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Diagenesis and Paragenesis in Miocene-Aged Carbonate Reservoir Rocks in the Nort West Java Basin

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Abstract**—***The North West Java Basin has very complex reservoir problems from depositional systems, successional facies, and lateral distribution and diagenesis problems related to reservoirs. This study aims to analyze and determine mineralogy and fossil susceptibility to the process and history of diagenesis in detail, which in turn will provide a comprehensive model of carbonate reservoir character. The data used are field data in the form of surface rock samples and pit data in the form of core, SWC, cutting, SEM, XRD, petrography, biostratigraphy, and petrophysics. Diagenesis and paragenesis processes play an important role in the development of reservoir characters since shortly after deposition from the early Miocene to the present day, and the diagenesis regimes are marine phreatic, freshwater phreatic to vadose and overland regimes. Mineralogy, packing, and cementation observed by microfacies describe the paragenesis that works starting from aragonite minerals, then calcite and dolomite, cement forms ranging from fibrous, equant blocky, syntaxial and present stylolite, dolomitization and placement of hydrocarbons. The Middle Cibulakan Formation has not been exposed, and this is interpreted as a mesogenetic phase of diagenesis, while the Upper Cibulakan Formation and Parigi Formation, which have been partially folded and lifted to the surface area in the mesogenetic and telogenetic phases of diagenesis. The benefit of this research is to determine diagenesis and paragenesis, and tectonic events are highly correlated with reservoir character in the form of porosity and reservoir conductivity triggers and when hydrocarbon placement occurs. The study of heterogeneous and very complex carbonate rocks requires microfacies, diagenesis, tectonic parameters, and studies of sea level changes in a narrow period of time. It is hoped that the published results can help increase exploration and production activities.*

Keywords*—Carbonate, Diagenesis, Microfacies, Miocene, Paragenesis.*

I. INTRODUCTION

The North West Java Basin is one of the hydrocarbon-producing basins of Miocene-aged carbonate rocks, which are derived from the Middle Cibulakan Formation (eq. Baturaja Formation), Upper Cibulakan Formation (Mid Main Carbonate), and Parigi Formation. Various characters of carbonate rocks are formed due to differences in depositional systems, successional facies, lateral facies, and diagenesis and tectonic processes at work. The formulation of the relationship between several factors that influence the individual character of carbonate rocks in this basin has never been discussed in an integrated manner. The integration in question is learning from aspects of the depositional system and the diversity of forming biota, the diversity of diagenesis, and the role of tectonic processes that occur by means of descriptive and interpretive learning based on field outcrop data and subsurface data. So, it is interesting to investigate and conduct research on the role of diagenesis and paragenesis parameters with a microfacies approach in influencing the Miocene-aged carbonate rock reservoir system in the North West Java Basin. Research conducted in this basin aims to:

1. Determine and classify the Miocene-aged carbonate rock-forming microfacies with parameters (1) biofacies, (2) lithofacies, (3) diagenesis, and (4) paragenesis.
2. Studying diagenesis and paragenesis systems associated with reservoir formation in the system and mineralogical susceptibility to diagenesis and tectonic environments.
3. Studying the most influential factors in the formation of reservoir rocks through the parameters of lithofacies, diagenesis, and paragenesis related to the deposition of oil and

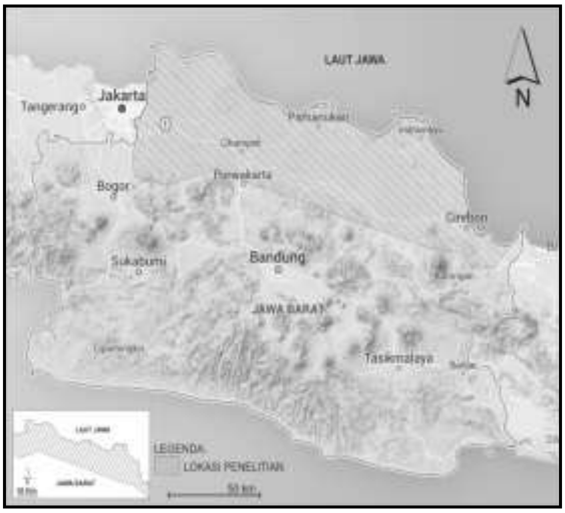

Fig. 1. Map of the location of the research area in the North West Java Basin, Land Area, which is the working area of PT. PERTAMINA EP.

