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Microfacies and Depositional Environment: Pamutuan Formation, Calcarenite Member, Selasari Area, Parigi Subdistrict, Pangandaran, West Java

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A R T I C L E I N F O

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A B S T R A C T

This journal provides an overview of the limestone facies model for the calcarenite member of the Pamutuan Formation. This limestone is quite well exposed in the southern part of Java Island, in Pangandaran Regency. The primary data for this study were obtained from 53 rock outcrops, within which there were 4 measured stratigraphic sections: the Selasari Traverse, the Bangunkarya Traverse, the Cimanggu Traverse, and the Kersaratu Traverse. One of these sections was analyzed using 3 samples that had been petrographically tested for microfacies analysis. The research results indicate that the Kalkarenit Member of the Pamutuan Formation is composed of clastic carbonate rocks. Microfacies analysis shows that the carbonate rocks generally consist of two facies zones according to the Facies Zone results: the inner part of the shelf or open sea (FZ7) and the inner part of the restricted shelf (FZ8). Various diagenetic processes occur after rock deposition, including cementation, micritization, compaction, neomorphism, and dissolution.

INTRODUCTION

In an effort to understand the characteristics of microphases and the process of diagenesis, this study took case studies in the Selasari area and its surroundings, Parigi District, Pangandaran Regency, West Java Province. Based on the Geological Map of the Pangandaran Sheet, there are two Formations, namely the Jampang Formation and the Pamutuan Formation, the carbonate units in the area are included in the Pamutuan Formation Calkarenite Members. Previous research described this member as part of a Middle Miocene-aged unit, with the dominant lithology in the form of calcilutite, sandy limestone, and napal (Supriatna et al., 1992), having an exposed thickness of about 500 meters, and forming in a shallow marine environment (Simandjuntak, 1981).

The results of preliminary surveys and previous detailed mapping showed variations in the facies and associations of carbonate rocks that make up the members. These findings are the basis for a more in-depth study that focuses on determining the types of microphases and interpreting their deposition environment, as well as identifying the various diagenesis processes and the environment they form in the carbonate rocks of the Pamutuan Formation.

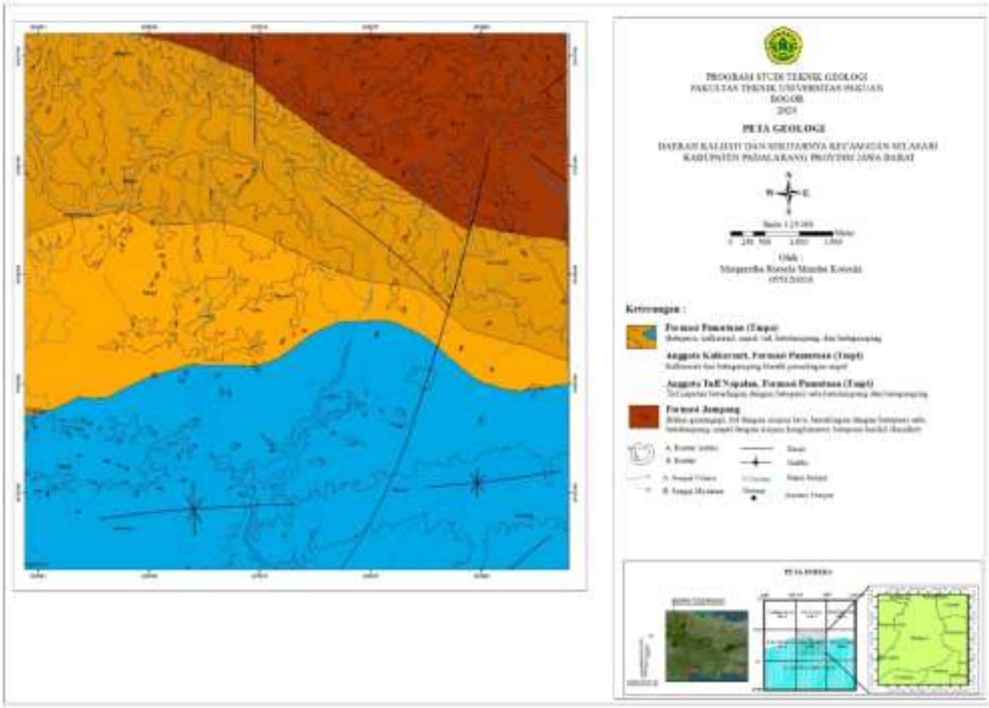


Figure 1. Geological Map of the Pangandaran Sheet in the research area

THEORETICAL REVIEW

Carbonate Microfacies Concept

Carbonate microfacies refer to the microscopic characteristics of carbonate rocks, including texture, grain composition, fossil content, and depositional structures, which are used to interpret depositional environments and sedimentary conditions. According to the classification proposed by Dunham (1962) and later refined by Embry and Klovan (1971), carbonate rocks are categorized based on depositional texture into mudstone, wackestone, packstone, grainstone, and boundstone. Microfacies analysis plays an important role in reconstructing paleoenvironmental conditions such as water depth, hydrodynamic energy levels, and biological activity within carbonate platforms, making it a key method in sedimentological and stratigraphic interpretations.

