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PALEONTOLOGY OF ACROPORA CORALS AND STANDARD FACIES BELT FROM UJUNGGENTENG AREA, WEST JAVA

PALEONTOLOGI ACROPORA KORAL DAN SABUK STANDAR FASIES DARI DAERAH UJUNGGENTENG, JAWA BARAT

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ABSTRACT The detail taxonomy analysis was performed to classify *Acropora* corals in Ujunggenteng Area. The research area was selected because the continuously exposed Quaternary coralline limestones, indicated the high variation and wide distribution of coral fossils. Moreover, the facies changes and contacts with shoreface sediments were clearly observed in this area. Detail taxonomy based on morphological description can classify *Acropora* corals in Ujunggenteng area into four species: *Acropora cervicornis*, *Acropora palifera*, *Acropora gemmifera*, and *Acropora humilis*. The study of coral paleontology and the application of the presence of corals as a standard facies belt were still rarely performed in Indonesia. Previous studies classified the coralline limestone into one standard facies belt, which was the organic build-up standard facies belt. Another approach was required to capture many conditions of coral fossil occurrences; not only in build-up condition but also in transported condition. Therefore, another purpose of this study is to modify the standard facies belt with a different approach using coral taphonomy and sediment association.

Keywords: Acropora, taxonomy, taphonomy, standard facies belt.

ABSTRAK *Analisis taksonomi secara detil dilakukan untuk mengklasifikasikan koral Acropora di daerah Ujunggenteng. Daerah penelitian dipilih karena tersingkapnya batugamping terumbu berumur Kuarter yang menerus, yang menunjukkan tingginya jumlah spesies dan distribusi fosil koral yang luas. Selain itu, perubahan fasies dan kontak dengan batupasir pantai dapat jelas diamati pada daerah ini. Taksonomi detil berdasarkan deskripsi morfologi dapat mengelompokkan koral Acropora di daerah Ujunggenteng menjadi empat spesies:* Acropora cervicornis, Acropora palifera, Acropora gemmifera, dan Acropora humilis. *Selain itu, studi mengenai paleontologi dan penggunaan kehadiran koral sebagai dasar pembagian sabuk standar fasies batugamping masih jarang dilakukan di Indonesia. Studi sebelumnya mengelompokkan batugamping terumbu menjadi satu sabuk standar fasies, yaitu build-up organik. Pendekatan yang lain diperlukan untuk menjelaskan kondisi koral lainnya pada batugamping, tidak hanya dalam kondisi tumbuh, tetapi juga dalam kondisi tertransportasi. Oleh karena itu, penelitian ini bertujuan untuk memodifikasi sabuk standar fasies dengan pendekatan berbeda menggunakan tafonomi koral dan asosiasi sedimen.*

Kata Kunci: *Acropora, taksonomi, tafonomi, sabuk standar fasies.*

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INTRODUCTION

Coral fossils are one of the essential components for the limestone characteristic. Several limestones in Indonesia were developed by coral fossils, which were called coralline limestone (Tomascik et al., 1997; Wilson, 2002). However, the detailed studies on the description and the taxonomy aspect of coral fossils have never received the primary attention. Several studies had reported the coral descriptions and applications. Premonowati (1996) introduced coral species as biostratigraphy zonation, which was applied in Rajamandala Limestone. Another study was published by Leloux and Renema (2007) who collected many coral samples in Timor and made the systematic taxonomy.

During a geology process, coral skeletons adapted with the process while live organisms buried, preserved and become part of fossils and geological records (Pandolfi, 2001). The study of many processes (including geology) that responsible for living organism to fossil preservation is called Taphonomy (Brett and Baird, 1986; Pandolfi, 2001). All of biology and geological records (including physic, environment, and sedimentation parameter) can be observed and reconstructed based on fossil data.

In Ujunggenteng Area, previous coral studies were revealed by Sukamto (1975) and Santoso *et al.* (2007). Sukamto (1975) noted the occurrence of coral fossils as quaternary coral limestone. The detail observation was performed by Santoso et al., (2017), which explained that the occurrence of coral fossil and classified the biofacies in Ujunggenteng area into three biofacies and showed the paleoecology based on coral species. To complete Santoso et al., (2017), this research creates a detailed taxonomy of *Acropora* paleontology in the Ujunggenteng Area.

Moreover, the condition of coral fossils can be used as the main indication of carbonate standard facies belt. The previous standard was proposed by Wilson (1975), which created a standard facies belt of limestone based on lithology characteristics and descriptions. The coralline limestone was classified into one standard facies belt, organic build-up. However, the appearance of coral fossils was not only in build-up condition but also in transported condition. The transported conditions were usually accumulated where the area near the source of organic build up had dense and close coral fragments. The coral fragments decreased farther away from the organic build-up source. Therefore, the purpose of this study is to modify the Wilson (1975) standard facies belt using coral taphonomy and sediment association, which is applied in the Ujunggenteng Area. Therefore, the standard can accommodate the occurrence of coral fossils in any conditions.

