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Geochemical Characteristics of Bintuni Oil Seep, Oil-Oil Correlation, and Oil-Source Rock Correlation Using Biomarker Data in The Bintuni Basin, West Papua

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ABSTRACT - This study conducts a geochemical analysis of oil seepage and its correlation with existing oil and source rock. Biomarker analysis indicates that the Bintuni oil seep likely originates from a Tertiary source rock deposited in a transitional environment under sub-anoxic conditions, with a dominant terrestrial input and experiencing slight biodegradation. The sample exhibits Pr/Ph values of 1.48 and 1.49, a dominance of C_{29} sterane, diasteranes/steranes ratios of 0.83 and 0.84, C_{29}/C_{30} hopane ratios of 0.39 and 0.43, homohopane indices of 0.01 and 0.02, and high oleanane indices of 0.69 and 0.61. Oil-oil correlation reveals that the Bintuni oil seep has a correlation with oil from the Salawati Basin and the Manimeri oil seep. The common characteristics among these three samples include the presence of oleanane, kerogen type II/III, Pr/Ph ratio, and redox conditions. However, these oil samples have dominant material input: the Bintuni oil seep is dominated by C_{29}, whereas Salawati oil exhibits a balanced C_{27}-C_{28}-C_{29} ratio, and C_{27} dominates Manimeri Oil Seep. Correlation with the Ofaweri-1 oil stain in the Bintuni Basin indicates similarities in the dominance of C_{29}. However, differences exist in the oleanane index and salinity, as the Bintuni oil seep has a higher oleanane index and lacks gammacerane. Oil to source rock correlation suggests that the Bintuni oil seep shares characteristics with samples from the Klasafet Formation, including type II/III kerogen, a land-plant source, the absence of gammacerane, high oleanane content, and similarly high C_{29} values. The difference between these two samples lies in the values of tricyclic terpanes, Pr/Ph value, and the oxidizing conditions. The Bintuni Oil Seep has lower tricyclic terpane values, lower Pr/Ph value, and was deposited under more anoxic conditions. The similarity in characteristics with several Tertiary oils and the Klasafet Formation indicates that the Bintuni oil seep likely originates from the Klasafet Formation.

Keywords: source rock, Bintuni Basin, oil seep, biomarkers, correlation.

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INTRODUCTION

The Bintuni basin is one of the hydrocarbon-producing basins located in the Bird's Head of West Papua. This basin contains several producing fields, such as the Mogoi, Wasian, and Ubadari fields (Yudhanto & Pasaribu 2012; Hendro et al. 2016). The largest field is the Tangguh field complex with reserves of 24 TCF, which includes strike slip fault of Wiriagar Deep (Handyarso & Saleh 2017), Ofaweri, Roabiba, and Vorwata Jurassic fields (Sahidu et al. 2018). Hydrocarbons were also discovered during exploration between 2010 and 2015 in the Mesozoic Petroleum System at Asap, Merah, Foroda, Kido, and Bedidi Deep fields (Lie et al. 2018) (Figure 1).

Studies on the origin of hydrocarbons in this basin have been conducted by researchers (Pigram & Panggabean 1981; Pigram et al. 1982; Pieters et al. 1983; Chevallier & Bordenave 1986; Dolan & Hermany 1988; Livsey et al. 1992; Perkins & Livsey 1993; Peters et al. 1999; Doust & Noble 2008; Subroto & Sapiie 2014; Lie et al. 2018; Fakhruddin 2024). The studies conducted include geochemical analysis, biomarker analysis, and oil-source rock correlation.

Oil-source rock correlation indicates that the oil in the Mogoi and Wasian fields likely originates from the Permian Aifat. In contrast, the oil in the Wiriagar field originates from the Upper Tipuma (Chevallier & Bordenave 1986). They stated that, in general, the post-Kais section is in an immature zone; however, this section could serve as a source rock in this field if it is located at a depth greater than 4000m and can migrate hydrocarbons for a long distance laterally. Dolan & Hermany (1988) identified three potential source rocks within the Pretertiary section from the Wiriagar field area; these are the Middle Jurassic Kembelangan, which is similar to the Tipuma Formation from Chevallier & Bordenave (1986), the Permian Ainim formation, which correlates with oils in the Mogoi and Wasian fields, and the Permian Aifat formation. They suggested that the oil in the Wiriagar field comes from the Jurassic Kembelangan. Perkins & Livsey (1993) identified three potential Source rocks in the Permian, Jurassic, and Tertiary sections. The Tertiary source rock is concluded based on the presence of the oleanane from the residual oil in Ofaweri-1 well, which was taken near the top of the Miocene Kais Limestone. This oil is related to the Salawati oils and characterized by a marine algal source with a terrestrial component.

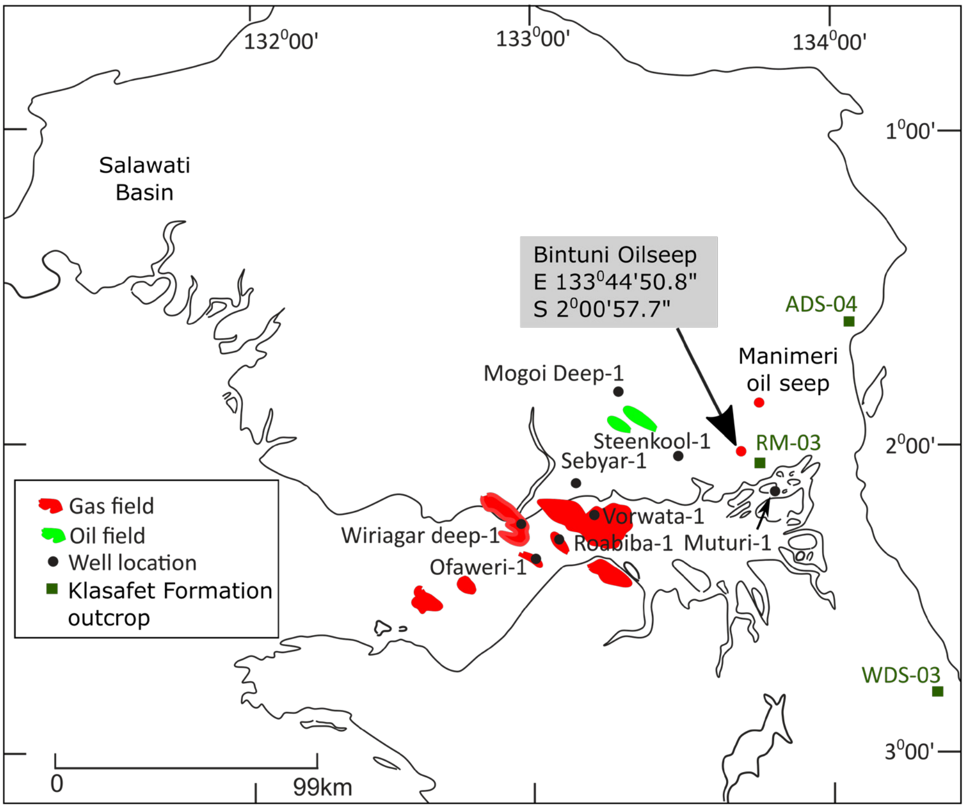

Figure 1. The map of oil and gas fields that are already in production in the Bintuni area and the location of the data used in the study (from Sahidu et al. 2018; Lie et al. 2018, and Fakhruddin 2024)

Peters et al. (1999) identified several crude oil samples from Eastern Indonesia. Based on the biomarker characteristics of each sample, they classified the oils in Eastern Indonesia into four main groups. They also categorized the oil in the Bintuni Basin into two main groups: the Lower-Middle Jurassic clay-rich marine clastic source rocks and the Miocene marine marlstone source rocks.

Fakhruddin (2024) utilized geochemical data from drilling wells, oil seeps, and outcrops to classify the oil in Papua Island. He divided it into two groups: Group A and Group B. Group A originates from higher plants and terrestrial sources, while Group B originates from marine phytoplankton. Then, Group A is further divided into two subgroups: Group A1, which originates from higher plants and has a terrestrial origin, and Group A2, which is restricted to organic matter from higher plants.

Geological settings

The Bintuni Basin is a Late Tertiary Basin which most rapidly developed during the Pliocene-Pleistocene age (Dolan & Hermany 1988). This basin is located in the Bird's Head microcontinent, which consists of some terranes (Pigram & Davies 1987) and is tectonically surrounded by the Koor dan Sorong fault to the north, Seram Trough to the southwest, and Lengguru and Arguni Thrust to the east (Dow & Sukamto 1984) (Figure 2).