Depositional Environment of Calcarenite Limestone

Calcarenite is a sand-sized carbonate rock commonly composed of skeletal fragments such as foraminifera, mollusks, algae, and coral debris deposited in shallow marine environments with moderate to high hydrodynamic energy. According to Tucker and Wright (1990), calcarenite typically forms in shoal complexes, open lagoons, and inner to middle carbonate platform settings where wave and current activities are significant. The grain-supported texture of calcarenite indicates active water circulation and relatively high-energy depositional conditions, which are characteristic of shallow marine carbonate environments influenced by tidal and wave processes.

Characteristics of the Pamutuan Formation

The Pamutuan Formation represents a Neogene carbonate sedimentary unit widely distributed in the southern part of West Java and is predominantly composed of clastic limestones, calcarenites, and marl intercalations. Regional stratigraphic studies indicate that this formation developed within a shallow marine carbonate platform influenced by tectonic activity associated with the southern Java subduction zone. The presence of abundant benthic larger foraminifera and other shallow marine bioclasts suggests deposition within a neritic zone characterized by warm, clear, and well-circulated seawater conditions favorable for carbonate-producing organisms.

Calcarenite Member of the Pamutuan Formation

The calcarenite member of the Pamutuan Formation is characterized by sand-sized carbonate grains dominated by skeletal fragments and bioclastic materials that reflect deposition under relatively high-energy shallow marine conditions. Sedimentologically, this member commonly exhibits packstone to grainstone textures, indicating deposition within shoal environments or inner carbonate platform settings affected by wave and current action. The occurrence of larger foraminifera, molluscan fragments, and calcareous algae supports the interpretation of an open shallow marine depositional setting with active hydrodynamic conditions and continuous carbonate production.

Depositional Environment of the Selasari Area, Pangandaran

Regionally, the Selasari area in Pangandaran is part of the southern West Java carbonate platform system that developed during the Neogene period under the influence of subduction-related tectonic activity along the southern margin of Java. Previous geological studies indicate that carbonate rocks in this area were deposited in shallow neritic environments ranging from inner platform to shoal settings influenced by sea-level fluctuations and wave energy variations. Microfacies analysis of the calcarenite member in the Selasari area is therefore essential for reconstructing spatial facies distribution and understanding the evolution of carbonate depositional systems within the southern West Java basin.

METHODOLOGY

This research method includes the collection of geological data at selected locations, followed by limestone petrographic analysis involving the characterization of microphases, identification of diagenesis traces, and interpretation of laboratory results. The field work stage began with the acquisition of geological data, especially the carbonate rock petrological data of the Pamutuan Formation Calkarenite Members which were revealed in the southern part of the research area. Sampling was carried out sequentially following measured stratigraphic columns, with the selection of samples that were still fresh to ensure representativeness.

Laboratory analysis includes the observation of thin incisions of limestone to determine lithological categories based on the composition and proportions of its constituent components, which are then used for rock naming. This stage is extended with the determination of microfacies and the introduction of diagenesis characteristics. A total of twelve carbonate samples from the Pamutuan Formation Limestone Members were analyzed petrographically. The classification of carbonate textures and fabrics refers to the Dunham (1962) system, while the determination of the type of supporting granules uses the classification of Folk (1962).

The division of microphases refers to the standard types of microphases (SMFs) according to Flügel (1982) and the zoning of facies (FZ) according to Wilson (1975). As a basis for the interpretation of the sedimentation environment, bathymetric depth information is also used (Tipsword, 1966) based on the presence of bentonic foraminifera and mollusks in Pamutuan mollusk limestone.

