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RISET
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CARBONATE BIOFACIES AND PALEOECOLOGY ANALYSIS BASED ON ACROPORA CORAL IN UJUNGGENTENG AREA, WEST JAVA PROVINCE, INDONESIA

BIOFASIES KARBONAT DAN ANALISIS PALEOEKOLOGI BERDASARKAN KORAL ACROPORA DI DAERAH UJUNGGENTENG, PROVINSI JAWA BARAT, INDONESIA

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ABSTRACT Biofacies concept was proposed to approach the carbonate facies determination by using coral species description and ecology reconstruction. Ujunggenteng area was selected for this study because it has modern carbonate rocks with continues distribution and contains many well-preserved coral fossils. Ujunggenteng area can be distinguished into three biofacies: *Acropora cervicornis – Acropora palifera biofacies*, *Acropora gemmifera – Acropora humilis* biofacies, and *Acropora cervicornis – Acropora palmata* biofacies. The paleobathymetry analysis had indicated that *Acropora cervicornis – Acropora palifera* biofacies grew in the deepest environment, between 8 – 13 meters depth. *Acropora gemmifera – Acropora humilis* biofacies lived in a shallower environment between 3 – 8 meters depth, and *Acropora cervicornis – Acropora palmata* biofacies was deposited between 0 – 3 meters. The Mg/Ca trend showed a negative correlation with the paleobathymetry result. Decreasing Mg/Ca ratio was related to increasing paleobathymetry. *Acropora cervicornis – Acropora palifera* biofacies has the smallest Mg/Ca ratio, between 14 – 15 mmol. *Acropora gemmifera – Acropora humilis* biofacies has Mg/Ca ratio between 17 – 21 mmol. *Acropora cervicornis – Acropora palmata* biofacies has the highest Mg/Ca ratio, between 23 – 24 mmol. Mg/Ca ratio value was related to paleotemperature, in which the decreasing of Mg/Ca ratio associated to decreasing paleotemperature.

Keywords: Acropora, biofasies, Mg/Ca ratio, paleobathymetry, paleoecology, paleotemperature.

ABSTRAK *Konsep biofasies dipilih dan diajukan sebagai salah satu pendekatan untuk penentuan fasies karbonat. Konsep ini menggunakan deskripsi dari spesies koral dan rekonstruksi dari ekologi untuk memecahkan permasalahan dalam fasies karbonat. Daerah Ujunggenteng dipilih untuk studi ini karena daerah ini menunjukkan perkembangan batuan karbonat yang menerus dan fosil koral yang terawetkan dengan baik. Daerah Ujunggenteng dapat dibagi menjadi tiga biofasies, yaitu biofasies Acropora cervicornis – Acropora palifera, biofasies Acropora gemmifera – Acropora humilis biofacies, dan biofasies Acropora cervicornis – Acropora palmata. Analisis paleobatimetri menunjukkan bahwa biofasies Acropora cervicornis – Acropora palifera tumbuh di lingkungan yang paling dalam, yaitu 8 – 13 meter. Biofasies Acropora gemmifera – Acropora humilis hidup di lingkungan yang lebih dangkal, yaitu 3 – 8 meter, dan biofasies Acropora cervicornis – Acropora palmata terendapkan di lingkungan yang lebih dangkal,*

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yaitu 0 – 3 meter. Analisis kadar Mg/Ca menunjukkan nilai yang berlawanan dengan paleobatimetri. Penurunan kadar Mg/Ca memiliki hubungan dengan peningkatan paleobatimetri. Biofasies Acropora cervicornis – Acropora palifera memiliki nilai kadar Mg/Ca paling rendah, yaitu 14 – 15 mmol. Biofasies Acropora gemmifera – Acropora humilis memiliki kadar Mg/Ca yang lebih tinggi dibandingkan dengan biofasies Acropora cervicornis – Acropora palifera, yaitu 17 – 21 mmol. Biofasies Acropora cervicornis – Acropora palmata menunjukkan nilai kadar Mg/Ca yang paling tinggi, yaitu 23 – 24 mmol. Kadar Mg/Ca memiliki hubungan dengan perubahan temperatur. Penurunan kadar Mg/Ca berasosiasi dengan penurunan paleotemperatur.