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

METHODS

The research area was selected along Ujunggenteng beach, West Java, Indonesia, with coordinates 7^0 21 '30"- 7^0 22' 30" Latitude and 106^0 24 '12.2 "- 106^0 25' 30" Longitude (Figure 1). Quaternary coralline limestone exposed along Ujunggenteng Beach (Sukamto, 1975), which showed wide distribution and well preserved coral. The younger age of (Holocene) fossils, (Sukamto, 1975), indicated that the taphonomy and geology processes were well recorded in the coral fossil.

A detail transect was performed to capture coral distribution, coral species, and geological record. Fifty samples were collected and cleaned to get the clear coral description. The samples from fieldwork were collected and cleaned by soaking process using hydrogen peroxide (H_2O_2) in the Paleontology Laboratory, Institut Teknologi Bandung. The samples were then stored as paratype material. The species identifications and some marks of taxonomic terms were based on taxonomic arrangements and descriptions from Wallace and Dai (1997) and van der Meij and Visser (2011).

RESULT AND DISCUSSIONS

Systematic taxonomy

Branching corals in Ujunggenteng area is classified into *Acropora* genus. The genus *Acropora* has the characters of the family Acroporidae with simple septa and no columella or diseppiments (Wells, 1956; Wallace, 1978; Veron and Wallace, 1984). The systematic taxonomy for *Acropora* coral is :

Kingdom	: Animalia Linnaeus,1758
Phylum	: Cnidaria Linnaeus,1758
Class	: Anthozoa Ehrenberg, 1834
Subclass	: Zoantharia deBlainville, 1830
Order	: Scleractinia Bourne, 1900
Suborder	: Astrocoeniina Vaughan and Wells, 1943
Family	: Acroporidae Verrill, 1902
Genus	: *Acropora* Oken, 1815

There are 4 (four) *Acropora* species found in the Ujunggenteng area: *cervicornis, palifera, gemmifera, and humilis.*

<u>(1) *Acropora cervicornis*</u>
Acropora cervicornis Lamarck, 1816
Madrepora cervicornis Lamarck, 1816
Madrepora cervicornis Pourtalés, 1871
Acropora cervicornis (Lamarck) Goreau and Wells, 1967
Acropora cervicornis (Lamarck) Veron, 2000
Acropora cervicornis Wallace and Dai, 1997

These corals have the complete morphology and fossilized in good condition. They have recrystallized, arborescent colony, branches spread horizontally, tubular branches, with diameter 26 – 34 mm and primary branches at 45 to 55 degrees angles (Figure 2). The paleoenvironment of *Acropora cervicornis* had depth range of 3 -30 meters (Jaap, 2002), with the optimum reproduction in 8 – 18 meters as a part of the fore reef zone. Some of this species were

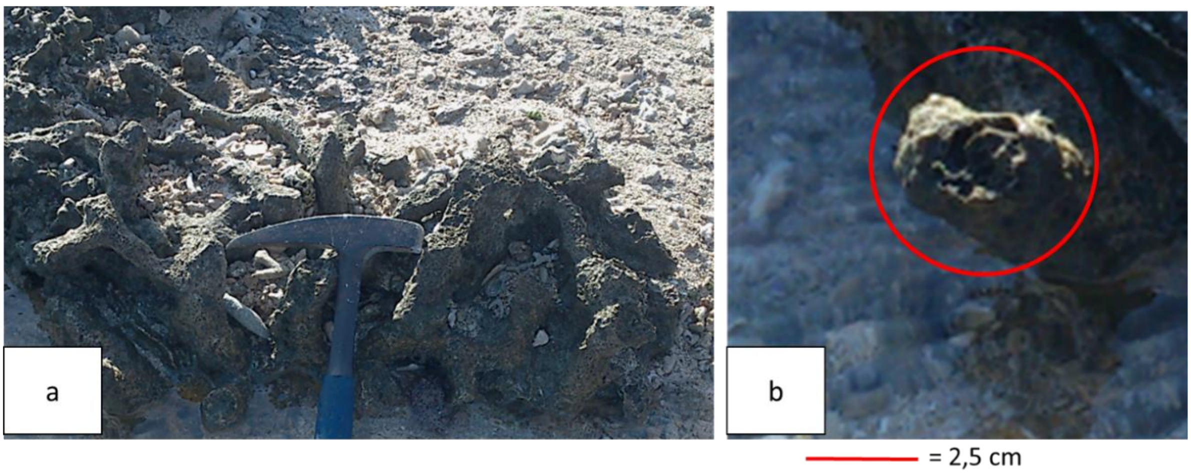


Figure 2. (a) *Acropora cervicornis* from Ujunggenteng area (Santoso et al., 2017); (b) tubular branches shape (red circle) of *Acropora cervicornis*.

reported could survive in 50 meters depth (Goreau and Wells, 1967). The location of these fossils in Ujunggenteng area is in the coordinate 7^0 21' 55'' latitude and 106^0 24' 16'' longitude.