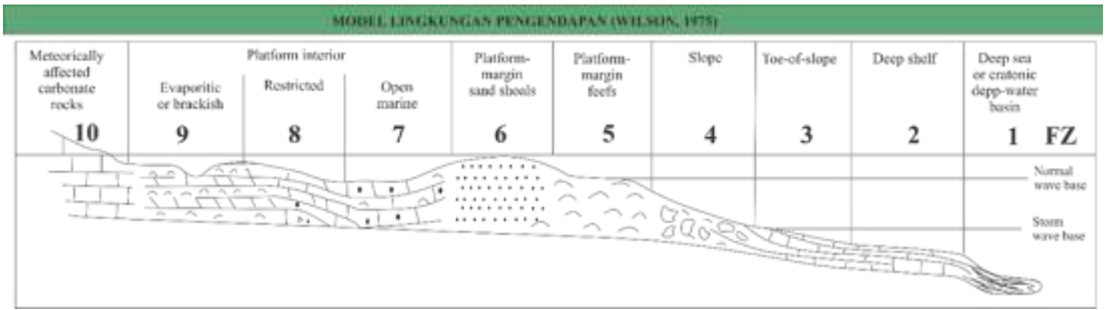


Figure 2. Sedimentation Environment Model (Wilson, 1975)

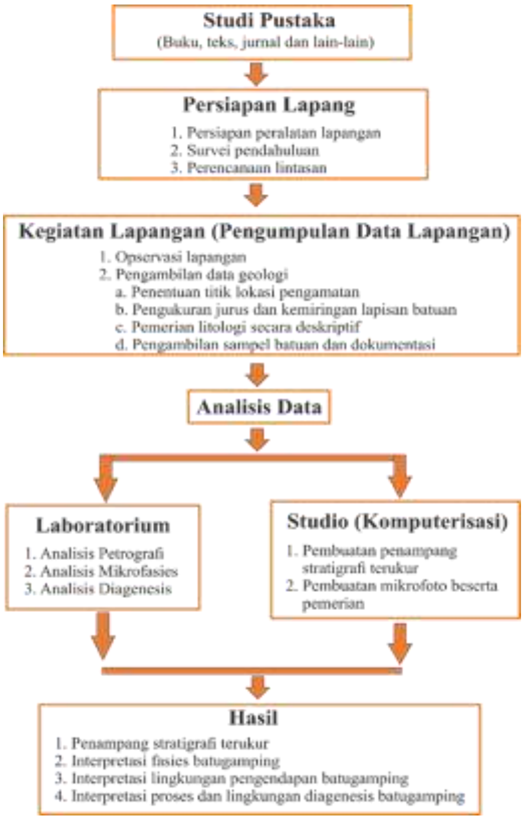


Figure 3. Research flowchart

Sub Chapter 1 Geological Conditions

Based on the results of the initial survey (reconnaissance) and detailed mapping on a scale of 1:25,000 that had been carried out previously and looking at the unofficial stratigraphic nomenclature (Martodjojo and Djuhaeni, 1996), the stratigraphy of the research area from old to young was composed of the Breksi Rock unit inserted in the Sand Rock and Batulempung (Jampang Formation) which is of Early Miocene age (N5-N7) formed in the upper bathiyal marine environment (200 m - 500 m). basalt lava rock units (Jampang Formation) of Early Miocene age (N5-N7) followed by a phase of sea shrinkage characterized by the growth of the carbonate phase which then formed a limestone unit of clay inserts (Members of the Pamutuan Formation Calcarenite) of Middle Miocene - Late Miocene (N12 - N15) formed in the middle neritic environment of the edge - Outer neritic (5 m - 200 m), the intermediate Limestone Limestone unit (Pamutuan Formation) which is of Middle Miocene age - The Early Late Miocene (N13-N15) was formed in the outer neritic environment (100 m - 200 m), the limestone units of the Silent Interval - Sandstone Inserts of the Clay and Napal (Pamutuan Formation) of Middle Miocene - Early Late Miocene (N13-N15) were formed in the outer neritic environment (100 m - 200 m), and the Alluvial Sediment Unit was formed in the terrestrial environment of Holocene age.

In addition, in the study area there are also several controlling geological structures, namely folding structures in the form of the Cikalong anticline and the Cintaratu syncline which are parallel to each other elongated in a relative west-east direction and faults in the form of the Cikadu ascending fault which lifts older rocks then the Sinistral Selasari fault, the Cimanggu sinistral fault, the

Bangunkarya sinistral fault which is located in the western and eastern parts of the research area and extends in a relative northeast direction - Southwest that cuts folds or ascending faults. The geological structure in the study area is suspected to be the result of the peak of compressive tectonic activity that occurred during the Plio-Pleistocene Period.