The research area is located in the North West Java Province on a land area geologically called the North West Java Basin. This basin extends from the Tangerang area in

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the west to the Cirebon area in the east, and the northern boundary is an area of water or offshore, while in the south is a hilly volcanic area that extends from the Bogor area in the west to the Kuningan area in the east. The research area is estimated to be only one-third of the total area of the North West Java Basin (Fig. 1).

II. Materials and Methods

This research uses the deductive reasoning method with a descriptive-explorative combination of reasoning with the hypothesis. The data/materials used in the study consist of primary data and secondary data, including:

- Primary data in the form of field data, namely rock outcrops that exist, especially for formations, namely Parigi Formation and Upper Cibulakan Formation, which are then made geological maps and geological cross-sections. And secondary data, namely (1). well log data (2). subsurface seismic recording data, (3). laboratory analysis data from Cutting, SWC, and Core samples.
- Secondary data of logging and seismic geophysics, well data, FMI, Core, SWC, Cutting, laboratory results in the form of petrography, SEM, XRD, cathodolumination, and geochemistry as well as petrophysical data obtained from a loan with the permission of the Directorate General of Oil and gas, PT. PERTAMINA EP, SKK Migas, or Oil Field Operator Company in North West Java Land Area. Supporting data such as geological, tectonic, and regional stratigraphic data from various published and unpublished sources.

The researcher begins with a literature review of previous research, especially on geology at the research site, browsing books and articles/journals related to the research. Then the analysis of biofacies analysis (macro and micro fossils), mineralogy, texture features, and diagenesis structures found in rocks, sedimentological analysis of carbonate stratigraphy, paleogeographic analysis, and facies distribution, geological structures both recorded at a specific time vulnerabilities are narrow as historical support. Diagenesis and subsurface analysis were processed from well data and geophysical data.

III. Results and Discussion

Observation Site Map and Geological Map

On the map of the observation location, there are 4 points (Fig.2) of observation locations that show the lithology that locations 1 and 2 are bindstone (Fig. 4 and 5). Locations 3 and 4 is bindstone – framestone (Fig. 6 and 7).

Fig. 2. Research Location Map that shows the lithology is bindstone and bindstone–framestone.

The regional geology of the study area shows that observation locations 1 and 2 are included in Klapanunggal Formation, and observation locations 3 and 4 are included in Parigi Formation (Fig. 3).

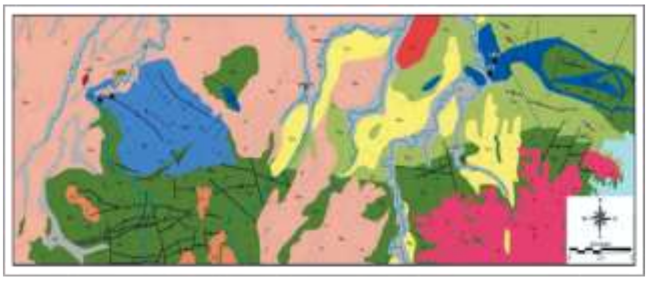


Fig. 3. Regional Geological Map that shows observation locations 1 and 2 are included in Klapanunggal Formation, and observation locations 3 and 4 are included in Parigi Formation.

Fig. 4. Research location 1, which is located in Cibinong, shows bindstone lithology.

Fig. 5. Research location 2, which is located in Klapanunggal, shows *bindstone* lithology.

Fig. 6. Research location 3, which is located in Pangkalan, shows *bindstone-framestone* lithology.

Fig. 7. Research location 4, which is located in Pangkalan, shows *bindstone-framestone* lithology.

Diagenesis of the Middle Cibulakan Formation

The main lithofacies characteristic is packstone – wackestone and dolomite facies, the second is grainstone to boundstone facies with a mixture of skeletal coral (coelenterate) biota content, orbitoids or foraminifera and rhodophytes or red algae, with another biota such as mollusks and echinoderms and ostracods.

- Dolomite Facies

In mineralogy, the composition of calcite is more dominant in many samples, but at a certain depth sample, the presence of dolomite minerals reaches up to 98%, with the term dolomite facies being packstone facies.

