Microfacies and Diagenesis of Limestone in Bojongmanik Formation in the Western Endut Mountain Area, Lebak Regency, Banten Province Based on Petrographical Analysis Methods

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Abstract. Bojongmanik Formation which especially formed in the Western Endut Mountain Area just has been done with very rarely research. Bojongmanik Formation exposed in the western Endut Mountain is a Late Miocene rock formation with limestone and sandy limestone lithology. This research used the analysis methods of petrographic observation, especially carried out on limestone lithology. Petrographic analyses have been carried out on 15 limestone samples from the research area. The petrographic analyses’ primary purpose is to determine the facies zone where the limestone are formed and to understand the diagenesis processes experienced by the rocks after its formation. The result shows that the limestone in the research area mainly consisted of framestone, bafflestone, Floatstone, Rudstone, and Packstone. Based on the analysis, limestone in this area has formed in slope, platform margin reef, and platform interior open marine facies zone. From the obtained facies zone, a two-dimensional model was made to get an overview of the paleo facies condition. It was concluded that the seaward was in the north and landward in the south. Various diagenesis processes that occurred after limestone in this area are formed are dolomitization, fracturing, micrite envelope, dissolution, recrystallization, inversion, marine cementation, burial cementation, and phreatic meteoric cementation. The diagenesis indicate burial, marine, and meteoric environment.

Keywords: Bojongmanik Formation, Diagenesis, Microfacies, Limestone, Petrography, Endut Mountain.

1. Introduction

Bojongmanik Formation is a rock formation that has extensive coverage, especially in Western Java Island. Bojongmanik Formation that focused on this research is located in the Western Endut Mountain Area. Bojongmanik Formation itself deposited in Late Miocene (Sujatmiko & Santosa, 1992). This formation has limestone and sandy limestone lithology (Sujatmiko & Santosa, 1992). This research is written in order to complete the research that written by Imtiyaz R.Z. (2020) about facies distribution and limestone depositional history in this area.
This research aims to determine the facies zone where the limestone is formed and understand the rocks' diagenesis processes around this area after its formation. This research focused on the carbonate petrographical analysis.

2. Materials and method/Experimental

This research is broadly divided into four stages: the literature and regional review stage, the fieldwork sampling stage, the petrographical laboratory stage, and the final stage. The scheme of each stage arranged in a flowchart in Figure 1 below:

![Flowchart of Research](image)

The fieldwork sampling stage has been carried out by obtaining 15 limestone rock samples. These 15 samples had a surface rock type sample that was carried out within a ±95 km² area depicted on the map in Figure 2. The fieldwork sampling stage was also included by macroscopic rock description. The petrographical laboratory stage is carried out after the surface rock sample has been cut into a sample with a thickness of about 0.03 mm. These samples were prepared with blue dye to determine the porosity and red alizarin to differentiate dolomite from calcite. In this stage, the sample is analyzed using a petrographical microscope to observe the bioclast component and diagenetic features. The final stage includes concluding the result and report writing.
3. Results and Discussion

3.1. Petrographical Description

Limestone in this area is divided into five types based on Embry & Klovan (1971) classification. These types are Framestone (BG-1, BG-3, BG-7, BG-13, BG-14, BG-15, and BG-16), Floatstone (BG-6, BG-9, BG-11, and BG-12), Bafflestone (BG-4 and BG-5), Rudstone (BG-10), and Packstone (BG-8). Results of petrographical description can be seen in the Table 1.

Framestone was found in seven samples on the southwest and northeast side of the research area. The framestone is characterized by frame structure that formed from rigid in situ organism, such as Porifera. These rocks have petrographic features with a parallel colorless appearance and a non-clastic texture. On average, this sample has a poor to medium sorting with grain sizes ranging from less than 2 mm to more than 2 mm. The fragments in these rock samples are mostly 35-70%, while the dominant matrix ranges from 25-35%. The samples' components consisted of Bivalves, Anthozoa, Red and Green Algae, Porifera, and Benthic Foraminifera. They also have a massive structure, with one sample have a porous structure. Based on the Embry & Klovan classification, this rock is included in the framestone.