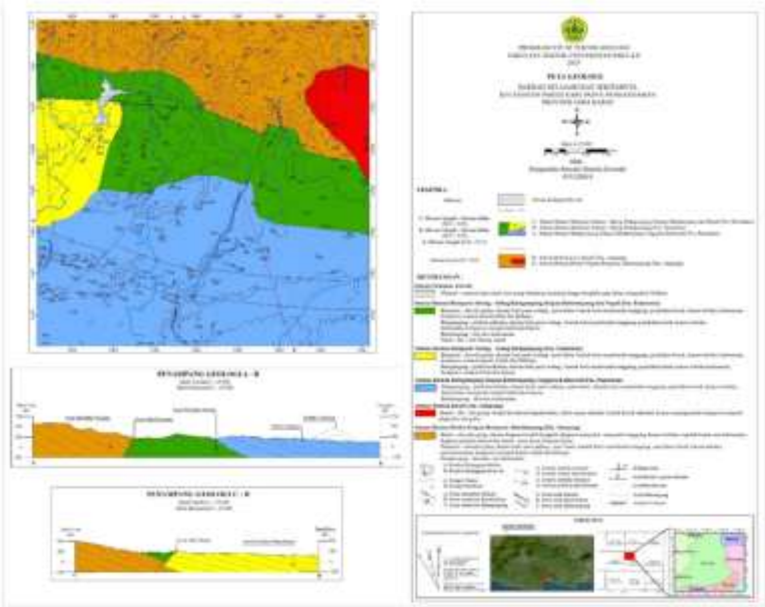


Figure 4. Geological map of the research area.

RESULTS

General Appearance

Based on the results of the geological observations that were then compiled in the geological map of the research area, focusing more on the study of microfacies and sedimentation environments in the Limestone Unit of the Batulempung Insert in Figure 3 is blue on the geological map of the research area, so in general this unit is composed of clastic limestone units that dominate the southern region of the research area. It has 4 tracks, namely:

Table 1. Tracks in the research area for sampling

Track	Number of samples
Bangunkarya	3
Selasari	3
Cimanggu	3
Kersaratu	3

Mymophagesia

Limestone in the study area generally has a relatively similar stratigraphic position and observation location in measured stratigraphic cross-section measurements that are not too far apart, so from the results of microfascie analysis several types of microfacies were obtained that characterize different deposition environments seen from megascopically, there are layered limestones and some are massive or unlayered and seen from petrographic incisions with the distribution between fossils and masses The basis and type of fossil, this is suspected to be the impact of seawater conditions that are quite volatile at the time the limestone deposition process in the research area is ongoing, but generally in relatively transgressive sea surface conditions. Based on regional data in the Middle Miocene, volcanic activity relatively began to weaken, followed by relatively transgressive sea level conditions, resulting in the sedimentation process of the Pamutuan Formation limestone in the southeastern part of West Java (Clements and Hall, 2007).

Based on the results of observations of twelve thin incision samples of carbonate rock petrographs in the measured stratigraphic sequence in the study area using microphages referring to the classification of limestone texture according to Dunham (1962), the approach to *Standard Microfacies Types* (SMF) according to Flugel (1982) and its distribution to the closed carbonate exposure fascia belt model *(rimmed shelf)* based on *facies zone* (FZ) according to Wilson (1975), based on the results of petrographic analysis, MS analysis, litifasies analysis, etc., the research area itself has at least several deposition environmental associations which include: Exposed or open sea (*Shelf Lagoon Open Circulation,* FZ 7) and Limited exposure inside (*Restricted Circulation Shelf and Tidal Flats,* FZ 8)

Zone Fasies 7

The results of the analysis of rock incisions included in this fascies zone are composed of *Wackstone* limestone and *Packstone* foraminifera (Dunham, 1962). The characteristics in general show a layering structure at the bottom but upwards it has a massive structure with a texture in the form of fragmental bioclastics with fine to medium grain. The main characteristic of this facies zone rock is that it is composed of dominance by bioclastics that floats on carbonate mud, another special characteristic of this rock incision is the replacement or filling of shell material by another material in the form of microcrit. This biocassette is in a whole form until it is fragmented, based on these characteristics this carbonate rock unit is integrated into SMF 9: *Strongly burrowed bioclastic wackestone* which is the characteristic of FZ7 (Wilson, 1975) was found in 5 thin incision samples, namely on the LP 112 Bangunkarya Track, LP 15 Selasari Track, Cimanggu LP 3 and LP 5 then on the Kersaratu LP 109 and LP 110 Tracks.