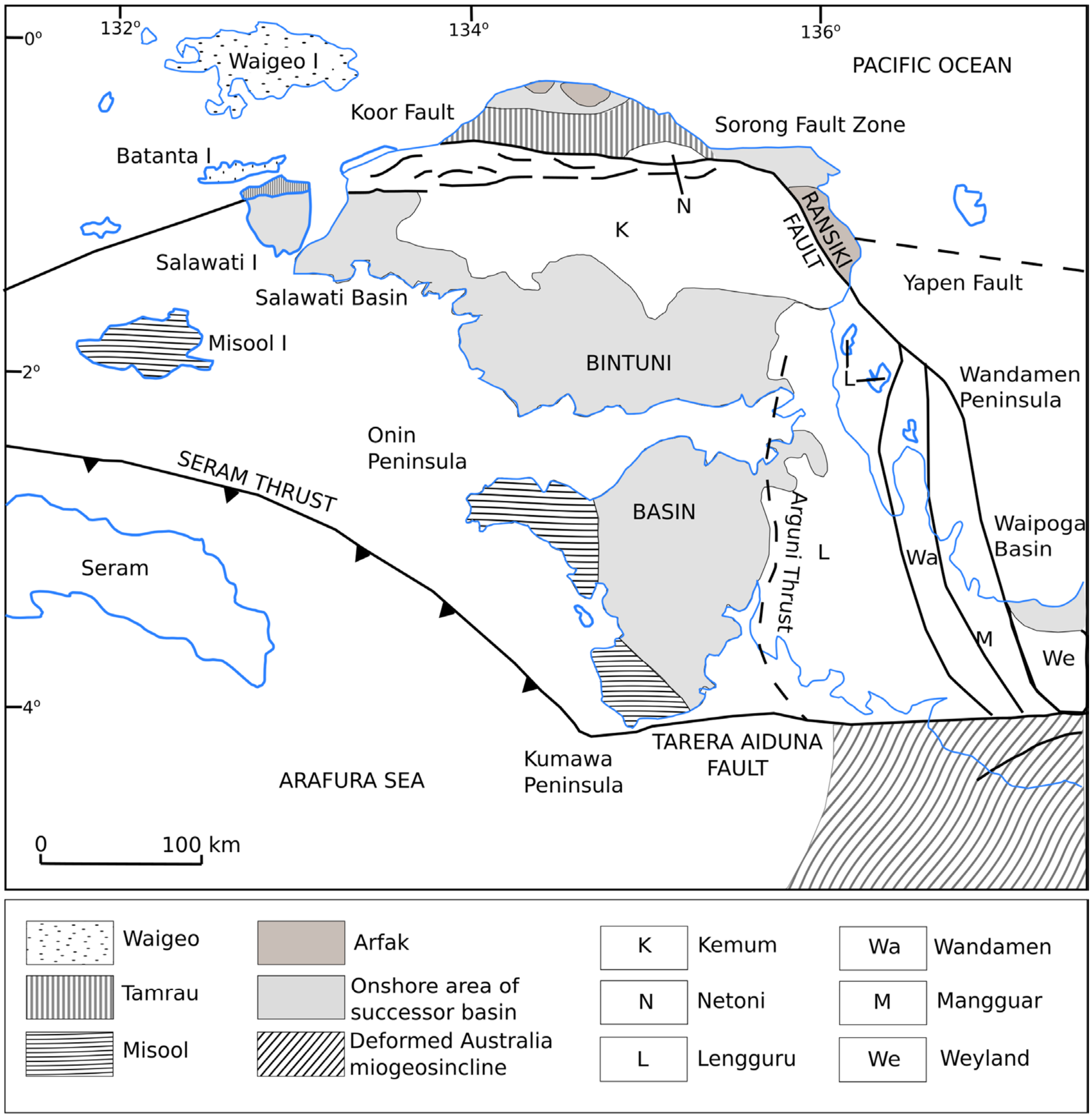

Figure 2. Map of terranes and tectonic elements of Western Irian Jaya (from Dow & Sukamto 1984; Pigram & Davies 1987)

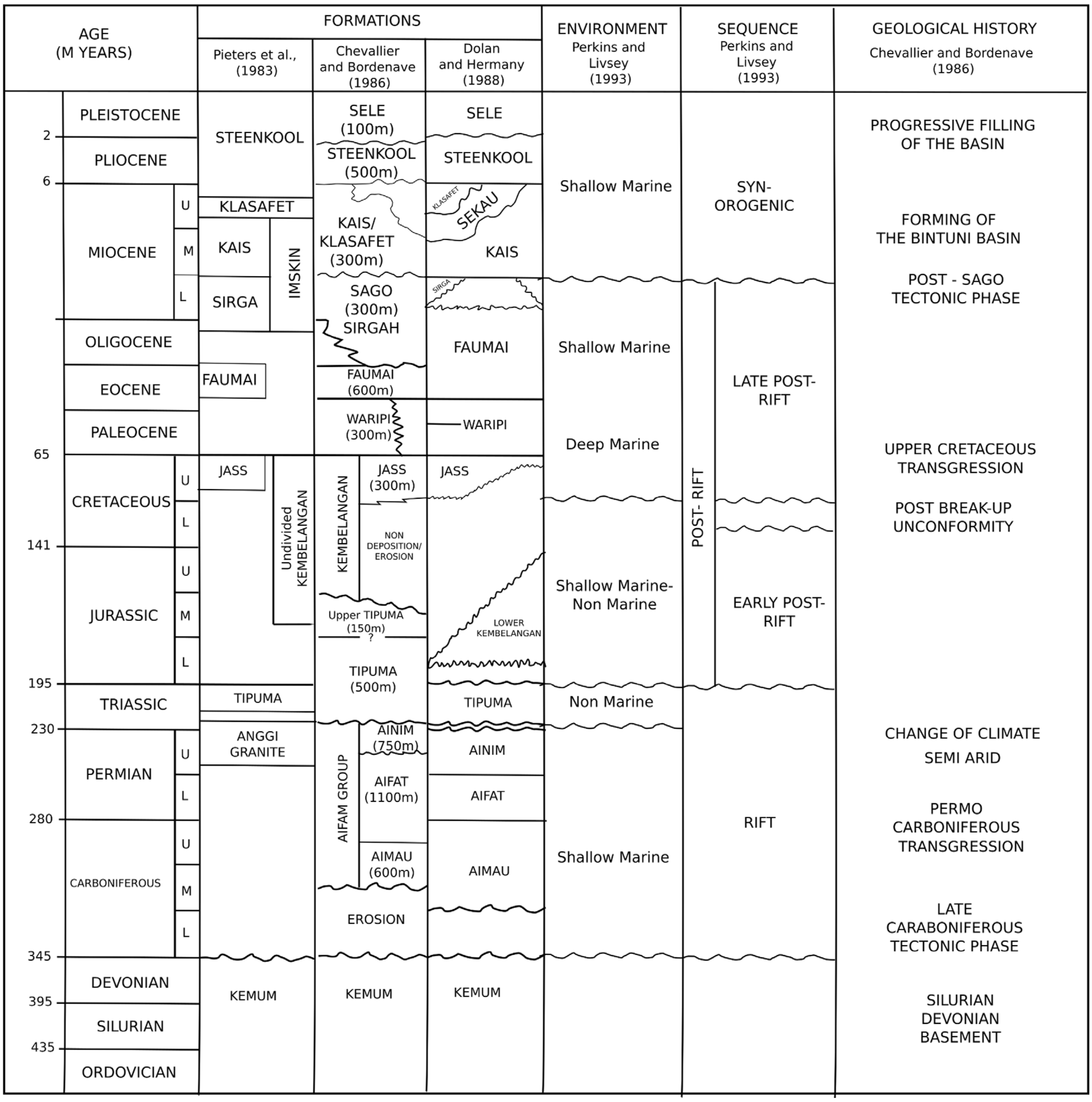

Figure 3. Generalized the tectonic setting and stratigraphic chart of Bintuni Basin (from (Pieters et al. 1983; Chevallier & Bordenave 1986; Dolan & Hermany 1988; Perkins & Livsey 1993)

The Bintuni Basin comprises three tectonic sequences, separated by two angular unconformities (Perkins & Livsey 1993). The basement of Bintuni Basin is the Kemum Formation, which consists of low-grade metamorphic rocks of distal turbidites (Pieters et al. 1993) and is intruded by granitic plutons during the post-Devonian Orogeny (Chevallier & Bordenave 1986). This basement is unconformably overlain by the rift sequence of the highly carbonaceous Aifam Group, characterized by a transgressive-regressive cycle spanning the upper Carboniferous to uppermost Permian age (Pigram & Panggabean 1981; Chevallier & Bordenave 1986; Dolan & Hermany 1988; Perkins & Livsey 1993) and deposited in non-marine to neritic environment (Lelono et al. 2010). The Aifam Group is unconformably overlain by the Triassic to Early Jurassic Tipuma Formation (Pigram & Panggabean 1984), marking the initiation of regression. This formation exhibits characteristics of red bed facies, indicating semi-arid conditions (Chevallier & Bordenave 1986). The Tipuma Formation is then overlain by the Early to Middle Jurassic sediments of the Kembelangan Group (Dolan & Hermany 1988), marking the beginning of the Early Post-Rift Subsequence (Perkins & Livsey, 1993). Sediments from the Permian–Triassic age were deposited in a terrestrial environment, then shifted to a transitional environment during the Cretaceous age (Setyaningsih 2014).

