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RESEARCH ARTICLE

The Influence of Asymmetrical Formation from Makassar Basin to the Geochemical Characteristics of Mallawa Formation

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Abstract

A functional hydrocarbon system relies on three key elements: source rock, reservoir rock, and seal rock. These components are essential in assessing the hydrocarbon potential of a region. In South Sulawesi, the Makassar Basin shows promise for petroleum development, particularly with the Mallawa Formation an Early to Late Eocene unit serving as a potential source rock. Source rocks play a critical role in generating and storing hydrocarbons. Indonesia's frequent oil and gas exploration activities are driven by the presence of numerous prospective hydrocarbon-bearing areas. It's crucial to recognize that source rocks typically form within sedimentary basins. The Makassar Basin, a land-based Tertiary sedimentary basin situated along western and southern Sulawesi, originated from tectonic activity, specifically the widening of the Makassar Strait, which began no later than the Early Paleocene. This tectonic evolution significantly affected the thermal maturation of the basin's source rocks. This study applies geochemical analysis of cutting samples to evaluate the maturity of these rocks. The findings contribute valuable understanding to hydrocarbon exploration in South Sulawesi, a region characterized by a complex tectonic framework. The results of laboratory analyses show that sustainable hydrocarbon exploration may be possible in South Sulawesi, especially in Balangbaru Formation, which is believed to be a potential source rock, in addition to the Mallawa Formation.

Keywords: Source Rock, Makassar Basin, Geochemical, South Sulawesi

1. Introduction

This research is driven by the need to better understand the challenges and characteristics of hydrocarbon systems to assess the hydrocarbon potential of specific areas. This Basin has shown promise as a petroleum system, particularly with the Mallawa Formation, dating from the Early to Late Eocene—identified as a potential source rock. This study focuses on how tectonic activity over time has influenced the geochemical characteristics of source rocks in this basin.

Managing oil and gas is key to national development. This drives economic and energy security. To achieve this, we need to increase production, reserves, and exploration and production continuity. Indonesia continues to face high demand for oil and gas across various industries. Current national reserves are estimated at 4.17 billion barrels, with 2.44 billion barrels confirmed as proven reserves. Without new discoveries, these reserves are projected to last approximately 9.5 more years (Menteri Energi dan Sumber Daya Mineral, 2022). Therefore, large-scale exploration is essential. Advancements in technology are also opening new frontiers for uncovering previously untapped oil and gas resources. Exploration and production efforts remain active in South Sulawesi, particularly in the South Makassar Basin, aiming to boost both reserves and output.

This research examines 62 samples obtained from well YS-3 in South Sulawesi, which was drilled to a depth of 7,511 feet (see Figure 1). Alongside the Mallawa Formation, the study also identifies the Balangbaru Formation—comprising interbedded mudstone, sandstone, and tuff—as having notable hydrocarbon potential.

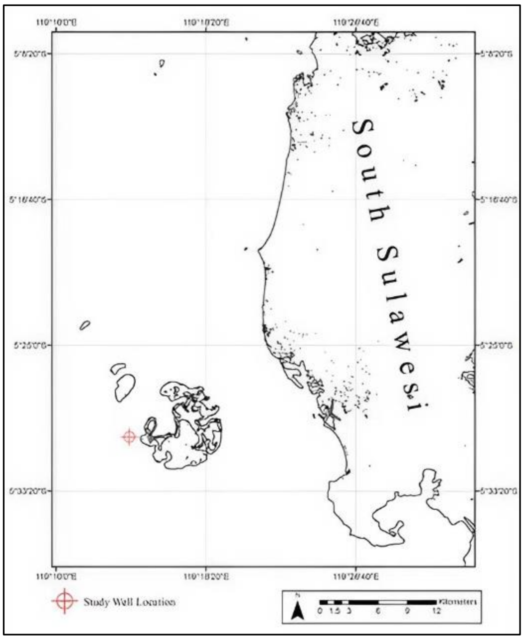


Fig 1. Research well location map.

Geologically, the South Makassar Basin is located within a tectonically intricate region influenced by the convergence of three major plates: the northward-moving Indo-Australian Plate, the southeastward-shifting Eurasian Plate, and the northwestward-moving Pacific Plate. The regional stratigraphy is thought to have developed from the Sunda Shelf margin or from sections of Kalimantan that were separated as a result of the Makassar Strait's formation. South Makassar Basin was formed in the southeast of Sundaland that was influenced by three large plates: Eurasia, India-Australia, and Pacific. It is bordered by Adang fault zone in the north and West Sulawesi fold belt in the east part. In the south bordered by Masalima High, and in the west bordered by Paternoster Platform (Hidayat et al., 2015). The basin's stratigraphic succession consists of the Basement at the base, overlain by the Balangbaru, Toraja/Mallawa, Tonasa, Camba, and Walanae Formations (Figure 2).

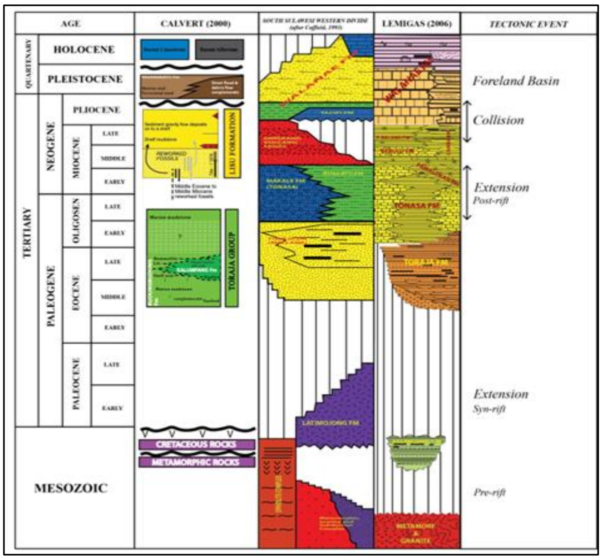


Fig 2. The stratigraphic framework of study area, adapted from (Calvert, 2000) with additional data integrated from Coffield (1991) and LEMIGAS (2006) *in* (Koesoemadinata, 2020).

