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RESEARCH ARTICLE

Quantitative Analysis of Thin Section using Frequency Measurement (Point Counting), a Case Study on Limestone of The Rajamandala Formation, Cikamuning, West Java, Indonesia

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Abstract

The description of thin sections observations has traditionally relied on the visual comparison method, often using a visual comparison chart. However, this method has interpretative limitations, as readings can vary between individuals, and the values produced tend to be rounded. The point counting method for determining frequency is one of the statistical approaches that quantitatively counts the presence of mineral grains or particles. The limestone samples were collected from the Rajamandala Formation in the Cikamuning area of West Java, Indonesia. The methodology involved petrographic observations using the point counting method, which entailed creating a grid on the thin sections with a total of 312 points and calculating the percentage of occurrence of the constituent rock compositions.

The analysis results showed constituent composition percentages of 33.65% for corals, 52.24% for matrix, 4.81% for cement, 2.56% for calcite, 3.85% for replacement, and 2.88% for porosity, categorizing the rock as coral wackstone. The facies is determined based on the presence of biota, while diagenesis is determined by the presence of cement types, secondary porosity, and grain contacts. In the research area, the identified facies is open marine (FZ 7), and the diagenesis includes marine phreatic, meteoric phreatic, and burial diagenesis.

Keywords: Facies and diagenetic, Limestone, Point counting, Rajamandala Formation, Thin sections

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1. Introduction

Petrography is one of the methods used to describe rocks in detail, encompassing their physical properties, mineral types, and rock texture. The Petrographic description is especially crucial for carbonate rocks because, in addition to identifying the constituents of carbonate rocks, it allows for the analysis of microfacies and diagenetic processes that occur within them.

This research aims to conduct an analysis using the point counting method to describe the components of limestone and assign rock names. Additionally, it seeks to elucidate the mechanism of petrographic description through a case study utilizing samples from the Rajamandala Formation limestone, in the Cikamuning area with sampling coordinates 107°27'30"E-107°28'15"E and 06°48'40"S-06°49'15"S.

1.1. Geology of Rajamandala

The limestone of Rajamandala Formation is one of the fascinating research subjects for studying Tertiary-aged reef limestone in Indonesia. This rock formation is considered a comprehensive representation of a carbonate platform system, making it a valuable model for studying reef systems during the Tertiary period in Indonesia.

The age of the Rajamandala Formation is determined by identifying the presence of large foraminifera fossils, specifically *Heterostegina borneensis*, *Miogypsina complanata*, and *Miogypsina formosensis*. These fossils indicate that the lower part of the formation dates back to the Late Oligocene. In the upper part, foraminifera fossils like *Lepidocyclina ephipioides* and *Miogypsinoides bantamensis* are present, suggesting an age corresponding to the Early Miocene. The combined evidence from these foraminifera fossils indicates that the Rajamandala Formation spans from the Late Oligocene to the Early Miocene. Research by Kupper 1941 and Martodjojo, 2003, indicates that the depositional environment of the Rajamandala Formation was shallow marine. Based on the fossil content of nannoplankton, the age of the Rajamandala Formation is Late Oligocene to Early Miocene (Prasetyo and Kapid, 2014).

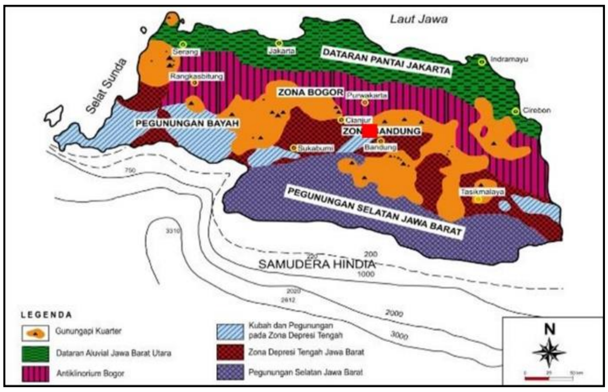

Fig 1. Physiography of Western Java (Modified from Van Bemmelen, 1949). The red shaded box indicates the research location

The Bandung Zone is a depression area nestled between mountains (intermontane depression) (Figure 1). This zone takes on a curved shape from Pelabuhan Ratu, following the Cimandiri Valley, continuing east through the city of Bandung, and ending at Segara Anakan at the mouth of the Citanduy River (Cilacap), with a width of approximately 20-40 km (Van Bemmelen, 1949)

1.2. Stratigraphy Regional

The Rajamandala Formation is found along the Padalarang - Sukabumi and Purwakarta roads, exhibiting prevalence in various areas such as Pasir Pabeasan, Pasir Cikamuning, Gunung Manik, and Pasir Sanghiangtikoro (Figure 2). According to Hutabarat 1972 and Martodjojo, 2003, the thickness of this formation varies between 60 to 100 meters. The morphology of the Rajamandala Formation is characterized by elongated hills and highlands featuring steep slopes. Its distinct hard limestone lithology distinguishes it in terms of elevation from the surrounding rocks.

