Limestone Diagenesis in the Bojongmanik Formation Based on Petrographic Analysis

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Abstract

The Bojongmanik Formation is part of Banten Block with age range from Middle Miocene to early Pliocene, and is interspersed with sandstone, marl, claystone, and limestone. The limestone in the Bojongmanik Formation contains mollusks with age equivalent to the Middle Miocene. This research aims to understand the diagenesis process that works on limestone in the Bojongmanik Formation, as well as to understand the stages of diagenesis and the relationship between the diagenesis process and limestone porosity. Based on the petrographic analysis from 15 samples of the Bojongmanik Formation, there are three types of limestones: packstone, floatstone, and wackestone, which undergo a process of diagenetic cementation, dissolution, neomorphism, microbial micritization, and compaction. The depositional environment of the limestone diagenesis of the Bojongmanik Formation is in the marine phreatic, burial, meteoric phreatic, and meteoric vadose environments. The dominant porosity was found to be vuggy and intraparticle types. The lower porosity value indicates that there is a little dissolving effect. The higher porosity value indicates much dissolving in the phreatic zone. Therefore, the factor that influences the process of diagenesis is the formation of secondary porosity in limestone.

Keywords: The Bojongmanik Formation, Petrography Analysis, Porosity, Limestone Diagenesis

1. Introduction

The Bojongmanik Formation belongs to the Banten Block range from Middle Miocene to early Pliocene, is composed of sandstone, marl, and claystone, and limestone (Sudana and Santosa, 1992). Limestone is a rock with a calcium carbonate content of up to 95%. Limestone refers to a type of sediment produced by calcium carbonate (CaCO3) as mineral calcite. It originates from various organisms, such as dead coral, snails, and clams (Reijers and Hsu, 1986). The limestone members of the Bojongmanik Formation are limestones containing mollusks with age equivalent to the Middle Miocene (Efendi, 1998).

This research was carried out using the pethographic analysis method to determine the composition of the minerals contained in limestone. It was conducted by observing thin sections of the sample using a microscope to find microscopic nomenclature, diagenetic process, and diagenetic environment of thin section of limestone Bojongmanik Formation in Pandeglang Regency, Banten. Microscopic nomenclature is done by observing information related to mineral content, textural characteristics, rock composition, and naming based on Dunham and Embry Klovan's classification (1971). Most diagenetic processes consist of six types: cementation, microbial micritization, neomorphism (recrystallization and replacement), dissolution, compaction, and dolomitization (Tucker and Wright, 1990). The final steps are to interpret the depositional environment from diagenetic process.

2. Literature Review

Based on the physiography of West Java, the study area is located on the domes and ridges of the West Java Central Depression Zone/Bayah Mountains Zone (van Bemmelen, 1949). The Bayah Mountains Zone extends from Ujung Kulon in the west to Pelabuhan Ratu in the east. This zone is in the south of Banten. This mountain range consists of three parts, namely the southern part (strongly folded), the middle part (old andesite), and the northern part (the transition of the Bogor Zone) (Darwanto, 2016). The Bayah area is part of an Oligocene magmatic arc (Sujanto and Sumantri, 1977). In addition, part of the Sundaland margin is West Java (Clements & Hall, 2007). The research zone is in the Banten Block, consisting of Neogene deposits along with volcanic and igneous rocks. The morphology of this zone is a dome-shaped mountainous area relative to the Tertiary age, which is controlled by the Banten Block structure with a dominant north-south direction.

2.1 Limestone Diagenesis

Diagenesis is a change that includes chemical and physical processes that are formed after cementation. These changes are not caused by pressure (metamorphism) or temperature changes (Scholle & Ulmer Scholle, 2003). Tucker and Wright (1990) divided the process of diagenesis into six types: cementation, micritization, microbial, neomorphism (recrystallization and replacement), dissolution, compaction, and dolomitization.

a. Cementation

Cementation of limestone requires a large enough $CaCO_3$ and an efficient fluid flow mechanism. The cementation process occurs when the cavity is supersaturated with cement constituents, and there is a lack of mechanical factors that inhibit cement precipitation. Aragonite, calcite with high or low Mg content, and dolomite are several types of cement formed in limestone (Tucker and Wright, 1990).

b. Microbial Micritization

Microbial micritization is a process that occurs in the marine environment, where bioclast components undergo alteration on the seabed by algae, fungi, and bacteria. In a stagnant environment, the marine and phreatic zones are important processes (Longman, 1980).