Kata Kunci: *Acropora, biofasies, kadar Mg/Ca, paleobatimetri, paleoekologi, paleotemperatur.*

INTRODUCTION

One of the critical issue in carbonate rock is a classification of carbonate facies. Several previous studies of carbonate facies were performed based on lithology characteristic. Dunham (1962) was made carbonate classification from lithology description; based on mud supported versus grain supported. All of the coralline limestones were classified as boundstone. Embry and Klovan (1971) improved the more detail classification on boundstone. Boundstone can be divided based on the coral and organism shape, consist of framestone (“head” coral), bindstone (“platy” coral), and bafflestone (“branching” coral). The application of carbonate facies in many carbonate outcrop in Indonesia still adopt lithology approach. Siregar and Praptisih (2008) applied Dunham (1962) and Embry and Klovan (1971) classification for carbonate facies in Campurdarat Formation, Trenggalek. Mukti *et al.*, (2005) used Jordan (1985) classification for carbonate facies in Wonosari Formation, Pacitan Area. Jordan classification (1985) proposed more detail in organism and coral, which classified into composition on carbonate facies. Premonowati (2012) used the similar approach by using Dunham (1962) and Embry and Klovan (1971) for the study in paleoreef in Punung Area, Wonosari Formation.

Carbonate facies determination approach is still open to many research opportunities. James and Borque (1992) proposed carbonate facies determination based on the relationship between coral shape and geometry of wave energy and sedimentation. The evidence for this classification is that many corals have similar geometries, but grew in the different environments. This study approached the carbonate facies determination based on coral biofacies. Coral species is the main parameter for carbonate facies classification. Species identification gave more detail classification and ecology reconstruction (Santoso, 2015). Thus, it proposed more consistent classification and carbonate paleoecology history.

MATERIAL AND METHODS

The research area is situated along Ujunggenteng beach, West Java, Indonesia, with coordinates 70 21' 31.2" - 70 22' 30" latitude and 1060 24' 12.2"- 1060 25' 30" longitude (Figure 1). This area has carbonate rock with continues distribution and well preserved coral fossils. Biofacies data and

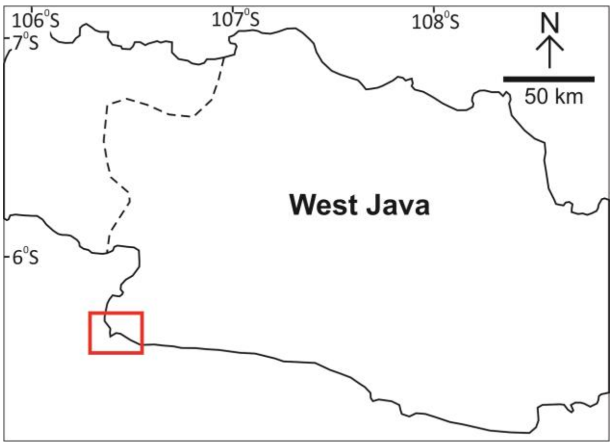

Figure 1. The research area location in Ujunggenteng Area (red box), West Java, Indonesia.

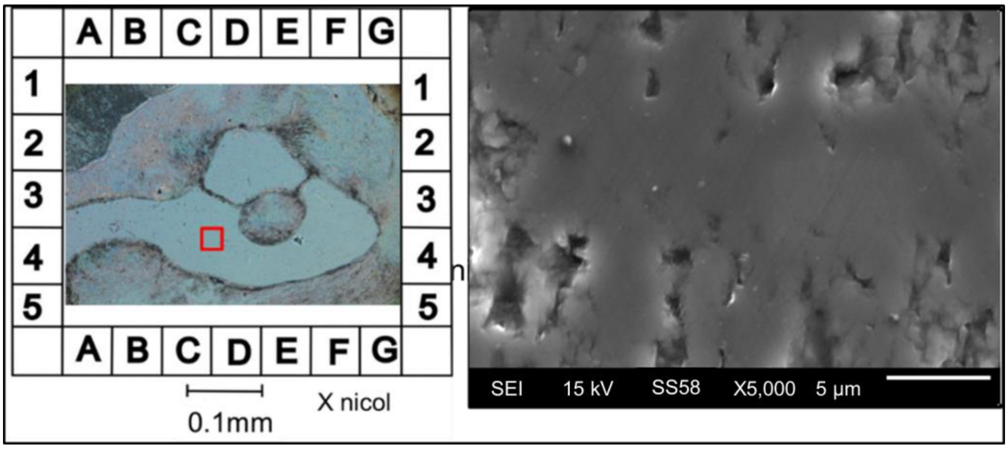

Figure 2. The initial aragonite without diagenetic traces from petrography (left). Red box area was analyzed by SEM–EDS. SEM–EDS result shows smooth surface morphology without secondary aragonite (right).