The development of Makassar Strait and the basin is associated with a rifting event that commenced at the latest by the Early Paleocene (Yarra Sutadiwiria, 2019). (Sutadiwiria et al., 2022) contributed to the discussion of the tectonogenesis of the Makassar Basin. The basin's asymmetric structure (horst and graben) aligns with the Wernicke model's strain tectonic type with simple shear kinematics. This can be seen on the gravity map, which shows no significant thinning of the continental crust in the central part of the basin (Sandwell and Smith, 1997). This is also supported by structural maps highlighting obliquely oriented grabens mainly on the eastern side of the basin (McClay and White, 1995), basement mapping (Brahmantyo, 2009), and isochron maps illustrating the thickness of syn-rift sediment deposits (Figure 3).

(Siringoringo and Noeradi, 2016) also stated that the forming of rifting was controlled by tension tectonic force (NW-SE trend), base on fault patterns and sedimen thickening.

A significant plate interaction initiated the tectonic development. The Indian Plate collided with the Eurasian Plate, which was moving east-southeast. This event triggered the southeastward movement of the Indochinese microcontinent along the Red River Fault, a major horizontal strike-slip fault (Brahmantyo, 2009). The early development of the Makassar Strait was characterized by the formation of a northwest-southeast trending strike-slip (wrench) fault, which subsequently led to rifting in the eastern part of Kalimantan. This fault system facilitated the southeastward movement and rifting of the East Kalimantan block, resulting in the development of an asymmetric horst and graben structure consistent with the Wernicke extensional model (Wernicke, 1985).

This asymmetric extension, characterized by simple shear deformation, is supported by interpretations of combined sea and land seismic data (Figure 4). Additional tectonic activity includes the extension and eastward displacement of the eastern block of West Sulawesi, driven by a major shear zone known as the electric fault mega shear. Overall, the South Makassar Basin formed during the Paleogene period as a result of back-arc extension linked to subduction-driven plate collision southwest of Sulawesi (Hall, 2012).

2. Method

There are three important things that are done in geochemical analysis. These include the determination of organic material, type of kerogen, and the maturity of hydrocarbon. Total Organic Carbon (TOC) is the amount of organic carbon deposited in the rock, measured as a percentage of dry weight. Organic carbon originates from organic materials, not carbonates. Analyzing samples gives a TOC value. Sedimentary rocks with a TOC below 0.5% likely won't produce hydrocarbons. Rocks with a TOC above 0.5% might be a source rock.

Rock-Eval Pyrolysis Analysis is based on S1 (free hydrocarbons) which indicates vaporizable hydrocarbons without kerogen degradation (Hunt, 1996). S1 is formed at 300°C and results from kerogen during deposition. The second parameter is S2 (pyrolyzable hydrocarbons) indicates the number of hydrocarbons produced through cracking, formed at 350-550°C. S3 is the third parameter which shows the amount of CO_2 present in the rock, formed at 300-390°C. Tmax is the maximum temperature of hydrocarbon cracking (S2), formed at 435–470°C.

Based on the results of TOC calculation, considering %TOC and S1+S2 values, the organic richness level of the sample is obtained (K.E. and Cassa, M.R. Peters, 1994) (Table 1). On the other hand, two parameters were used to assess the maturity of organic materials: Tmax and vitrinite reflectance (Ro). Ro is a parameter that reflects the effect of temperature on vitrinite reflectance, because vitrinite maceral reflectance also increases with temperature (Table 2).

Table 1. Source rock classification according to TOC content, as defined by (K. E. and Cassa, M. R. Peters, 1994).

Quantity	TOC (wt%)	S1 (mg HC/g rock)	S2 (mg HC/g rock)
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

In order to determine the kerogen type and the degree of hydrocarbon maturity, it is necessary to identify the characteristics of the organic materials and their quantification in the source rock, and to evaluate the temperature changes during hydrocarbon formation ((K. E. and Cassa, M. R. Peters, 1994), Table 3; (Dow, 1977), and (Senftle and Landis, 1991) (Table 4).

A modified Van Krevelen diagram is used to plot the Hydrogen Index (HI) values against Tmax in the analysis, following (Hunt, 1996), which is essential for assessing the maturity level of source rocks in hydrocarbon generation. As organic matter undergoes maturation, its chemical characteristics evolve over time due to geological processes, including tectonic activity and sedimentation. Gas chromatography–mass spectrometry (GC-MS) was one of the methods used. It was used to identify the source facies of rock samples from selected well depths, chosen based on high TOC and HI values (refer to Table 6). The resulting sterane ratios were plotted on the sterane ternary diagram (Huang and Meinschein, 1979); (Peters et al., 2004), (see Figure 13). Consequently, geochemical methods including Total Organic Carbon (TOC) analysis, Rock-Eval Pyrolysis (REP), Vitrinite Reflectance (VR), kerogen classification, and GC-MS are essential for assessing the hydrocarbon potential and source facies in well YS-3. Refer to Table 5 for a visual representation of the research flowchart.