In general, the lithology of the Rajamandala Formation predominantly comprises limestone with varying lateral alterations. The boundary between the Rajamandala Formation and the underlying Batuasih Formation is characterized as a conformable contact (Baumann et al., 1972 and Martodjojo, 2003). This is evident in the gradual transition from the non-limestone Batuasih Formation to the limestone characteristics of the Rajamandala Formation. Furthermore, the contact between the Rajamandala Formation and the Citarum Formation is also identified as a conformable contact, as described by Baumann et al., 1972 and Martodjojo, 2003. According to the research by Nugroho et al., 2015, there are 5 facies belts in the Rajamandala area, namely basin margin, foreslope, platform margin reef (windward), platform interior, and platform margin reef (leeward) (Nugroho et al., 2015).

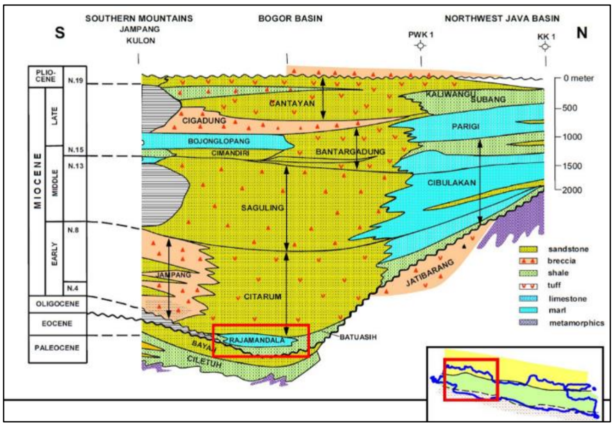

Fig 2. Physiography of Western Java (Martodjojo, 2003). The red shaded box indicates the research location

1.3. Visual Comparison Chart

A visual comparison chart involves comparing the appearance of thin sections with comparison diagrams (Figure 3 and Figure 4). Simply put, it is used to determines the percentage occurrence of minerals, grains, and other constituent materials in thin sections. This method allows for quick and intuitive analysis, although the resulting figures tend to have even values. Advantages and disadvantages of the charts (Figure 3 and Figure 4): The most commonly used Baccelle and Bosellini chart has the advantage of displaying images that can be attributed to common carbonate grain types. However, a limitation of these charts is that variations in grain size are not adequately considered. When examining the images using digital image analysis, slightly different percentage values (± 5%) may be obtained, especially for well-rounded grains (Flügel, 2010).

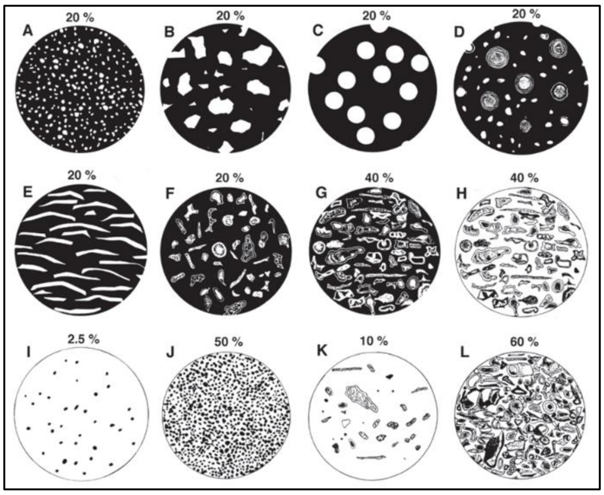

Fig 3. Comparison charts for visual percentage estimation developed for limestones (Baccelle and Bosellini, 1965)

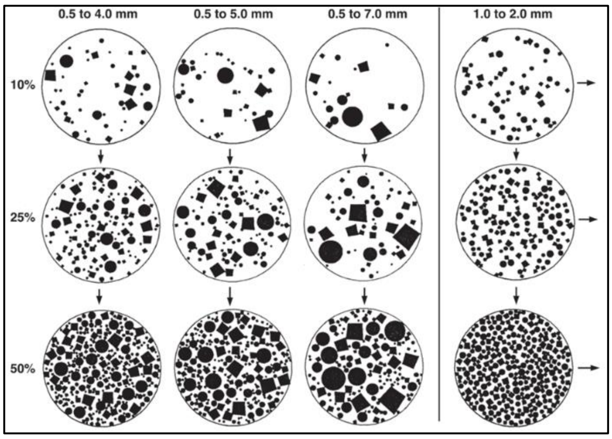

Fig 4. Examples from 'Visual comparison charts' (Matthew et al., 1991) for studying ceramic materials. In contrast to the Baccelle and Bosellini charts, these charts also compare differences in grain sizes and sorting.

