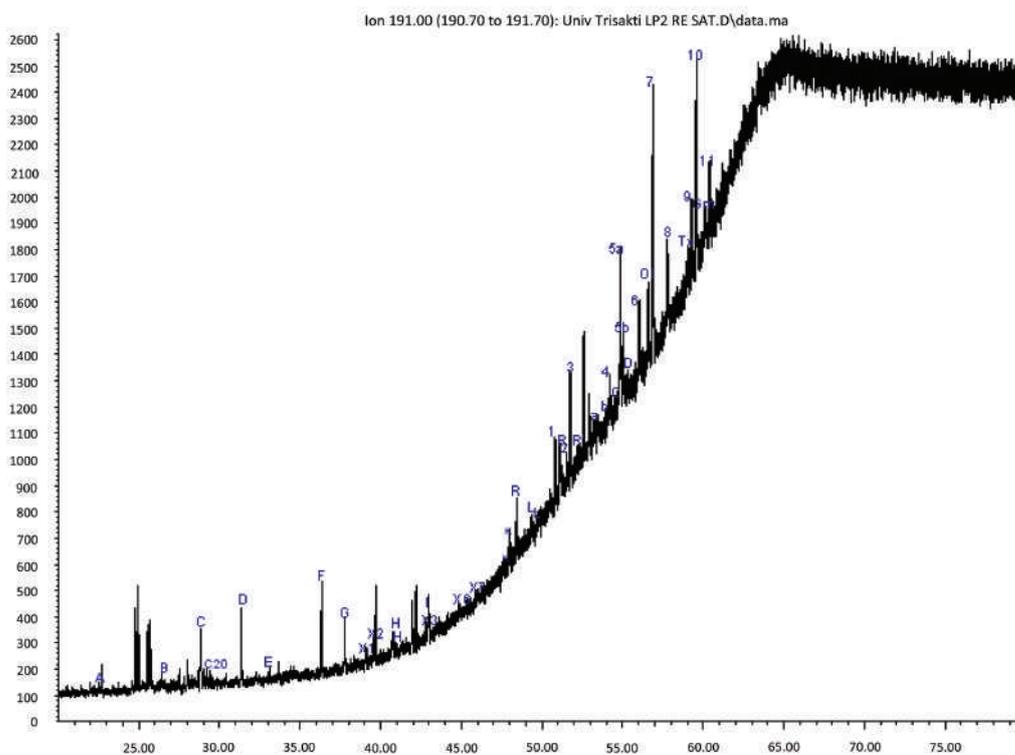


Figure 9c
GCMS results in the form of m/z 191 showing the distribution of extract sample LP-11, Banyumas Basin. See Table 2 for the key to labels

Oil to Source Rock Correlation of Besuki Area and its Role in Petroleum System of Banyumas Basin
(Yarra Sutadiwiria, et al.)