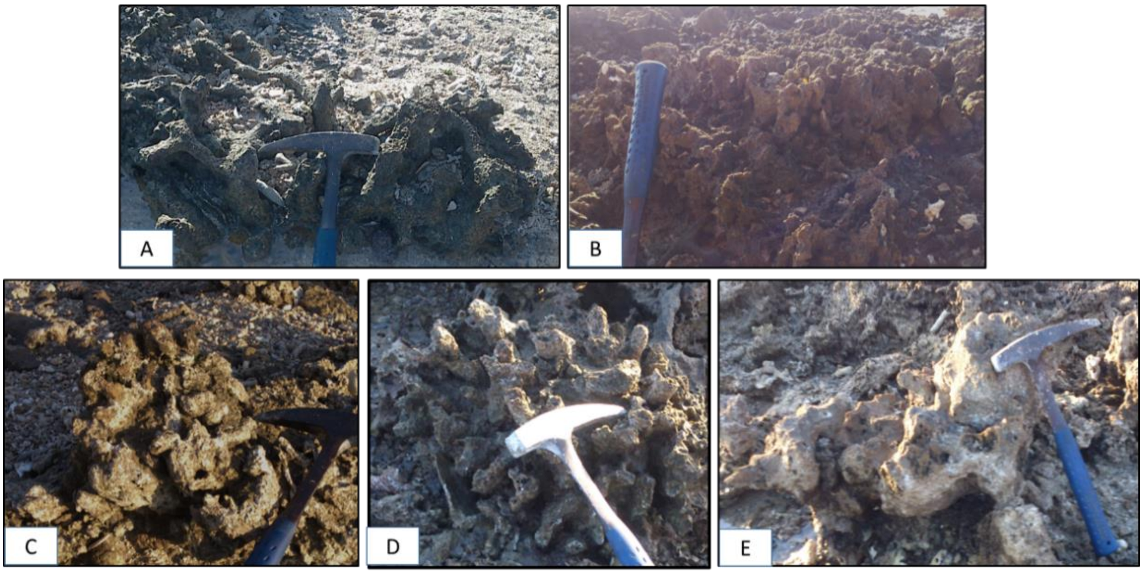

Figure 3. The five species *Acropora* in Ujunggenteng area: (A) *Acropora cervicornis*, (B)*Acropora palifera*, (C) *Acropora gemmifera*, (D) *Acropora humilis*, and (E) *Acropora palmata.*

fossil samples were collected during fieldwork with detail transects and mapping.

Eight samples of coral fossils, which represent each of facies, were examined for petrography and SEM-EDS (Scanning Electron Microscope – Energy Dispersive Spectroscopy) analysis. Petrography was analyzed using polarisation microscope Nikon model Eclipse Ci-Pol 100-240 kV, 0.8A, 50/60 Hz at Paleontology Laboratory, Institut Teknologi Bandung and Mineralogy Laboratory Ehime University, Japan. The purpose of petrography analysis was selecting initial calcite with good condition and without diagenetic alteration (Figure 2). The initial calcite must be selected because aragonite, which has diagenetic alteration traces, contributes an error in geochemistry analysis and cooler paleotemperature around 70^{o} C (Sayani *et al.*, 2011; Eipsten *et al.*, 1953).

After petrography analysis, the marked initial calcites were analyzed by SEM-EDS. SEM-EDS analysis was conducted using JSM – 65101 LV,15 kV voltage, beam current 0.8 nA located at Mineralogy Laboratory, Ehime University, Japan. SEM-EDS analysis used to investigate the morphology (Figure 2) and geochemistry of pristine young fossil corals (Sayani *et al.*, 2011). Geochemistry analysis was selected using Mg/Ca ratio from SEM-EDS calculation.

