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Carbonate Facies and Depositional Environment of Pre-Parigi Carbonate in Ardjuna Sub-basin: Application of Core-facies Coding and Electro-facies

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Abstrak – Formasi Pre-Parigi merupakan salah satu formasi penyusun Cekungan Jawa Barat Utara yang berpotensi menjadi reservoir. Batuan karbonat dari Formas Pre-Parigi memiliki heterogenitas batuan yang tinggi akibat proses pengendapan dan diagenesisnya, sehingga diperlukan suatu metode yang komprehensif untuk dapat menentukan distribusi reservoirnya. Oleh karena itu, pada penelitian ini dilakukan interpretasi distribusi fasies dari batuan karbonat Formasi Pre-Parifi dengan menggunakan integrasi data *core* dan log sumur. Pada data core dilakukan pengodean dan klustering fasies untuk menginterpretasi asosiasi fasies. Kemudian, asosiasi fasies yang teridentifikasi diintegrasikan dengan karakter log untuk dapat disebarkan pada seluruh interval dan seluruh sumur. Hasil akhir dari studi ini adalah interpretasi sebaran fasies karbonat Formasi Pre-Parigi. Berdasarkan hasil analisis, karbonat Pre-Parigi di daerah penelitian tersusun atas lima asosiasi fasies yaitu *deep shel*f (FA 1), *fore-slope* (FA 2), *near-reef lagoon* (FA 3), *lagoon* (FA 4), dan *restricted circulation shelf – tidal flat* (FA 5). FA 1 ditandai dengan nilai GR yang sangat tinggi, dengan karakter *serrated*, FA 2 dicirikan oleh GR yang tinggi, *serrated*, diselingi dengan lapisan dengan nilai GR rendah dan menghalus ke atas, FA 3 dicirikan oleh GR yang rendah dengan karakter *blocky*, FA 4 juga dicirikan oleh GR dengan nilai yang cukup rendah, namun memiliki pola yang cenderung *serrated*, serta FA 5 dicirikan oleh karakter GR yang *serrated* dengan nilai yang sedikit lebih tinggi dari FA 4. Berdasarkan integrasi seluruh interpretasi, karbonat Pre-Parigi di daerah penelitian dapat dibagi menjadi dua urutan pengendapan (DS) yang cenderung menunjukan fase transgresif, dimana DS-1 berkembang di semua daerah sebagai inisiasi *build-up*, kemudian DS-2 hanya berkembang di sumur MVA-1 dan tidak berkembang di sumur MVA- 6 sumur (memasuki fase give-up). Setelah DS-2, carbonate Pre-Parigi diduga mengalami fase "*give-up*" yang merupakan fase transisi sebelum terbentuknya carbonate Formasi Parigi pada fase regresif. Secara umum, interpretasi fasies dengan metode pengkodean fasies inti dan karakterisasi elektrofasies cenderung efektif dan memberikan interpretasi yang lebih meyakinkan.

Kata kunci: Batuan Karbonat Pre-Parigi, Fasies karbonat, *Core-facies coding*, Sub-cekungan Ardjuna.

Abstract *– The Pre-Parigi Formation is one of the formations in the West Java Basin North as a potential reservoir. However, the carbonate rocks of the Pre-Parigi Formation are considered to have high heterogeneity due to the rock and depositional processes and its diagenesis, so an appropriate approach is needed to understand its reservoir distribution. Therefore, in this study, the interpretation of the facies distribution of the Pre-Parigi Formation was carried out using the integration of core data and well logs. On the core data, facies coding and clustering is performed to interpret the facies association. Then, the identified facies associations are integrated with the characters so that facies interpretation can be carried out for all intervals and all wells. The result is an interpretation of the distribution of the facies of Pre-Parigi Carbonate. Based on the analysis results, the Pre-Parigi Carbonate in the study area is composed of five facies associations, such as deep shelf (FA 1), fore-slope (FA 2), near-reef lagoon (FA 3), lagoon (FA 4), and restricted circulation shelf – tidal flat (FA 5). FA 1 is characterized by a very high value, slightly serrated gamma-ray character, FA 2 is characterized by a high gamma-ray, serrated, intercalated with a fining-upward low gamma-ray layer, FA 3 is characterized by a low value and blocky gamma-ray, FA 4 is also characterized by a gamma-ray with a fairly low value, but has a pattern that tends to be serrated, and then FA 5 is characterized by a serrated gamma-ray character with a slightly higher value than FA 4. Based on the integration of all interpretations, the Pre-Parigi Carbonate in the study area can be divided into three depositional sequences (DS) which is tend to shows the transgressive phase, where DS-1 develops in all areas as a reef initiation, DS-2 developed in the MVA-1 well and did not develop in the MVA-6 well (had a give-up phase). After DS-2, the Pre-Parigi carbonate is thought to a "give-up" phase which is a transitional phase* *before the Parigi Formation carbonate is formed in the regressive phase. In general, facies interpretation using the core-facies coding and electro-facies characterizing methods tends to be effective and provides a more confident interpretation.*

***Keywords**: Pre-Parigi Carbonate, Carbonate facies, Core-facies coding, Ardjuna Sub-basin.*

INTRODUCTION

The Pre-Parigi Formation is one of the formations in the West Java Basin North with a developed a carbonate reservoir. This formation is quite widely distributed in the North West Java Basin from offshore to on land and in the past it has not been widely exploited due to its different types of hydrocarbons dominated by biogenic dry gas. However, along with developments in technology facilities and market needs then this formation becomes more attractive to be exploited, moreover the depth is quite shallow so it is more makes drilling easier. Like other carbonate reservoirs, the Pre-Parigi carbonate reservoir also has high heterogeneity due to the process of deposition of rocks and diagenesis so an appropriate approach is needed to understand the quality of the carbonate reservoir of the Pre-Parigi Formation is related to reservoir distribution, storage capacity and flow rate.

Interpretation of the distribution of carbonate reservoirs is strongly influenced by the distribution of facies and the diagenetic processes experienced by these carbonate rocks. Facies distribution can be identified by using log and seismic data correlation. However, if there is core data, it will be very helpful in the process of log and seismic validation. For diagenesis interpretation, it is generally done by identifying diagenetic features from core and petrographic data. However, this still needs to be connected with the interpretation of the stratigraphic sequence because the diagenetic process will generally be affected by the exposure or sinking of carbonate rocks. Therefore, in this study, the interpretation of facies distribution was carried out using the integration of core data and well logs. In addition, interpretation is also carried out regarding the effect of sea level changes on the distribution of carbonate facies from one well to another.

This study is located in the south North West Java Basin to be exact Ardjuna sub-basin, offshore Java West (Figure 1). North West Java Basin is generally bounded by the Bogor Basin to the south, to the northwest bounded by the Seribu Platforms, to the north limited by Sunda shelf as well as part the northeast is bounded by the Karimun Jawa Arc. Pre-Parigi Formation in the Java Basin West North is the interval of this study. From the results of this study, it is hoped that the facies distribution of the Pre-Parigi Formation can be identified, which is used to interpret the potential reservoir distribution of the formation.

REGIONAL STRATIGRAPHY OF PRE-PARIGI FORMATION

Pre-Parigi Formation was deposited in conformable above the Cibulakan Formation. The Pre-Parigi position in the regional stratigraphy of the North West Java Basin according to Kohar et al. (1996, in Manaf and Yarmanto, 2016) can be seen in Figure 2. The constituent lithology of this interval is porous–fossiliferous light gray limestone, minor dolomite, and sandy limestone. Composing limestone This formation has the characteristics of light gray, porous, and also found accumulation of reddish-brown dolomite (Arpandi and Patmosukismo, 1975).