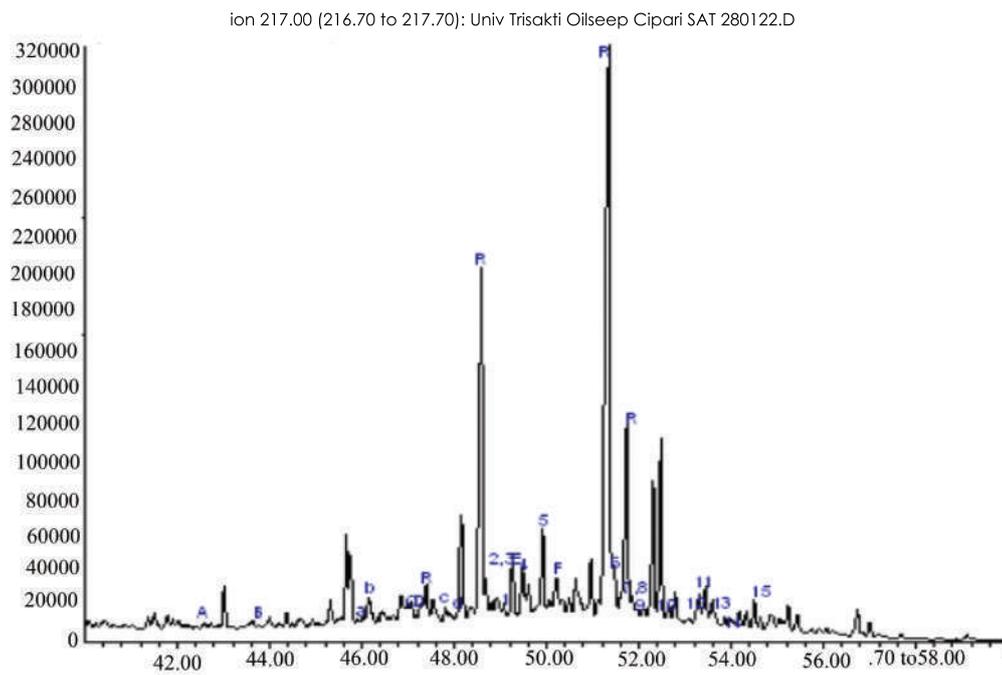


Figure 9d
GCMS results in the form of m/z 217 showing the distribution of oil seep Cipari (OS-1), Banyumas Basin. See Table 2 for the key to labels

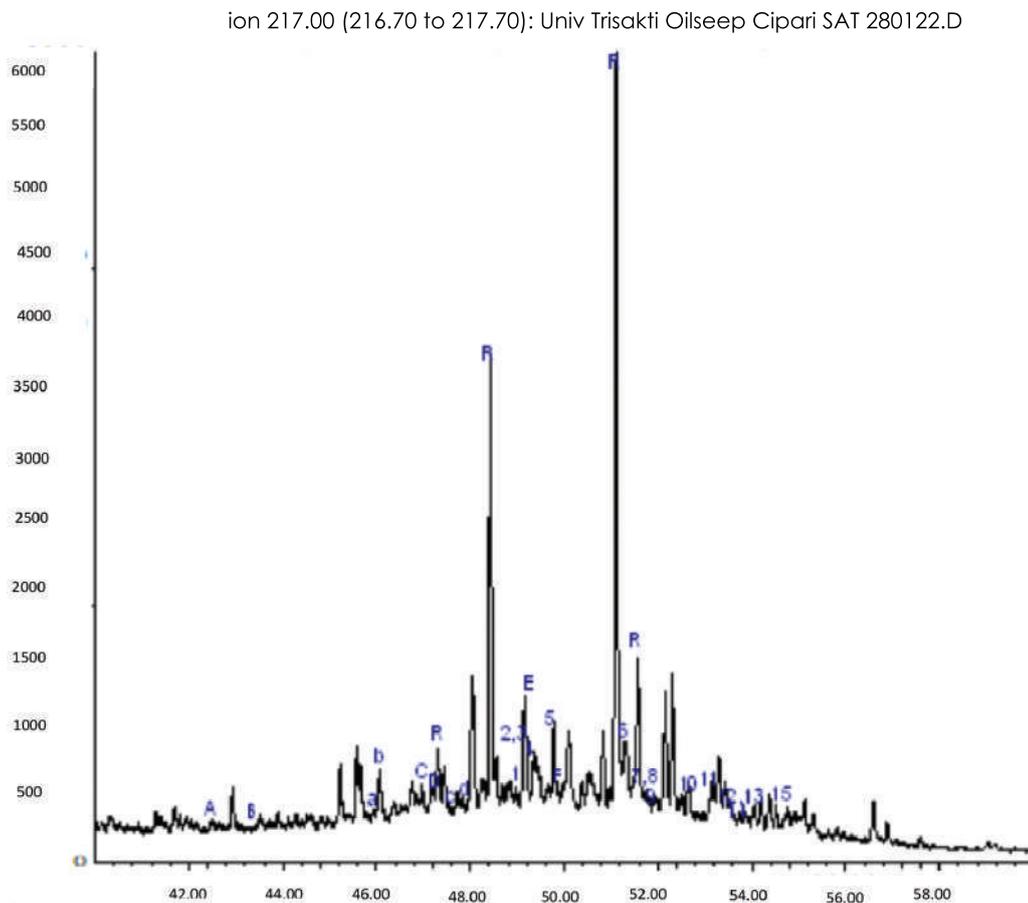


Figure 9e
GCMS results in the form of m/z 217 showing the distribution of oil sample LP-1 (OS-2), Banyumas Basin. See Table 2 for the key to labels