c. Neomorphism

It is divided into two main processes: replacement and recrystallization (Folk, 1965 in Tucker and Wright, 1990). Recrystallization is the process of changing the size of the mineral but does not change the mineralogy. For example, coarsening of the size of the crystals in carbonate mud, as well as micrite and calcite cement, was found as a substitute for shells (Tucker, 1991).

d. Dissolving

Dissolving usually occurs when the pores of the carbonate rock are in an unsaturated state of carbonate minerals (Tucker and Wright, 1990). Dissolution can also occur if the mineral is in an unstable state or there is a displacement of the diagenesis area. In general, a dissolution process occurs in freshwater vadose and freshwater phreatic environments (Longman, 1980).

e. Compaction

Compaction consists of two types, namely mechanical compaction, and chemical compaction (Tucker and Wright, 1990). The existence of grains that touch, crack in the grains, or loading is called mechanical compaction. Meanwhile, grains touch each other, and form contact sutures or concavo-convex due to dissolution called chemical compaction. In addition, if the compaction process continues to produce a stylolite.

f. Dolomitization

According to Murrow (1982), diagenetic dolomitization is a replacement process through precipitation or cementation in deep burial and mixing zones. There is an increase in Mg content in carbonate rocks which causes dolomitization. In addition, there is the term dedolomitization, which replaces the mineral dolomite with calcite.

2.2 Stages of Diagenesis

Eogenesis stage (Shallow burial) is a condition when mineral changes occurred, rock fragments rearranged, and bioturbation proceeds. The initial process of deposition is dominated by the influence of pores in the rock. This stage also shows a weathering process with a relative depth of 1-10 meters.

The mesogenesis stage is a diagenetic process that occurs after deposition. The formation of cementation, dissolution, compaction, neomorphism, due to changes in temperature and pressure and reduced the pore space.

At the telogenesis stage, rocks are exposed to the surface, and meteoric water reacts. There is a dissolution process that causes secondary porosity in the rock. The meteoric phreatic and meteoric vadose stages occur in this stage.

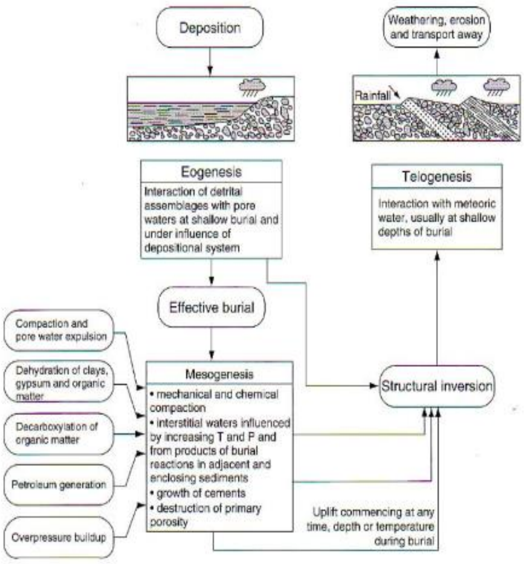


Figure 1. Diagenesis Regime Flowchart
(Source: Burley, 2003)

The Diagenetic Environment

The diagenetic environment is a factor that influences the outcome of limestone diagenesis. According to Tucker and Wright (1990), dividing the diagenetic environment into several zones, including:

a. The Marine Phreatic Zone is an environment where seawater fills all cavities with sediment. This environment is divided into two: the environment is associated with little water circulation, characterized by micritization and local cementation. This environment is associated with good water circulation, where intergranular cementation and cavity filling are more intensive. Other features of this environment are fibrous aragonite cement and Mg Calcite.

b. The mix zone is a zone of mixing vadose freshwater zone with the phreatic freshwater zone with the characteristics of still brackish water. The entire cavity is filled with seawater and replaced with fresh water. One characteristic of this environment is the existence of dolomitization when the surrounding water is low and the formation of Mg Calcite needles if the salinity is high.

c. The Vadose Meteoric Zone is an environment above the water and below the surface. The primary process in this environment is marked by the presence of secondary porosity and cement pendant by saturation formed due to the dissolution process. This makes meteoric water fill the cavity that is formed.

d. The Meteoric Phreatic Zone is a zone that is between the vadose meteoric zone and the mixing zone. Neomorphic processes with or without intensive calcite cementation are characteristic of this environment.

e. Burial is a zone characterized by chemical compaction or mechanical compaction. The presence of grain failure, stylolite, and dissolution seam from calcite cement or coarse dolomite are characteristic of this environment.