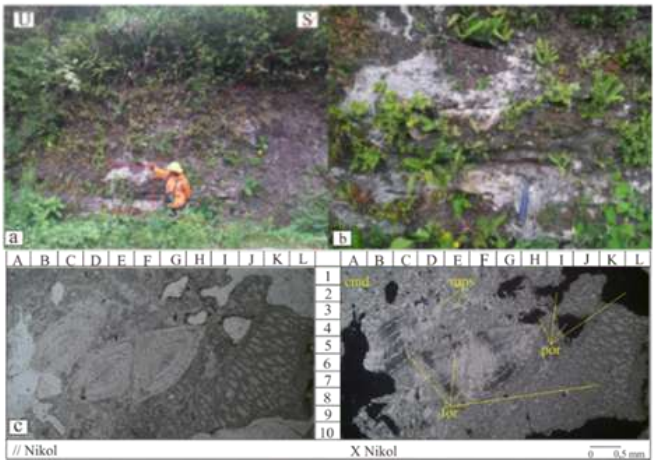


Figure 5. observation location LP 112 a. human-scale outcropping, b. hammer-scale outcrop c.Wackestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

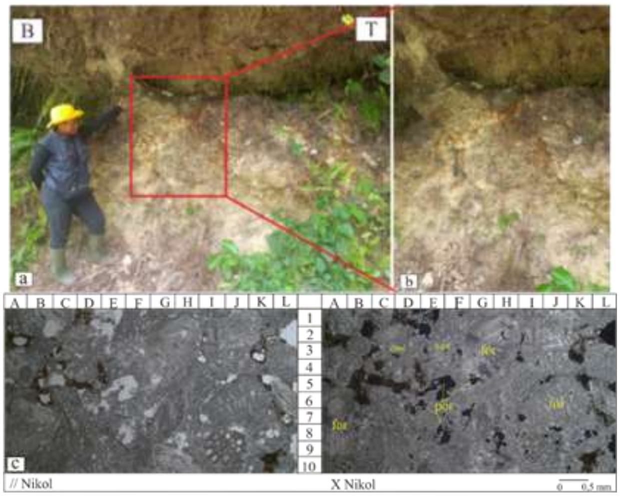


Figure 6. observation location LP 110 a. human-scale outcropping, b. hammer-scale outcrop c.Wackestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

Figure 7. observation location LP 109 a. human-scale outcropping, b. hammer-scale outcrop c.Wackestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

Figure 8. Observation location LP 5 a. human scale outcropping, b.Wackestone is composed of large foram red ganging (ral) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced by microsparite (msp), present dissolved cavities (por).

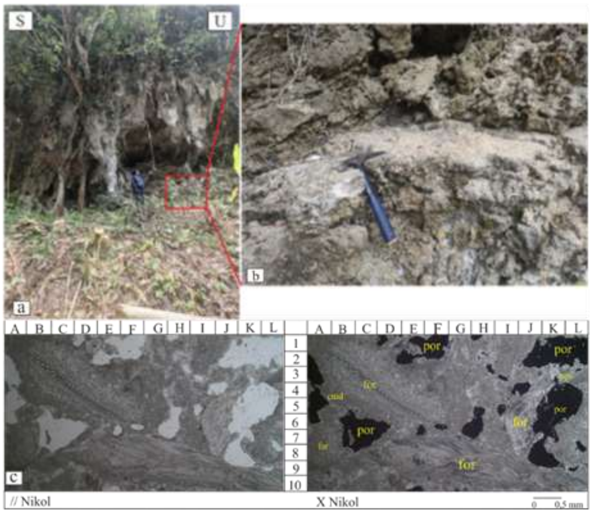


Figure 9. LP 3 observation location a. human-scale outcropping, b. hammer-scale outcrop c.Wackestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

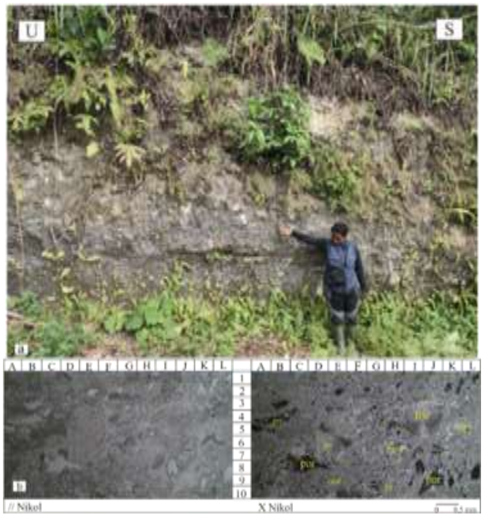


Figure 10.observation location LP 15 a. human scale outcropping, b.Packestone is composed of large (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced by microsparite (msp), present dissolved cavity (por).