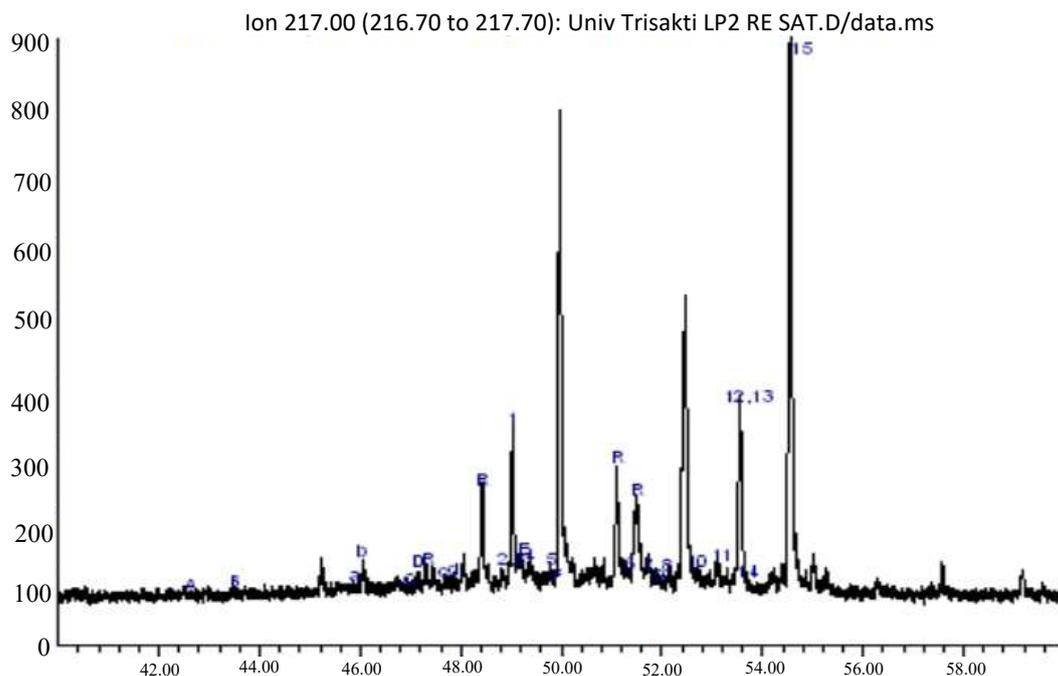


Figure 9f

GCMS results in the form of m/z 217 showing the distribution of extract sample (LP-11), Banyumas Basin. See Table 2 for the key to labels

These components are considered to be specific for resinous, higher plant input to Tertiary-sourced oils throughout Southeast Asia (Cox et al., 1986; Grantham dkk., 1983, Sutadiwiria et al., 2018). According to Huang and Meinschein (1979), C_{27} sterols are mainly derived from algae, while C_{29} sterols are usually associated with higher plants. Figure 10 shows a ternary diagram of the relative abundance of sterane (C_{27} - C_{29}) in Cipari and Besuki areas. Oil seep samples at both locations showed a relatively higher proportion of C_{27} sterane (38.24% - 42.77%) compared to C_{28} (29.55% - 35.91%) sterane and C_{29} (25.85% - 27.68%) sterane. This reflects the significant contribution of aquatic algal organic matter with a small contribution from terrigenous organic matter (Peters et al., 2005).

Plots of the sterane distribution on the Huang and Meinschein paleoenvironment diagrams show that the oil seeps are located in an “*open marine – estuary or bay*” region. The distribution of regular sterane (m/z 217) for the extracted sample showed the dominance of C_{29} sterane (R) (72,75%) compared to the C_{27} form (22,33%). This implies a significant contribution of terrestrial organic matter, with minor algal contributions to the source rock (Moldowan et al., 1994, Figure 10). The plot of the sterane distribution on the Huang and Meinschein ternary diagrams shows that the extract is located in the “*terrestrial*”

region. Finally, oil to oil and oil to source rock correlations exercise were carried out to include both oil seeps (OS-1 and OS-2) and one extract bitumen (LP-II). The correlation was carried out based on GC, GC-MS (terpane and sterane), and tricyclic terpane. The GC traces of both oils are heavily biodegraded hence correlation based on GC cannot be obtained.