A post-breakup unconformity separates the Jurassic sediments from the Late Cretaceous shallow marine and fluvio-deltaic sediments (Pigram & Panggabean 1984). This unconformity is associated with uplift, followed by rapid subsidence and volcanic activity, marking the initiation of the Late Post-Rift Subsequence, which consists of the Upper Kembelangan Group and the New Guinea Limestone Group (Perkins & Livsey 1993).

The Late Post-Rift Subsequence is bounded by a major angular unconformity related to Late Miocene compression, which allowed for the deposition of the Sirga Formation (Chevallier & Bordenave 1986; Dolan & Hermany 1988). The Sirga Formation is conformably overlain by the reef complex of the Kais Limestone (Pieters et al. 1983). The Late Miocene-Recent Syn-Orogenic Sequence consists of the Steenkool Formation, which conformably overlies the Kais Limestone (Pieters et al. 1983; Perkins & Livsey 1993), resulting from the uplifting of the Kemum Block (Chevallier & Bordenave 1986; Dolan & Hermany 1988). The Steenkool Formation is unconformably overlain by the Sele Formation, which is detached by an unconformity caused by tectonic activity, resulting in NW-SE anticlines (Chevallier & Bordenave 1986). The geological setting of the Bintuni Basin is summarized in Figure 3.

METHODOLOGY

The data used for this study was derived from the geochemical analysis of an oil seep sample located in the Manimeri area, Bintuni sub-province, West Papua, with coordinates of E 133°44’50.8” and S 2°00’57.7”. The data consist of n-alkanes, m/z 217 steranes, and m/z 191 terpanes. The other data is derived from well drilling and outcrop data in the Bintuni and Salawati Basins, as well as data from previous researchers.

Lemigas Geochemical Services performed the geochemical analytical work. The sample analysis was performed twice to minimize the risk of technical errors during laboratory work. High-temperature GC analysis of the saturated fractions was conducted using an Agilent 6980N gas chromatograph, equipped with a 10m × 0.21mm i.d. DB-I (J&W) fused-silica capillary column. GC-MS analysis of the branched/cyclic fraction was performed using an Agilent 6890N capillary GC coupled to an Agilent 5973 series MSD, integrated with a computer data system, and fitted with a 60m × 0.25mm i.d. DB-5-MS (J&W) fused-silica capillary column. The parameters used from the gas chromatogram of n-alkanes include the ratios of pristane to phytane (Pr/Ph), pristane to nC_{17} (Pr/nC_{17}), and phytane to nC_{18} (Ph/nC_{18}). The parameters derived from the m/z 217 mass chromatogram include the values of C_{27}, C_{28}, and C_{29} steranes. The parameters from the m/z 191 mass chromatogram consist of the oleanane index, the C_{29}/C_{30} hopane ratio, and the C_{35} homohopane index.

The first step of the analysis involves identifying the characteristics of the oil sample, which can be observed through the mass chromatograms. A plot of Pr/nC_{17} against Ph/nC_{18} is utilized to determine the dominant kerogen type, the primary organic matter input, and the presence of biodegradation. Additionally, a ternary diagram of steranes is employed to infer the depositional environment of the source rock. The oleanane index serves as an indicator of the source rock’s geological age. The next step involves confirming the identified characteristics. The origin of the oil sample is further validated through plots of C_{27}/C_{29}, C_{29}/C_{27}, $C_{27}/(C_{27}+C_{29})$, and hopane/sterane against Pr/Ph. These plots are also used to assess the redox conditions during the deposition of the source rock. All these defined parameters and characteristics will be utilized for correlation purposes.

RESULT AND DISCUSSION

N-Alkanes

The gas chromatogram (GC) trace of Oil Seep-I shows predominance nC_{10} to nC_{21}, this sampel has a higher Pr value than nC_{17} and a higher Ph value than nC_{18} which indicating biodegradation (Wenger et al., 2002) (Fig. 4). The GC trace of Oil Seep-II exhibits a relatively similar pattern; however, no identifiable peaks were detected from the laboratory analysis except for Pr and Ph. Oil Seep-I has Pr/nC_{17} and Ph/nC_{18} value of 5.5 and 3.3 respectively (Table 1). The plot of these values suggests that Oil Seep-I contains a mixed Type II/III kerogen, with more dominant terrestrial influence (Peters et al. 2005) (Figure 5). This plot also indicates biodegradation as previously mentioned. Oil Seep-I and Oil Seep-II have Pr/Ph ratios of 1.48 and 1.49, respectively, suggesting marine material input (Powell 1988).

nC_{17}

Table 1. Summary of the data used in this study

No	Sample	N-Alkanes			Sterane			Hop.	Dias.	Homhop.	C_{29}	Ol
		Pr/Ph	Pr/nC_{17}	Ph/nC_{18}	C_{27}	C_{28}	C_{29}	Ster.	Ster.	Index	C_{30}	Index
1	Bintuni Oil Seep-I	1,48	5,5	3,33	24,4	24,18	51,4	9,09	0,84	0,01	0,47	0,69
2	Bintuni Oil-Seep-II	1,49	-	-	24	25	51	8,3	0,83	0,02	0,39	0,61
3	Group II Salawati											
	Cendrawasih	1,17	1,38	1,28	32,3	32,3	35,4					
	Cendrawasih	1,16	1,36	1,26	32,8	33,3	33,9					
	Kasim	2,18	1,08	0,51	30,7	32,9	36,4					
	Klalin 2	1,83	0,9	0,57	31,2	33,7	35,1					
	Klalin	2,22	1,03	0,51	32,6	34,4	33					
	Klamono				30,2	37,2	32,6					
	Linda A-5	1,35	2,12	1,73	32	35,9	32,1					
	LindaB	1,24			33,1	34,7	32,2					
	Matoa	1,29	0,66	0,52	28,8	33,2	38					
	Southwest	1,84	0,67	0,43	27,4	32,9	39,8					
	Jaya (2B)	1,96	1,01	0,58	34,1	36,3	29,6					
	Kasim Barat (2B)	1,9	0,97	0,53	32,5	34,4	33,1					
	Klain 2 (2B)	2,35	0,92	0,54	33,2	33,4	33,4					
	Linda T-1 (2B)				36,3	32	31,7					
4	Group III Salawati (Walio)	1,72	1,28	0,8	28,3	27,7	43					
5	Ofaweri-1											
	Oil (3557')	1,18	0,79	0,69	32	20	49	1,96			0,9	0,3
	Oil stain (3564')	1,1	0,48	0,47								
	Oil stain (3600')	0,96	0,61	0,57								
	Oil stain (7800')	1,16	0,69	0,39	23	21	56	2,18			0,91	0,12
	Oil stain (9667')	1,56	0,83	0,55	19	19	61	1,67			0,85	0,12
6	Manimeri Oil Seep	-	-	-	56,5	15,65	27,83	1,61			0,61	0,56
7	Klasafet Formation											
	RM-03	4,12	4,14	2,46	31,6	16,71	51,65	2,14			1,45	0,52
	WDS-3				37,1	12,42	50,47	9,81			0,88	0,06
	As-04	1,48	0,4	0,27	33,9	43,12	22,94	2,34			1,61	

Hop. = Hopane
Ster. = Sterane
Dias. = Diasterane
Homhop. = Homohopane
C_{29}/C_{30}=Hopane
Ol Index = Oleanane Index

Secondary data :
No. 3 and 4 (Peters et. al., 1999)
No. 5 (Fakhruddin 2024 and well report)
No. 6 and 7 (Fakhruddin 2024)

Biomarkers steranes and terpanes

The m/z 217 mass chromatogram of Oil Seep I and II has very similar patterns, characterized by the dominance of C_{29}, indicative of land plant material. C_{29} has a value of 51 and 51.4%, while C_{28} and C_{27} have values of 24 and 24.18% and 24 and 24.42%, respectively. A ternary diagram based on these values suggests that the Oil Seep samples originate from source rocks deposited in a bay or estuarine environment (Huang & Meinschein 1979) (Figure 7). These samples also exhibit diasterane/sterane ratio values of 0.83 and 0.84, indicating the presence of carbonate material. The peak of terpanes is labelled in Figure 6 and listed in Table 2.

The m/z 191 mass chromatogram of Oil Seep I and Oil Seep II also exhibits a very similar pattern, which consists of 18(H) oleananes, C_{30}αβhopane, and C_{29}αβhopane as major compounds. From these chromatograms, it can also be observed that C_{29} has a lower value than C_{30}, with ratios of 0.47 and 0.39, indicating a shale source rock. This interpretation is supported by the homohopane index values of 0.01 and 0.02. The samples also have an oleanane index of 0.69 and 0.61, suggesting an origin from higher plants of the Cretaceous age or younger. Additionally, the absence of C_{30} gammacerane indicates that these samples originate from a non-salinity environment. The peak of terpanes is labelled in Figure 8 and listed in Table 2.