Pre-Parigi Formation was deposited in the Late Miocene in a shallow marine environment as a bioherm associated with the paleo high (Yaman et al., 1991). In offshore areas, bioherm has a north-south orientation up to 400 ft thick. While on the south side onshore and offshore, the bioherm direction has a northeast-southeast orientation in thickness up to 1500 ft. This difference in orientation is thought to be due to the influence of paleogeography’s characters and ancient current directions (Yaman et al., 1991). In the northern part, the reservoir lithology trend of the Pre-Parigi Formation is composed of skeletal-foramainiferal packstone with little coral, whereas parts the south has many thriving reefs with coral and algae. Reservoir quality in the Pre-Parigi and Parigi Formations is tight due to cementation by calcite to very good due to the development of secondary porosity. The porosity that develops ranges from up to more than 30%, while the permeability is up to 2000 mD (Yaman et al., 1991).

During the Middle Miocene – Late Miocene (transgression phase) sea level conditions tend to rise so that it is precipitated the Pre-Parigi Formation is above the Cibulakan Formation in a shallow marine middle neritic environment. The formation of Pre-Parigi and Parigi just before changes in sea conditions is decreasing into a paralic environment in the late Miocene – Pliocene (regression phase), which is the depositional environment Cisubuh Formation.

Kartikasari (2011) and Setiadi (2011) have conducted research using the seismic inversion method at the Pre-Parigi interval. From the results of this study identified the potential for gas hydrocarbons in Pre-Parigi Carbonate. Yulianus et al. (2018) also confirmed the same thing where at the Pre-Parigi interval the Belut structure was identified to contain hydrocarbons. This is an additional validation related to the importance of identifying the distribution of reservoirs in Pre-Parigi Carbonate.

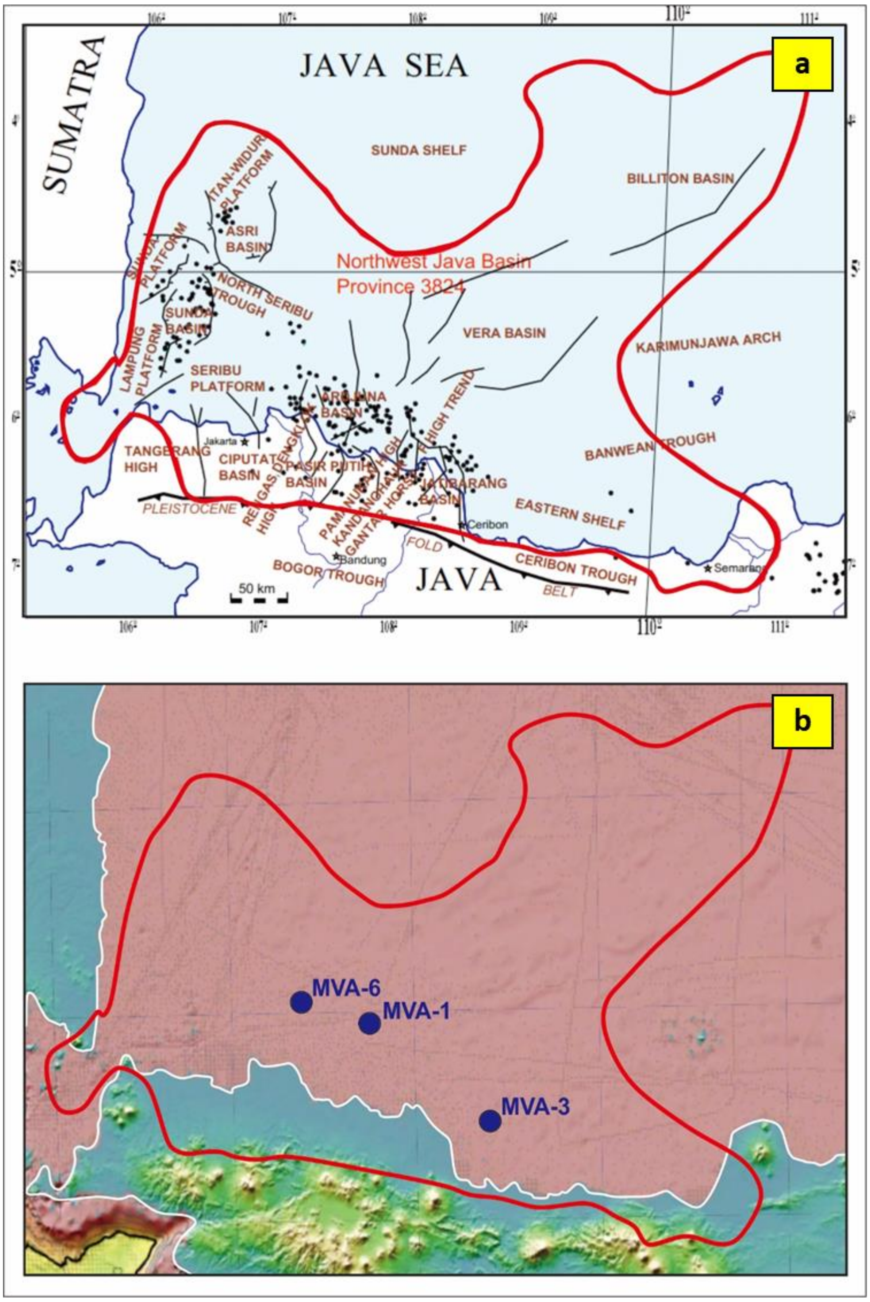

Figure 1. (a) North West Java Basin and its developing structural pattern (Bishop, 2000), (b) well location (draw on SRTM15+ Global Topography from Tozer et al., 2019 in https://topex.ucsd.edu).

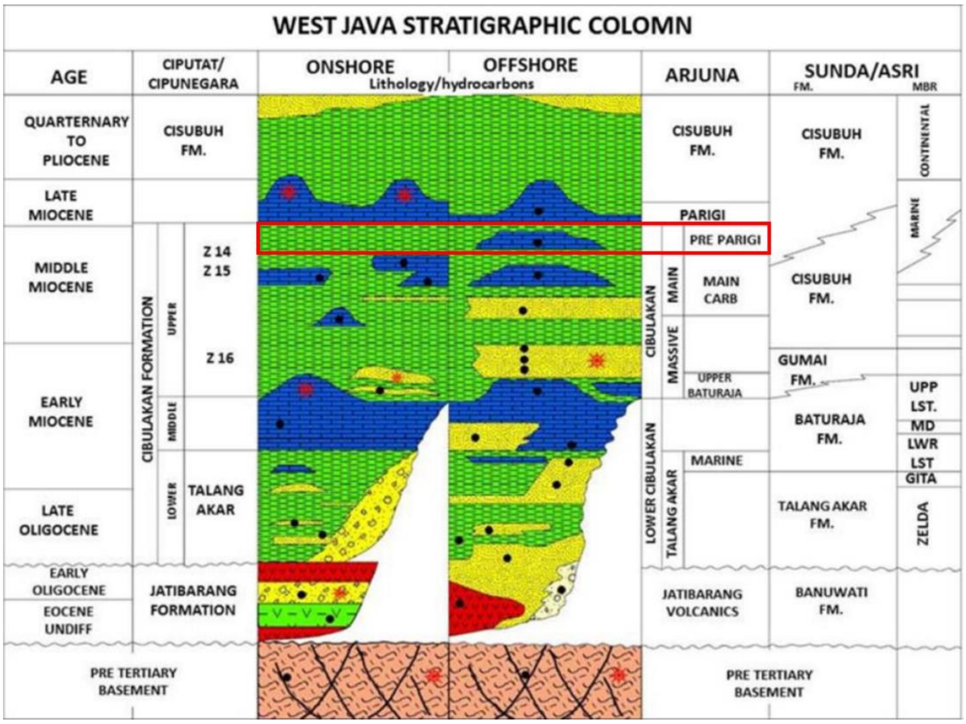

Figure 2. Regional stratigraphic column of North West Java Basin (Kohar et al., 1996, in Manaf and Yarmanto, 2016). The study interval shows by red box.