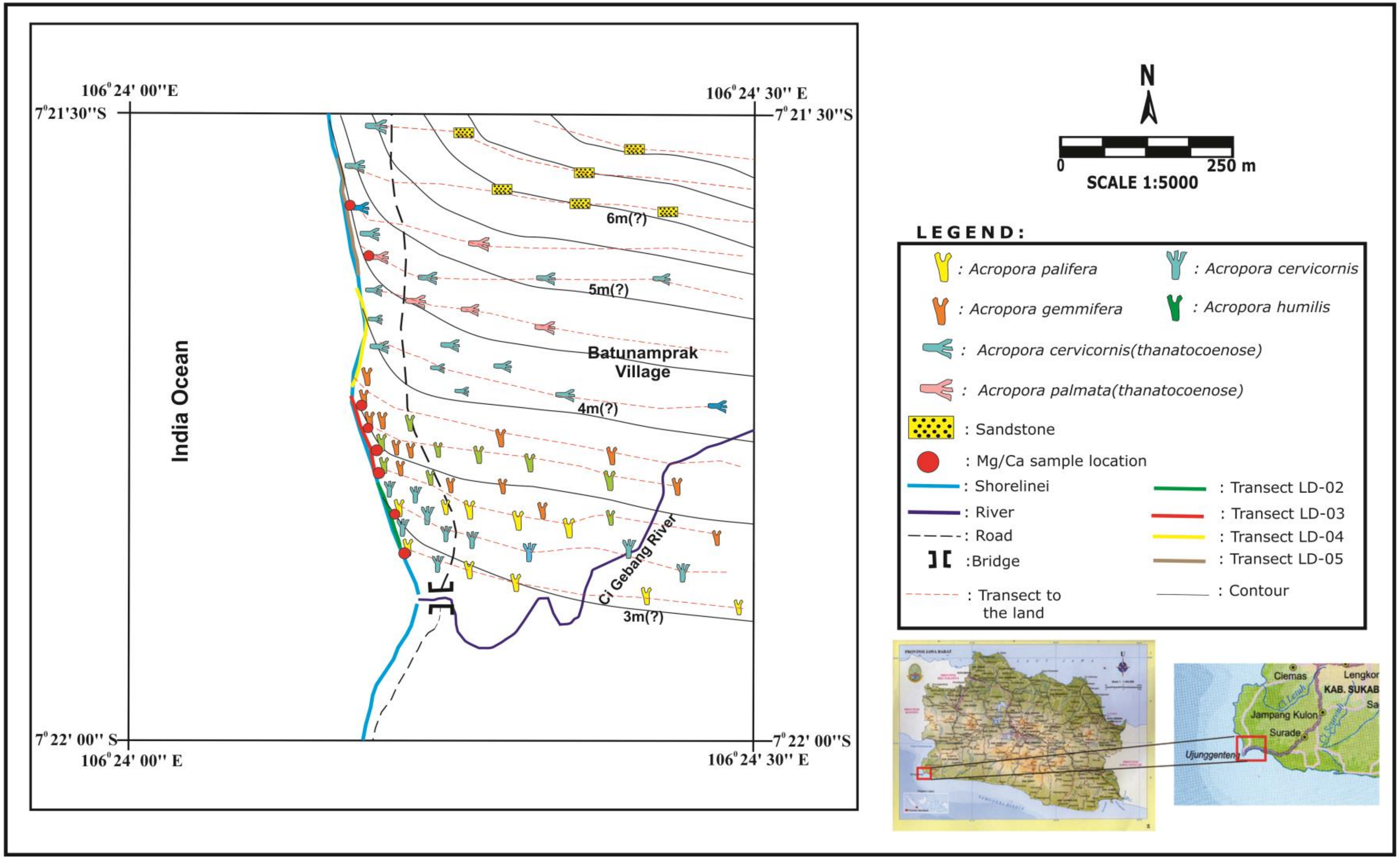

Figure 4. The map of coral distribution in Ujunggenteng Area.