Floatstone was found in four samples on the north and northwest sides of the research area, composed of ex-situ organism. These rocks have petrographic features with a parallel colorless appearance and a bioclastic texture. On average, this sample has poor sorting with grain sizes ranging from less than 2 mm to more than 2 mm. The fragments in these rock samples are mostly in the range of 50-60%, while the dominant matrix ranges from 38-49%. The components in the samples consisted
of Bivalves, Algae, Anthozoa, and Foraminifera. They also have a massive structure in general. Based on the Embry & Klovan classification, this rock is included in the Floatstone.

Bafflestone was found in two samples on the east side of the research area, characterized by baffle structure from in situ organisms. These rocks have petrographic features with a parallel colorless appearance and a non-clastic texture. On average, this sample has a poor to well sorting with grain sizes ranging from less than 2 mm to more than 2 mm. The fragments in these rock samples are mostly in the range of 45-65%, while the dominant matrix ranges from 35-50%. The components in the samples consisted of Bivalves, Green Algae, Anthozoa, and Foraminifera. They also have a massive structure in general. Based on the Embry & Klovan classification, this rock is included in the Bafflestone.

Rudstone was found in one sample on the northwest side of the research area, composed of ex-situ organisms. This rock has petrographic features with a parallel colorless appearance and a bioclastic texture. This sample has a moderate sorting with grain sizes up to more than 2 mm. The fragments in the rock sample are approximately 60%, while the dominant matrix is 37%. The components in the sample dominantly consisted of bivalve. This sample also has a massive structure. Based on the Embry & Klovan classification, this rock is included in the Rudstone.

Packstone was found in one sample on the north-northeast side of the research area, composed of ex-situ organisms. This rock has petrographic features with a parallel colorless appearance and a bioclastic texture. This sample has well sorting with grain sizes less than 2 mm. The fragments in the rock sample are approximately 50%, while the dominant matrix is 40%. The components in the sample dominantly consisted of large benthic foraminifera. This sample has a porous structure. Based on the Embry & Klovan classification, this rock is included in the Packstone.
| BG-1  |  |  |  |  |  |  |
|-------|---|---|---|---|---|---|
| Struc | Massi | Massive | Massive | Massive | Massive | Porous |
| Texu | Nonclasti | Nonclasti | Nonclasti | Nonclasti | Nonclasti | Bioclasti |
| Sorti | Mdoera | Poor | Poor | Poor | Moder | Poor |
| Grain Size | > 2 mm | < 2 - > 2 mm | < 2 - > 2 mm | < 2 - > 2 mm | > 2 mm | < 2 - > 2 mm |
| Fragn % | 70 | 70 | 60 | 50 | 49 | 75 |
| Matr % | 22 | 28 | 38 | 49 | 50 | 23 |
| Poros | 8 | 2 | 2 | 1 | 1 | 2 |
| Fragn Type | Porifer a, Red Algae, & Benthic Foraminifera |  |  |  |  |  |

**Table 1. Results of Petrographical Description**
3.2. Microfacies Analyses

This research area is formed in three different facies zones, namely facies zone 5, facies zone 7, and facies zone 18. This facies zone division is based on the classification made by Flugel (2010). This classification is determined from various factors, including the characteristics of the limestone, the type of limestone, and the constituent components of the limestone. The results of microfacies analyses can be seen in Table 2.

The facies zone 5 is characterized by a number of fossil organisms that live in reefs, such as bivalves, which are packed very densely so that they will form a lithology in the form of a rudstone or floatstone. In this facies zone 5, it is estimated that it will have a rock structure that tends to be chaotic with fossils that are typical to have undergone destruction or cracking. This is very supportive of this facies depositional environment a high enough energy due to the steep slope.

Facies zone 7 is characterized by the presence of organic limestones, which have well-growing internal organisms. So that the characteristic of limestone that is formed in these facies usually comes from the boundstone group. In the research area, the boundstone group was formed in the form of framestone and bafflestone.