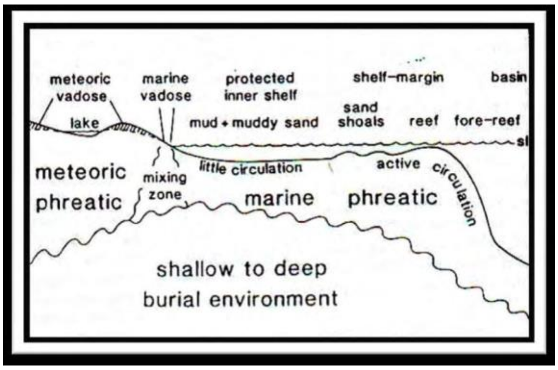


Figure 2. Diagenesis Environment (Tucker and Wright, 1990)

3. Research Method

This research is focused on petrography description and analysis. The primary data used is thin section data for geological field mapping of the 2017 batch of limestone in the Bojongmanik Formation. The distribution of limestone of Bojongmanik Formation is derived from geological map of the Cikarang sheet by Sudana & Santosa (1992).

In the pre-processing stage, before carrying out laboratory analysis, data was recollected on the thin incisions used for research and collecting information related to these incisions, including coordinates and formations found in rocks.
The method used in this study should be analysis of microstructural and microtextural of the limestone based on its physical properties, such as porosities and permeabilities and diagenetic processes.

In this research, microscopic nomenclature was known by using a microscope through observations from several viewpoints from Plane Polarized Light (PPL), Cross Polarized Light (XPL) and Gibbs.

Determination of the diagenesis process is carried out by observing thin sections of limestone, which, according to Tucker and Wright (1990), consist of the level of cementation, compaction, dissolution, neomorphism (recrystallization and replacement), microbial micritization, dolomitization and the type of porosity present in the rock.

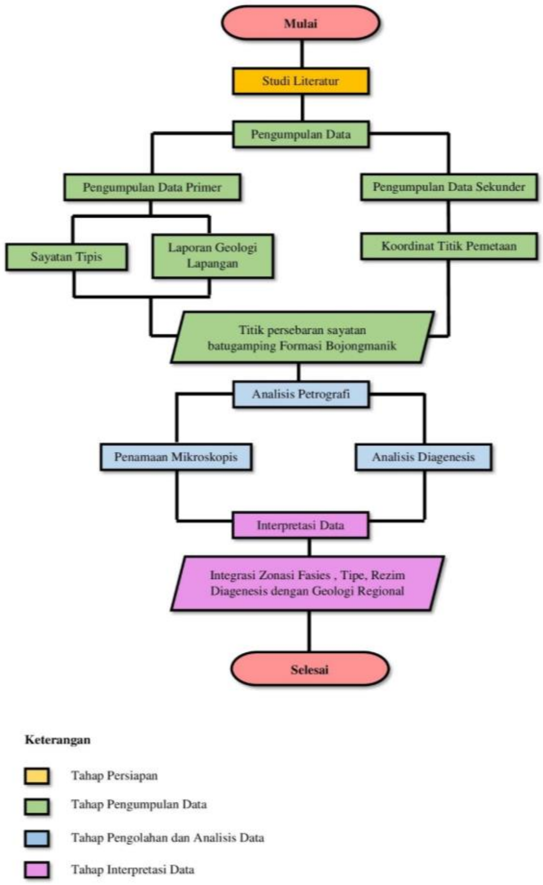


Figure 3. Research Flow Chart

4. Result and Discussion

Figure 4 depicts the distribution of Bojongmanik limestone which scattered at several points. Three limestone facies were found as packstone, floatstone, and wackestone. There are five processes of diagenesis: cementation, dissolution, microbial micritization, neomorphism, and compaction. Samples and diagenesis processes are presented in the Table "Porosity of Each Sample" (Table 1). Diagenesis analysis is used to determine the environment.

a. Cementation

The types of cementations in the Bojongmanik Formation are equant, fibrous, and bladed. Bladed, fibrous cement types were only found in some incision samples (Figure 5).