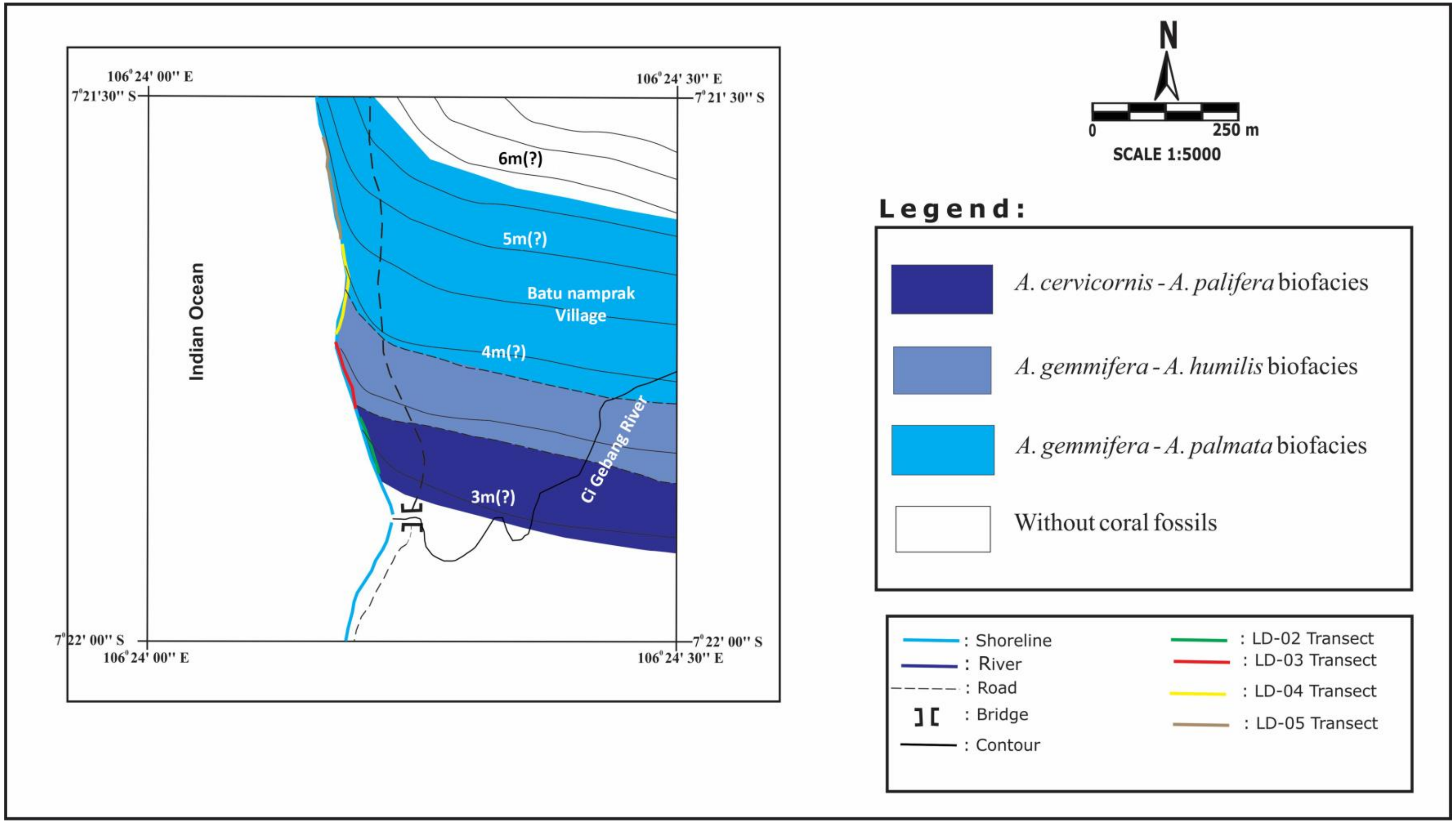

Figure 5. Biofacies map based on *Acropora* corals in the Ujunggenteng Area.

RESULT AND DISCUSSION

Coral Biofacies

Coral fossils in Ujunggenteng area were classified into Acropora genus. The genus Acropora has the characters of the family *Acroporidae* (*synapticulotheca*, simple septa, and no columella or dissepiments). Acropora was defined by its mode of growth, in which a central or axial corallite extends and buds off subsidiary or radial corallite at branch tips (Wells, 1956; Wallace, 1978; Veron and Wallace, 1984). For detail taxonomy, species of Acropora genus can be divided based on growth form, shape of branches diameter, and the angle between branches (Wallace and Dai, 1997; Van der Meij and Visser, 2011). Five species can be identified from Acropora corals in Ujunggenteng area, namely *Acropora cervicornis, Acropora palifera*, *Acropora gemmifera*, *Acropora humilis,* and *Acropora palmata*. The photograph of this species can be seen in Figure 3. The distribution of coral fossils in Ujunggenteng area can be seen in Figure 4.