METHODS

In this study, facies analysis was performed using core and well log data on three wells, namely MVA-1, MVA-3, and MVA-6 well. MVA-1 and MVA-6 well consist of core data from Pre-Parigi Carbonate (main interval in this study), while MVA-3 consist of core data from Baturaja Carbonate. Core data from MVA-3 is used as additional data in clustering and coding litofacies to produce more input facies, but is not used in the interpretation of the development of Pre-Parigi carbonate rocks because they are located at different intervals. From the core data, facies interpretation and clustering are carried out. Furthermore, facies association and depositional environment interpretation of each well are performed. The facies associations and depositional environment of the cores are integrated with log data to validate and provide a basis for electrofacies interpretation. Finally, a correlation was performed from all wells to determine the deposition sequence and its impact on the distribution of facies that developed in the Pre-Parigi Formation at the study area.

The classification of carbonate rocks refers to Dunham (1962), where they are grouped based on the texture of the deposition. The constituent elements that influence classifications are mud, granular, and organism**.** Then, the classification of siliciclastic sedimentary rocks refers to Wentworth (1922), where they are classified based on the size of the constituent grains of rock. In this study, the use of Wentworth (1922) classification was modified by adding 'calcareous', because the entire interval tends to contain carbonate material.

Furthermore, for the interpretation of facies associations and depositional environment, this study refers to the carbonate facies model according to Wilson (1975). Changes in the facies association from the bottom up from each well will be the basis for the interpretation of the depositional sequence and facies distribution of the Pre-Parigi Formation.

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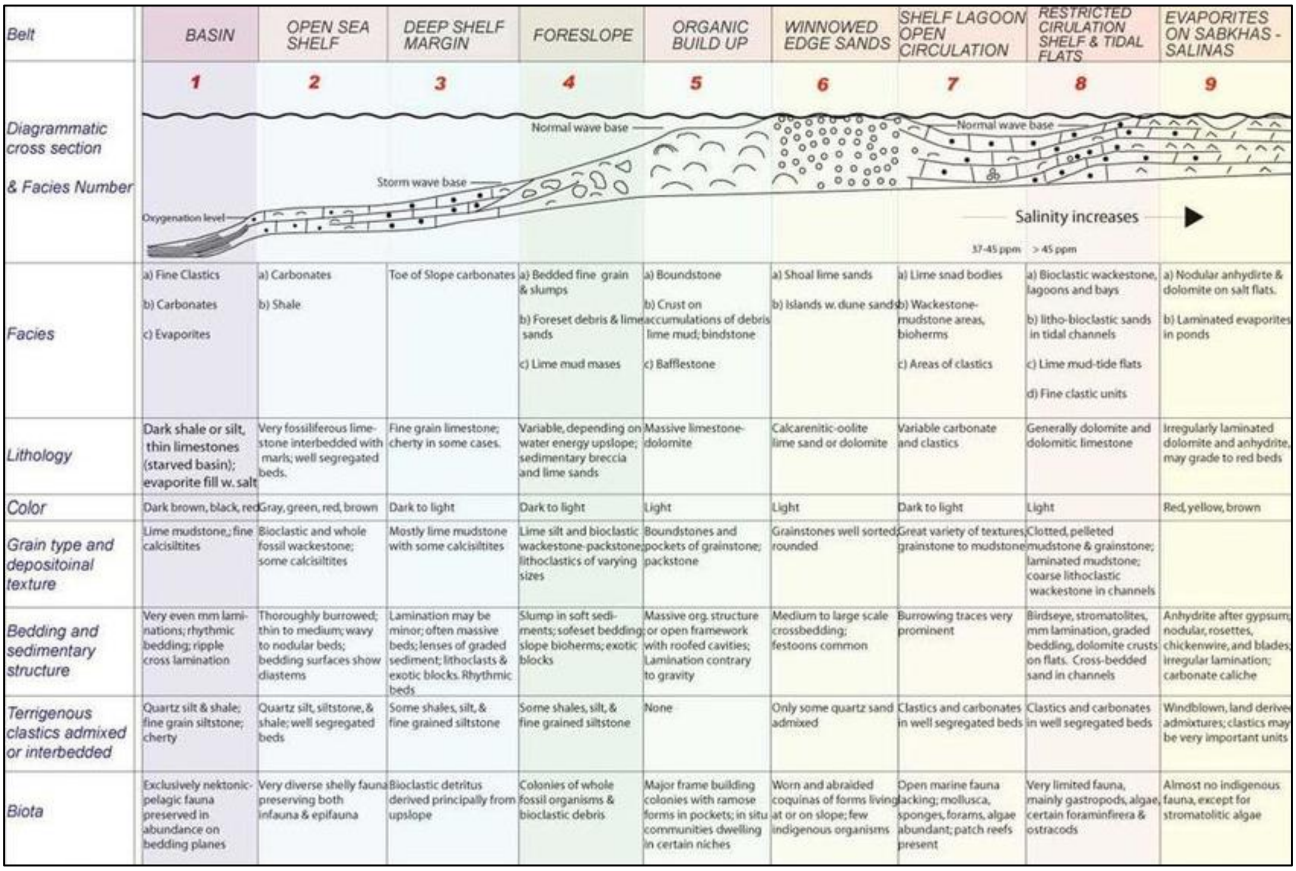

Belt	BASIN	OPEN SEA SHELF	DEEP SHELF MARGIN	FORESLOPE	ORGANIC BUILD UP	WINNOWED EDGE SANDS	SHELF LAGOON OPEN CIRCULATION	RESTRICTED CIRULATION SHELF & TIDAL FLATS	EVAPORITES ON SABKHAS - SALINAS
Diagrammatic cross section & Facies Number	1	2	3	4	5	6	7	8	9
Facies	a) Fine Clastics b) Carbonates c) Evaporites	a) Carbonates b) Shale	Toe of Slope carbonates	a) Bedded fine grain & slumps b) Foreset debris & lime sands c) Lime mud mases	a) Boundstone b) Crust on accumulations of debris lime mud; bindstone c) Bafflestone	a) Shoal lime sands b) Islands w. dune sands	a) Lime snad bodies b) Wackestone-mudstone areas, bioherms c) Areas of clastics	a) Bioclastic wackestone, lagoons and bays b) litho-bioclastic sands in tidal channels c) Lime mud-tide flats d) Fine clastic units	a) Nodular anhydirte & dolomite on salt flats. b) Laminated evaporites in ponds
Lithology	Dark shale or silt, thin limestones (starved basin); evaporite fill w. salt	Very fossiliferous lime-stone interbedded with marls; well segregated beds.	Fine grain limestone; cherty in some cases.	Variable, depending on water energy upslope; sedimentary breccia and lime sands	Massive limestone-dolomite	Calcarenitic-oolite lime sand or dolomite	Variable carbonate and clastics	Generally dolomite and dolomitic limestone	Irregularly laminated dolomite and anhydrite, may grade to red beds
Color	Dark brown, black, red	Gray, green, red, brown	Dark to light	Dark to light	Light	Light	Dark to light	Light	Red, yellow, brown
Grain type and depositoinal texture	Lime mudstone,; fine calcisiltites	Bioclastic and whole fossil wackestone; some calcisiltites	Mostly lime mudstone with some calcisiltites	Lime silt and bioclastic wackestone-packstone; lithoclastics of varying sizes	Boundstones and pockets of grainstone; packstone	Grainstones well sorted; rounded	Great variety of textures; grainstone to mudstone	Clotted, pelleted mudstone & grainstone; laminated mudstone; coarse lithoclastic wackestone in channels	
Bedding and sedimentary structure	Very even mm lami-nations; rhythmic bedding; ripple cross lamination	Thoroughly burrowed; thin to medium; wavy to nodular beds; bedding surfaces show diastems	Lamination may be minor; often massive beds; lenses of graded sediment; lithoclasts & exotic blocks. Rhythmic beds	Slump in soft sedi-ments; sofeset bedding; slope bioherms; exotic blocks	Massive org. structure or open framework with roofed cavities; Lamination contrary to gravity	Medium to large scale crossbedding; festoons common	Burrowing traces very prominent	Birdseye, stromatolites, mm lamination, graded bedding, dolomite crusts on flats. Cross-bedded sand in channels	Anhydrite after gypsum; nodular, rosettes, chickenwire, and blades; irregular lamination; carbonate caliche
Terrigenous clastics admixed or interbedded	Quartz silt & shale; fine grain siltstone; cherty	Quartz silt, siltstone, & shale; well segregated beds	Some shales, silt, & fine grained siltstone	Some shales, silt, & fine grained siltstone	None	Only some quartz sand admixed	Clastics and carbonates in well segregated beds	Clastics and carbonates in well segregated beds	Windblown, land derived admixtures; clastics may be very important units
Biota	Exclusively nektonic-pelagic fauna preserved in abundance on bedding planes	Very diverse shelly fauna preserving both infauna & epifauna	Bioclastic detritus derived principally from upslope	Colonies of whole fossil organisms & bioclastic debris	Major frame building colonies with ramose forms in pockets; in situ communities dwelling in certain niches	Worn and abraided coquinas of forms living at or on slope; few indigenous organisms	Open marine fauna lacking; mollusca, sponges, forams, algae abundant; patch reefs present	Very limited fauna, mainly gastropods, algae, certain foraminfirera & ostracods	Almost no indigenous fauna, except for stromatolitic algae