The marine phreatic environment is characterized by bladed and fibrous cementation (Scholle and Ulmer-Scholle, 2003). Equant or blocky cementation with calcite composition was also found in the Limestone samples of the Bojongmanik.

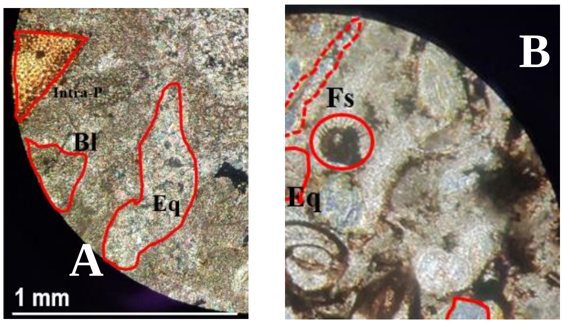


Figure 5. Equant cement (Eq), Bladed cement (Bl) in sample C2 (A) Fibrous cement (Fs) in sample B1 (B)

b. Microbial Micritization

The microbial micritization process was found in sample B1 (Figure 6). The activity of microorganisms produces a micrite envelope, namely a layer of micrite surrounding the fossil shell. The products of microbial micritization diagenesis occur in the initial phase of syngenetic marine diagenesis (Scholle and Scholle, 2003).

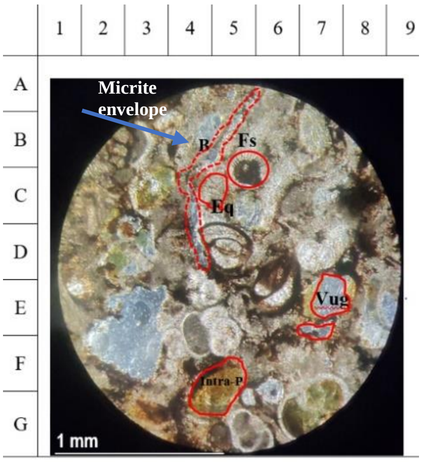


Figure 6. Microbial micritization process on sample B1

c. Neomorphism

The process of neomorphism that occurs in limestone incisions of the Bojongmanik Formation generally takes the form of small micrite recrystallization into poloids. Eleven samples found such recrystallization. The meteoric phreatic environment and burial environment are commonly found in recrystallization processes (Tucker & Wright, 1980). In addition to recrystallization, peloid mineral replacement was also found to become a calcite mineral (Figure 7).

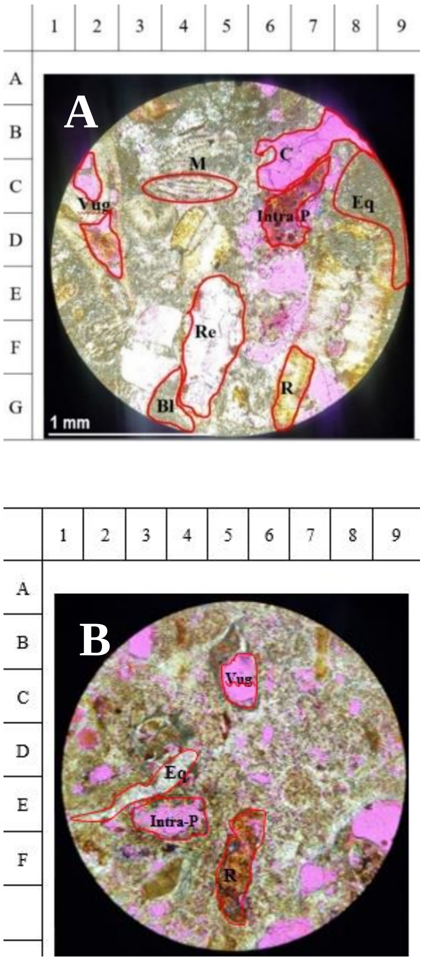


Figure 7. Neomorphism process of micrite crystallization to become peloid (R) and replacement of Peloid to become calcite (Re) in sample C1 (A), sample A6 (B).