The distribution of sterane data for both oils generally has a similar significant contribution of terrestrial organic matter in the original source rock facies, whilst the extract LP-II is of mixed terrestrial and marine algal (Moldowan et al., 1985). Both oil seep samples (OS-1 and OS-2) and extract (LP-II) contained high bicadinane (R (resin) annotation) and oleanane indicating both extract and oils to have an input of Tertiary-sourced higher plant (Figure 9a-f). Based on tricyclic terpane peaks A-L on m/z 191, organic facies of both oil seeps are derived from terrestrial dominant environments that produced tricyclics dominated by C_{19} - C_{21} (BD). The ratio of C_{29}/C_{30} hopane shows low values of <1 and high ratios of C_{19}/C_{23} tricyclics (>1), this indicates the dominant influence of land plants (Zumberger, 1983, Figure 11). This indicates that these oils originated from the fluviodeltaic clastic host rock (Moldowan et al., 1985). Unlike the source rock extract, having low C_{19}/C_{23} tricyclics (<1), this most likely suggests a different depositional environment (Figure 11).

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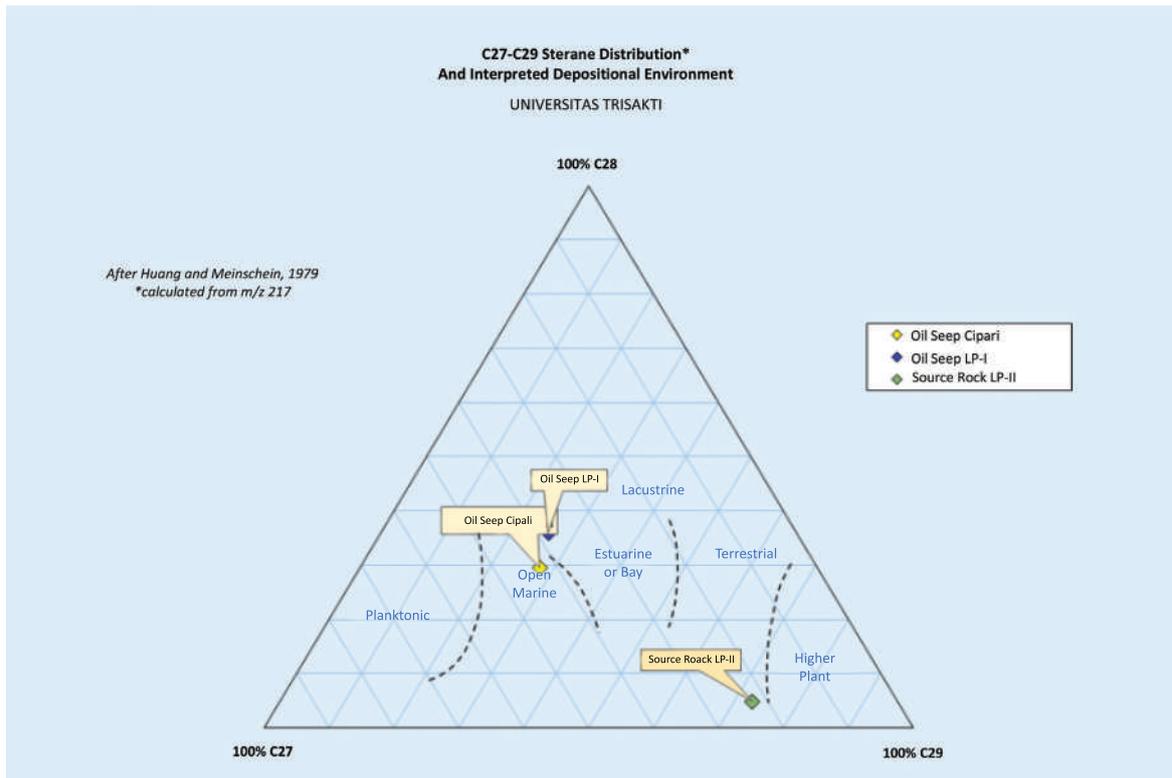


Figure 10
The carbon numbers of C27, C28, and C29 sterane, the saturated fractions of oil seeps (OS-1 and OS-2), and extract (LP-11) on Huang and Meinschein's (1979) ternary diagram