Figure 3. The carbonate standard facies belt of Wilson (1975 in Santoso et al., 2018)

RESULTS AND DISCUSSION

Lithofacies

In this study, core descriptions from the Pre-Parigi interval of wells MVA-1 and MVA-6 were performed. Core description from MVA-3 well (Baturaja carbonate) are added as additional data in clustering and coding litofacies to produce more input facies, but is not used in the interpretation of the development of Pre-Parigi carbonate rocks because they are located at different intervals.ini Description of the core in the MVA-1 well (Figure 4) was carried out at depths of 1455 – 1462 ft, 1479 – 1509 ft, 1509 – 1516 ft, and 1534 – 1544 ft. Based on the results of the core description in the MVA-1 well, 11 lithofacies were identified, namely calcareous siltstone (SH), bioclastic wackestone (WS-B), coralline-algae wackestone (WS-CA), bioclastic packstone (PS-B), coralline packstone (PS-C), coralline-algae packstone (PS-CA), bioclastic grainstone (GS-B), coralline floatstone (FS-C), coralline rudstone (RS-C), coralline-algae rudstone (RS-CA) and coralline -algae packstone-rudstone interbeds and coralline-algae packstone-wackestone interbeds. In core interval 1 (1455 – 1462 ft), it is dominated by the bioclastic wackestone (WS-B) facies, and in core interval 2 (1479 – 1509 ft), it is dominated by the coralline-algae packstone-wackestone interbeds facies. Furthermore, in core intervals 3 (1509 - 1516 ft) and 4 (1534 - 1544 ft) it is dominated by the coralline-algae wackestone (WS-CA) facies, whereas in core interval 4 thin inserts of calcareous siltstone (SH) facies are found.

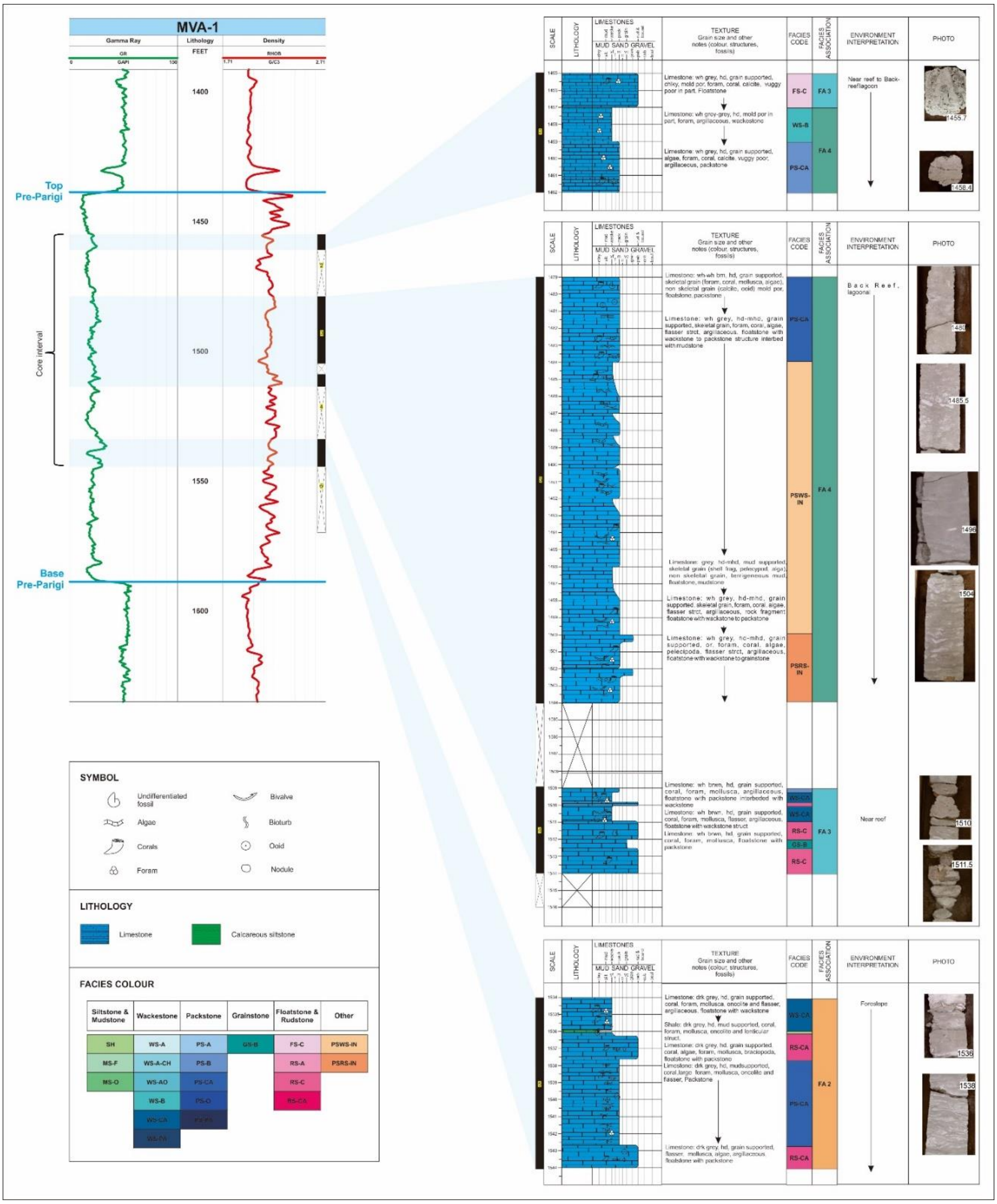

Figure 4. Core description of MVA-1 well and its position in well log

The core description in the MVA-6 well (Figure 5) was carried out at depths of 1671 - 1682 ft, 1701 - 1721 ft, and 1731 - 1756 ft. Based on the description of the core in the MVA-6 well, 6 lithofacies were identified, namely calcareous siltstone (SH), calcareous siltstone with mollusk fragment (SH-M), bioclastic wackestone (WS-B), bioclastic packstone (PS-B), coralline- algae packstone (PS-CA), and coralline-algae rudstone (RS-CA). In core interval 1 (1671 - 1682 ft) and core interval 2 (1701 - 1721 ft), dominated by calcareous siltstone (SH) and calcareous siltstone with mollusk fragment (SH-M) facies, respectively, indicating a low energy environment. Then in core interval 3 (1731 - 1756 ft), only composed by facies coralline-algae rudstone (RS-CA), indicating an environment with relatively high energy.