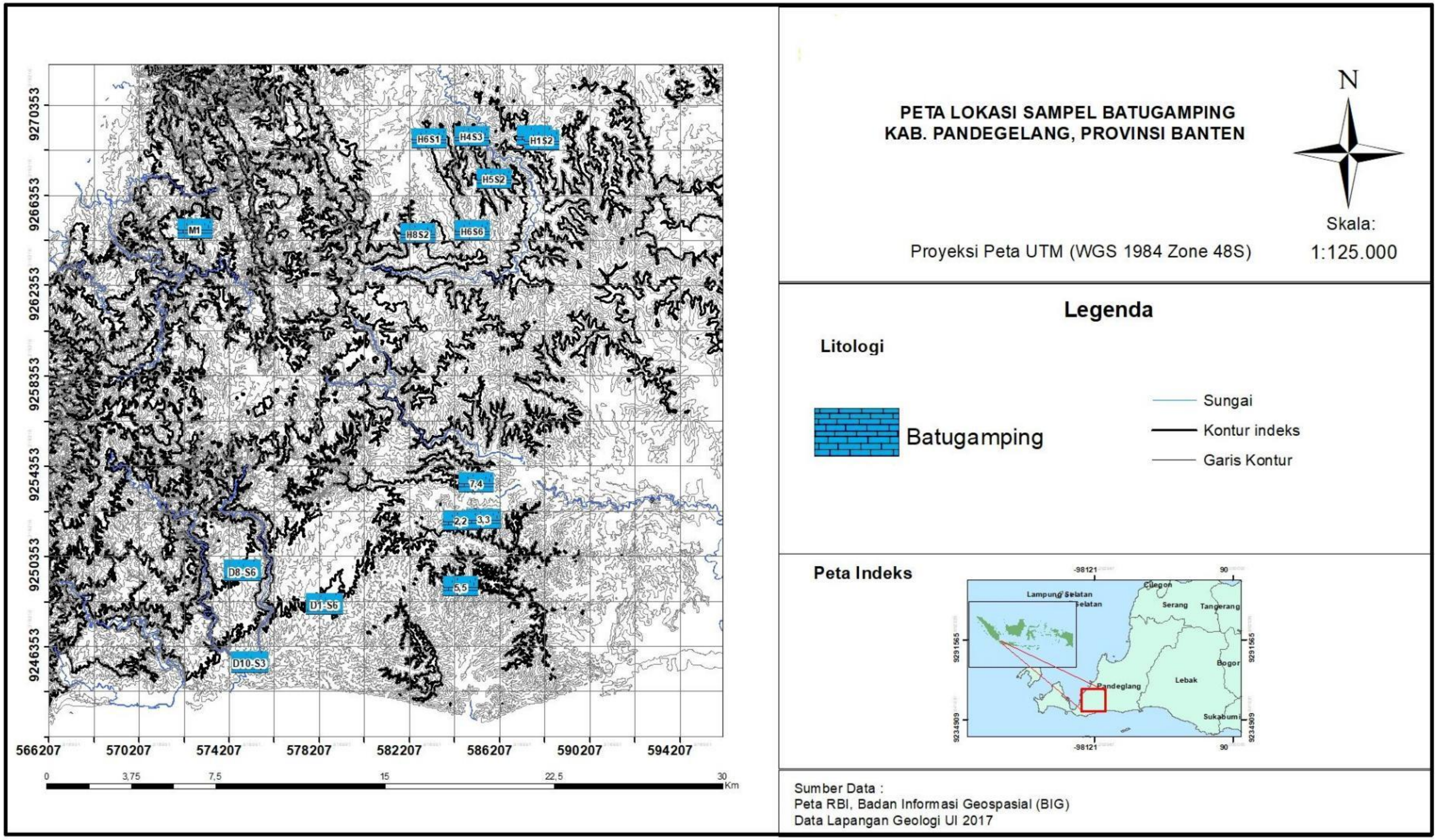


Figure 4. Limestone Distribution Map

d. Dissolving

The dissolving process is the most significant contributor to the rock samples of the Bojongmanik Formation. The pink color in the image indicates an area of dissolution processes in the rock. Meteoric vadose environments are typical in dissolution processes. Moldic, vug, and intraparticle porosity types were the dominant porosities (Figure 8).