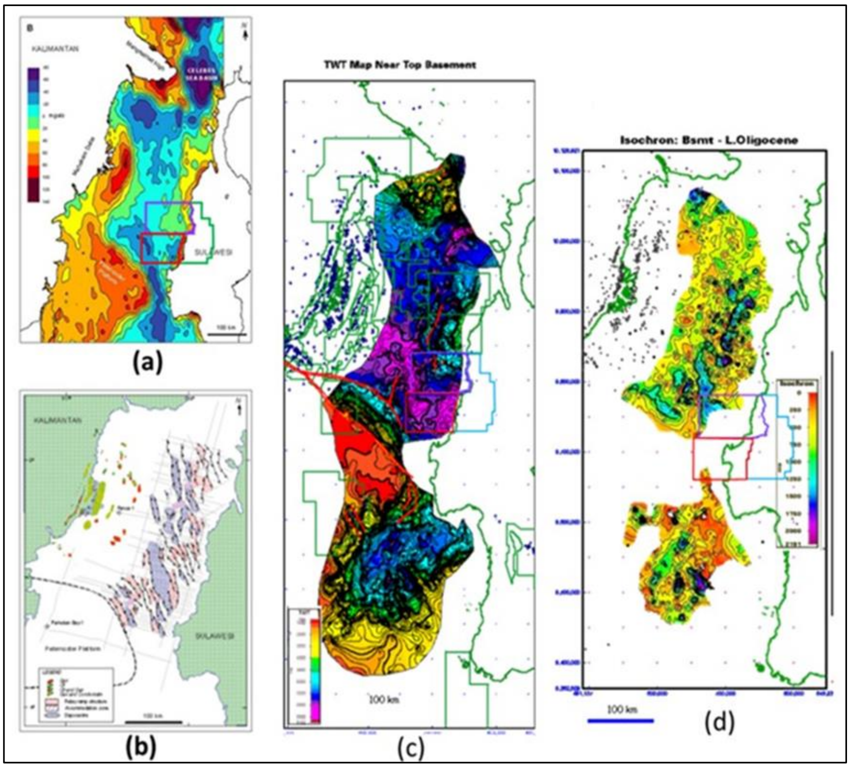


Fig 3. (a) Gravity map of the North Makassar Basin; (b) Structural map showing graben features and depocenters; (c) Bedrock structure map (in time domain) of the Makassar Basin; (d) Isochron map (TWT thickness) of synrift sediments filling the grabens in the Makassar Basin.

Table 2. Organic material maturity parameters (K. E. and Cassa, M. R. Peters, 1994).

Parameter	Ro (%)	Tmax (°C)	TAI	Bit/TOC	Bitumen (ppm)	PI
Immature	0.20 – 0.60	< 435	1.5 – 1.26	< 0.05	< 50	< 0.10
Early Mature	0.60 – 0.65	435 – 445	2.6 – 2.7	0.05 – 0.10	50 – 100	0.10 – 0.15
Peak Mature	0.65 – 0.90	445 – 450	2.7 – 2.9	0.15 – 0.25	150 – 250	0.25 – 0.40
Late Mature	0.90 – 1.35	450 – 470	2.9 – 3.3	–	–	> 0.40
Post Mature	> 1.35	> 470	> 3.3	–	–	–

Table 3. Kerogen type classification based on Hydrogen Index values (adapted from (K. E. and Cassa, M. R. Peters, 1994).

Kerogen Type	HI (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	50-200	1-5	0.7-1.0	Gas
IV	<50	<1	<0.7	No Hydrocarbon Production

Table 4. The maturity classification is determined using % Ro values, following the guidelines of (Dow, 1977) and (Senftle and Landis, 1991).

Oil-Prone Generation		Gas-Prone Generation	
Generation Stage	Ro (%)	Generation Stage	Ro (%)
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		

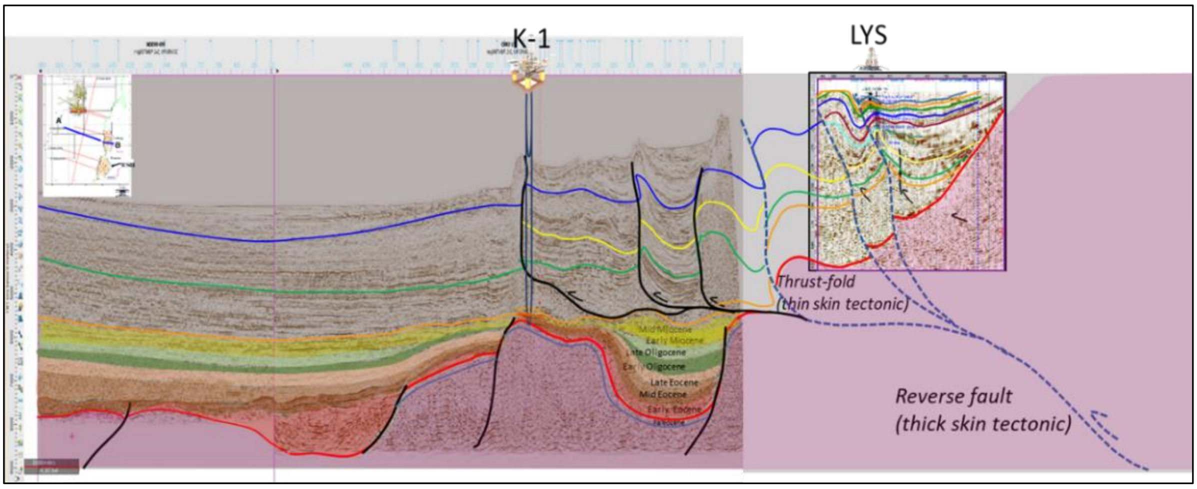
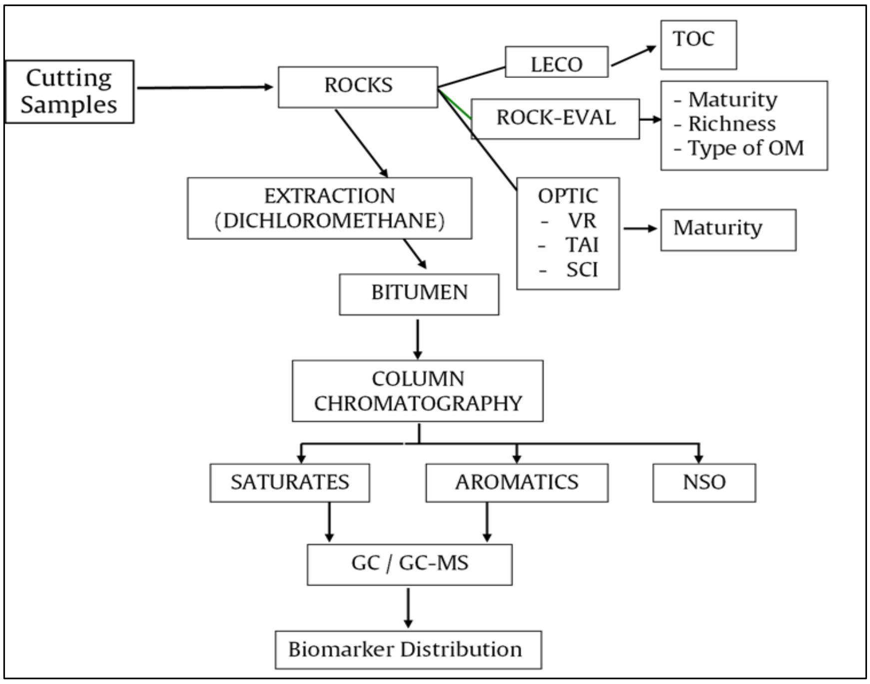


Fig 4. Offshore geological framework of the eastern Makassar Strait and the onshore region of West Sulawesi, interpreted from composite seismic data crossing the K-1 and LYS reference wells (adapted from (Sutadiwiria et al., 2019).