Source of the Bintuni oil seep

Since biomarker parameters alone cannot definitively determine the characteristics of the oil, and the parameters used are not conclusive, such as the conflicting results between the C_{29}αβ-hopane to C_{30}αβ-hopane ratio, the C_{35} homohopane index, and the diasterane to sterane ratio along with the Pr/Ph ratio, several plots between these parameters have been applied to better characterize the Bintuni oil seep.

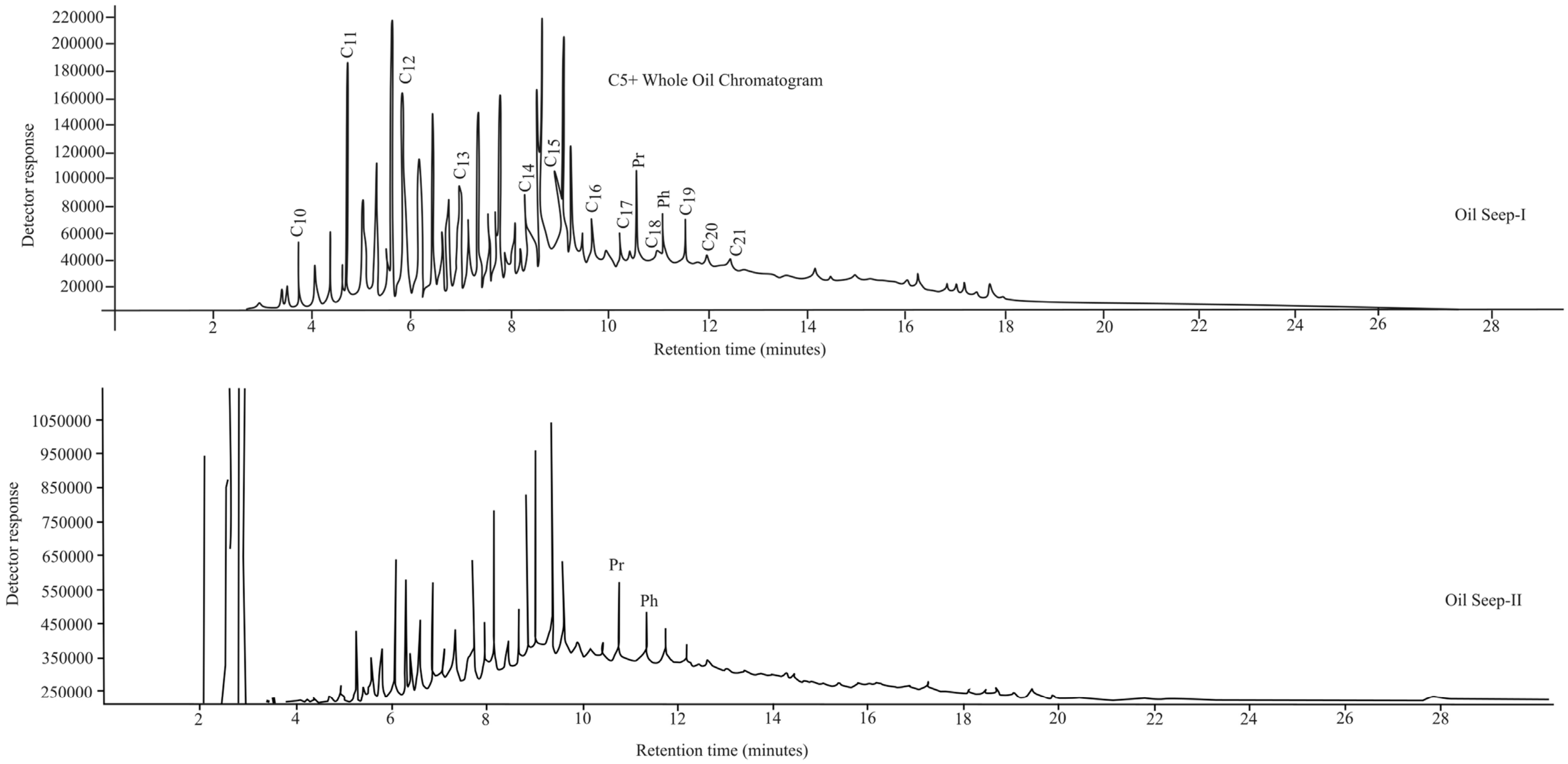

Figure 4. The gas chromatogram traces of Manimeri oil seep, which show abundant n-alkanes and isoprenoids, also show higher values of Pr against nC_{17} and Ph against nC_{18}, which is indicative of slight biodegradation (Wenger et al. 2002)

Table 2. The labels were used for peak identification of m/z 217 and m/z 191chromatogram

m/z 217

Peak	Carbon	Name
Diasteranes		
βαS 27	C_{27}	13β, 17α-Diacholestane 20S
βαR 27	C_{27}	13β, 17α-Diacholestane 20R
βαS 28	C_{28}	13β, 17α-Diacholestane 20S
βαR 28	C_{28}	13β, 17α-Diacholestane 20R
βαS 29	C_{29}	13β, 17α-Diacholestane 20S
βαR 29	C_{29}	13β, 17α-Diacholestane 20R
W	C_{30}	cis-cis-trans Bicadinane
T	C_{30}	trans-trans-trans Bicadinane
T'	C_{30}	Bicadinane
R	C_{30}	Bicadinane
Steranes		
αααS 27	C_{27}	5α, 14α, 17α-Cholestane 20S
αββR 27	C_{27}	5α, 14β, 17β-Cholestanes 20R
αββS 27	C_{27}	5α, 14β, 17β-Cholestane 20S
αααR 27	C_{27}	5α, 14α, 17α-Cholestanes 20R
αααS 28	C_{28}	5α, 14α, 17α-Ergostane 20S
αββR 28	C_{28}	5α, 14β, 17β-Ergostanes 20R
αββS 28	C_{28}	5α, 14β, 17β-Ergostanes 20S
αααR 28	C_{28}	5α, 14α, 17α-Ergostane 20R
αααS 29	C_{29}	5α, 14α, 17α-Stigmastane 20S
αββR 29	C_{29}	5α, 14β, 17β-Stigmastanes 20R
αββS 29	C_{29}	5α, 14β, 17β-Stigmastanes 20S
αααR 29	C_{29}	5α, 14α, 17α-Stigmastanes 20R

m/z 191

Peak	Carbon	Name
αβTs		Ts
αβTm		Tm
αβ29	29	17α, 21β-30-Norhopane
βα29	29	17β, 21α-30-Normoretane
D	30	Diahopane
18(H)30	30	18(H) Oleananes
αβ30	30	17α, 21β-Hopane
βα30	30	17α, 21β-Moretane
αβ31	31	17α, 21β-Homohopane 22S
βα31	31	17α, 21β-Homohopane 22R
αβ32	32	17α, 21β-Bishomohopane 22S
βα32	32	17α, 21β-Bishomohopane 22R
αβ33	33	17α, 21β-Trishomohopane 22S
βα33	33	17α, 21β-Trishomohopane 22R
αβ34	34	17α, 21β-Tetrahomohopane 22S
βα34	34	17α, 21β-Tetrahomohopane 22R
αβ35	35	17α, 21β-Pentahomohopane 22S
βα35	35	17α, 21β-Pentahomohopane 22R

The oil seep has C_{29}/C_{27} values of 2.1 and 2.13, C_{27}/C_{29} values of 0.48 and 0.47, and $C_{27}/(C_{27}+C_{29})$ values of 0.32. The C_{29}/C_{27} and Pr/Ph plots indicate that the oil seep originates from land plant organic matter deposited under anoxic conditions (Hakimi et al., 2011) (Fig. 9a), as also shown by the $C_{27}/(C_{27}+C_{29})$ and Pr/Ph plot (Adebayo et al., 2018) (Fig. 9b). The C_{27}/C_{29} against Pr/Ph and Pr/Ph against hop/ster plots illustrate the redox conditions of the oil seep. The C_{27}/C_{29} and Pr/Ph plots suggest that the oil seep generally consists of terrestrial input deposited under sub-anoxic conditions (Figure 9c). In contrast, the Pr/Ph and hop/ster plots indicate that the oil seep originates from source rock deposited under anoxic to sub-oxic conditions with terrestrial influence (Figure 9d).

All of the identified parameters mentioned above conclude that the oil seep is likely to originate from a Tertiary source rock deposited in a transitional environment under anoxic conditions, with a predominantly terrestrial origin, and exhibit slight biodegradation.