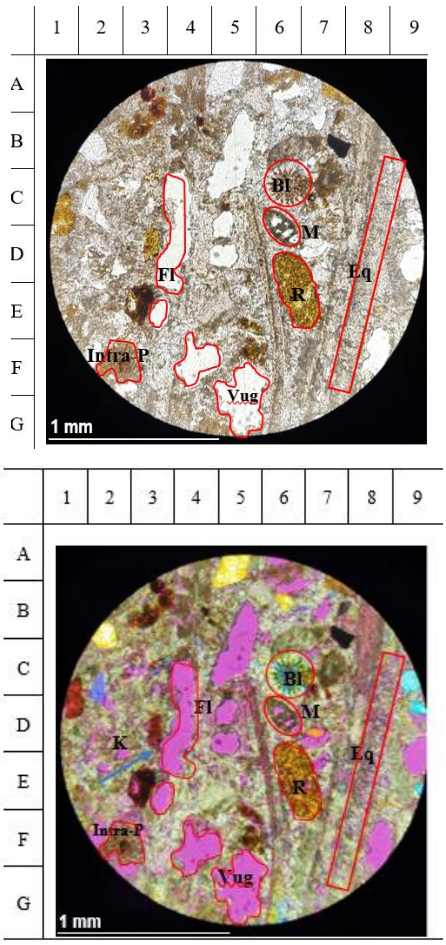


Figure 8. Dissolution with Moldic (M) porosity type, vuggy (vug) porosity type in sample A4.

e. Compaction

The compass process of the Bojongmanik Formation sample shows the contact between grain points and longs. Contact with algae grains is caused by physical compaction due to loading (Fig. 9). The compaction process occurs in the diagenesis burial environment.

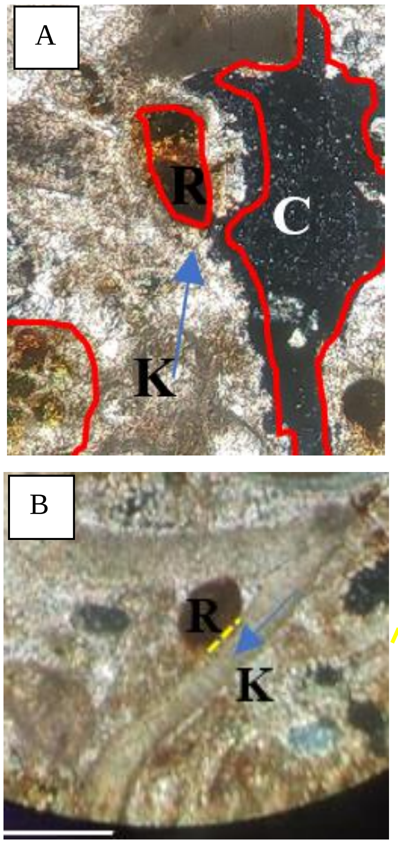
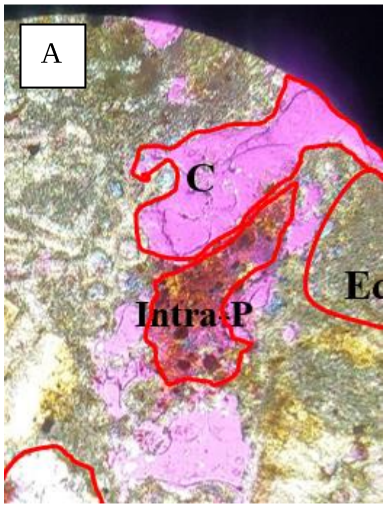


Figure 9. Compaction process between point contact grains in sample C3 (top) and long contact in sample C4 (bottom).

Porosity

According to Choquette & Pray (1970), the dominant type of porosity is found in the Bojongmanic Formation with intraparticle and vuggy porosity (Figure 10).



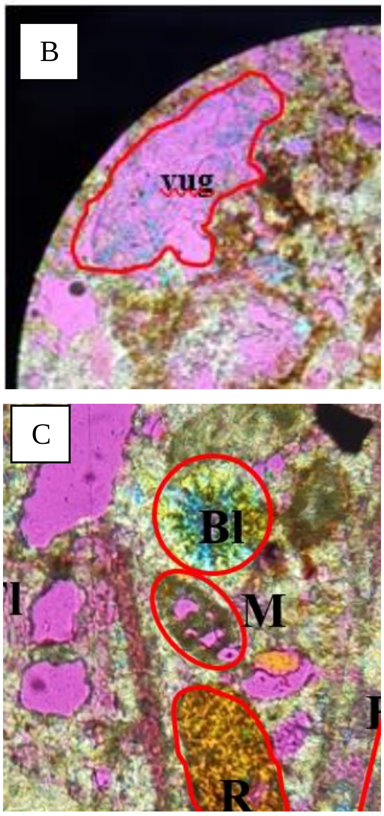
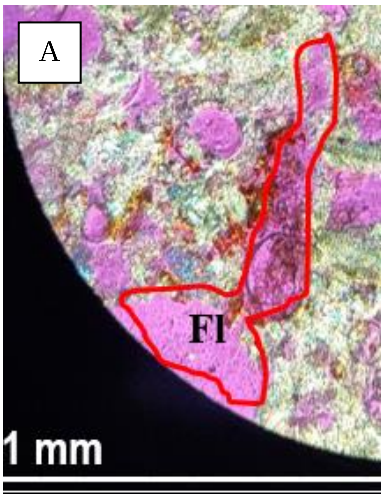