Table 5. The research flowchart (E. Subroto, *Pers. Comm*, 2024)



A total of 62 cuttings samples were analyzed in the study area, having been subjected to TOC analysis prior to assaying. The samples selected for analysis are those identified as source rock, consisting of shale and coal.

Tectonostratigraphic analysis of source rock geochemistry—grounded in regional stratigraphic and tectonic contexts—focuses on evaluating the relationship between source rock geochemical characteristics and tectonic activities in the study area.

This includes understanding the influence of structural features on source rock development, as well as investigating the evolutionary development of the South Makassar Basin, with particular emphasis on the geochemical properties of the Mallawa Formation.

3. Result and Discussion

3.1 Findings from the Geochemical Analysis of Samples in the Study Area

There are two formations in the wells of the study area, which are the Mallawa Formation as a source rock and Balangbaru Formation. Based on TOC analysis, there are eight (8) samples from Mallawa Formation and four (4) samples from Balangbaru Formation. These samples are further analyzed for REP, VR, and kerogen type (K. E. and Cassa, M. R. Peters, 1994)(Table 4).

Rock-Eval Pyrolysis (REP) analysis produced values for Hydrogen Index (HI) and Tmax (see Figure 5). Samples originating from the Mallawa Formation typically show an immature thermal maturity, and are primarily gas-prone (Type III kerogen, Table 6). In contrast, some samples from the Balangbaru Formation also fall within the immature range but show aligning with Type II/IIb kerogen, which is capable of generating both oil and gas (Table 6). Vitrinite reflectance (Ro) analysis was performed on selected samples at representative depths for each formation. The Mallawa Formation samples display Ro values between 0.31% and 0.38%, indicating immature organic matter. Meanwhile, the Balangbaru Formation samples exhibit Ro values ranging from 0.51% to 0.97%, which correspond to immature to peak oil generation maturity levels.

Table 6. The results analysis of TOC, REP, and GC-MS.

No	Depth (feet)	Sample Type	Formation	Lithology	Peters and Cassa Classifications (1994)	Rock-Eval Pyrolisis										Average %Ro	GCMS		
						TOC	S1	S2	S3	Hydrogen Index (HI)	Oxygen Index (OI)	Potential Yield (S1+S2)	OPI	Kerogen Type	Tmax (°C)		C27	C28	C29
WELL : YS-3																			
1	3910 - 3920	Cuttings	Mallawa	Coal	Excellent	4.83	0.09	6.76	2.36	140	49	6.85	0.01	Type III	428	0.36	-	-	-
2	3930 - 3980	Cuttings	Mallawa	Coal	Excellent	6.11	0.15	7.36	2.31	120	38	7.51	0.02	Type III	425	0.33	27.39	25.69	46.92
3	3990 - 4040 (A)	Cuttings	Mallawa	Coal	Very Good	3.82	0.1	4.42	1.71	116	45	4.52	0.02	Type III	426	0.38	-	-	-
4	3990 - 4040 (B)	Cuttings	Mallawa	Coal	Very Good	3.87	0.05	2.54	1.32	66	34	2.59	0.02	Type III	427	0.33	-	-	-
5	4050 - 4100	Cuttings	Mallawa	Coal	Excellent	5.6	0.15	12.01	2.2	214	39	12.16	0.01	Type II/IIb	425	0.31	24.17	23	52.83
6	4110 - 4160	Cuttings	Mallawa	Coal	Very Good	3.22	0.07	5.62	1.42	175	44	5.69	0.01	Type III	427	0.31	-	-	-
7	4170 - 4210	Cuttings	Mallawa	Coal	Very Good	2.3	0.06	4.24	0.92	184	40	4.3	0.01	Type III	429	0.35	24.87	20.35	54.78
8	4220 - 4280	Cuttings	Mallawa	Coal	Good	1.92	0.03	3.03	0.94	158	49	3.06	0.01	Type III	429	0.33	-	-	-
9	6610 - 6650	Cuttings	Balangbaru	Shale	Good	1.46	0.23	1.46	0.81	100	55	1.69	0.14	Type III	428	0.51	-	-	-
10	7080 - 7110	Cuttings	Balangbaru	Shale	Excellent	7.41	4.65	16.37	9.49	221	128	21.02	0.22	Type II/IIb	335	0.89	55.51	16.73	27.76
11	7140 - 7170	Cuttings	Balangbaru	Shale	Good	1.09	0.6	3.79	3.01	348	276	4.39	0.14	Type II	334	0.97	-	-	-
12	7320 - 7350	Cuttings	Balangbaru	Shale	Good	1.74	0.69	3.64	3.39	209	195	4.33	0.16	Type II/IIb	330	0.93	46.59	18.56	34.85

In addition, there is a significant change in maturity value beginning at a depth of 7080 feet in Balangbaru Formation in the crossplot between HI and %Ro value (Figure 6). This indicates that there is a thicker.