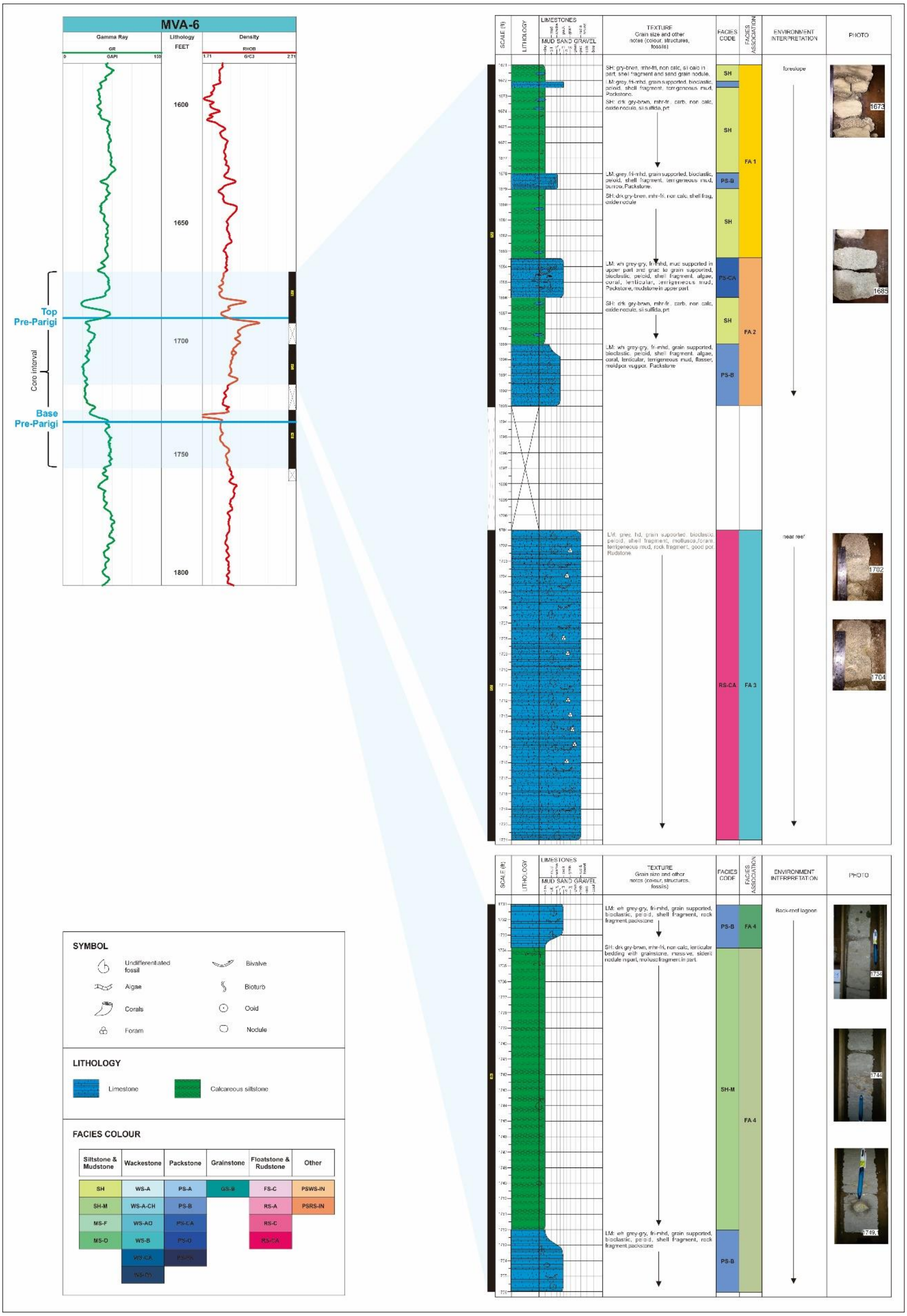

Figure 5. Core description of MVA-6 well and its position in well log

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The core description of the MVA-3 well (Figure 6) was carried out at depths of 3800 - 3860 ft, and 3860 - 3920 ft in Baturaja Carbonate interval. Core data from MVA-3 is used as additional data in clustering and coding litofacies to produce more input facies, but is not used in the interpretation of the development of Pre-Parigi carbonate rocks because they are located at different intervals. Based on the results of the core description in the MVA-3 well, 12 lithofacies were identified, namely foraminiferal mudstone (MS-F), oolitic mudstone (MS-O), algae wackestone (WS-A), chalky algae wackestone (WS-AC), algae- oolitic wackestone (WS-AO), coralline-algae wackestone (WS-CA), pelecypods-algae wackestone (WS-PA), algae packstone (PS-A), oolitic packstone (PS-O), pelecypods-algae packstone (PS -PA), as well as algae rudstone (RS-A) and coralline-algae rudstone (RS-CA). In core interval 1 (3800 - 3860 ft), dominated by algae wackestone (WS-A) and coralline-algae wackestone (WS-CA) facies. Then in core interval 2 (3860 - 3920 ft), dominated by algae packstone (PS-A), oolitic packstone (PS-O), pelecypods-algae packstone (PS-PA) facies. The predominance of facies containing algae indicates an environment with high enough energy and quite close to the reef.