Figure 10. Intraparticle porosity in sample C1 (A) and vug porosity in sample A3 (B), and moldic porosity (M) in sample A4 (C).

In addition, moldic, Cavern, and Fenestral porosity types were also found (Figure 11).



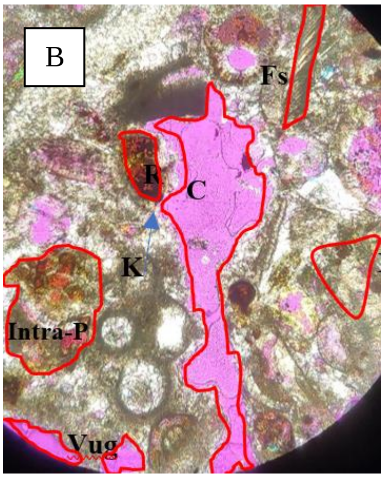


Figure 11. Type Fenestral porosity in sample A5 (A) and channel porosity in sample B3 (B).

Stages of Diagenesis in the Research Area

The Eogenesis stage occurs when mineral changes occur, rearrangement of rock fragments, and bioturbation processes. The initial process of the dominant deposition of the influence of pores on the rock, this stage also shows the weathering process. Aquifers, aquitards form this stage, and synsedimentary faults, aquifer permeability affects depth. Therefore, porosity can change significantly because of deposition or dissolution.

The formation of cementation, dissolution, compaction, neomorphism, due to changes in temperature and pressure and reduced pore water. At the stage of Mesogenesis, the process of diagenesis occurs after deposition. Primary mineralogy, lost material, presence of oil fluids, and geochemistry of pore waters are contributing factors in this stage. Between eodiagenesis and mesodiagenesis, the boundaries may change depending on temperature and humidity. The stages of mesogenesis are characterized by the dissolving of cement, matrix, and granules (Ramadhani, H. 2017).

In the Telegenesis stage, the rock is exposed to the surface, and meteoric water reacts. There is a dissolution process that causes secondary porosity in the rock. In the environment of meteoric phreatic and meteoric vadose, these stages occur.