Correlation with salawati oil

Salawati oil is classified into two groups among the five oil groups in Eastern Indonesia. Group II consists of oils from Matoa, Linda, Kalin, Klamono, and Kasim Barat, while Group III includes oil from Walio. These groups share similar characteristics such as kerogen type, redox condition, lithology, and age. The primary difference lies in the oleanane index, where Group II exhibits a higher oleanane index than Group III. Furthermore, Group II is subdivided into Group IIA and Group IIB (Peters et al. 1999).

The Salawati oil originates from source rocks characterized by the following features: Tertiary age, high organic content, significant marine influence, predominantly composed of marine algal kerogen with minor terrestrial input, and in some areas, associated with carbonate deposits and anoxic lagoon environments. Based on these characteristics, the source rocks that generate oil in the Salawati Basin are shale of the Kais and Klasafet Formations (Satyana 2016).

Several biomarker parameters and characteristics defined for the oil sample exhibit similarities with Salawati oils. Both the Salawati oils and the oil sample are generated from Type II/III kerogen, which was deposited under sub-anoxic conditions during the Tertiary period. Based on the oleanane index and the m/z 191 mass chromatogram, the oil sample

Table 3. Comparison of the characteristics of each sample used in the correlation

Parameters	Bintuni Oil Seep	Group II	Group III	Ofaweri-1 Oil Stain	Manimeri Oil Seep	Klasafet Formation (RM-03)
Pr/Ph	1,48 and 1,49	1.2-2.4	1.1-2.2	1.16	-	4.12
OL Index	0,61 and 0,69	0.49-0.73	0.24-0.48	0.12	0.56	0.52
Redox	Sub-anoxic	Sub-Oxic	Sub-Oxic	Sub-Anoxic	Oxic	Oxic
Kerogen	Type II/III	Type II/III	Type II/III	Type II/III	Type II/III	Type II/III
Dominant input	Terrestrial	Marine	Marine	Terrestrial	Mixed	Terrestrial

Group II and Group III are oils were groupped from Salawati Basin (Peters et al., 1999)
Group II :Oil from Matoa, Linda, Klamono, Kasim
Group III : Oil from Walio oil
Pr/Ph : Ratio of Pristane againt Phytane
OL Index : Oleanane/(Oleanane + Hopane)

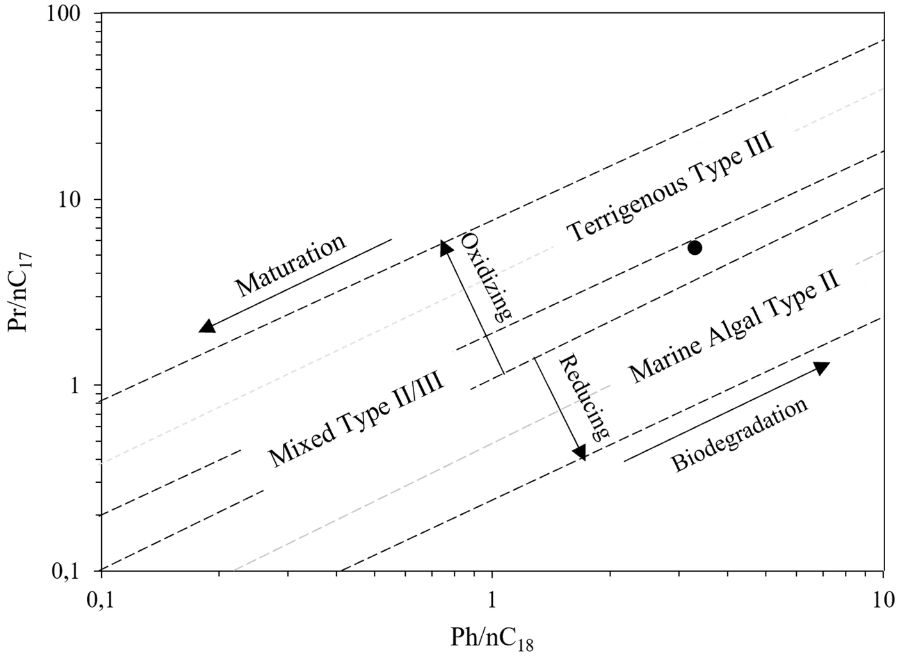

Figure 5. Plot of Pr/nC_{17} against Ph/nC_{18}, which shows the oil sample originated from mixed type II/III kerogen of source rock and experienced biodegradation (from Peters et al. 2005)

shows characteristics that are more similar to Group II than to Group III. Although these parameters and characteristics indicate similarities, the Salawati oils and the oil sample differ in their dominant organic material input. The Salawati oils predominantly contain marine algal kerogen with minor terrestrial input, whereas the oil sample is primarily composed of terrigenous input.

Correlation with Bintuni oil

Tertiary oil in the Bintuni Basin has been identified in the residual oil of the Ofaweri-1 well (Perkins & Livsey 1993). They stated that the residual oil in this well originated from a Tertiary source rock, as indicated by the presence of oleanane. This source rock is characterized by a marine origin with a significant terrestrial component, carbonate

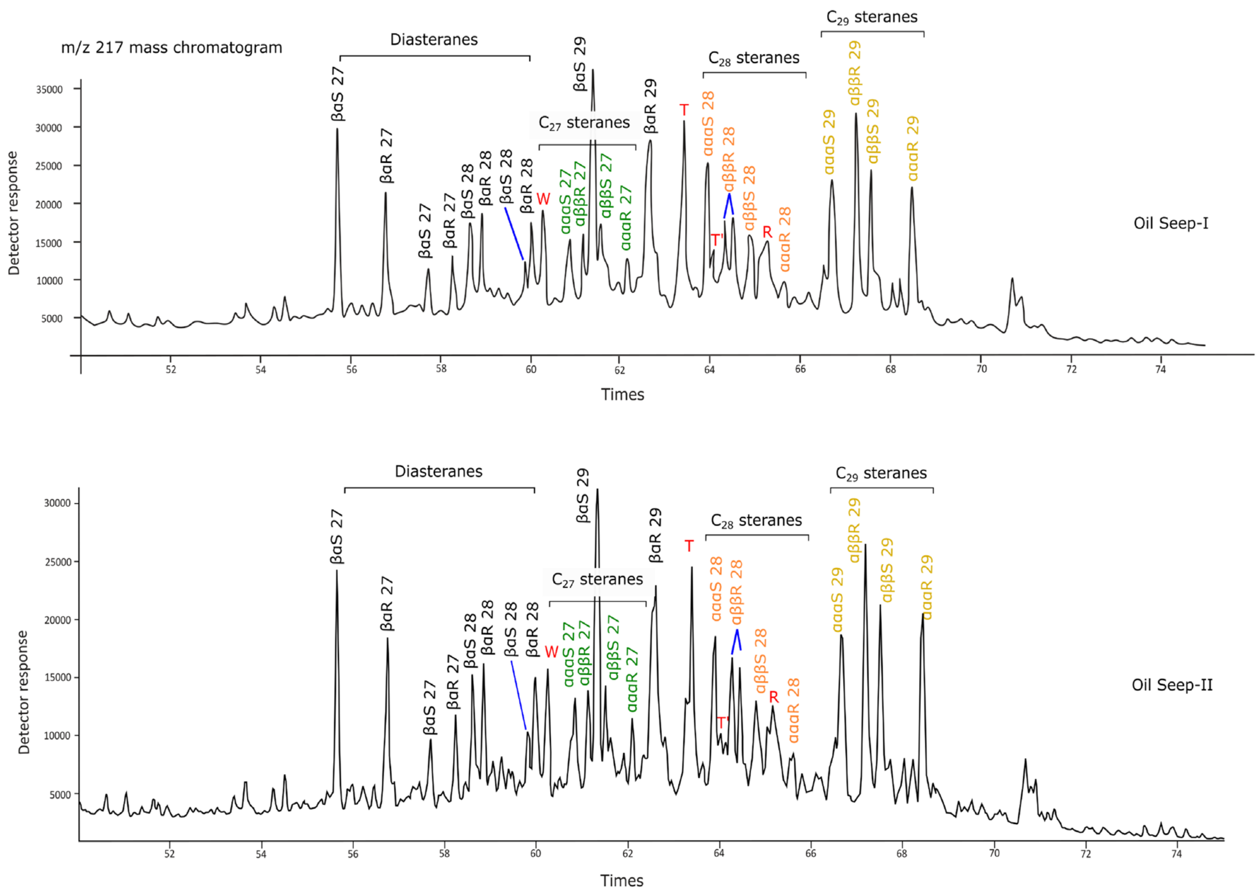

Figure 6. The m/z 217 mass chromatograms of oil seep I and II show a predominance of C_{29} steranes, indicating the presence of organic matter derived from land plants.

presence, and a highly saline environment. The source rock shows a closer correlation with Salawati oil than with Roabiba condensate or Wiriagar oil.