2. Methodology

The method used in the research is quantitative thin-section description using frequency measurement methods on limestone rocks of the Rajamandala Formation. The research stages include: field data collection, preparation of thin sections, petrographic observation and description using point counting method, rock naming, and determination of rock facies and diagenesis.

2.1. Frequency Measurement Methods

There are several frequency measurement methods that can be used in thin section descriptions, including point counting, the ribbon method, and the line method (Figure 5). One of the commonly used methods is the frequency measurement method using point counting. This method involves counting the number of points that fall on each type of mineral or grain in the thin section to obtain information about the relative distribution of these components.

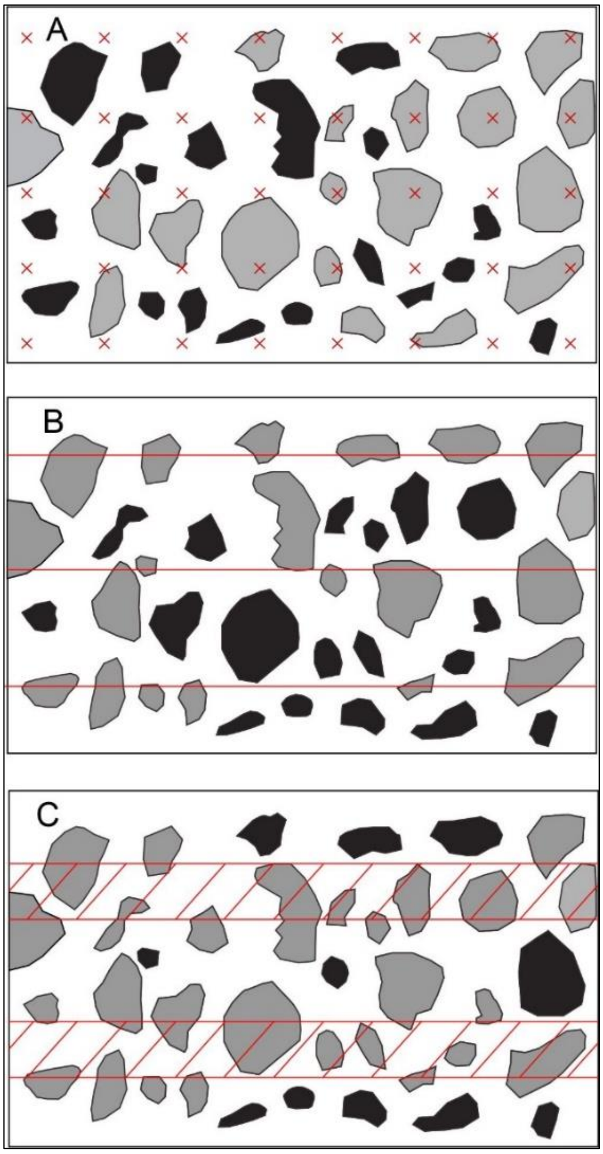

Fig 5. The difference between A - point counting, B - line method, C - ribbon method for calculating frequency values lies in how they quantify the presence of grains or minerals. In all three ways, black-colored grains are not included in the count, while gray-colored grains are considered in the frequency of their presence

A Point Counting: This method involves counting the number of points that fall on each type of mineral or grain in the thin section.

B Line Method: In this method, a line is drawn across the thin section, and the number of times it crosses a specific mineral or grain type is counted. The interval distance used is approximately equal to the diameter of the largest particle.

C Ribbon Method: The ribbon method entails drawing a narrow band across the thin section, and counting the number of times it intersects with a particular mineral or grain type. Ribbon counting requires measurement of all grains occurring within ribbons oriented parallel to the sedimentary bedding. Individual ribbons are vertically separated by unassessed ribbons of a width approximately equal to or twice the diameter of the largest grain or just spaced randomly.

These methods provide quantitative assessments of the relative distribution and abundance of specific minerals or grains within the thin section, with variations in the counting approach.

2.1. Point Counting

The Point counting method is used to determine the frequency of mineral or grain composition in a rock by counting the number of points that fall on each type of mineral or grain in thin sections. In the context of rock naming, point counting can be used to quantitatively describe the mineral composition of the rock. The number of points necessary for a statistically reliable result depends on the distribution and size of the particles. Accuracy is related to selected grid density and the number of points counted. The mean deviation decreases with an increasing number of points and increases with an increasing percentage of particles, that is up to 50%, whereupon the mean deviation again drops. In order to keep sampling errors small, several hundred (at least 300 to 500) points must be counted; for limestones with variously sized and poorly sorted grains as many as 1000 points and more (Flügel, 2010). The steps of the point counting method are as follows:

1. Creating a grid: The initial step in using the point counting method is establishing a grid on the thin section with a minimum of 300 intersection points. The number 300 is obtained from statistics that are believed to provide adequate accuracy in frequency measurements. This commonly used number is based on the equation for calculating heavy mineral grains and studies on the frequency of modern foraminifera. The reliability of point counting results can be assessed using a graph developed by Van der Plas and Tobi (1965). This graph allows the relationship between the number of points counted and the accuracy of the results to be estimated.
2. Identifying grains or minerals: Identify and differentiate the existing minerals or grains based on their visible optical properties and morphology. Then, assign specific codes such as bryozoans (B), mollusks (M), large foraminifera (LF), coral (C), and red algae (RA), or you can also use distinct colors to distinguish between different grains.
3. Calculating frequencies: After identifying the grains or minerals, the frequency of mineral or grain composition is calculated based on the number of points for each type of mineral or grain. This frequency can be presented as a percentage or relative proportion of the total points counted.