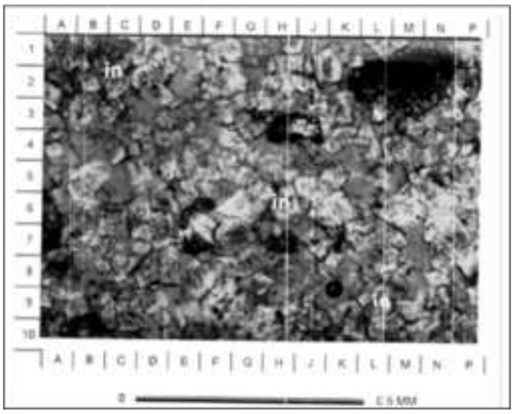


Fig. 8. The view of the petrographic incision from the core sample of the TBN well, Middle Cibulakan Formation, the name of the rock is Dolostone (parallel nickel, 126x magnification). Diagenetic processes in these rocks include intensive dolomitization, compaction, dissolution, and cementation by small amounts of pyrite. Based on the analysis results, the visual porosity of this incision is 17.5% with grain dissolution and intercrystalline (in) types.

- Packstone Dolomitic Litofacies

The packstone facies observed in the core consist of depositional components, namely, allochemical grains, including onkoids, and complete and separate red algae. The base mass is entirely micrite with almost the same abundance as oncoid fragments, shell fragments, echinoid plate and spine, bryozoans, agglutinating foraminifera, and large foraminifera are also present in these facies. Some of the non-carbonate allochems that were present consisted of terrigenous detrital material, phosphatic material, and glauconite pellets (Fig. 9).

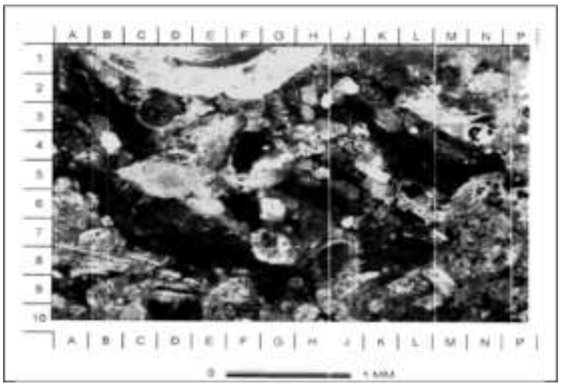
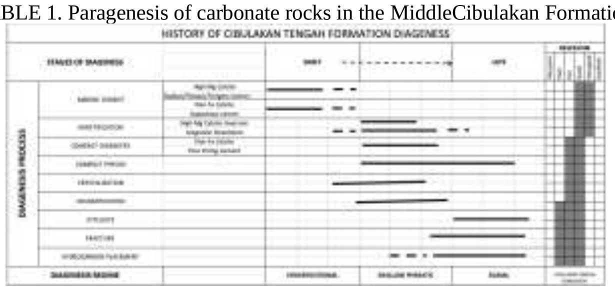


Fig. 9. Petrographic section view of the sample core well TBN MiddleCibulakan Formation, rock name: Red Algae–Larger Forams Dolomitized Packstone (aligned nickel, 126x magnification). Diagenetic processes in these rocks include compaction, micritization, dolomitization, replacement, local dissolution, and calcite precipitation. Based on the analysis results, the visual porosity of this incision is 4.5% with grain dissolution and fracture types.

The history of diagenesis of the Middle Cibulakan Formation as a whole is the beginning of diagenesis characterized by the formation of pyrite framboids. The beginning of carbonate cementation in these facies is represented by calcite which is radial and fibrous at the periphery of non-ferrous and isopachous calcite, which is generally formed in marine phreatic diagenesis environments. Then, the smelting of aragonite minerals in the freshwater vadose zone environment or the freshwater-phreatic diagenesis environment will eliminate the initial texture, as indicated by the high magnesium calcite turning into low.

TABLE 1. Paragenesis of carbonate rocks in the MiddleCibulakan Formation.



This dissolution results in the formation of secondary porosity of the shell, which dissolves but is retained as a mold by the carbonate (biomoldic) sludge. The next event of diagenesis is dolomitization, where intercrystalline porosity develops, and a small amount of hydrocarbons is also trapped in this porosity. The last diagenesis is the formation of stylolites which are formed by sediment overburden or overburden loading (Table 1).

Diagenesis of the Upper Cibulakan Formation

The lithofacies characteristics of carbonate rocks from the Upper Cibulakan Formation observed from core and SWC data from megascopic and microscopic analysis (petrography and SEM) are predominantly packstone and wackestone with the main biota being large foraminifera (Fig. 10) and Rhodophyta, while the main constituent minerals are microcrystalline calcite and dolomite. While the physical characters are megascopic and microscopic, it can be seen the presence of vuggy porosity, stylolite, and fractures. The depositional components in the form of allochems present in this lithofacies consist of part of the shell crust, coral fragments, and pieces of red algae material. The carbonate sludge is deposited at the same time as the allochems and fills the majority of the gaps between the grains. Some of the gaps are not filled and remain as primary porosity (Fig. 11).