Coral fossil distribution and association were used as primary constraint to developed carbonate biofacies. Biofacies was characterized by two corals domination in each of facies. The nomenclature of biofacies indicated that the first word is the dominant coral at the facies.

The name of the other species found was used as the second word. Based on that, Ujunggenteng area can be distinguished into three carbonate biofacies (Figure 5): *Acropora cervicornis – Acropora palifera* biofacies, *Acropora gemmifera - Acropora humilis* biofacies, and *Acropora cervicornis – Acropora palmata* biofacies.

Acropora cervicornis – Acropora palifera biofacies occupies the southern area in Ujunggenteng. The characteristic of this facies is the dominancy of Acropora cervicornis and *Acropora palifera* with biocoenose condition. Another organism contained on this biofacies is *Favosites* and *Fungia* on thanatocoenose condition. The paleobathymetry analysis indicated that *Acropora cervicornis – Acropora palifera* biofacies was deposited in 8 – 13 meters depth (Gabioch *et al.*, 1999; Goreau and Wells, 1967).

Acropora gemmifera - Acropora humilis biofacies can be found in the middle part of Ujunggenteng area. Domination of *Acropora gemmifera* and *Acropora humilis* with biocoenose condition is the main characteristics of this biofacies. Broken mollusks and undetermined coral fragments were found in this biofacies. The paleobathymetry analysis indicated that this facies was deposited in 3 – 8 meters depth (Wallace, 1999; Goreau and Wells, 1967).

This biofacies occupies the northern part of Ujunggenteng area. *Acropora cervicornis* and *Acropora palmata* with thanatocoenose condition is the primary characteristic of this biofacies. All of corals were preserved as fragmented materials, but the ornament of coral still can be identified.

Paleoecology

Coral is one type of organism that susceptible to ecology changes (Wilson, 1975). Several paleoecology factors, which influence the coral growth, consist of temperature (Glynn, 1984;

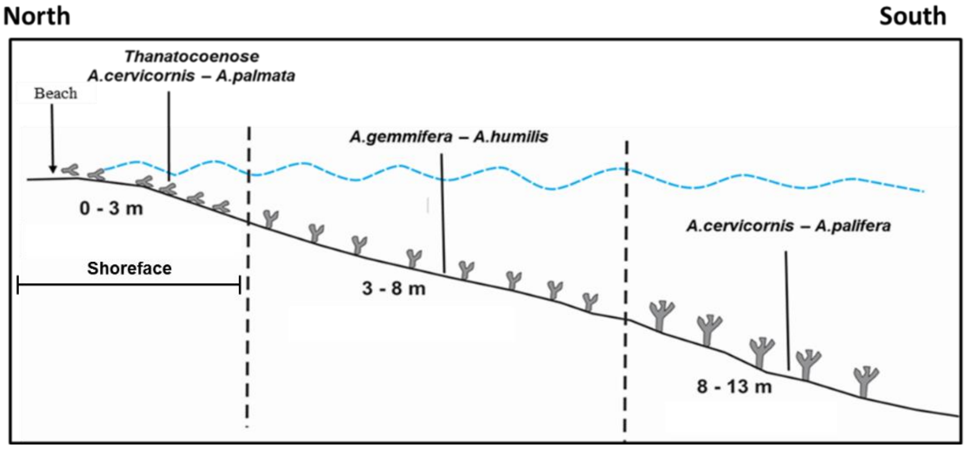

Figure 6. Paleobathymetry model of carbonate biofacies in Ujunggenteng area.