Point Counting Calculation Formula:

$$\mathrm{Pm} = \frac{\mathrm{Sm}}{\mathrm{Tm}} \times 100 \qquad (1)$$

Where:
Pm = Percentage of mineral (grain)
Sm = The number of points on a specific mineral (grain).
Tm = Total number of measured points.

4. Rock Naming: The results from frequency calculations can be used to give a name based on the deposition texture of the limestone and the percentage composition of minerals represented in the rock. Rock naming may refer to a petrographic classification scheme established beforehand; the classification of rocks is based on Dunham, 1962.

After calculating the percentage of grain/mineral presence and determining the rock names, the next step is to identify the facies and diagenesis in the limestone samples from the Rajamandala Formation. Facies determination is conducted using the classification by Wilson (1975), while the determination of diagenetic environments employs the classification by Flügel (2010).

3. Results And Discussion

The physiography of the research area is located within the Bandung Zone, known as the Rajamandala Hills, and it is geologically part of the Rajamandala Formation. The discussion on rock description using the point counting method is carried out on a single rock sample to demonstrate how the point counting description method is applied.

3.1. The Geology of the Research Area

Geologically, the study area is located within the Rajamandala Formation, which consists of both clastic limestone and reef limestone. The topography of the research area is characterized by a structural hill that extends and demonstrates a notable variation in elevation in comparison to the surrounding terrain. This suggests the influence of geological processes that have contributed to the distinctive topographical features in this particular region.

3.2. Thin Section Observation with Point Counting

The creation of the grid and thin section observation using the point counting method can be seen in Figure 5. The grid is created by drawing 17 lines along the X-axis and 19 lines along the Y-axis, resulting in a total of 312 intersection points. Next, color codes are assigned to the intersection points for each component of the rock constituents, and the percentage of mineral or grain occurrence at these intersection points is calculated (Figure 6). There are no specific rules for color coding; in this case, the colors are: dark green for the matrix, blue for porosity, orange for coral, yellow for cement, purple for sparite, red for large foraminifera, and dark blue for planktonic foraminifera