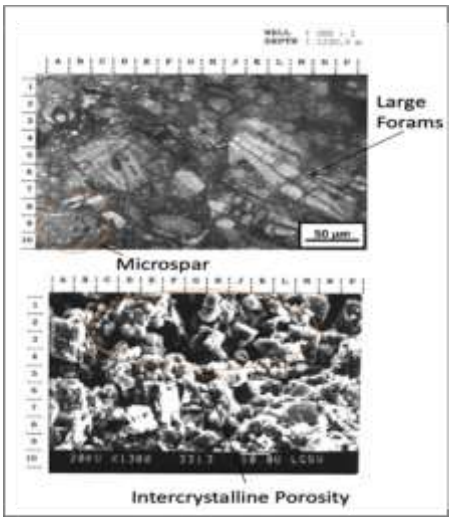


Fig. 10. The SEM section of limestone shows coarse grains consisting of Larger Forams, Planktonik Forams, and Mollusc Fragments. Diagenesis processes that occur are dolomitization, neomorphism, and porosity dissolution, which are visible are intercrystalline and vuggy.

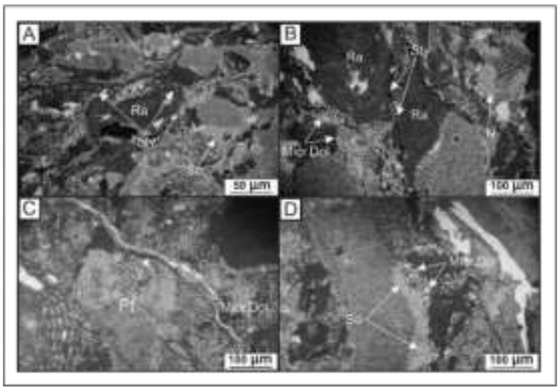
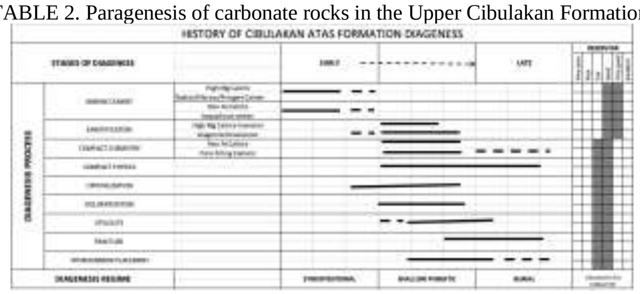


Fig. 11. The appearance of Wackstone-Packstone limestone in the CORE-23 well at a depth of 91.7 m of the Upper Cibulakan Formation; (Photo. A) Indicates the presence of red algae (Ra), which also coincided with the presence of stylolite (Sty), syntactical overgrowth (So) cement was seen covering the fragments. (Photo. B) the presence of red algae (Ra) and stylolite (Sty), and the presence of neomorphism in the fragments, micro dolomite (Mic. Dol) is present in this limestone. (Photo. C) Fracture porosity (Ft) is visible, as well as micro dolomite (Mic. Dol) (Photo.D), Syntaxial overgrowth cement (So), and also micro dolomite (Mic. Dol).

The diagenesis history of the Middle Cibulakan Formation is the cementation of the non-ferrous calcite and allochems present to fill the primary pore space. This isopachous cement was deposited in the marine diagenesis environment and the freshwater phreatic diagenesis environment in the vadose zone. Furthermore, the echinoid plates and spines exhibited syntactical overgrowths of cement, which reverted to non-ferrous low magnesium calcite when in a freshwater phreatic environment. Furthermore, there will be the dissolution of aragonite mineral which causes the development of moldic porosity along with the primary porosity of the initial texture, which is not visible. Then, the formation of stylolites which are zig-zag shaped on the surface and irregular, occurs due to overburden pressure. Some of the hydrocarbons migrate along the stylolites. Dolomitization occurs patchy in certain parts of this facies, and the hydrocarbons occupying this rock are in intercrystalline porosity (Table 2).

TABLE 2. Paragenesis of carbonate rocks in the Upper Cibulakan Formation.