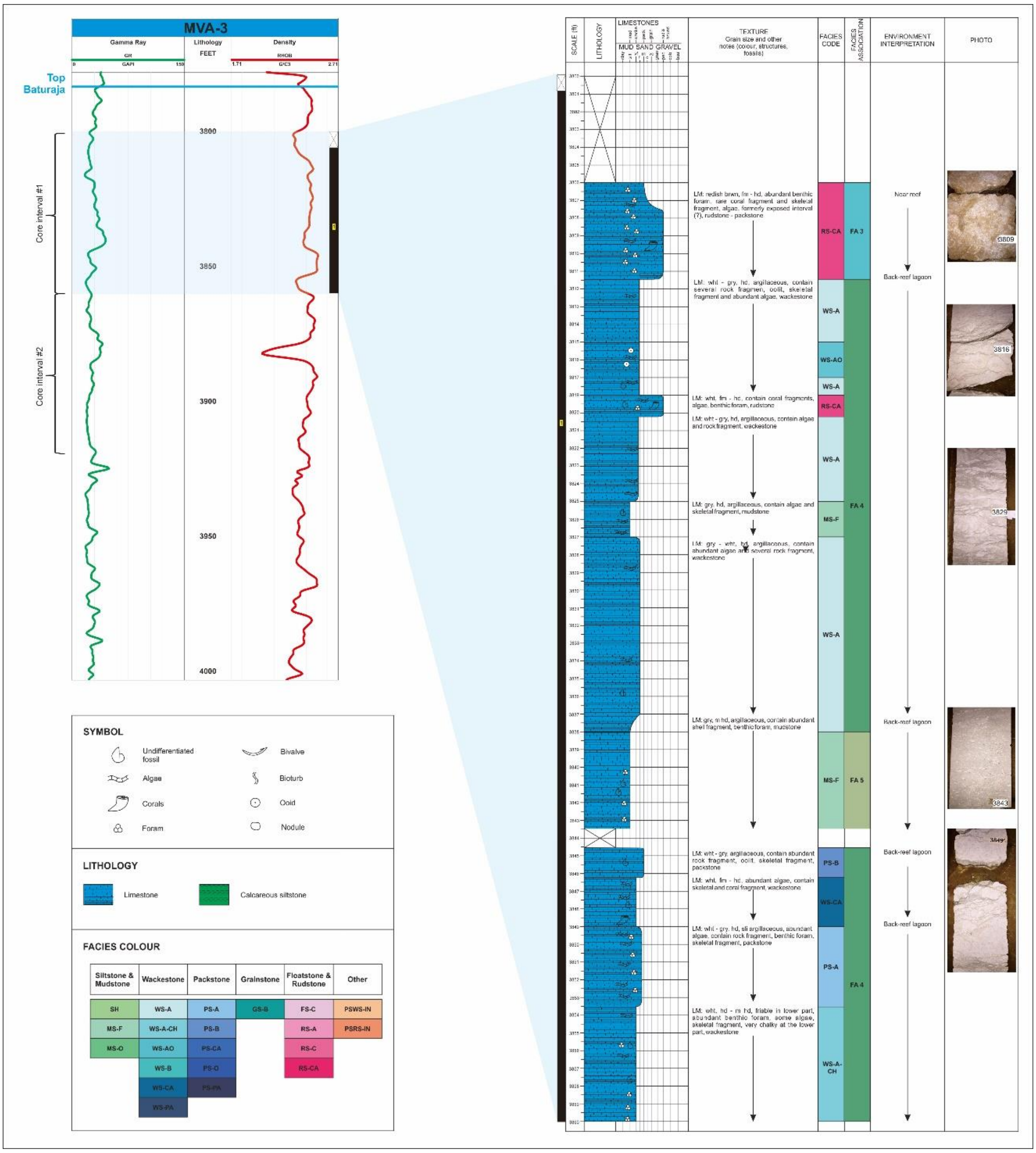

Figure 6. Core description of MVA-3 well and its position in well log

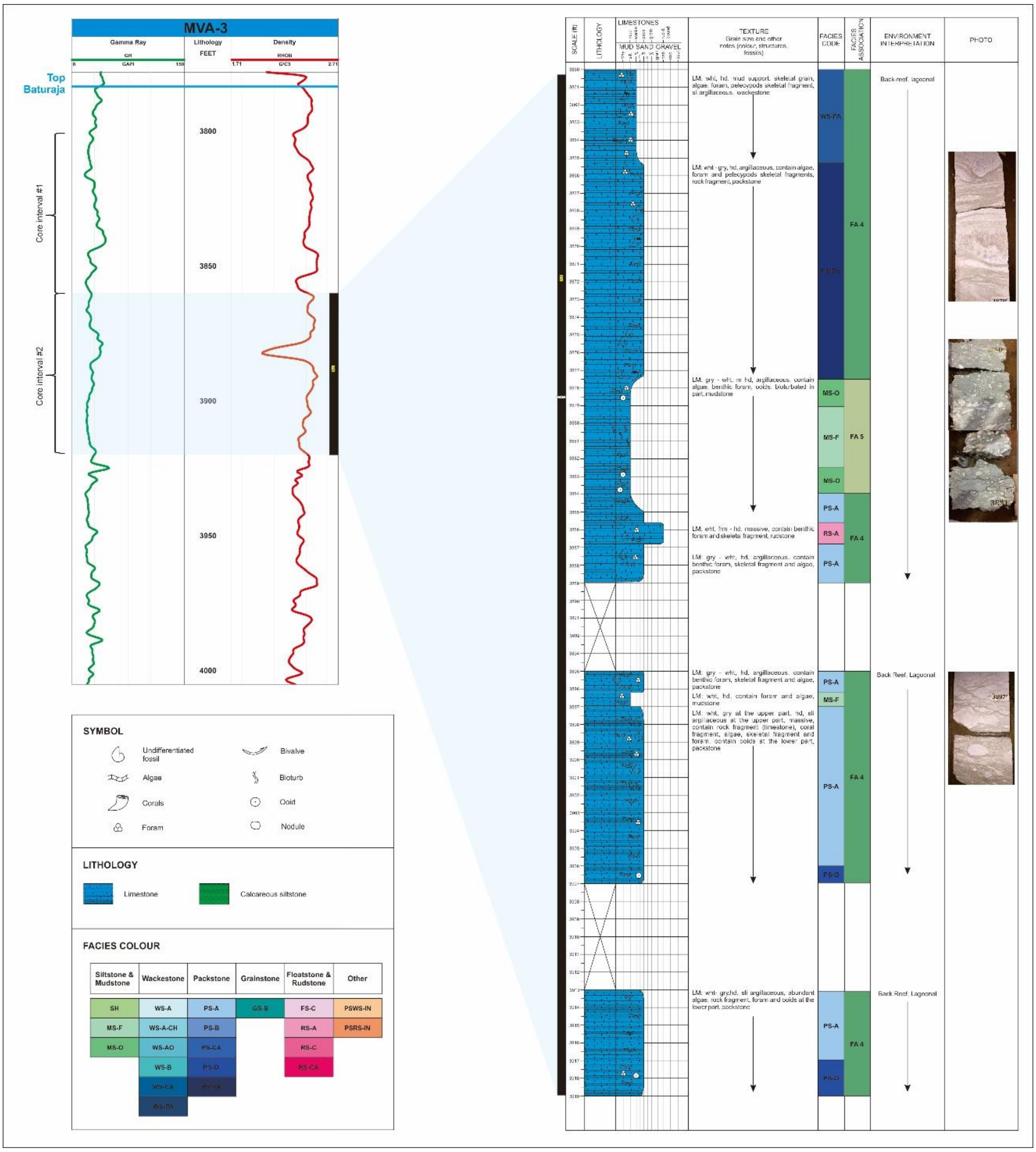

Figure 6 (con't). Core description of MVA-3 well and its position in well log

Facies Association and Depositional Environment

Based on facies coding of all core data, interpretation of facies associations and depositional environment is performed by identifying clustering lithofacies. The results of the interpretation of facies associations can be seen in Table 1. In general, the Pre-Parigi Formation at the study site can be divided into five facies associations, namely deep shelf (FA 1), fore-slope (FA 2), near-reef (FA 3), lagoon (FA 4) and restricted shelf – tidal flat (FA 5).

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Table 1. Core-facies coding and facies association interpretation.

No	Facies codes	Facies description	FA 1	FA 2	FA 3	FA 4	FA 5
1	SH	Calcareous siltstone	D	M			
2	SH-M	Calcareous siltstone with mollusc fragment					D
3	MS-F	Foraminiferal mudstone				M	M
4	MS-O	Oolitic mudstone					D
5	WS-A	Algae wackestone				M	
6	WS-A-CH	Chalky algae wakstone			M	M	
7	WS-AO	Algae-oolitic wackestone				M	
8	WS-B	Bioclastic wackestone	D	M		M	
9	WS-CA	Coralline-algae wackestone		D		M	
10	WS-PA	Pelecypods-algae wackestone				M	
11	PS-A	Algae packstone			M	M	
12	PS-B	Bioclastic packstone	M			M	M
13	PS-CA	Coralline-algae packstone		D			
14	PS-O	Oolitic packestone			M	M	
15	PS-PA	Pelecypods-algae packestone				D	
16	GS-B	Bioclastic grainstone			D		
17	FS-C	Coralline floatstone			D		
18	RS-A	Algae rudstone			D	M	
19	RS-C	Coralline rudstone			D	M	
20	RS-CA	Coralline-algae rudstone		D	D	M	
21	PSRS-IN	Coralline-algae packstone-rudstone interbeds				D	
22	PSWS-IN	Coralline-algae packstone-wackestone interbeds				D	
Depositional Environment			Deep shelf	Foreslope	Near-reef	Lagoon	Restricted shelf and tidal flat

The association of facies 1 (deep shelf) is composed of dominant calcareous siltstone (SH) and bioclastic wackestone (WS-B) facies, with minor bioclastic packstone (PS-B). In the carbonate facies model by Wilson (1975), this facies association belongs to a deep-shelf or lower-slope depositional environment. This depositional environment has a fairly low energy and minimal fragments of reef fragments (coral) and algae organisms. Low energy and minimal reef fragments are indicated by facies that tend to be dominated by facies with fine grain size.