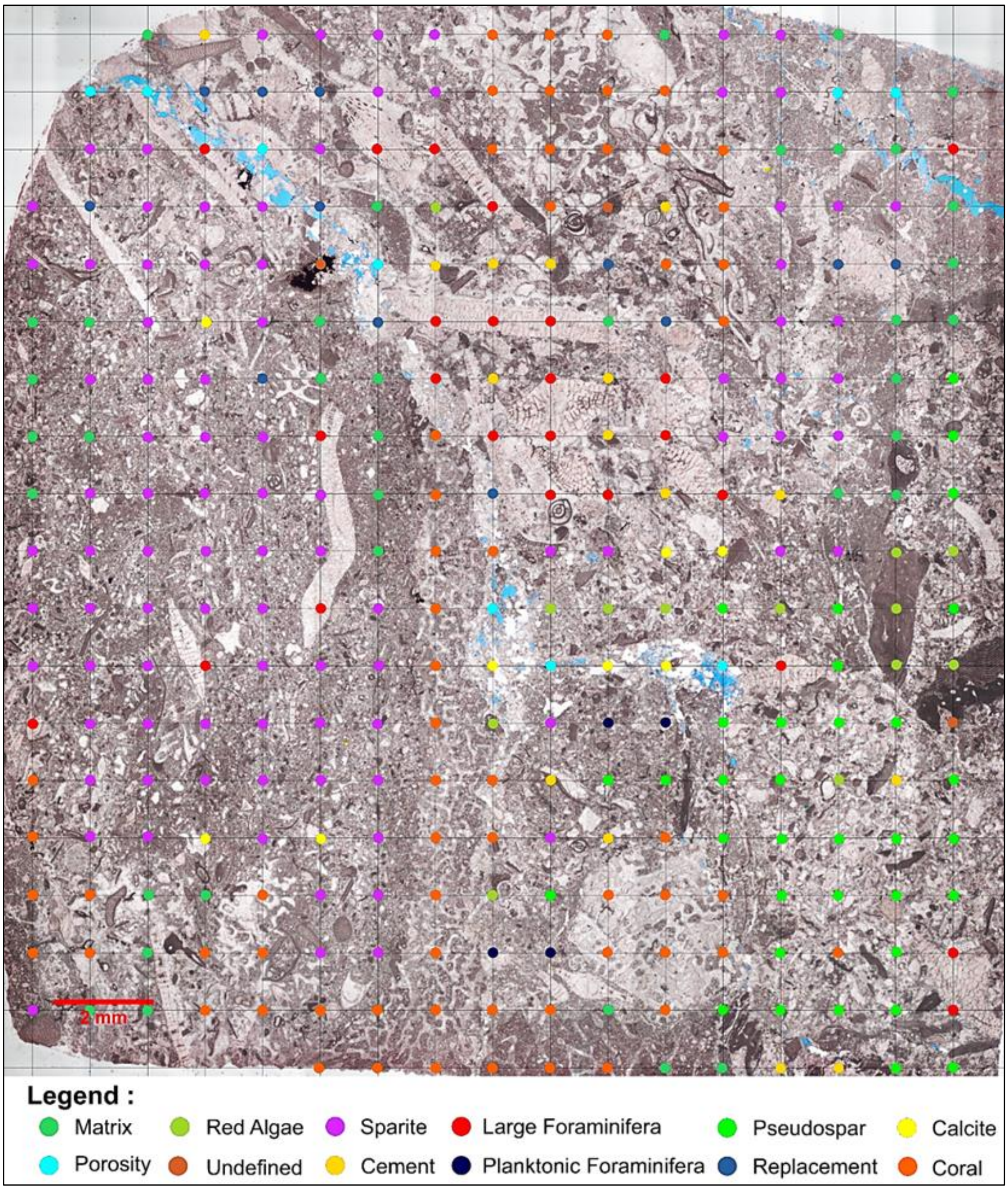

Fig 6. Observation under parallel nicols in thin section 2N sample code, X 17 lines, Y 19 lines, total of 312 grids (intersection points vertical vs horizontal).

Based on the grain/mineral calculation in thin section analysis, using equation (1), the grain count is determined as follows:

Red Algae	= (13/312) x 100	= 4.17 %
Planktonic F	= (4/312) x 100	= 1.28 %
large Foram	= (24/312) x 100	= 7.69 %
Coral	= (61/312) x 100	= 19.55 %
Micrite	= (163/312) x 100	= 52.24 %
Porosity	= (9/312) x 100	= 2.88 %

The petrographic observations of the sample indicate that the grain composition, which consists of skeletal grains such as red algae, planktonic foraminifera, large foraminifera, and coral, amounts to 33.65%. The matrix, comprising micrite, sparite, and pseudospar, accounts for 52.24%. Cement makes up 4.81%, calcite makes up 2.56%, and replacement, consisting of calcite and dolomite, is at 3.21% and 0.64% respectively. Additionally, porosity measures at 2.88% (Table 1).

Based on the comparison between the composition of grains and the matrix, the limestone at the research site is classified as coral wackestone, according to Dunham, 1962. Table 1 indicates that the top row displays the composition based on the number of points, while the bottom row shows the percentage after dividing by 312 points and multiplying by 100.

Table 1. Description / Percentage of thin section observation using the point counting method indicates that the rock is classified as coral wackstone from 2N code Sample.

Number of point	Code Sample	Skeletal Grain (number of point)					tot	Matrix (number of point)			Cement	Calcite	Replacement		Porosity	number of point	Total (number of point)
		Red Algae	Planktonic	Large Forams	Coral	Undefined		Micrite	Microspar	Pseudospar			Cal	Dol			
	2N	13	4	24	61	3	105	37	92	34	15	8	10	2	9	312	312
Point counting	Code Sample	Skeletal Grain (%)					tot	Matrik (%)			Cement	Calcite	Replacement		Porosity	number of %	Total (%)
		Red Algae	Planktonic	Large Forams	Coral	Undefined		Micrite	Microspar	Pseudospar			Cal	Dol			
	2N	4.17	1.28	7.69	19.55	0.96	33.65	11.86	29.49	10.90	4.81	2.56	3.21	0.64	2.88	100	100

3.3. Facies and Diagenetic

3.3.1. Facies

Facies are defined as a rock body that has a combination of characteristics that are related to the physical, biological, or chemical aspects seen in rock lithology, sedimentary structures that distinguish the rock body from the rocks above, below, or laterally in other parts (Walker and James, 1992). In carbonate rocks, the determination of facies is based on thin section analysis, referred to as microfacies. Microfacies studies seek to identify overarching patterns that provide insights into the history of carbonate rocks. This is achieved through a detailed analysis of the sedimentological and paleontological features inherent in these rocks (Flugel, 2010).

The identification of facies in thin sections is based on the presence of organisms. The rock-forming organisms consist of corals, mollusks, large foraminifera, and red algae, suggesting formation in an open marine environment, falling within the facies zone (FZ 7) (Figure 8). Figure 7 shows the constituent organisms in the thin section. The presence of milliolid large foraminifera (ml) indicates that the rock formed in an open marine environment.