Diagenesis of the Parigi Formation

The lithofacies characteristics of carbonate rocks from the Upper Cibulakan Formation observed from the core and cuttings have lithofacies characteristics for carbonate rocks in the Parigi Formation are (1) packstone and dolomitic packstone facies (Fig.12), (2) dolomite facies) (Fig 13), and 3) mudstone facies. The depositional components in the form of allochems were presently consisting of shell fragments, echinoid plates and spines, coral keratin, red algae grains, large foraminifera (Fig. 14), unidentified skeletal fragments, and unusual peloids which probably originated as red algae and consisted of allochemical grains.

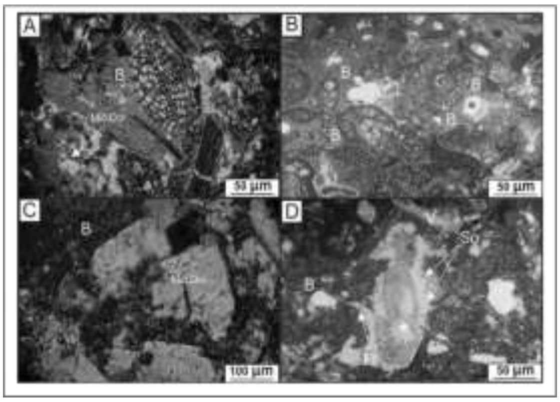


Fig. 12. The appearance of Packstone-Grainstone limestone in the Core-23 well at a depth of 19.2 m Parigi Formation; (Photo. A) The appearance of Blocky cement (B) is red to pink, some micro Dolomite (Mic. Dol) is present in this limestone. (Photo.B) The presence of Blocky cement (B) in the red-pink limestone and also the presence of vuggy porosity (V). (Photo. C) The appearance of blocky cement (B) and micro dolomite (Mic. Dol). (Photo.D) Syntaxial Overgrowth (So) cement is present in this limestone and is also fractured by the filled porosity Fracture (Ft), Blocky cement (B), and vuggy porosity (V), which are visible in blue.

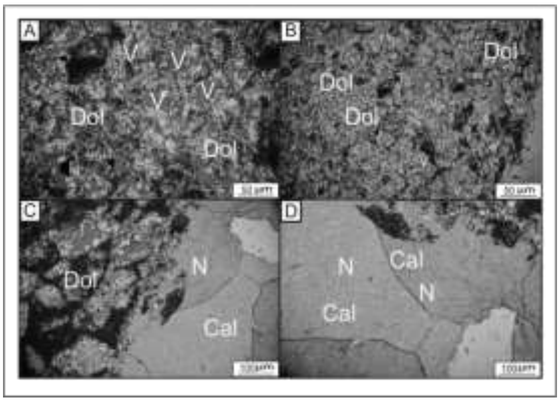


Fig. 13. The appearance of Dolostone limestone in LP 1WP POS 1 Klapanunggal area, Parigi Formation; (Photo. A) The presence of dolomite (Dol) predominates, and also vuggy porosity (V) is formed. (Photo. B) Dolomite also (Dol) fills almost all corners of this limestone incision, and vuggy porosity (V) (Photo. C) Dolomite (Dol) on the left, and neomorphism (N) and presence of Calcite (Cal) (Fig. Foto.D) Traces of the Neomorphism (N) process indicated by the presence of Calcite (Cal).

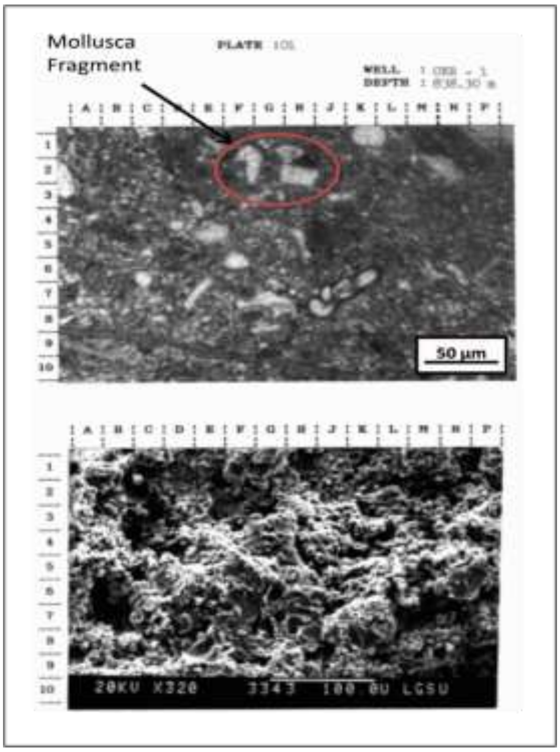


Fig. 14. Limestone SEM section showing Floatstone-Wackstone texture, consisting of coral debris (P1) (diameter more than 4mm), Larger Forams debris (A-H,8-10), Mollusca fragments (F-K,1-2) Miliolids (J, 7) Gastropods. Porosity with intraparticle, intercrystalline, and vuggy types. The process of Neomorphism and dissolving of unstable grains is dominant.