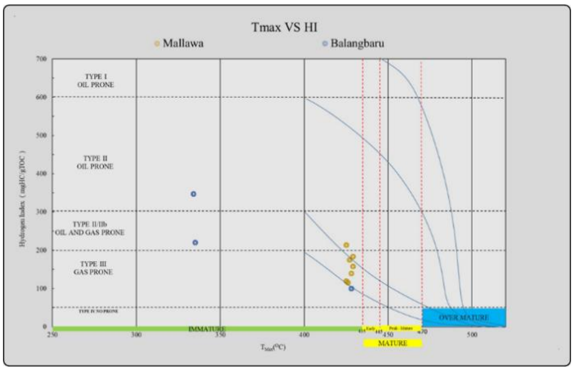


Fig 5. The cross-plot of HI versus Tmax for the study area, presented on a Van Krevelen diagram (adapted from (Hunt, 1996).

Sediment accumulation in Balangbaru Formation, which makes the % Ro value larger. The figure below shows the maturity results based on the HI versus %Ro cross plot (Figure 6).

Based on the presence of foraminifera, it can be seen that Balangbaru Formation was deposited in the inner neritic area at a depth of 7511-5850 feet (Figure 7). However, at a depth of 5850-4280 feet, the depositional environment is supratidal. The change of environment from sea to land at the age of Late Cretaceous to Early Paleocene, due to a significant decrease of sea water (regression).

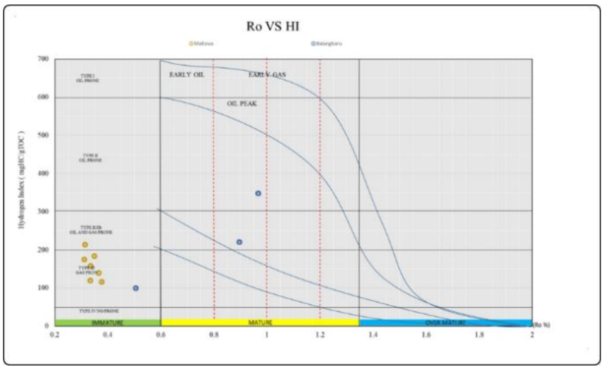


Fig 6. Crossplot result of Hydrogen Index (HI) vs Vitrinite Reflectance (%Ro)

This is also supported by the GC-MS results. At depths of 7350 - 7320 feet and 7110 - 7080 feet, the source facies is open marine or lacustrine, with percentages of C_{27} values of 46.59% and 55.51%, respectively, and C_{29} values of 34.85% and 27.76%, respectively (Figures 8, 9, and 13).

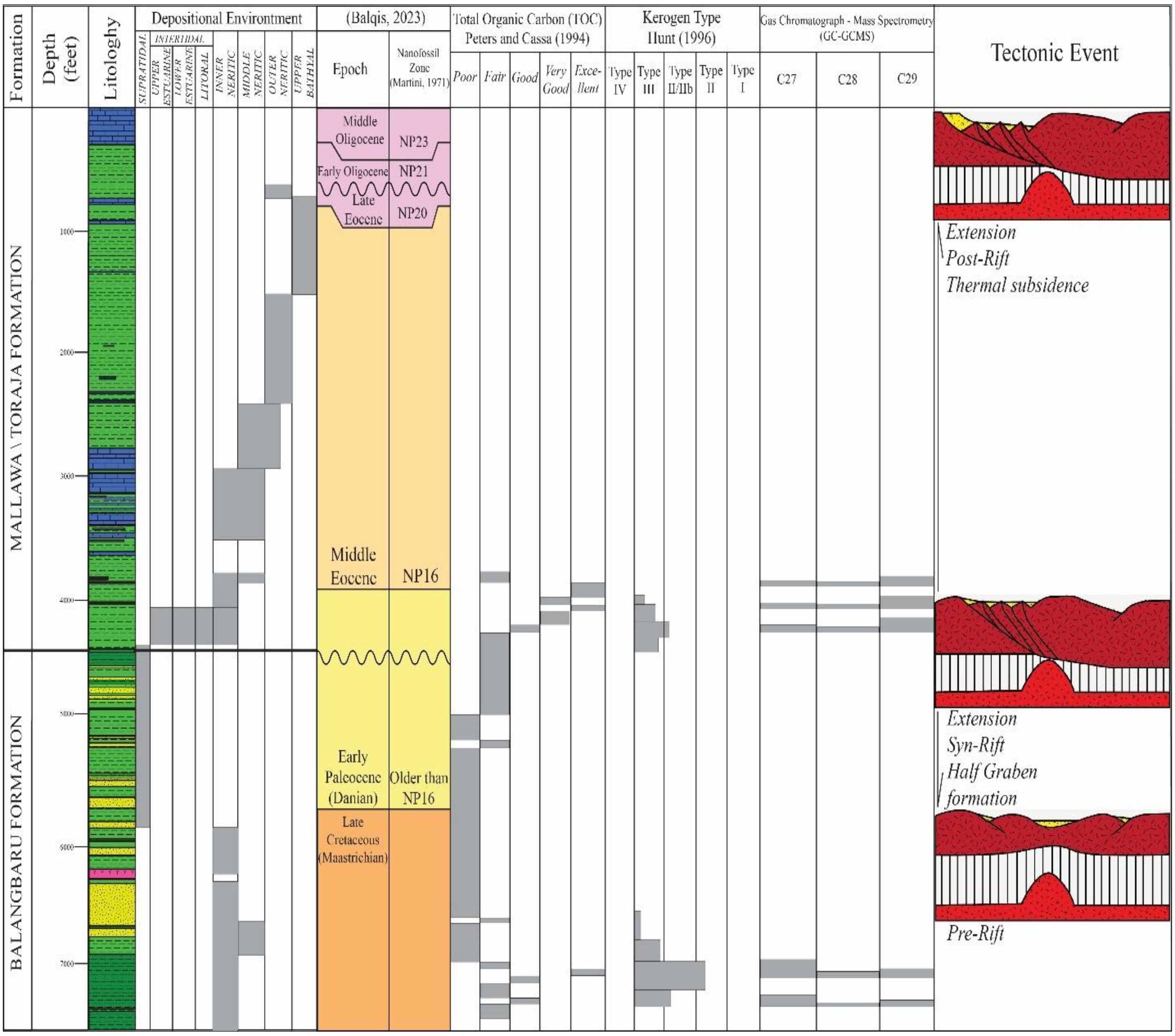


Fig 7. The relationship between tectonic events and the well's geochemical properties (TOC) in the area.