Based on these characteristics, Ofaweri-1 oil shares both similarities and differences with oil seep samples. The similarity is the dominance of C_{29}, indicating a significant terrestrial input. The differences between the two samples lie in the oleanane index, where the Ofaweri-1 oil stain has a lower value than the oil seep. Another key difference is salinity; Ofaweri-1 oil originates from a carbonate source rock deposited in a highly saline environment, whereas the oil seep is derived from a source rock deposited in a freshwater environment, as evidenced by the absence of gammacerane.

Correlation with Manimeri oil seep

The Manimeri oil seep is likely derived from a Tertiary-aged source rock. This oil seep exhibits characteristics consistent with being sourced from a shaly source rock deposited in an open marine, oxic environment, with a mixture of marine and terrestrial organic material. Paleontological and geochemical analyses from REP indicate that the source rock of this oil seep is likely from the Klasafet Formation (Fakhruddin 2024).

Based on these characteristics, the Manimeri oil seep differs from the Bintuni oil seep, which was deposited in a transitional environment with a dominant terrestrial input. However, m/z 191 analysis reveals that the Manimeri oil seep shares a similar pattern with the oil seep and exhibits relatively comparable oleanane values, while having higher tricyclic terpane values than the oil seep.

Correlation with the Klasafet Formation

The Bintuni oil seep and the Klasafet Formation share several similarities, including the presence of Type II/III kerogen, a land-plant organic source, the absence of gammacerane, high oleanane content, and similarly elevated C_{29} sterane values. However, some differences have been identified, including the values of tricyclic terpanes, Pr/Ph ratios, and redox conditions. The Bintuni oil seep exhibits lower tricyclic terpane values, lower Pr/Ph ratios, and was deposited under more anoxic conditions.

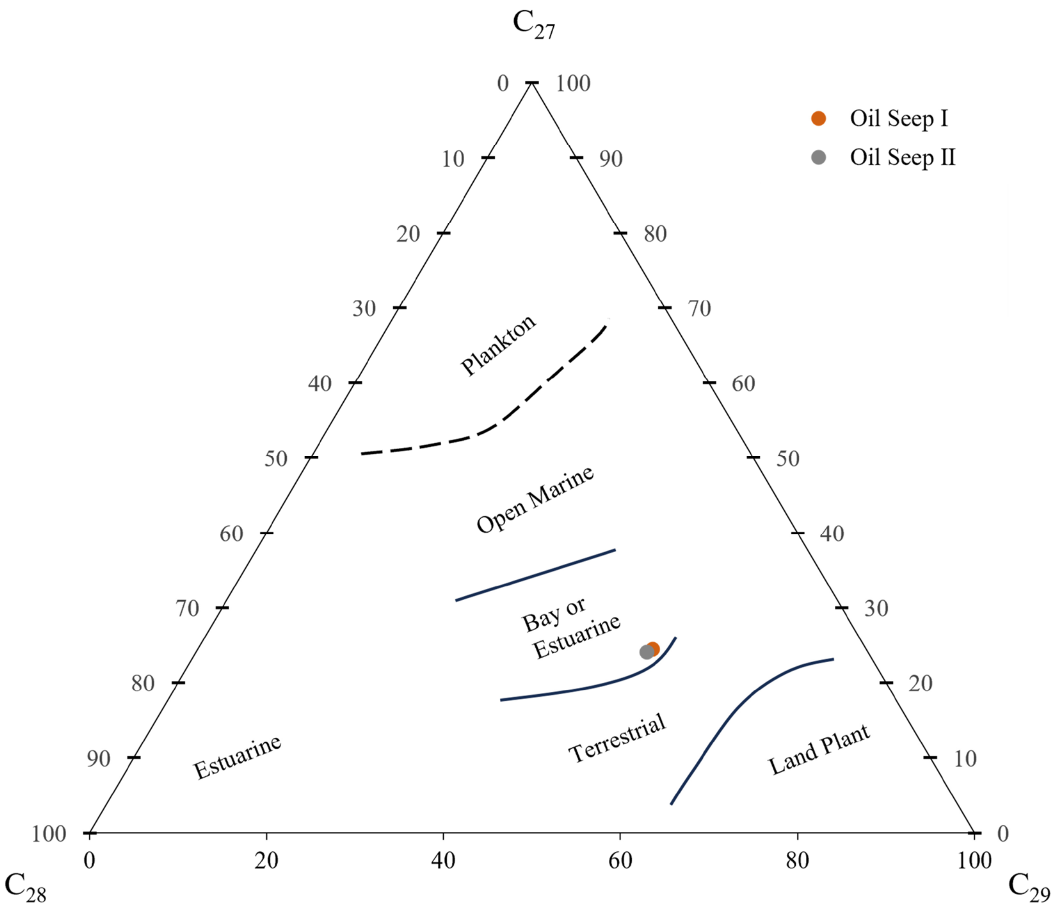

Figure 7. The ternary diagram of $C_{27\text{-}28\text{-}29}$ steranes indicated this oil seep was deposited in the bay or estuarine environment (from Huang & Meinschein1979)

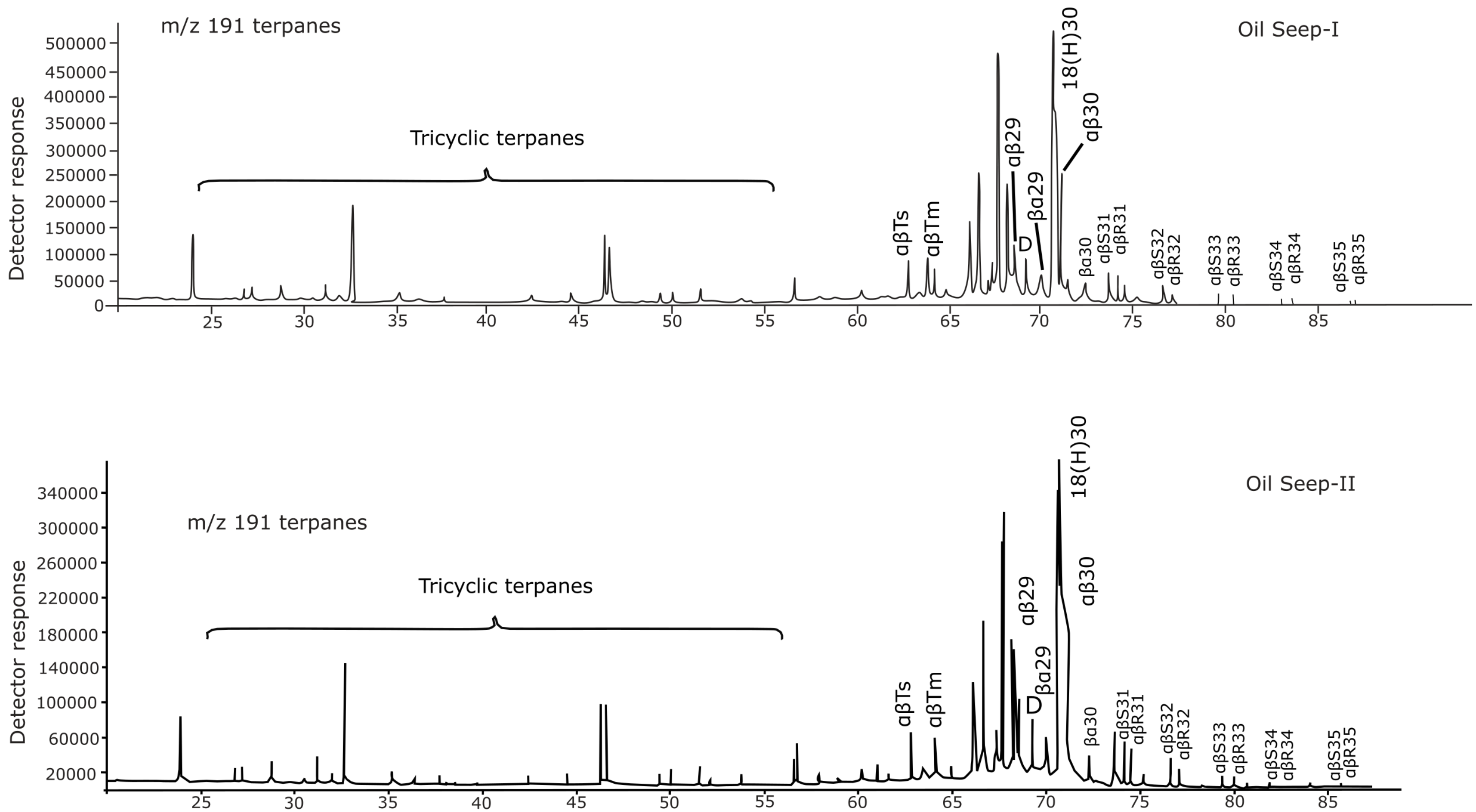

Figure 8. The m/z 191 mass chromatogram of the oil seep sample which show 18α(H) oleananes, C30αβhopane, and C29αβhopane as major compounds