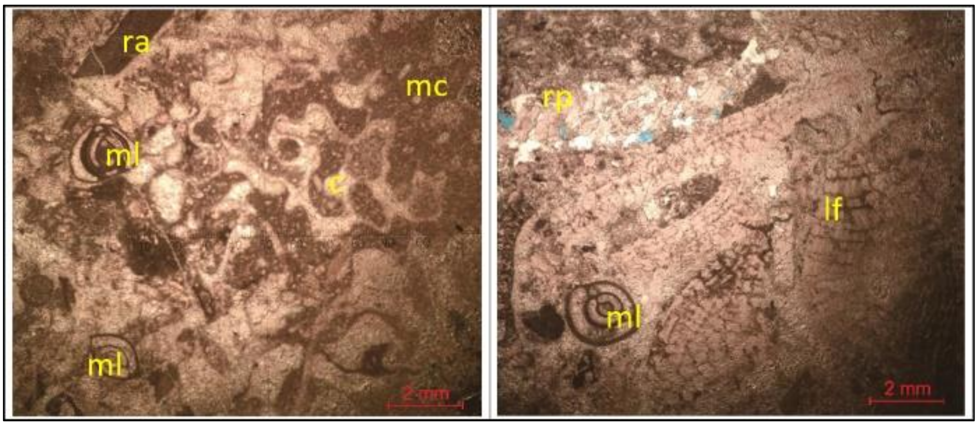

Fig 7. The petrography of Sample 2N, (ml) mollusks, (c) coral, (lf) large foraminifera, (ra) red algae, (mc) micrite, (rp) replacement. The observation is at 5x magnification and using a parallel Nicol.

The FZ 7 type is situated on a platform linked to the open sea, providing a consistent environment with stable salinity and temperature. When shielded by sand shoals, islands, or reefs emerging from the platform's base, this region is termed a lagoon. The water depth in this area varies from a few meters to tens of meters. The deposits in this zone encompass lime mud, muddy sand, and clean sands, with variations depending on the local sediment's grain size and the effectiveness of winnowing by waves and tidal currents.

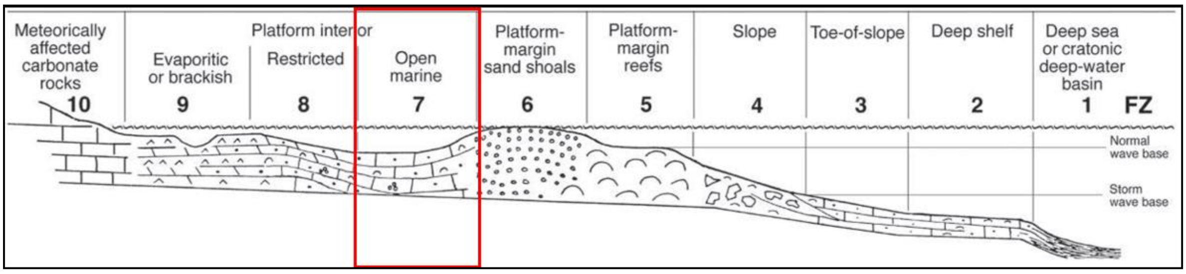

Fig 8. Rimmed Carbonate Platform: standard facies zoning, modification of (Wilson, 1975). The red box represents the facies zoning of the limestone sample

3.3.2 Diagenetic

The diagenetic environment is a zone on or beneath the Earth's surface that specifically influences the diagenetic processes of rocks with varying characteristics, especially in terms of their cement morphology. There are three diagenetic environment in which carbonate porosity is formed or modified, such as marine, meteoric, and subsurface (burial) (Choquette and Pray, 1970) (Figure 9).

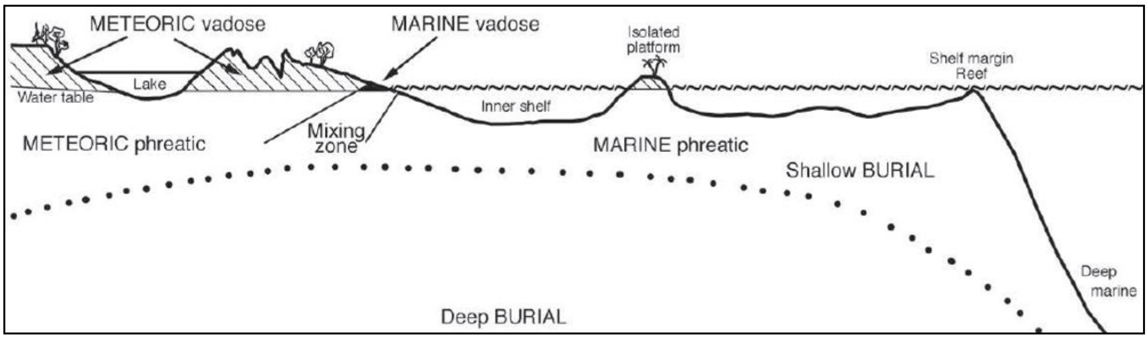

Fig 9. Diagenetic carbonate environment (Flugel, 2010).