Facies 2 association (fore-slope) is composed of coralline-algae rudstone (RS-CA), coralline-algae packstone (PS-CA), and coralline-algae wackestone (WS-CA) facies, as well as bioclastic wackestone facies (WS-B) in a minor way. In the carbonate facies model by Wilson (1975), this facies association is included in the depositional environment of the fore-slope or upper slope. This depositional environment has high energy due to its position close to the carbonate shelf break. This facies association is characterized by the abundance of coral fragments and algae in the developing facies.

Facies 3 association (near-reef) is composed of coralline-algae rudstone (RS-CA), coralline rudstone (RS-C), algae rudstone (RS-A), coralline floatstone (FS-C), and bioclastic grainstone (GS- B) which is quite dominant, and the facies of chalky algae wackestone (WS-AC), oolitic packstone (PS-O) and algae packstone (PS-A) are minor. In the carbonate facies model by Wilson (1975), this facies association belongs to the lagoon depositional environment. However, in this study to distinguish between lagoonal areas that are closer and farther away from the reef, this facies association is referred to as the facies near-reef association, which is a lagoonal area that is quite close to the reef. This depositional environment has moderate to low energy due to its position close behind the carbonate shelf break (back-reef), but contains quite abundant coral fragments. In addition, this facies association is also characterized by quite a lot of algae content, as well as the presence of coralline floatstone and oolitic grains. This indicates an environment with a predominance of fine materials and is in an area associated with waves.

Facies association 4 (lagoon) is composed of almost all the facies identified in this study, except calcareous siltstone (SH). In the carbonate facies model by Wilson (1975), this facies association belongs to the lagoon depositional environment. However, in this study, this facies association is referred to as a lagoonal facies association, which is a lagoonal area that is further away from the reef. This depositional environment has moderate to low energy, but it is still common to find coral fragments. This facies association is distinguished from FA 3 by the less abundance of coral and algae, the absence of the coralline floatstone (FS-C) facies, and the oolitic grains that are still developing but in the wackestone facies, not packstone. This indicates an environment with a predominance of fine material, located in an area associated with waves, but already quite far from the reef.

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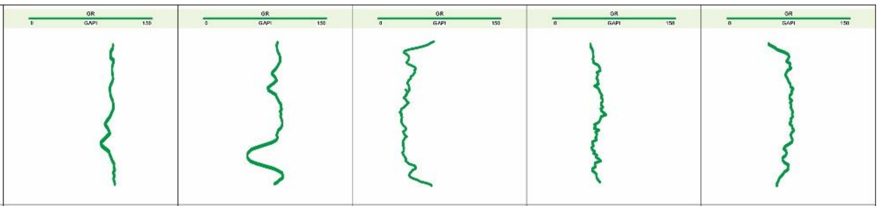
Association of facies 5 (restricted circulation shelf or tidal flat) is composed of calcareous siltstone facies with mollusk fragment (SH-M) and oolitic mudstone (MS-O) which are quite dominant and minor foraminiferal mudstone facies. In the carbonate facies model by Wilson (1975), this facies association is included in the restricted circulation shelf to tidal flat depositional environment, which is an environment with very low energy. This is evidenced by the growing facies, which is dominated by facies with very fine grain sizes. In addition, the content of mollusk is also additional evidence, where mollusk are organisms that live by eating nutrients in mud.

Electro-facies clustering

From the results of the interpretation of facies associations based on core data, integration is performed with gamma-ray and density log data to see the characteristics of each facies association. This is intended to be able to interpret the uncored interval using well-log data, but still have a strong basis. The log characteristics of each facies association can be seen in Figure 7.



GR Log Pattern					
Lithofacies Facies	SH, WS-B, PS-B	WS-CA, PS-CA, RS-CA, SH	FS-C, RS-A, RS-C, RS-CA, GS-B, PS-A, WS-A	MS-M, WS-A, WS-AO, WS-CA, WS-PA, PS-A, PS-CA, PSPA, RS-C, PSRS-IN, PSWS-IN	SH-M, MS-O, MS-F
Facies Association	FA 1	FA 2	FA 3	FA 4	FA 5
Depositional Environment	Deep Shelf (Lower slope)	Foreslope (Upper slope)	Near reef (Lagoon, closer to reef)	Lagoon (far enough from reef)	Restricted circulation shelf and tidal falt

Figure 7. The GR-log character of each facies association.

Based on the integration of the interpretation of the facies core associations and the log data, it is concluded that the gamma-ray log is sufficiently usable in differentiating each facies association. FA 1 is characterized by a high-value, slightly serrated gamma-ray log character, with several gamma-ray inserts with slightly lower values. Similar characteristics develop in FA 2, but the low-gamma-ray layer inserts are quite thick and tend to show a bell-shaped (fining-upward) pattern. Then, FA 3 is characterized by gamma-rays with low values and a dominant blocky pattern. FA 4 is also characterized by gamma-rays with relatively low values but has a pattern that tends to be serrated and shows low (dominant) and slightly higher gamma-ray repeats. Finally, FA 5 is characterized by a serrated gamma-ray character with a slightly higher value than FA 4, but not higher than the gamma-ray characteristics of FA 1 and FA 2.

Facies Distribution

Interpretation of the facies distribution in this study was carried out by identifying the facies from all Pre-Parigi intervals using the log character, and then facies correlations were carried out from all the wells used. The facies correlation of the MVA-6, MVA-1, and MVA-3 wells (NE-SW section) and also the comparison of facies association with Wilson (1975, in Moore and Wade, 2013) can be seen in Figure 8.

Based on the interpretation of the flattened facies correlation on the Pre-Parigi base, three depositional sequences were identified during the formation of the Pre-Parigi Formation. In depositional sequence 1 (DS-1), facies developed with a lagoon depositional environment in the MVA-6 well (most northwestern well), and changed to a near-reef lagoon facies association in the MVA-1 well. DS-1 is interpreted as the build-up initiation phase of the Pre-Parigi Formation.

At the end of DS-1, it is interpreted that there was a fairly rapid transgression which caused the carbonate in MVA-6 to experience a "give-up" phase and change into a fore-slope (upper slope) and deep-shelf (lower slope) environment. At that time, the carbonate in the MVA-1 wells still caught-up and formed carbonate rock in depositional sequence 2 (DS-2) which was composed of near-reef and lagoon facies associations on MVA-1.

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At the end of DS-2, the previous pattern tends to repeat itself, where a transgression occurs which causes the carbonate in MVA-1 to experience a "give-up" phase and change into a fore-slope (upper slope) and deep-shelf (lower slope) environment. After DS-2, the Pre-Parigi carbonate is thought to a “give-up” phase which is a transitional phase before the Parigi Formation carbonate is formed in the regressive phase.