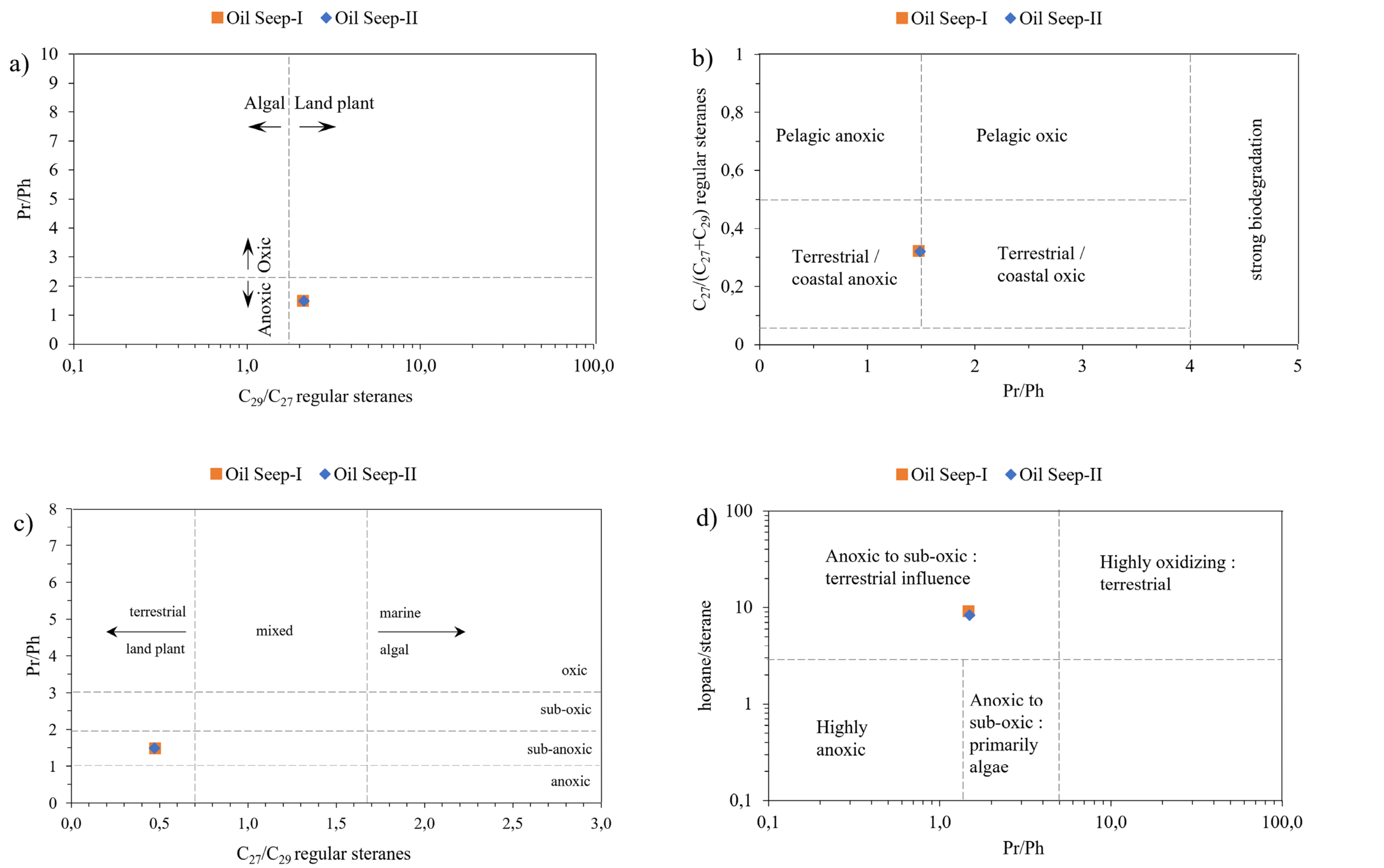

Figure 9. Source and redox condition of source rock identification by plots of a) C_{29}/C_{27} steranes against Pr/Ph (Hakimi et al. 2011), b) $C_{27}/(C_{27}+C_{29})$ against Pr/Ph (Adebayo et al. 2018), c) C_{27}/C_{29} steranes against Pr/Ph (Zhang et al. 2023), and d) Pr/Ph against hopane/sterane (Syamsuddin et al. 2019). All of these plots conclude that the oil seep sample has a dominant terrestrial input that was deposited in sub-anoxic conditions

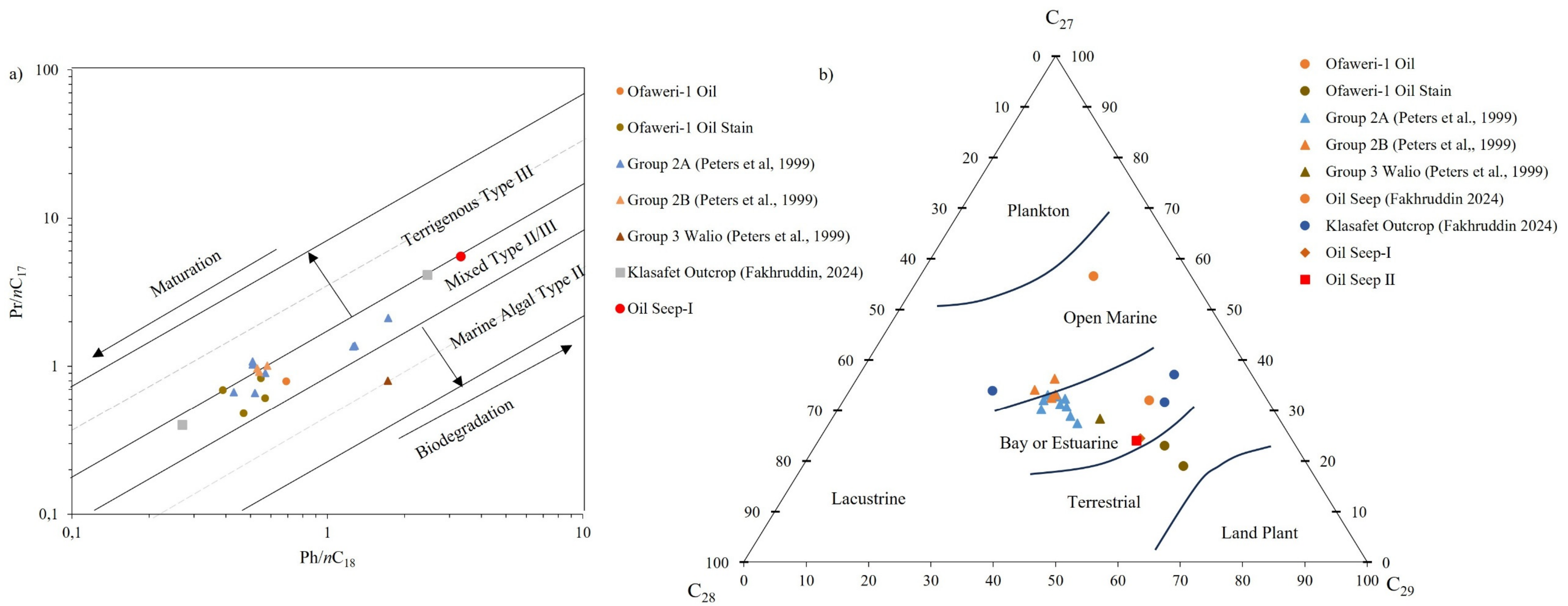

Figure 10. Plots of biomarker parameters used in the correlation: a) Pr/nC_{17} vs. Ph/nC_{18} plot, b) Ternary diagram of $C_{27–C28–C29}$ steranes.