Several diagenetic features are indicated by the type of cement, grain-to-grain contacts, and porosity characteristics (Moore, 1989., and Scholle and Scholle., 2003). Compaction is evidenced by grain contacts in the form of points, long contacts, and concavo-convex contact. Micrite envelope and fibrous cementation indicate formation in a marine phreatic environment, while isopach cement indicates formation in a phreatic zone environment. Secondary porosities formed include vugs and channels. The characteristic of burial diagenesis is the presence of several point contacts, long contacts, and concavo-convex contacts (Figure 10).

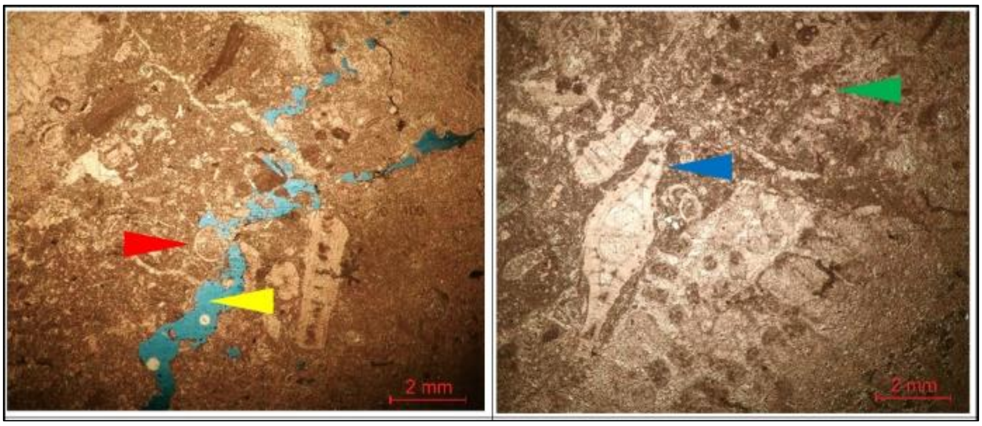

Fig. 10 Petrography of thin section sample 2N, red arrows indicate fibrous cement, blue arrows indicate blocky cement, green arrows indicate concavo-convex contacts, and yellow arrows indicate channel porosity. The observation is at 5x magnification and using a parallel Nicol.

7. Conclusion

Using the point counting method, rock naming can be made more objective and standardized. This quantitative approach allows for more accurate comparisons between different rock samples and different observers. It also provides a strong foundation for describing the grain composition or mineralogy of the rock in more detail.

Based on petrographic observations, the composition of the grain is 33.65%, matrix 52.24%, cement 4.81%, calcite 2.56%, replacement consisting of calcite 3.21% and dolomite 0.64%, with porosity at 2.88%. The rock is named coral wackstone (Dunham, 1962).

The rock is formed in open marine (FZ 7) facies characterized by various biota such as coral, milliolids large foraminifera, and red algae. Diagenesis begins with marine phreatic diagenesis, characterized by the presence of a micrite envelope and fibrous cement. Meteoric phreatic diagenesis is indicated by isopachous cement, and burial diagenesis is marked by the presence of plastic deformation contacts (point and long contacts) as well as concavo-convex contacts.

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References

Adhari, M. R., and Hidayat, R., 2023. A geological overview of the limestone members of the Woyla Group of Sumatra, Indonesia, Journal of Geoscience, Engineering, Environment, and Technology, Riau, Indonesia. vol 08, No 03. doi:https://doi.org/10.25299/jgeet.2023.8.3.12190

Aulia, I., and Aditiyo, R., 2021. Diagenesis Study of Jatiluhur Formation at Cipamingkis River, Bogor Regency, West Java, Indonesia, Journal of Geoscience, Engineering, Environment, and Technology, Riau, Indonesia. vol 06, No 04. doi:https://doi.org/10.25299/jgeet.2021.6.4.7646

Baccelle, L., and Bosellini. A., 1965. Diagrammi per la stima visiva della composizione percentuale nelle rocce sedimentarie. – Annali della Università di Ferrara, Sezione IX, Science Geologiche e Paleontologiche, 1, 59-62.

Baumann, P., Oesterle, H., and Suminta, Wibisono., 1972. The Cenozoic of Java and Sumatera, in: Proc. Indon. Petrol. Assoc.,. 1st Ann. Conv. Presented at the First Annual Convention, June 1972, Indonesian Petroleum Association (IPA), Jakarta, pp. 31-42.