The facies zone 18 is characterized by a high presence of benthic foraminifera and green algae. In the study area, the limestone was found with the type of Packstone, which is described in the BG-8 sample. The abundance of foraminifera in these facies is because these facies have an open sea system with a depth that still tends to be shallow so that benthic foraminifera can develop well there.

Table 2. Results of Microfacies Analyses

| Sample Code | Type of Limestone | SMF Type | Facies Zone |
|-------------|------------------|----------|-------------|
| BG-1        | Framestone       | SMF 7    | FZ 5        |
| BG-3        | Framestone       | SMF 7    | FZ 5        |
| BG-4        | Bafflestone      | SMF 7    | FZ 5        |
| BG-5        | Bafflestone      | SMF 7    | FZ 5        |
| BG-6        | Floatstone       | SMF 5    | FZ 4        |
| BG-7        | Framestone       | SMF 7    | FZ 5        |
| BG-8        | Packstone        | SMF 18   | FZ 7        |
| BG-9        | Floatstone       | SMF 5    | FZ 4        |
| BG-10       | Rudstone         | SMF 5    | FZ 4        |
| BG-11       | Floatstone       | SMF 5    | FZ 4        |
| BG-12       | Floatstone       | SMF 5    | FZ 4        |
| BG-13       | Framestone       | SMF 7    | FZ 5        |
| BG-14       | Framestone       | SMF 7    | FZ 5        |
| BG-15       | Framestone       | SMF 7    | FZ 5        |
| BG-16       | Framestone       | SMF 7    | FZ 5        |

| Facies Zone | Description                  |
|-------------|------------------------------|
| FZ 4        | Slope                        |
| FZ 5        | Platform Margin Reef         |
| FZ 7        | Platform Interior Open Marine|
The microfacies analysis results are then mapped to get a better visualization of the facies zones that were formed in the past, which can be seen in Figure 3.

![Figure 3. Map of Facies Zone in Research Area](image)

### 4. Diagenesis Analyses

Diagenesis processes in the limestone of the Bojongmanik Formation in the study area include dolomitization, fracturing, micrite envelope, dissolution, recrystallization, inversion, and marine cementation, burial cementation, and meteoric cementation. A summary of the diagenesis that occurs in each sample and its intensity can be seen in Table 3.

Dolomitization is a process of carbonates minerals replacement into dolomite. It can be seen that dolomite's appearance does not change color to red when alizarin solution is added to the sample. According to Scholle et al. (2003), this diagenesis is usually interpreted to occur in a marine environment (semi-closed to the closed marine system).

The fracture occurs because the limestone has previously received considerable pressure. Fracturing is interpreted to be caused by the physical compaction process of burial activity in the limestone sample. This is based on the formation of the former fracture cavity, which has relatively small dimensions and is not continuous.

Micrite envelopes are also found in many sample samples. This diagenesis is characterized by a thick black outline on the outside of the skeletal carbonate fragments. The diagenesis is produced by the alteration of the original mineralogy of the fragment to micrite. According to Scholle et al. (2003), this diagenesis is interpreted as the marine environment's diagenesis.
Dissolution was also found in some samples with small intensity. This dissolution causes the formation of small porosity, which is spread unevenly in several samples. This dissolution is interpreted as a result of the diagenesis process in the meteoric environment.

Recrystallization in this study was found to be present in moderate to high intensity, which was scattered in almost all samples. Seen in the picture is an organism from a sponge that undergoes crystallization of calcite, which initially comes from the sponge body's skeleton, which turns into calcite with a drussy mosaic texture. This recrystallization is actually not a specific marker of where the diagenesis occurs but generally occurs in the environment of meteoric and burial diagenesis.

The inversion in this study was weak and was only found in a small sample. Inversion in this study occurred in the case of aragonite with a needle structure that turned into a more stable mineral, namely calcite with a blocky structure.

The cementation in this study found three types of cementation, namely marine cementation and burial cementation with moderate to strong intensity found in many samples, and meteoric cementation, which was only found in one sample with low to moderate intensity. Marine cementation is present as the mineral aragonite formed at the inner boundary of the organic material in the image. Burial cementation is evidenced in carbonate minerals that are formed in a drusy form. Meteoric Phreatic Cementation, in this case, is characterized by the formation of carbonate minerals in blocky form.