At the beginning of its formation, the Mallawa Formation was in a supratidal depositional environment. Then, due to the sea level rise (transgression) at the age of Early Paleocene, the depositional environment changed to inner neritic to upper bathyal at the age of Middle-Late Eocene, as evidenced by the presence of foraminifera. GC-MS views (Figures 10, 11, 12, and 13) at depths of (4210-4170) feet, (4100-4050) feet, and (3980-3930) feet also show terrestrial source facies with C_{29} values of 54.78%, 52.83%, and 46.92%, respectively, and C_{27} values of 24.87%, 24.17%, and 27.39%, respectively.

Gas chromatography-mass spectrometry (GCMS) analysis revealed several terrestrial biomarkers, including oleanane (OL), bicadinane, and gamaserane (Gm), notably the m/z 191 ion within the saturated hydrocarbon fraction. Bicadinane was identified as components a, b, c, and d derived from higher plants. Taraxastane (Tx) was also detected in multiple samples, alongside oleanane.

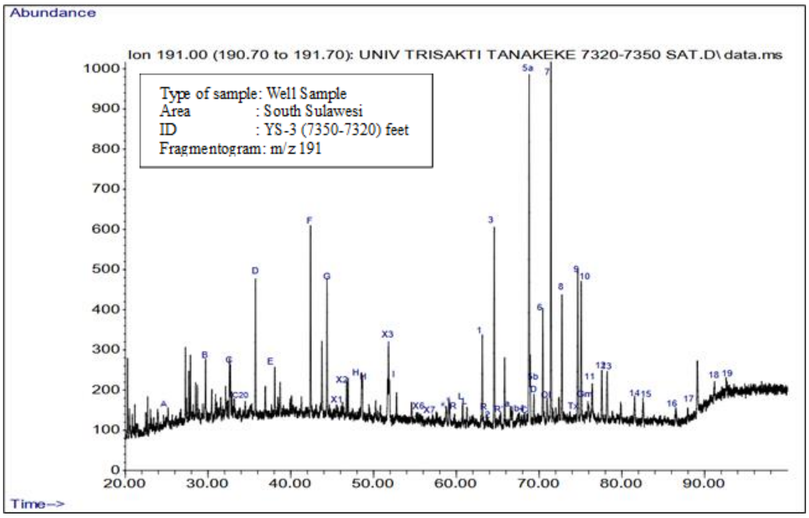


Fig 8. Partial mass chromatograms (m/z 191) showing the distribution of triterpane in sample YS-3 at 7350 to 7320 feet.

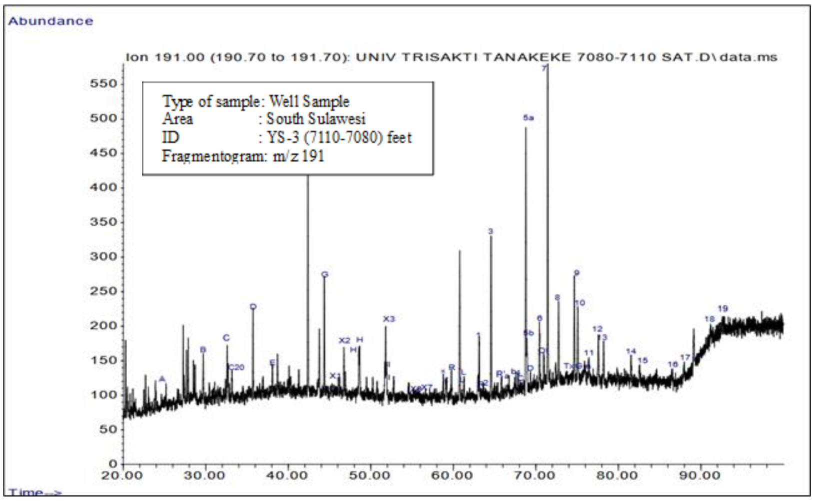


Fig 9. Partial mass chromatograms (m/z 191) showing the distribution of triterpane in sample YS-3 at 7110–7080 feet.

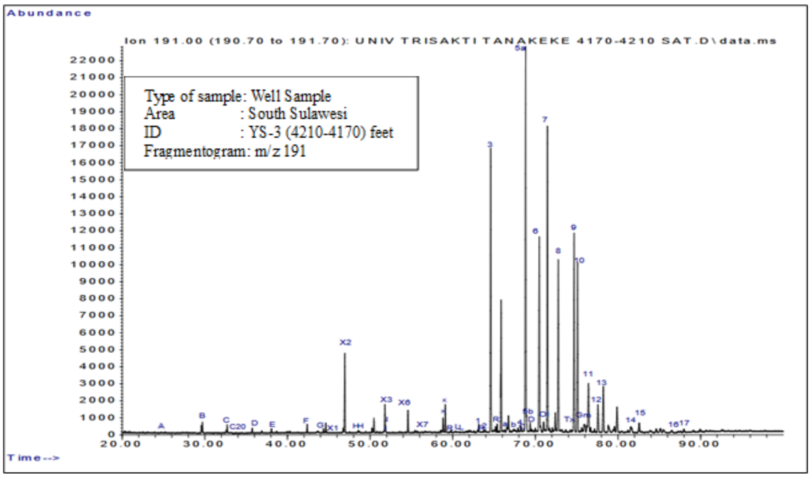
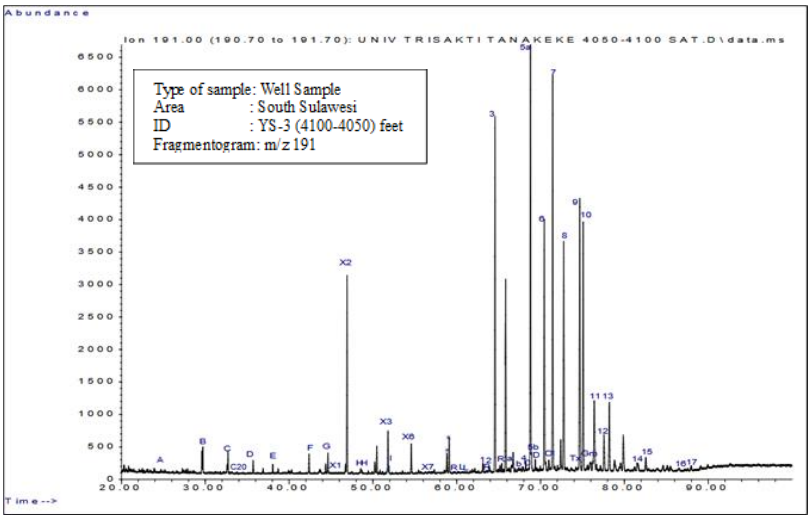
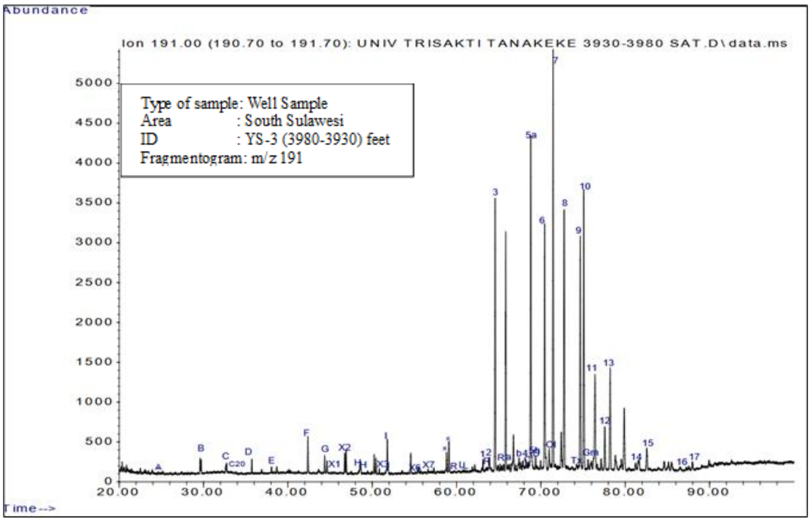