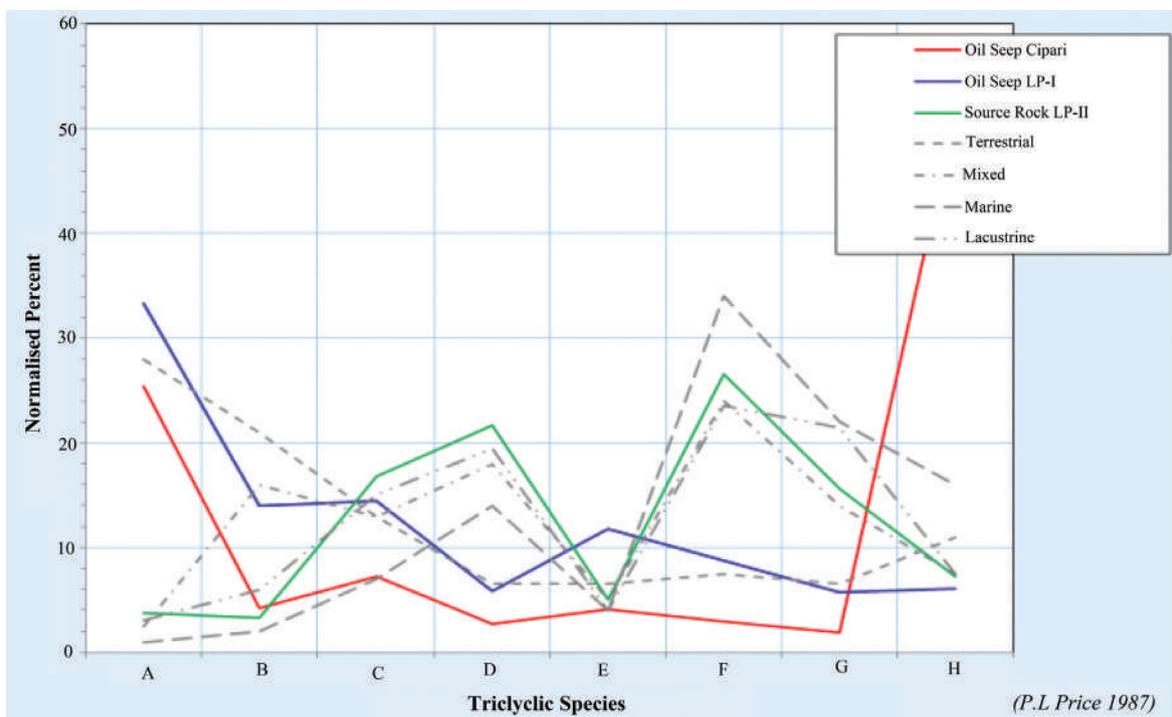


Figure 11
Tricyclic Terpane Distribution of Oil Seeps (OS-1 and OS-2) and extract sample, Banyumas Basin

CONCLUSIONS

Based on similarities/differences in the characteristics of the biomarkers of alkanes, isoprenoids, triterpene, and sterane data, both oil seep samples (OS-1 and OS-2) shared similar biomarker characteristics suggesting positive correlation suggest derivation from a mature terrestrial source rock. However, both oil seep samples do not show a similarity with the extract sample (LP-11). This suggests the oil seeps and the extract have negative correlation. Paleofacies of rocks that are expected as source rocks are terrestrial (higher plant), with the contribution of material from algae (marine algae). There may be different source rocks, from different families in Banyumas Basin which come from rocks that are not from the Pemali Formation.

GLOSSARY OF TERMS

Unit	Definition	Symbol
Tmax	Maximum Temperature	
TOC	Total Organic Carbon	
REP	Rock Eval Pyrolysis	
GC	Gas Chromatography	
GC-MS	Gas Chromatography Spectrum Mass	
HI	Hydrogen Index	
OI	Oxygen Index	
C ₂₇	Heptakosana	
C ₂₈	Methyl Cholestane	
C ₂₉	Methyl Ergostane	
C ₃₀ Hopana	C ₃₀ 17A,21B-Hopane	
C ₁₉ , C ₂₁ , C ₂₃	Tricyclics Diterpanes	
m/z	Fragmentogram mass	
R	Resin	