in SMF 10 - Bioclastic packstone or wackestone with worn skeletal grains These microfacies show intense bioturbic activity, characterized by microchips containing fossil fragments that have been irregularly mixed due to the activity of digging organisms. The matrix consists of fine pelmikrite to pelsparite, the sedimentation environment includes shallow lagoons with open circulation or below the wavebed which is the characteristic of FZ7 (Wilson, 1975) found in 5 thin incision samples, namely on the LP 111 and LP 37 Bangunkarya Tracks, Cimanggu LP 7 Tracks and then on the Kersaratu LP 108 Track

Figure 11. observation location LP 111 a. human scale outcropping, b. hammer scale outcrop c.Packestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced by microsparite (msp), present dissolved cavity (por).

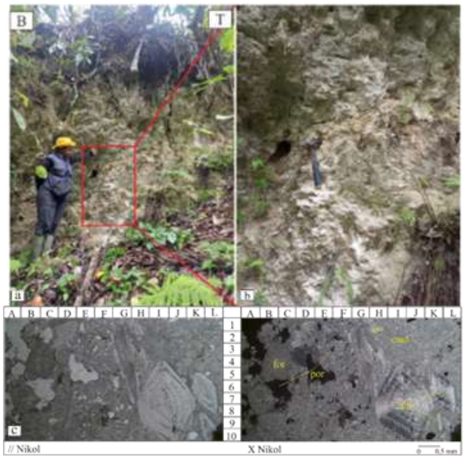


Figure 12. observation location LP 108 a. human-scale outcropping, b. hammer scale outcrop c.Wackestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

Figure 13. observation location LP 7 a. human scale outlet, b. hammer scale outcrop c.Wackestone is composed of large foram (for) which has been

partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

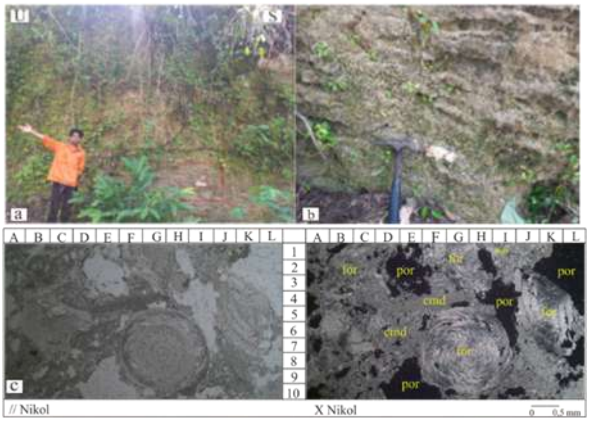


Figure 14. observation location LP 37 a. human-scale outcropping, b. hammer-scale outcrop c.Packestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced by microsparite (msp), present dissolved cavity (por).

Zone Fasies 8

The results of the analysis of rock incisions that are included in this fascies zone are composed of Wackstone foraminifera limestone (Dunham, 1962). The characteristics in general show a layering structure at the bottom but upwards it has a massive structure with a texture in the form of fragmental bioclastics with fine to medium grain. The main characteristic of this facies zone rock is that it is composed of dominance by bioclastics that floats on carbonate mud, another special characteristic of this rock incision is the replacement or filling of shell material by other materials in the form of microcrites and the presence of minerals from land, namely plagioclase and quartz. This biolcastic is in intact form but more predominantly the fossil is not intact or fragmented, based on these characteristics the carbonate rock unit is integrated into SMF 19: Densely laminated bindstone/mundstone according to Flügel (1982). These fasies are a representation of FZ 8 : Interior platform - Restricted (Open Marine) in the framework of the rimmed platform exposure model described by Wilson (1975). found in 2 thin incision samples, namely on the Selasari Track LP 12 and LP 10.