Fig 10. Partial mass chromatograms (m/z 191) showing the distribution of triterpane in sample YS-3 at 4210–4170 feet.



Type of sample: Well Sample
Area : South Sulawesi
ID : YS-3 (4100-4050) feet
Fragmentogram: m/z 191

Fig 11. Partial mass chromatograms (m/z 191) showing the distribution of triterpane in sample YS-3 at 4100–4050 feet.



Type of sample: Well Sample
Area : South Sulawesi
ID : YS-3 (3980-3930) feet
Fragmentogram: m/z 191

Fig 12. Partial mass chromatograms (m/z 191) showing the distribution of triterpane in sample YS-3 at 3980–3930 feet.

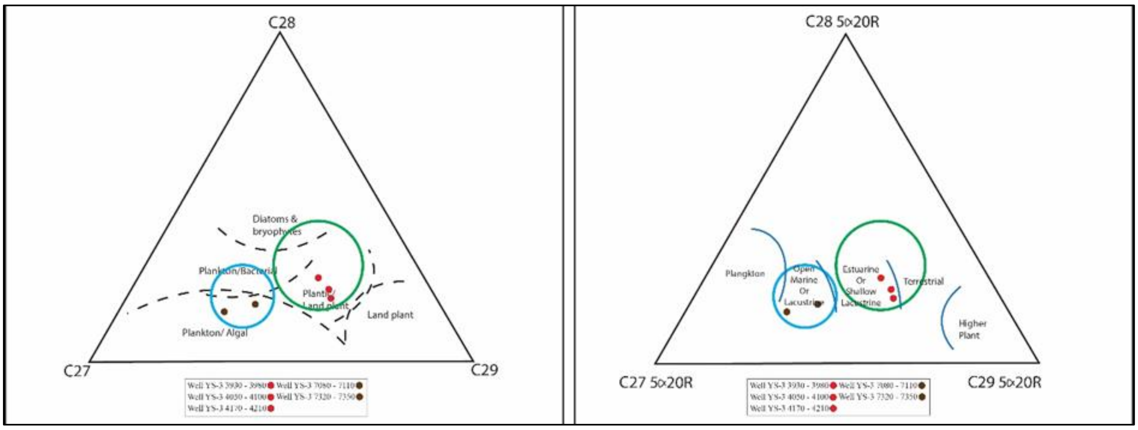


Fig 13. Sterane carbon numbers C_{27}, C_{28}, and C_{29} from the saturate fraction of the YS-3 well cutting sample plotted on ternary diagrams based on (Peters et al., 2004)(left) and (Huang and Meinschein, 1979) (right).

Figure 13 displays a relative abundance plot of steranes (C_{27}-C_{29}). It shows that the percentage of C_{27} steranes (range 46.59-55.51)% in the Balangbaru Formation is relatively significant. Meanwhile, the percentage of C_{29} steranes (range 46.92-54.78)% in the Mallawa Formation changes to a significant level. The dominance of C_{29} sterane is likely due to the presence of radiolarians or diatoms in the source rock (Volkman, 1986); (Hartono et al., 2023).

As (Sutadiwiria et al., 2017) and (Sutadiwiria et al., 2018) reported that the source rock in western Sulawesi is a deltaic and near-coastal environment. A GC-MS biomarker analysis shows that the oil seep in Lariang, West Sulawesi, can be traced back to terrestrial and marine organic material (Yarra Sutadiwiria, 2019). The same authors also confirmed that the organic material in the area was deposited in an intertidal-fluviodeltaic environment (Sutadiwiria et al., 2022) and (Yarra Sutadiwiria, 2024).

3.2 The Connection between Tectonic Activity and Geochemical Properties in the Study Area

The South Makassar Basin is classified as a foreland basin, shaped by a prolonged tectonic evolution. According to (Sutadiwiria et al., 2019), biostratigraphic evidence indicates that initial rifting in the Makassar Basin began no later than the Early Paleocene. Nanofossil data from the stratigraphic column and well sections reveal the presence of the oldest formation in the area—the Balangbaru Formation—dating back to the Upper Cretaceous–Early Paleocene. This formation is characterized by a mixture of mudstone (black shale) and interbedded sandstone breccia. The tectonic setting during this time corresponds to a pre-rift phase associated with the early stages of subduction of the Bantimala Complex, driven by plate convergence.