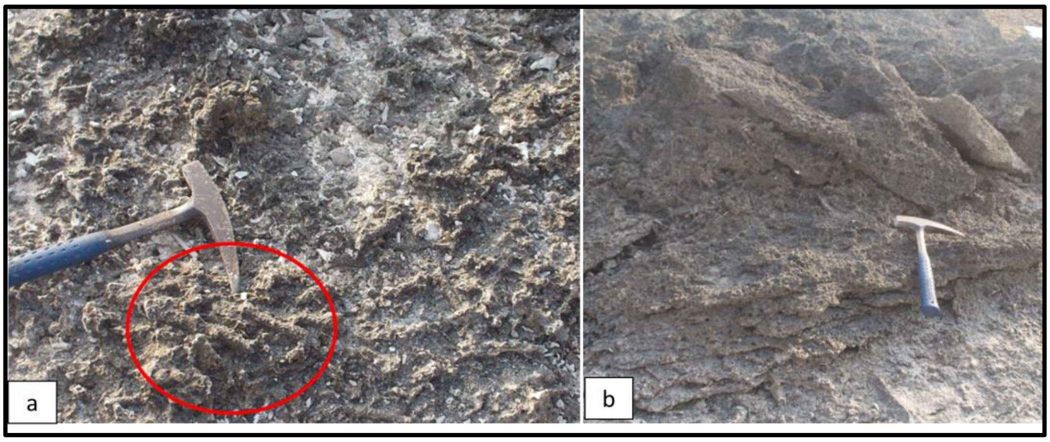

Figure 7. *Acropora cervicornis* in thanatocoenose condition (red circle) which associates with shoreface sediment (left) and the photograph of shoreface sediment shows hummocky cross bedding structure (right).

Table 1. Mg/Ca ratio result from *Acropora* corals in Ujunggenteng area.

Coral species	Transect	Mg/Ca (mmol)
Acropora cervicornis	LD-05	24
Acropora palmata	LD-05	23
Acropora gemmifera	LD-03	21
Acropora gemmifera	LD-03	20
Acropora humilis	LD-03	20
Acropora humilis	LD-03	17
Acropora palifera	LD-02	15
Acropora palifera	LD-02	14

James and Borque, 1992), bathymetry (Gabioch *et al.*, 1999), sediment stress (Hernadez-Delgado *et al.*, 2010), and water turbidity (Hernadez-Delgado *et al.*, 2010). Paleoecology factor was revealed in this study including paleobathymetry and paleotemperature trend. The paleobathymetry was analyzed from coral association and biofacies (Figure 6). *Acropora cervicornis* – *Acropora palifera* is the deepest coral facies in Ujunggenteng area. Both corals grew in 8 – 13 meters depth. Moved to the north, *Acropora gemmifera* - *Acropora humilis* was deposited in a shallower paleobathymetry than *Acropora cervicornis* – *Acropora palifera*. This biofacies showed paleobathymetry in 3 – 8 meters depth. *Acropora cervicornis* – *Acropora palmata* biofacies is occupied in the northern part of research area. Both corals were observed in thanotocoenose condition. This biofacies was deposited in the shallowest paleobathymetry. Because of thanatocoenose condition and associates with shore face sediment (Figure 7), both corals in this facies were transported from deeper environment to shallower environment, and deposited in 0 – 3 meters depth around shore face environment. The transport mechanism of coral fragments might be triggered by storm waves, which eroded and created the mechanical destruction of corals. The nature of storm waves can be observed by various sizes of coral fragments and associated with hummocky cross lamination sandstone (Figure 7).

Paleotemperature trend was analyzed based on Mg/Ca ratio trend. The result of Mg/Ca ratio from coral fossils in Ujunggenteng area can be seen in