Figure 15. observation location LP 10 a. human scale outcropping, b. hammer scale outcrop c.Wackestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

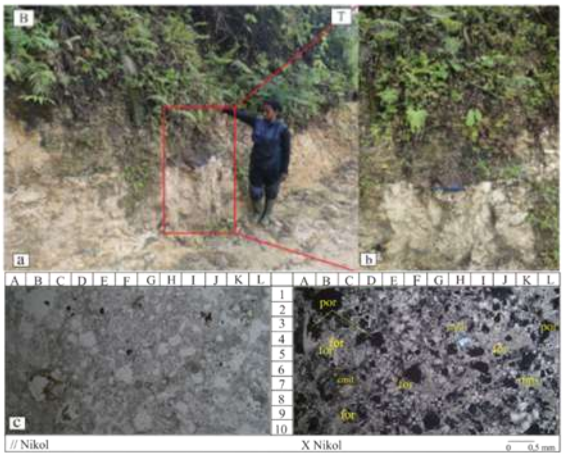


Figure 16. observation location LP 12 a. human-scale outcropping, b. hammer scale outcrop c.Wackestone is composed of large foram (for) which has been partially replaced by pseudosparite with carbonate sludge (cmd) which is replaced into microsparite (msp), present with dissolved cavities (por).

Model Fasies

Based on the results of observations and descriptions of 12 thin incision samples of limestone at the research site analyzed using standard microfacies types (SMF) according to Flügel (1982) and rimmed type carbonate exposure belt facies belt model according to Wilson (1975), it is known that the study area includes two sedimentation environments, namely shallow marine exposure with open marine ; FZ 7) as well as shallow exposure with limited circulation (restricted marine; FZ 8).

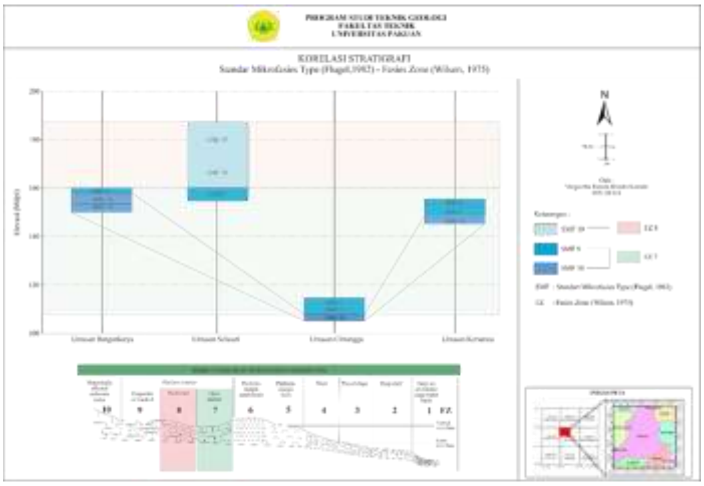
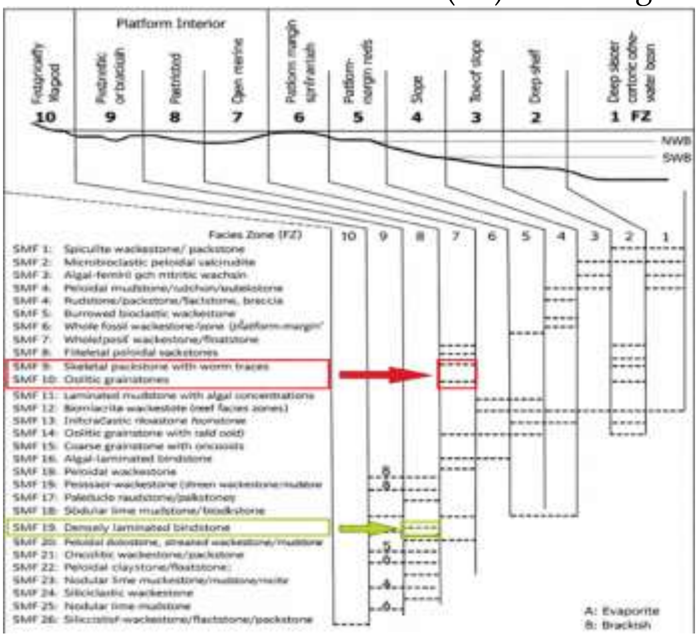


Figure 17. The interpretation of the blood deposition environment of the study used a closed carbonate exposure model based on the facies zone (FZ) according to Wilson (1975).

Table 2. The distribution of microfacies in the study area used Standard Microfacies Types (SMF) according to Flugel (1982) and the rimmed carbonate exposure belt model based on the facies zone (FZ) according to Wilson (1975).



Diagenesis

Based on diagenesis analysis, the diagenesis of the Pamutuan Formation limestone trajectory includes four main stages, namely marine phreatic, burial, meteoric phreatic, and meteoric vadose. These diagenesis processes took place from the time the limestone began to settle until it was finally exposed on the surface today. The records of the diagenesis results show that the initial stage takes place in the marine phreatic environment, then there is a decrease in sea level so that the fasies zone of FZ 7: marine phreatic is deposited again on it FZ 8: restricted marine which is characterized by initial cementation as a litification process. The cement that is formed is generally in the form of fine to medium-sized orthosparits, filling the cavities between the grains and some of the cavities in the grain. In some parts, the process of microscopy is also seen, namely the accumulation of carbonate sludge around grains or fossils, although the amount is limited, it shows marine phreatic diagenesis activity.