Another significant unit present in the study area is the Mallawa (or Toraja) Formation, dated to the Early Paleocene to Middle Oligocene. This formation is primarily composed of mudstone, occasionally accompanied by coal and isolated limestone beds.

The formation of the Makassar Strait and the initiation of the South Makassar Basin occurred during the Early Paleocene. Rifting commenced during this time, forming a half-graben structure due to extensional faulting, as noted by (Sutadiwiria et al., 2019). This tectonic phase also marked the beginning of Tertiary sediment deposition. By the Early Oligocene, the region entered a post-rift phase, characterized by a cessation of rifting activity, declining crustal temperatures, and reduced volcanism (Nur'Aini, 2005).

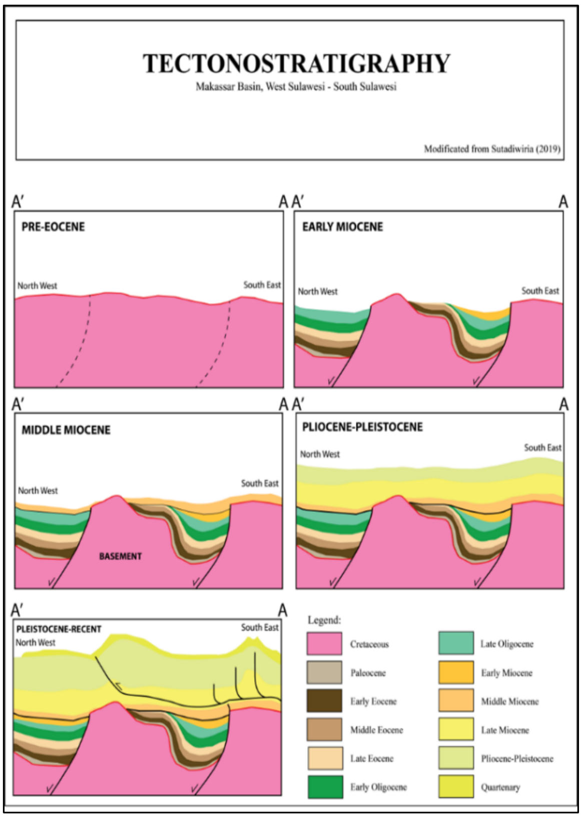


Fig 14. Tectonostratigraphy of the Makassar Basin, West-South Sulawesi through seismic reinterpretation (Modified from (Yarra Sutadiwiria, 2019)).

Figure 14 shows a new look at seismic data that illustrates the tectonics of the Makassar Basin in West and South Sulawesi. The objective of the study is to determine the impact of structural geological processes on the thermal maturity of source rocks and the potential of hydrocarbon. To achieve this, the characteristics of well data—including formation age, lithology, and geochemical properties—are analyzed in conjunction with tectonic events to get more understand about the correlation between source rock maturity and geochemical indicators in the area.

4. Conclusion

The study area well contains two distinct formations with different characteristics. The oldest is the Balangbaru Formation, dated to the Late Cretaceous to Early Paleocene, composed of black shale interbedded with tuffaceous sandstone. This formation represents an open marine or lacustrine source facies. The associated tectonic setting during this time corresponds to a pre-rift phase. The deposition of black shale and volcanic rocks reflects arc-front basin sedimentation located to the west of the subduction zone, with subduction progressing westward along the southern margin of Kalimantan.

By the Early Paleocene, rifting began, opening the Makassar Strait and forming an asymmetric half-graben structure. Due to the rifting process, the Balangbaru Formation displays a wide range of organic carbon content varying from 0.07% to 7.41% (ranging from poor to excellent), with kerogen types II to III, indicating a mixed gas-oil potential. Vitrinite reflectance (%Ro) values range from 0.51% to 0.97%, suggesting immature to peak maturity levels.

After rifting, Tertiary sedimentation occured. The Mallawa Formation (Early Paleocene-Middle Oligocene) was deposited above or directly on the basement in the South Makassar Basin. It consists of mudstone with coal and isolated limestone, and represents a terrestrial source facies. Rifting ceased by the Late Eocene, transitioning into a phase of thermal subsidence during the Early Oligocene, marked by a reduction in depositional temperatures.

Geochemical analysis of the Mallawa Formation shows organic carbon concentrations range from 0.77% to 6.11% (good to very good), with predominantly Type III kerogen, indicating a tendency for gas generation. Ro percentages vary from 0.31% to 0.38%, placing it in the immature stage of thermal maturity.

After a comprehensive post-drilling laboratory study, the South Sulawesi is still suitable and similar to West Sulawesi. South Sulawesi, particularly within the Mallawa Formation, shows promise and low exploration risk. In addition, the Balangbaru Formation is currently acknowledged as having potential as a source rock, as is the Mallawa Formation.

This research will help increase exploration activities in the research area and its surroundings. It will improve the assessment of opportunities and risks for exploration activities by evaluating 3G data and adjusting to post-drilling laboratory analysis.

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Glossary

Symbol	Definition
Tmax	Maximum Temperature
TOC	Total Organic Carbon
w.t%	Weight percent (of TOC)
REP	Rock Eval Pyrolisis
GC	Gass Chromatography
GC-MS	Gass Chromatography and Mass Spectroscopy

HI	Hydrogen Index
OI	Oxygen Index
PI	Production Index
VR	Vitrinite Reflectance (Ro)
S1	Free hydrocarbons
S2	Pyrolisable hydrocarbon
S3	Amount of CO_2 content present
HI = mg/gr rock/% TOC	the amount of hydrogen relative to the amount of organic carbon present in a sample
C	Carbon
H	Hydrogen
O	Oxygen
N	Nitrogen
S	Sulfur
°C	Degrees Celsius
K-1 well	Well Kaluku
LYS well	Well LYS
Type II/IIB	Oil and Gas Prone
Type III	Gas Prone

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