Choquette, P. W. and Pray, L. C., 1970. Geologic nomenclature and classification of porosity in sedimentary carbonates, The American Association of Petroleum Geologists Bulletin, 54, 207 – 250. doi:https://doi.org/10.1306/5D25C98B-16C1-1D7-8645000102C1865D

Dunham, R.J., 1962. Classification of carbonate rocks according to depositional texture. – In: Ham, W.E. (ed.): Classification of carbonate rocks. A symposium. – Amer. Ass. Petrol. Geol. Mem., 1, 108-171. doi: https://dx.doi.org/10.11113/jt.v79.9987

Flügel, E., 2010. Microfacies of carbonate rocks: analysis, interpretation and application, Second Edition. Springer-Verlag, New York, 976. doi: https://doi.org/10.1007/978-3-642-03796-2

Handoyo, H., Sudarsana, M. R., and Almiati., R, 2016. Rock Physics Modeling and Seismic Interpretation to Estimate Shally Cemented Zone in Carbonate Reservoir Rock, Journal of Geoscience, Engineering, Environment, and Technology, Riau, Indonesia. vol 01, No 01. doi: https://doi.org/10.24273/jgeet.2016.11.6

Hutabarat, M., 1971. Stratigrafi Batuan Karbonat daerah Tagogapu, Bandung : Institut Teknologi Bandung (thesis)

Khorniawan, W.B., 2022. Litofasies dan Diagenesis Batugamping Formasi Rajamandala di Lintasan Cikamuning, Jurnal Penelitian dan Pengabdian kepada Masyarakat (ETHOS) Vol 8 No 1, Bandung, Indonesia, 59-66. doi: https://doi.org/10.29313/ ethos.v8i1.5077

Koesoemadinata, R.P., Siregar, S., 1984. Reef Facies Model Of The Rajamandala Formation, West Java, Proceedings Indonesian Petroleum Association.

Kupper, H., 1941. Bijdrage tot de stratigraphy van het Tagogapoe and Gn. Masigit gebied (Noord Prianger, Java): De Ing. Ned. ind., no. 12: 105-109.

Martodjojo, S., 1984. Evolusi Cekungan Bogor, Jawa Barat: Institut Teknologi Bandung (dissertation)

Martodjojo, S. 2003. Evolusi cekungan Bogor Jawa Barat, ITB Press, Bandung, 1 - 258.

Matthew, A.J., Woods, A.J., Oliver, C., 1991. Spots before eyes: new comparison charts for visual estimation in archaeological material. – In: Middleton, A., Freestone, I. (eds.): Recent developments in ceramic petrology. – British Museum London, Occasional Paper, 81, 211-263.

Moore, C.H., 1989. Carbonate Diagenesis and Porosity. In: Developments in Sedimentology, Vol. 46, Amsterdam, Elsevier, 46-338

Nugroho, D., Simo, J.A., Noeradi, D., Sapiie, B., dan Suparka, E., 2015. Stacking Pattern and Sequence Stratigraphy Analysis of the Oligo-Miocene Rajamandala Limestone, Padalarang Area, West Java, Indonesia, AAPG ICE 2015 Proceeding, Melbourne Australia. doi: https://doi.org/10. 1190/ice2015-2211526.

Prasetyo, U., and Kapid, R., 2014. Nannoplankton Biostratigraphy of The Rajamandala Area, Jurnal of Geology and Mineral resource, Bandung, Indonesia vol 15, 185 – 194. doi:https://doi.org/10.33332/jgsm.geologi.v15i4.57

Sapiie, B., Noeradi, D., Suryanugraha, A. M., Kurniawan, W., Simo, T., dan Nugroho, D. 2010. 3D Palinspatic reconstructions of Rajamandala Carbonate Complex as implication of paleogeography in the Western Java, Indonesia. Proceedings Indonesian Petroleum Association 34th

Scholle, P. A. dan Ulmer-Scholle, D.S., 2003. A color guide to the petrography of carbonate rocks: grain, textures, porosity, diagenesis, American Association of Petroleum Geologists Memoir, Vol. 77, 2003, pp. 1-477. doi: https://doi.org/10.1306/M77973

Siregar, M. Safei., 2005. Sedimentasi Dan Model Terumbu Formasi Rajamandala di Daerah Padalarang-Jawa Barat, RISET- Geologi dan Pertambangan, Jilid 15 No. 1 Tahun 2005, hal 61 - 81, 10. doi:http://dx.doi.org/10.14203/risetgeotam2005.v15.189

Van Bemmelen, R. W., 1949. The geology of indonesia vol. 1A, Government Printing Office, Martinus Nijhoff, The Hague, Netherlands, 1094.

Van der Plas, L., Tobi, A.C., 1965. A chart for judging the reliability of point counting results. – American Journal of Science, 263, 87-90

Walker, R.G., and James, N.P., 1992. Facies Models : Response To Sea Level Change. Geological Association of Canada: Ontario.

Wilson, J.L., 1975. Carbonate Facies In Geologic History. Springer-Verlag, Berlin, 471 p. doi: https://doi.org/10.1007/978-1-4612-6383-8