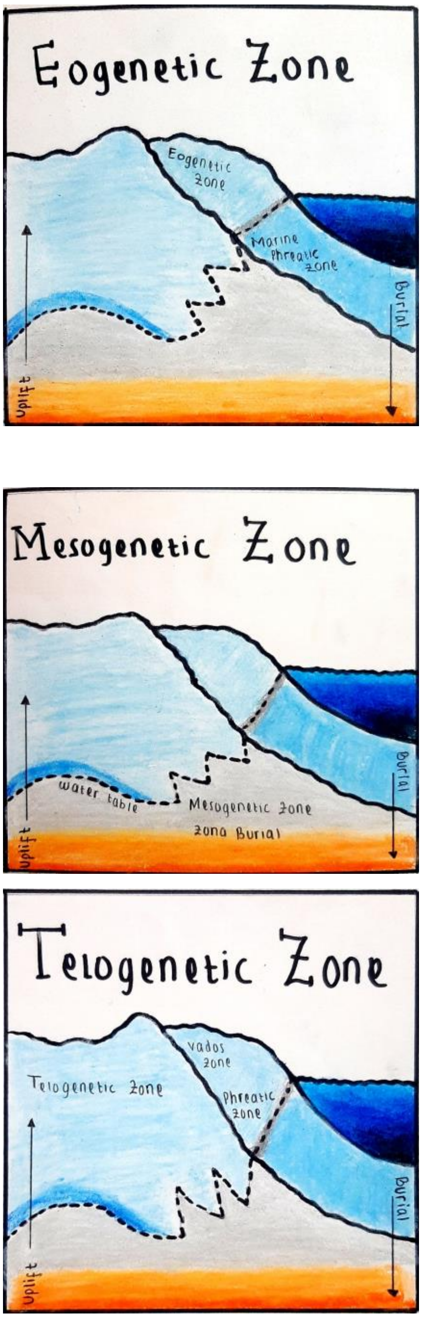


Figure 12. Stages of Diagenesis in the Research Area

Diagenesis Environment

The petrographic analysis of the diagenetic environment found that they included marine phreatic, meteoric phreatic, burial, and meteoric vadose. Microbial micritization resulting in a micrite envelope is characteristic of a marine phreatic environment. The burial environment is characterized by contact between grain points and long compaction. The formation of equant or blocky cement and the occurrence of neomorphism characterizes the meteoric phreatic environment. According to Longman (1980), the discovery of moldic dissolution from coral shells, foraminifera, mollusks, algae, and large vuggy is a feature of the meteoric vadose environment.

Limestone Diagenetic Process Relationship with Porosity Analysis

The process of diagenesis is common in carbonated rocks. One factor that influences the process of diagenesis is the formation of secondary porosity in carbonated rocks. The lower porosity value in the sample shows that this limestone is not dissolved by water because it is in the position of the vadose zone, which is only slightly affected by the effects of dissolution. Meanwhile, porosity with a high value is interpreted to be in the phreatic zone, which is located below the vadose zone. It has a large moldic/vuggy type of porosity.

Tabel 1. Porosity of Each Sample

Sample Name	Stone Name	Porosity (%)	Diagenesis Process	Environment	Diagenesis Stages
A1	Packstone	Vuggy (11,3%), Intraparticle (5,3%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
A2	Floatstone	Vuggy (11,3%), Intraparticle (5,3%), moldic (3,67%)	Cementation, dissolution, and neomorphism	Meteoric vadose	Telogenesis
A3	Floatstone	Vuggy (23%), Intraparticle (6,3%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
A4	Wackestone	Vuggy (8,33%), Intraparticle (8,33%), moldic (1,3%), Fenestral (6,67%)	Cementation, dissolution, neomorphism, and compaction.	Burial	Mesogenesis
A5	Wackestone	Vuggy (15,34%), Intraparticle (4,67%), Fenestral (7,67%)	Cementation, dissolution, and neomorphism	Meteoric vadose	Telogenesis
A6	Wackestone	Vuggy (11,34%), Intraparticle (9%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
A7	Packstone	Vuggy (9,34%), Intraparticle (6,34%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
B1	Packstone	Vuggy (16%), Intraparticle (5,3%)	Cementation, dissolution, microbial micritization and neomorphism	Marine phreatic	Eogenesis
B2	Wackestone	Vuggy (7,67%), Intraparticle (2,67%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
B3	Floatstone	Vuggy (6,67%), Intraparticle (5%), Channel (10,3%)	Cementation, dissolution, neomorphism, and compaction.	Burial	Mesogenesis
B4	Wackestone	Vuggy (9,34%), Intraparticle (6,67%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
C1	Wackestone	Vuggy (3,34%), Intraparticle (6%), Channel (12,67%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
C2	Packstone	Vuggy (3%), Intraparticle (4,67%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
C3	Wackestone	Vuggy (8,67%), Intraparticle (7,67%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis
D1	Packstone	Vuggy (16,67%), Intraparticle (11,34%)	Cementation, dissolution, and neomorphism	Meteoric phreatic	Telogenesis

5. Conclusion

Based on the results of the analysis conducted in the research area in the Banten Block, to be precise in the Bojongmanik Formation, it can be concluded that:

1) There were 15 samples analyzed petrographically based on Dunham's (1962) classification consisting of 3 types: packstone limestone, floatstone limestone, and wackestone limestone.
2) Based on observations of the diagenetic process in the limestone in the study area, there are five processes: cementation, dissolution, microbial micritization, neomorphism, and compaction. In addition, the stages of diagenesis in the research area consist of 3 stages: Eogenesis and Mesogenesis. and Telegenesis stages.
3) From the observations on petrographic incisions, it can be interpreted that the research area consists of marine phreatic, burial, and freshwater phreatic. The relationship between the diagenetic process and porosity shows that the low porosity value is due to being in the vadose zone, which is only slightly affected by the dissolving effect. Meanwhile, the high porosity is caused by being in the phreatic zone, which is located just below the vadose zone and has a large vuggy/moldic porosity.

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