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REFERENCES

- Anil.** 2021. Analisis Biomarker dari Sampel Rembesan Minyak Dan Sampel Batuan Pada Sub-Cekungan Banyumas. Bachelor thesis of Geological Engineering Universitas Trisakti (*unpublished*).
- Cox, H.C., de Leeuw, J.W., Schenck, P.A., van Koningsveld, H., Jansen, J.C., van de Graaf, B., van Geerestein, B., Kanters, J.A., Kruk, C., and Jans, A.W.R.,** 1986. Biscadinane, a C₃₀ pentacyclic isoprenoid hydrocarbon found in crude oil. *Nature* 319, 316-318.
- Grantham, P.L., Posthuma, J., and Baak A.,** 1983. Triterpanes in a number of Far-Eastern crude oils. Dalam Bjojay, M. (eds). *Advances in organic geochemistry 1981*. Wiley, Chichester, 675-683.
- Huang W.Y and Meinschein W.G.,** 1979. Sterols as Ecological Indicators. *Geochimica and Cosmochimica Acta* 43 739-45.
- Kabul Y.A., Aswan, and Purwasatriya E.B.,** 2012. Studi formasi Pemali daerah Besuki dan sekitarnya, Kecamatan Lumbr, Kabupaten Banyumas, Jawa Tengah. *Jurnal JTM*. 19 (4): 181-190.
- LEMIGAS,** 2005. *Summary on Petroleum Geology of Indonesia's Sedimentary Basins*, Prepared for Patra Nusa Data, Jakarta.
- Lunt, P., Burgon, G., and Baky, A. A.,** 2008. The Pemali Formation of Central Java and Equivalents: Indicators of Sedimentation on an Active Plate Margin, *Journal of Asian Earth Sciences*.
- Moldowan, J.M., Dahl, J., and Huizinga, B.J.,** 1994. The molecular fossil record of oleanane and its relation to angiosperms. *Science* 265, 768 -771.
- Noeradi, D., Subroto E.A., Wahono H.E., Hermanto E., and Zaim Y.,** 2006, Basin Evolution and Hydrocarbon Potential of Majalengka-Bumiayu Transpression Basin, Java Island, Indonesia: *AAPG 2006 International Conference and Exhibition*, Perth, Australia, 32p.

- Peters, K.E., Walters, C.C., and Moldowan, J.M.,** 2005. *The Biomarker Guide*, Vol. I & II. Cambridge University Press, Cambridge.
- Peters, K.E. and Cassa, M.R.,** 1994. Applied Source Rock Geochemistry. The Petroleum System from Source to Trap. *The American Association of Petroleum Geologists Memoir*, 60.
- Purwasatriya E.B. and Waluyo G.,** 2012. Studi potensi minyak dangkal dengan pendekatan metode statistik berdasar data geologi permukaan di Cekungan Banyumas. *Jurnal Dinamika Rekayasa*. 8 (2): 48-55.
- Purwasatriya E.B., Surjono S.S., Amijaya D.H., Saputra F.E., and Hendaryono, Said S.,** 2018, Tectono-stratigraphy of Banyumas Basin and Its correlation to Petroleum Potential. *Proceedings South East Asia Technology University Conference (SEATUC)*. Yogyakarta, 58.
- Purwasatriya, E. B., Surjono, S. S., and Amijaya, D, H.,** 2019. Sejarah Geologi Pembentukan Cekungan Banyumas Serta Implikasinya Terhadap Sistem Minyak dan Gas Bumi. *Jurnal Dinamika Rekayasa*. 15(1): 23-3.
- Subroto, E., Noeradi, D., Priyono, A., Wahono, A.E., Hermanto, E., Praptisih, and Santoso, K.,** 2007, The Paleogene Basin Within the Kendeng Zone, Central Java Island, and Implication to Hydrocarbon Prospectivity: *Proceedings Indonesian Petroleum Association*, 31st annual convention & exhibition, Jakarta, 14p.
- Subroto, E., Ibrahim, A.M.T., Hermanto, E., and Noeradi, D.,** 2008, Contribution of Paleogene and Neogene sediments to the Petroleum System in the Banyumas Sub-Basin, Southern Central Java: *AAPG International Conference and Exhibition*, Capetown, 6p.
- Sutadiwiria, Y., Hamdani, A.H., Sendjaja, Y.A., Haryanto, I., and Yeftamikha,** 2018. The Biomarker Composition of Some Oil Seeps from West Sulawesi, Indonesia. *Indonesian Journal on Geoscience*, 5, No. 3, 214-215.
- Sutadiwiria, Y., Yeftamikha, Hamdani, A.H., Sendjaja, Y.A., Haryanto, I., and Sunardi, E.,** 2017. Origin of Oil Seeps in West Sulawesi On-shore, Indonesia: Geochemical Constraints and Paleogeographic Reconstruction of the Source Facies. *Journal of Geological Sciences and Applied Geology*, I (1), Universitas Padjadjaran, Faculty of Geological Engineering, Bandung, Indonesia, 10-15.
- Wenger, L.M. and Isaksen, G.H.,** 2002. Control of hydrocarbon seepage intensity on level of biodegradation in sea bottom sediments. *Organic Geochemistry* 33, 1277-1292.