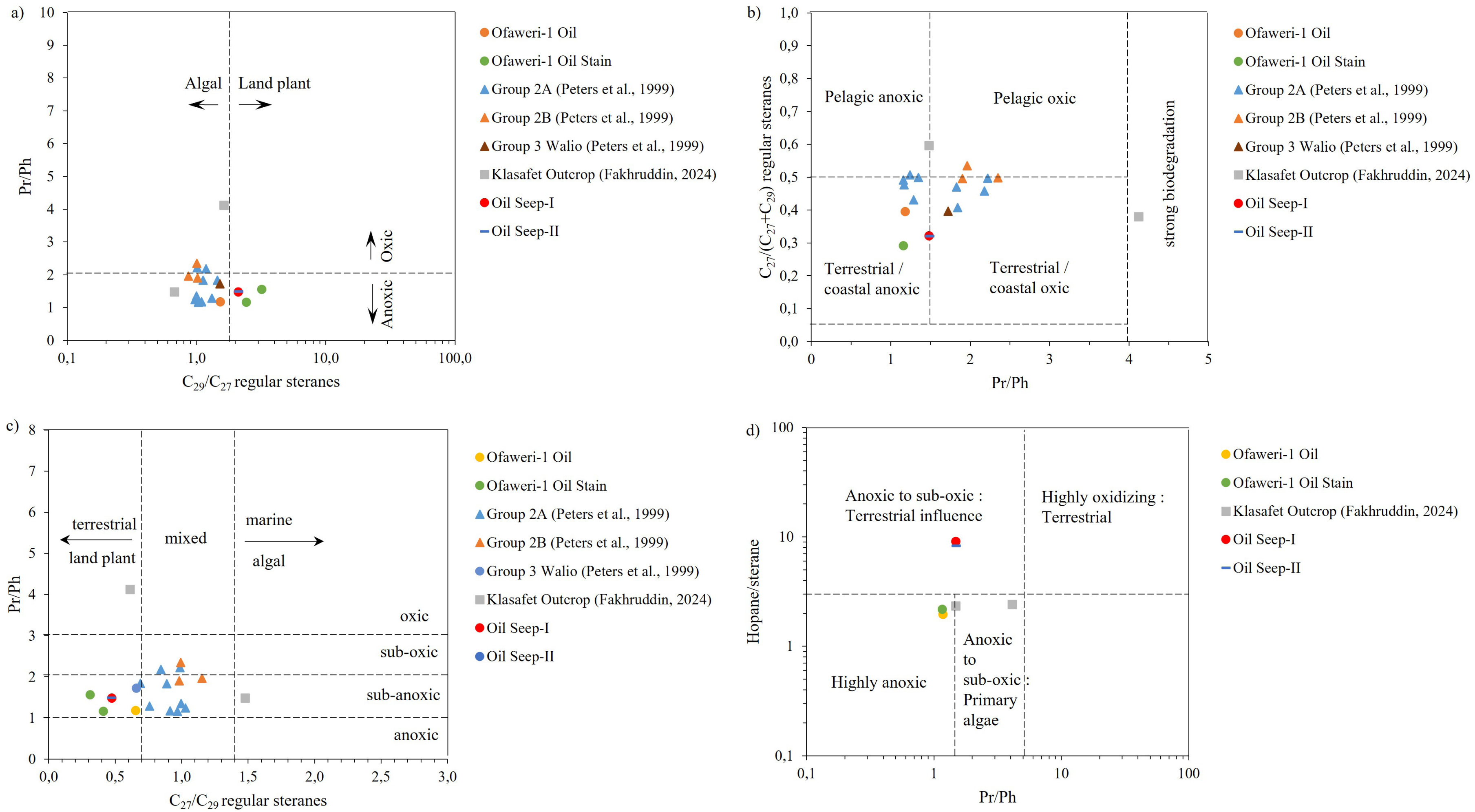

Figure 11. Plots of biomarker parameters used in the correlation to determine source and redox conditions: a) C_{29}/C_{27} steranes vs. Pr/Ph, b) $C_{27}/(C_{27}+C_{29})$ vs. Pr/Ph, c) C_{27}/C_{29} steranes vs. Pr/Ph, and d) Pr/Ph vs. hopane/sterane.

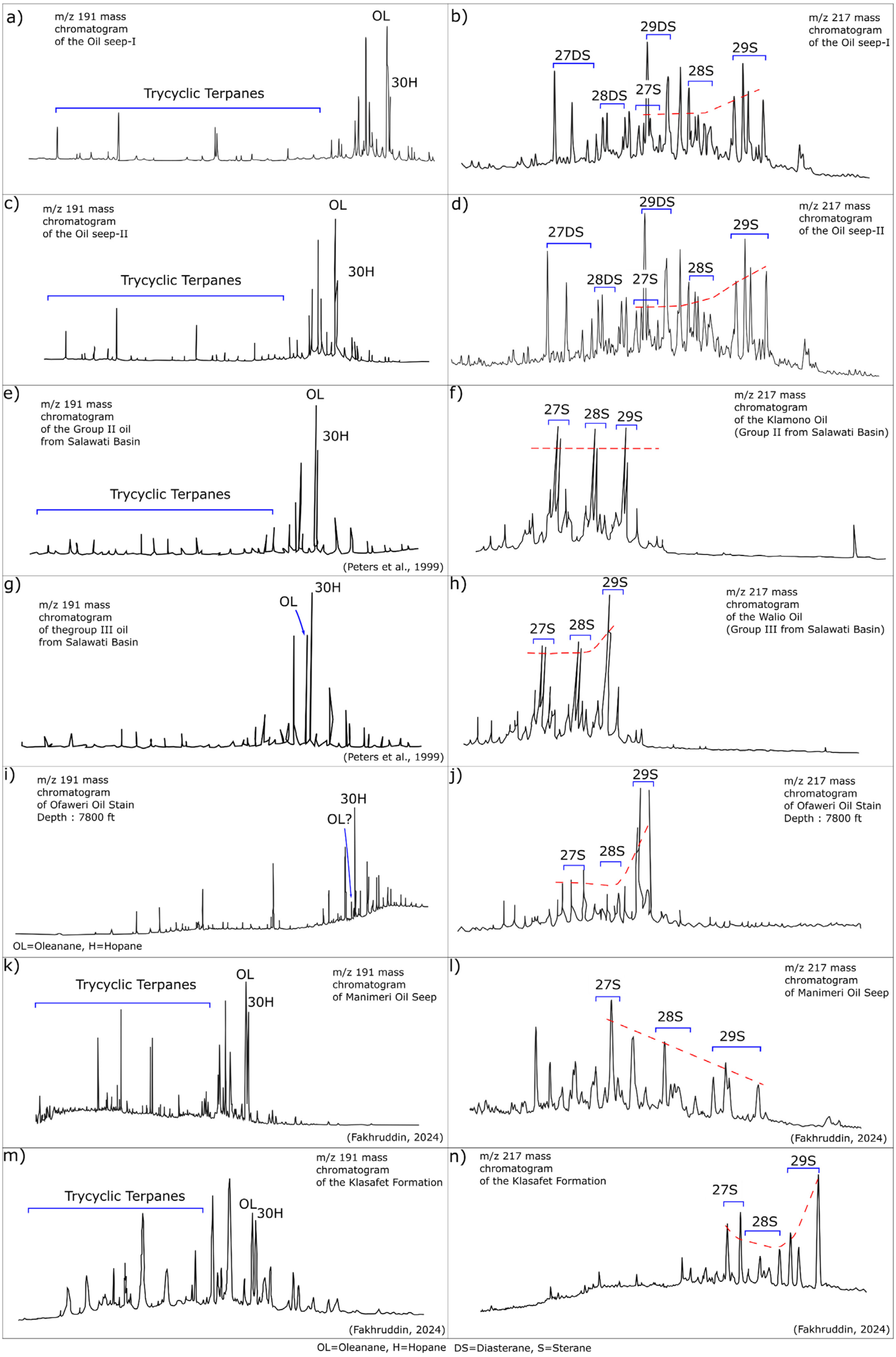

Figure 12. The m/z 191 and m/z 217 chromatograms from each sample were used for the correlation.

CONCLUSIONS

Geochemical analysis, oil–oil correlation, and oil–source rock correlation has provided new insights into Tertiary oil occurrences in the Bintuni Basin. Biomarker analysis indicates that the oil seep originates from predominantly terrestrial organic matter deposited in a transitional environment under sub-anoxic conditions, with only minor biodegradation. Correlation results show that the oil seep shares similar geochemical characteristics with Salawati Oil and the Manimeri Oil Seep, including high oleanane values, kerogen type, Pr/Ph ratio, and redox conditions, although differences exist in the dominant organic input: C_{29} dominates the oil seep, Salawati Oil exhibits an equal C_{27}–C_{28}–C_{29} distribution, and C_{27} dominates the Manimeri Oil Seep. In contrast, the oil seep and the Ofaweri-1 oil stain display distinct characteristics, particularly in oleanane index and salinity.

Comparison with the Klasafet Formation reveals strong similarities such as high oleanane values, dominant terrestrial input, C_{29} dominance, comparable redox conditions, and similar salinity although differences are noted in tricyclic terpane values, Pr/Ph ratios, and certain redox indicators. The overall similarity between the Bintuni oil seep, Salawati Oil, Manimeri Oil Seep, and the Klasafet Formation strongly suggests that the oil seep's source rock is likely the Klasafet Formation.

These results support the model proposed by Dolan & Hermany (1986), which posits that the eastern part of the Bintuni Basin has the potential to mature young sedimentary rocks, thereby increasing confidence in exploration prospects in the area.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
GC	Gas Chromatography	
GC-MS	Gas Chromatography and mass spectometry	
Hop/ster	Hopane/sterane ratio	
OL Index	Oleanane/(Oleanane+Hopane)	
m/z	Fragmentogram mass	
Ph	Phytane	
Pr	Pristane	
TCF	Trillion Cubic Feet	

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