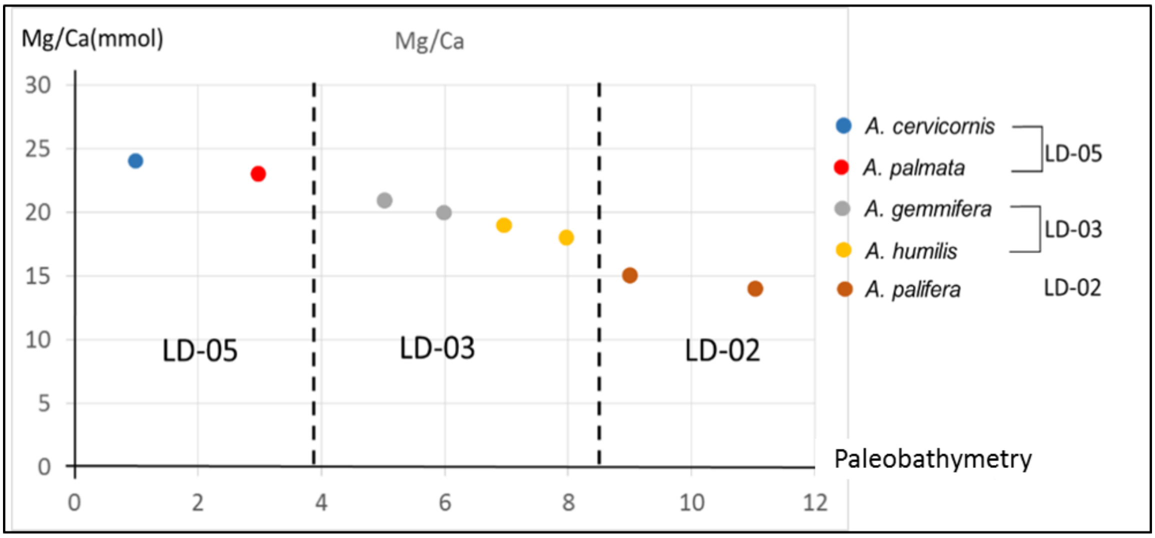

Figure 8. Cross plot between Mg/Ca ratio with paleobathymetry.

Table 1. Cross plot analysis between paleobathymetry and Mg/Ca ratio was conducted to find the relationship between them (Figure 8). The trend shows in the cross plot indicated that the decreasing of Mg/Ca ratio has correlation with the increasing paleobathymetry. The similar trend was published from several previous studies. Vielzeuf, *et al.*, (2013) revealed the similar relationship between paleobathymetry and Mg/Ca ratio from the samples from Marseille (France) and Madras (Spain).

The negative trend between Mg/Ca ratio and paleobathymetry were related to paleotemperature. Decreasing of Mg/ Ca ratio associated with decreasing paleotemperature (Fallon *et al.*, 1999; Mitsuguchi *et al.*, 1996; Sinclair *et al.*, 1998). Increasing paleobathymetry would be followed by decreasing of paleotemperature, so that it might indicate by decreasing of Mg/Ca ratio. Based on the analysis, *Acropora cervicornis* – *Acropora palifera* biofacies, which has Mg/Ca ratio 14 – 15 mmol, grew in the coolest environment. *Acropora gemmifera* - *Acropora humilis* biofacies has Mg/ Ca ratio higher than *Acropora cervicornis* – *Acropora palifera* biofacies with 17 – 21 mmol. It was indicated that *Acropora gemmifera* - *Acropora humilis* built in warmer temperature than *Acropora cervicornis* – *Acropora palifera*. *Acropora cervicornis* – *Acropora palmata* biofacies shows the highest Mg/Ca ratio with 23 – 24 mmol. However, this value cannot represent the valid value of paleotemperature, because both corals were observed in thanatocoenose condition. It indicated that *Acropora cervicornis* – *Acropora palmata* was transported from their initial ecology.

One of coral adaptation to different environmental conditions is through variation in colony morphology. All of the biofacies in the Ujunggenteng area consist of robust branching corals. Compared to recent reef ecology, robust branching coral colonies achieve the optimum growth in the reef crest zone (Aronson, 2007; Pandolfi and Jackson, 2006). The assemblage of branching corals can be regarded as medium to high-energy, high salinity, reef crest or upper fore reef zone, at depths less than 13 meters below mean low tide level (Pandolfi and Jackson, 2006; Camoin and Montaggioni, 1994). The abundance of branching corals is a common feature in the Indian Ocean and Pacific reefs.

CONCLUSION

This study used biofacies approach as the main parameter for carbonate facies determination and explored the relationship between biofacies and paleoecology parameters. Carbonate from Ujunggenteng area can be distinguished into three biofacies: *Acropora cervicornis* – *Acropora palifera* biofacies, *Acropora gemmifera* – *Acropora humilis* biofacies, and *Acropora cervicornis* – *Acropora palmata* biofacies. The paleobathymetry analysis indicated that *Acropora cervicornis* – *Acropora palifera* biofacies grew in the deepest environment of 8 – 13 meters depth.

Acropora gemmifera – Acropora humilis biofacies live in a shallower environment of 3 – 8 meters depth. And *Acropora cervicornis – Acropora palmata* biofacies was deposited in 0 – 3 meters depth. The Mg/Ca trend has negative correlation with paleobathymetry result, and positive correlation with paleotemperature. A decreasing Mg/Ca ratio was related to an increasing paleobathymetry, while a decreasing Mg/Ca ratio was followed by a decreasing paleotemperature.

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