Furthermore, with the process of stockpiling, the limestone enters a burial environment characterized by compression and orientation of grains that appear parallel. The next stage is the phreatic meteoric environment triggered by tectonic uplift, characterized by the occurrence of neomorphism in the form of the transformation of the carbonate mud matrix into microsparits, as well as the transformation of grains into pseudosparites. At this stage, re-cementation in the form of calcite with a fine to medium-sized anhedral drusi mosaic texture was also found, which filled the cavities between grains, some cavities in grains, and sometimes cavities resulting from dissolution.

The diagenesis journey ends at the meteoric vadose stage when limestone is lifted to the surface, which is characterized by a dissolution process so that a vuggy type cavity is formed and in some parts develops into a channel.

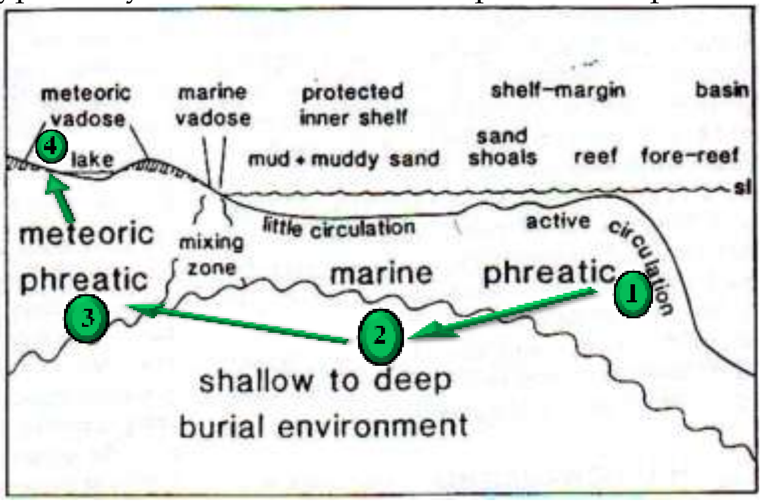


Figure 18. The diagenesis environment that occurs in limestone in the study area (Tucker and Wright, 1990).

CONCLUSIONS AND RECOMMENDATIONS

In the initial phase of deposition, certain conditions occur of sea level rise that shifts the sedimentation environment towards shallow exposure with open circulation (FZ 7: Interior Platform – Normal Marine). Fasies that represent this environment were identified in thin incisions of LP 5, LP 3, LP 7, LP 15, LP 37, LP 108, LP 109, LP 110, and LP 112 samples which showed the presence of fossil fragments in obsolete and difficult to identify conditions. This characteristic indicates the existence of a transport process before depositing, so this limestone is interpreted according to Whole fossil wackstone/floatstone, SMF 9: Burrowed bioclastic Wackestone and SMF 10: Bioclastic Packstone/Wackstone with worn skeletel grain (Flügel, 1982).

Furthermore, limestone is in shallow exposure environments with limited water circulation, particularly behind reefs (FZ 8: Interior Platform – Restricted). Evidence of this condition can be seen in samples of LP 10, and LP 12 which are characterized by foraminifera with low to moderate variation and fragments of green algae. These characteristics correspond to SMF 19 (Densely laminated bindstone/mundstone) according to Flügel (1982).

FURTHER STUDY

Future research on the microfacies and depositional environment of the Pamutuan Formation, particularly the calcarenite member in the Selasari Area, Parigi Subdistrict, Pangandaran, West Java, is recommended to incorporate more detailed petrographic, biostratigraphic, and geochemical analyses to refine interpretations of depositional settings and stratigraphic correlations. The integration of quantitative microfacies classification with larger benthic foraminiferal assemblage studies and stable isotope data ($\delta^{13}C$ and $\delta^{18}O$) would improve reconstructions of paleoenvironmental conditions such as water depth, salinity variations, and paleoclimate influence during carbonate deposition. Additionally, future studies should expand regional comparisons with equivalent Neogene carbonate formations in southern Java to better understand the evolution of the carbonate platform system in relation to tectonic activity along the southern Java subduction zone and sea-level fluctuations that controlled sediment distribution and facies development.

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