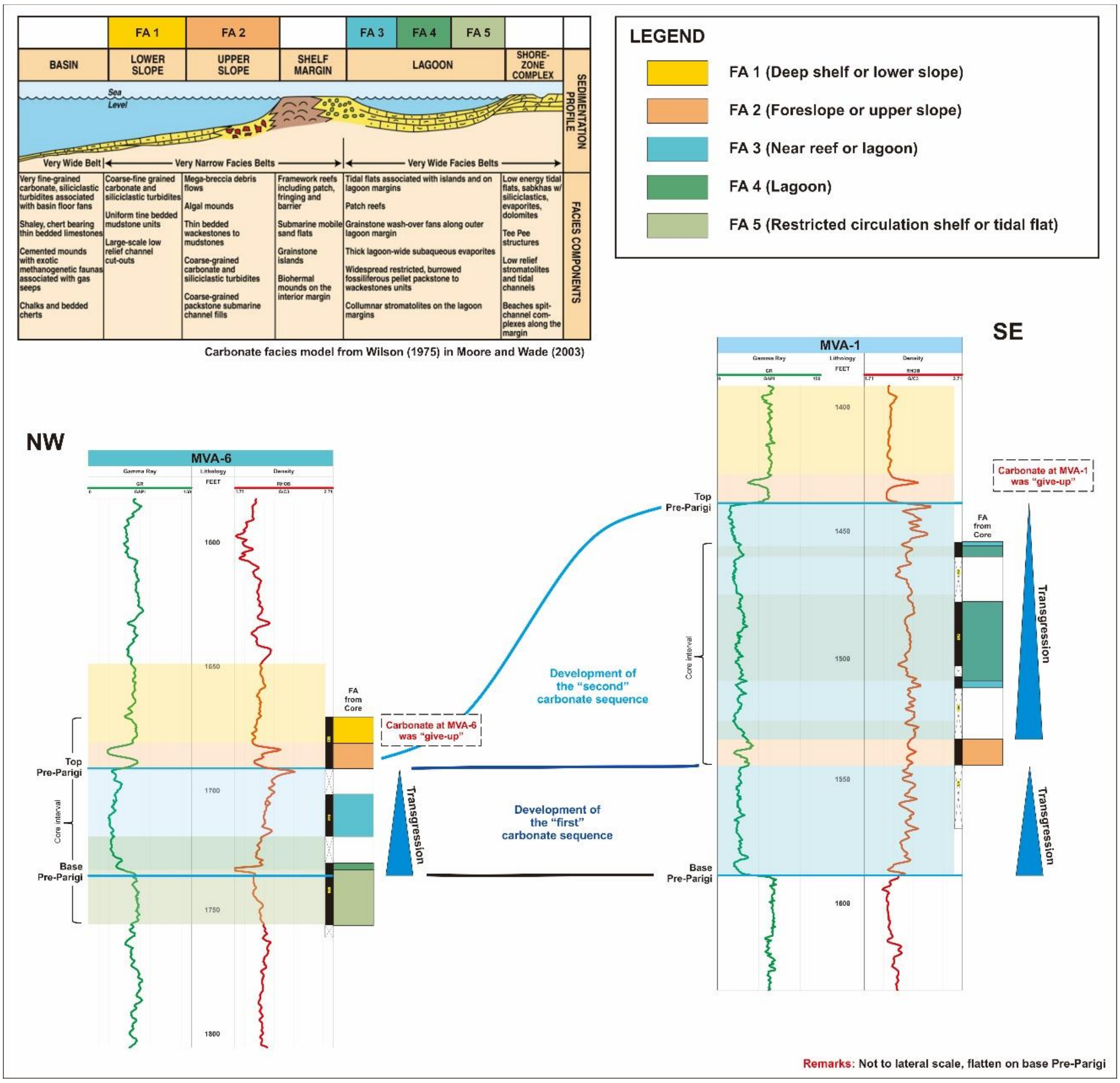

Figure 8. Carbonate depositional sequence interpretation and correlation. Note: flattened on base Pre-Parigi

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The Pre-Parigi Formation in the study area is composed of five facies associations, namely deep shelf or lower slope (FA 1), fore-slope or upper slope (FA 2), near-reef lagoon (FA 3), lagoon (FA 4), and restricted circulation shelf – tidal flat (FA 5). FA 1 is characterized by a very high value, slightly serrated gamma-ray log character. FA 2 is characterized by a high gamma-ray, serrated, insert with a fining-upward low gamma-ray layer. FA 3 is characterized by a low value and blocky gamma-ray. FA 4 is also characterized by a gamma-ray with a fairly low value but has a pattern that tends to be serrated. FA 5 is characterized by a serrated gamma-ray character with a slightly higher value than FA 4.

Based on the integration of all interpretations, the Pre-Parigi Formation in the study area can be divided into three depositional sequences (DS). DS-1was developed in all three wells used. DS-2 was developed in the MVA-1, while in the MVA-6 well it did not develop (had a give-up phase). After DS-2, the Pre-Parigi carbonate is thought to a “give-up” phase which is a transitional phase before the Parigi Formation carbonate is formed in the regressive phase.

Recommendations

In interpreting facies associations, this study uses the facies coding method. This method tends to be effective and provides a more well-founded interpretation of results. Then, this study also provides information that the gamma-ray logs from the wells in the study area can be used to distinguish the character of each facies association of the Pre-Parigi Formation. However, in interpreting facies distribution, integration using seismic data is required to produce a more comprehensive interpretation and confidence.

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REFERENCES

Arpandi and Patmosukismo, S., 1975, The Cibulakan Formation as One of the Most Prospective Stratigraphic Units in The Northwest Java Basinal Area, *Indonesian Petroleum Association Proceedings*.

Bishop, M.G., 2000, Petroleum Systems of the Northwest Java Province, Java, and Offshore Southeast Sumatra, Indonesia, USGS Report

Dunham, R.J., 1962, Classification of Carbonate Rocks According to Depositional Texture. In: Ham, W.E., Ed., *Classification of Carbonate Rocks*, AAPG, Tulsa, 108-121.

Kartikasari, E., 2011, *Estimasi Sebaran Porositas Reservoar Karbonat Berdasarkan Inversi Seismik pada Formasi Pre-Parigi, Lapangan "Elnusa", Cekungan Jawa Barat Utara*, Geophysics Study Program, Universitas Gadjah Mada [Skripsi].

Moore, C. H., and Wade, W. J., 2003, Carbonate Reservoir: Porosity and Diagenesis in a Sequence Stratigraphic Framework, *Developments in Sedimentology*, 67, 3-21.

Setiadi, W., 2011, *Identifikasi Gas pada Batuan Karbonat, Formasi Pre-Parigi, Lapangan Soelaiman Menggunakan Metode Inversi Seismik "Model-Based"; Identification of Gas on Carbonate, Pre-Parigi Formation, Soelaiman Field Using Model-Based Seismic Inversion*, Geophysics Study Program, Universitas Gadjah Mada [Skripsi].

Santoso, W. D., Zaim, Y., Rizal, Y., 2018, Paleontology of Acropora Corals and Sandard Facies Belt from Ujunggenteng Area, West Java, *Riset Geologi dan Pertambangan*, 28, 129-140.

Tozer, B., Sandwell, D. T., Smith, W. H. F., Olson, C., Beale, J. R., and Wessel, P., 2019, Global bathymetry and topography at 15 arc seconds: SRTM15+, *Earth and Space Science*, https://topex.ucsd.edu

Wentworth, C.K., 1922, A Scale of Grade and Class Terms for Clastic Sediments. *Journal of Geology*, 30, 377-392.

Wilson, J. L., 1975, *Carbonate Facies in Geologic History,* New York: Springer – Verlag Berlin Heidelberg, 471 p.

Yaman, F., Ambismar, T., and Bukhari, T., 1991, Gas Exploration in Parigi and Pre-Parigi Carbonate Buildups, NW Java Sea, *Indonesian Petroleum Association Proceedings*

Yulianus, L. F., Setiawati, Y., D., Radiansyah, S., and Prawoto, I. S., 2018, Unlocking Potential Reservoir of Pre-Parigi Carbonate to New Opportunity Gas Field. A Case Study of Belut Structure – Offshore West Java, *Indonesian Petroleum Association Proceedings*.