### Table 3. Results of Diagenesis Analyses

|     | A | B | C | D | E | F | G | H | I |
|-----|---|---|---|---|---|---|---|---|---|
| BG-1| 2 | 1 | 2 | 1 | 4 | 1 | 2 | 4 | 1 |
| BG-3| 2 | 2 | 1 | 1 | 1 | 1 | 4 | 1 |   |
| BG-4| 1 | 1 | 1 | 2 | 3 | 1 | 1 | 3 | 1 |
| BG-5| 2 | 2 | 2 | 1 | 4 | 1 | 3 | 3 | 1 |
| BG-6| 2 | 2 | 2 | 1 | 4 | 2 | 2 | 3 | 1 |
| BG-7| 2 | 2 | 2 | 1 | 4 | 2 | 1 | 1 | 1 |
| BG-8| 1 | 1 | 1 | 1 | 4 | 1 | 1 | 4 | 1 |
| BG-9| 1 | 2 | 2 | 2 | 4 | 1 | 4 | 1 | 1 |
| BG-10| 2 | 1 | 1 | 1 | 4 | 1 | 4 | 1 | 1 |
| BG-11| 2 | 2 | 2 | 1 | 3 | 1 | 1 | 4 | 1 |
| BG-12| 2 | 2 | 2 | 1 | 4 | 1 | 3 | 1 | 1 |
| BG-13| 1 | 1 | 2 | 2 | 3 | 1 | 1 | 3 | 1 |
| BG-14| 2 | 1 | 2 | 2 | 3 | 1 | 1 | 3 | 1 |
| BG-15| 2 | 2 | 2 | 1 | 4 | 1 | 1 | 1 | 1 |
| BG-16| 1 | 1 | 1 | 2 | 3 | 1 | 1 | 4 | 1 |

|     | A   |     | B  |     | C       |     | D |     | E       | F     | G |     | H |     | I |     |
|-----|-----|-----|----|-----|---------|-----|---|-----|---------|-------|---|-----|---|-----|---|-----|
|     | Dolomitization | Fracturing | Mictite Envelope | Dissolution | Recrystallization | Inversion | Marine Cementation | Burial Cementation | Meteoric Cementation |     |
| 1   | Very Weak - None | Weak | Intermediate | Intensive | Very Intensive |     |     |     |     |     |
| 2   |     |     |     |     |     |     |     |     |     |     |
| 3   |     |     |     |     |     |     |     |     |     |     |
| 4   |     |     |     |     |     |     |     |     |     |     |
| 5   |     |     |     |     |     |     |     |     |     |     |
Figure 4. Results of diagenesis petrographic observations. (A) Dolomitization by appearance white patches between another carbonates minerals in pink due to the effect of red alizarine (B) Fracturing which is seen cutting the thin section (C) Micrite Envelope with the darker line that appeared in the outer boundary of the organic material (D) Dissolution that marked by the existence of porosity in blue patches (E) Recrystallization with carbonate mineral that reformed filling the porosity that has been formed before (F) Inversion, it can be seen there is a change from aragonite with a needle structure changed into more stable calcite mineral with blocky structure (G) Marine Cementation that marked by the existence of the mineral aragonite that forms in the inner edge of the organic material (H) Burial Cementation with carbonate minerals that are formed in drusy form (I) Meteoric Cementation that characterized by the formation of carbonate minerals in blocky form.

5. Conclusion

The result shows that the limestone in the study area mainly consisted of framestone, bafflestone, Floatstone, Rudstone, and Packstone. Based on the analysis, limestone in this area has formed in slope, platform margin reef, and platform interior open marine facies zone. Various diagenesis processes that occurred after limestone in this area are formed are dolomitization, fracturing, micrite envelope, dissolution, recrystallization, inversion, marine cementation, burial cementation, and phreatic meteoric cementation. The diagenesis indicates burial, marine, and meteoric environment.
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