The history of diagenesis of the Parigi Formation begins with the formation of non-ferrous fibrous radial calcite cement around coral fragments which indicates diagenesis in a marine phreatic environment. Then there is an inversion of high magnesium calcite as in the previous diagenetic formation. Dissolution of aragonite from coral fragments and other biota occurs in the phreatic diagenesis environment because there is no texture supporting the vadose environment. The resulting primary porosity and moldic porosity spaces will be filled with ferrous calcite cement, which is a characteristic of freshwater phreatic diagenesis environments. The last event was dolomitization which resulted in the formation of intercrystalline porosity (Table 3).

TABLE 3. Paragenesis of carbonate rocks in the Parigi Formation.

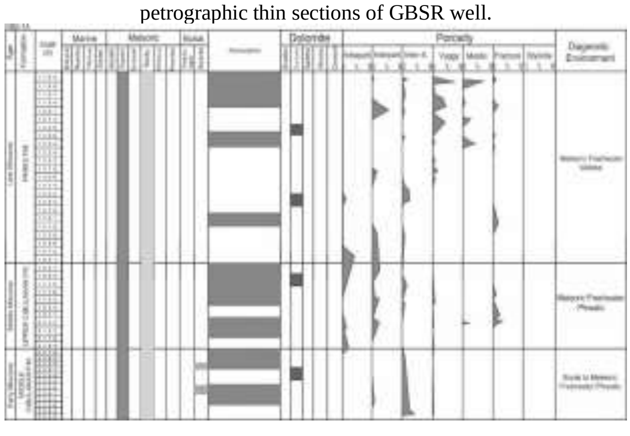
Then attached the integration of diagenesis with lithofacies on visual porosity is presented in the table (Table 4).

TABLE 4. Resume of lithofacies integration, environmental diagenesis, porosity from CKR-1 well petrography.

WELL	FORMATION	AGE	FACIES GROUP	SYMBOL	DEPOSITIONAL ENVIRONMENT	DIAGENETIC ENVIRONMENT	VISUAL POROSITY PETROGRAPHY
CIKARANG-1	PARIGI FM.	Late Miocene	Dolomitic Red Algae Wackstone		Reef Complex	Mixing Zone	5%
							Depth : 986 M
	UPPER CIBULAKAN FM.	Middle Miocene	Dolomitic Large Foraminifera Packstone		Reef Complex		5%
							Depth : [illegible] M
	MIDDLE CIBULAKAN FM.	Early Miocene	Dolomitic Red Algae Packstone		Reef Complex		8%

The diagram of diagenesis indications from the analysis of petrographic thin sections and GBSR wells (Table 5).

TABLE 5. Diagram of diagenesis indications from the analysis of petrographic thin sections of GBSR well.



IV. CONCLUSIONS

The main lithofacies of carbonate rocks in the North West Java Basin are the coral framestone facies, orbitoid facies, rhodophita facies, and dolomite facies found in all existing formations. From all samples in the Middle Cibulakan

Formation, Upper Cibulakan Formation, and Parigi Formation, the distribution is spread in the porosity range of 5 – 16% with a permeability of 1 – 7 mD including poor to moderate reservoir quality. It can be concluded that good to excellent porosity and permeability values are shown by the diagenesis environment of the freshwater vadose zone. Referring to the results that show the reservoir quality is generally quite good, and it is necessary to consider aspects of the geological or tectonic structure involved where these carbonate rocks have been uplifted and exposed and eroded at least during the Quaternary period, of course, in the telogenesis phase. The diagenesis regimes in this study consisted of marine neomorphism, freshwater neomorphism to vadose and burial regimes. The mineralogy, packing, and cementation found in the study area illustrate the paragenesis that begins with aragonite minerals, then calcite and dolomite, and micrite, with cement forms ranging from fibrous cement, equant blocky and syntaxial to even stylolite, dolomitization, fracture and placement of hydrocarbons.

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