<u>(2) *Acropora palifera*</u>

Acropora palifera Lamarck,1816
Acropora palifera Lamarck,1816
Isopora palifera (Lamarck) Pourtalés, 1871
Acropora palifera Wallace and Dai, 1997

The corals have the complete morphology and fossilize in good condition. They had undergone a recrystallization process and digitate colony. The branches were usually upright with a thick and short size. The diameters were around 20 – 22 mm. The top of branches was flattened. Primary branches were large, and close together with the angles 13 to 15 degrees (Figure 3). The species was reported to live in 5 – 15 meters depth. *Acropora palifera* found in the deeper parts of reef flat, reef slopes and sub-tidally. Sometimes occurred in encrusting forms on the reef edge with the bathymetry around 8 – 14 meters (Wallace and Dai, 1997). The location of the fossils in Ujunggenteng area is in the coordinate of 7^0 21 '45'' latitude and 106^0 24' 20'' longitude.

<u>(3) *Acropora gemmifera*</u>

Acropora gemmifera Brook,1892
Madrepora gemmifera Brook, 1892
Acropora gemmifera Veron and Wallace, 1984
Acropora gemmifera Veron, 1986:
Acropora (Acropora) gemmifera Wallace and Dai
Acropora (Acropora) gemmifera Wallace and Wolstenholme, 1998
Acropora (Acropora) gemmifera Wallace, 1999
Acropora gemmifera Veron, 2000

The corals have the complete morphology and fossilized in good condition. Corals had undergone the recrystallization process, in digitate - corymbose colony. The branches had tubular shape, slightly terete, thick and short, 22 – 24 mm in diameter, and up to 50 mm long. Primary branches were narrow and small, with the angles 18 to 20 degrees (Figure 4). This species occurred in a shallow, tropical reef environment. It was found on exposed upper reef slopes and flats, intertidally and subtidally on reef tops, upper slopes, and submerged reefs (Wallace, 1999) with depth about 1 - 15 meters. The location of these fossils in Ujunggenteng area is in the coordinate of 7^0 21' 45'' latitude and 106^0 24' 15'' longitude.

<u>(4) *Acropora humilis*</u>

Acropora humilis Dana,1846
Madrepora humilis Dana, 1846
Acropora humilis Moll, 1983
Acropora humilis Veron and Wallace, 1984:
Acropora humilis Veron, 1986
Acropora (Acropora) humilis Wallace and Dai, 1997
Acropora (Acropora) humilis Wallace and Wolstenholme, 1998
Acropora (Acropora) humilis Wallace, 1999
Acropora humilis Veron, 2000

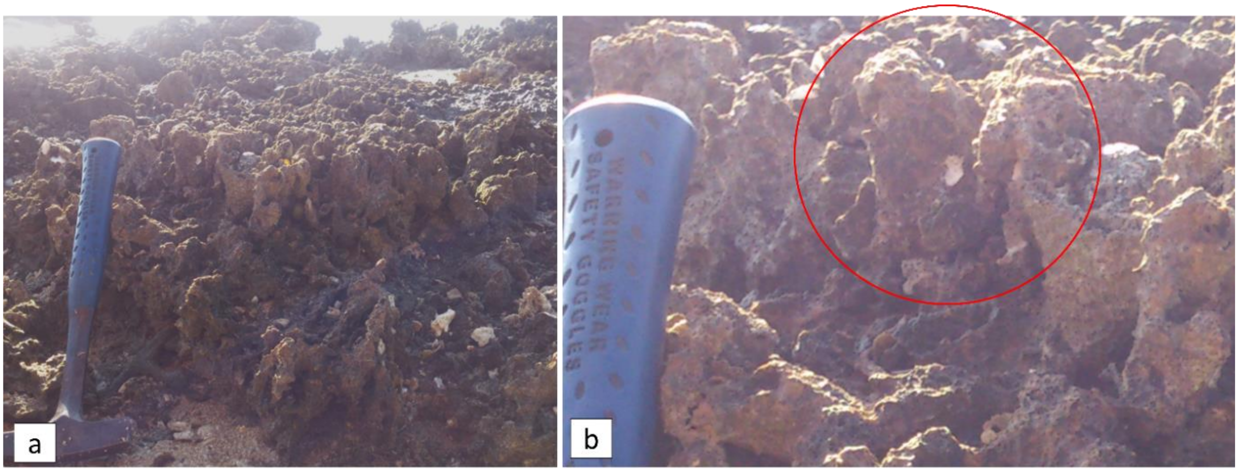


Figure 3. (a) *Acropora palifera* from Ujunggenteng area (Santoso et al., 2017); (b) *Acropora palifera* branch with upright position, thick and short shape (red circle).

Figure 4. *Acropora gemmifera* from Ujunggenteng area (Santoso et al., 2017).

Figure 5. *Acropora humilis* from Ujunggenteng area (Santoso et al., 2017).

The corals had a complete morphology and fossilized in good condition. They had undergone the recrystallization process and had corymbose colony. The branches were tapering or slightly terete. Branches shapes were thin and small. Finger-like branches arises vertically with diameter 20 – 22 mm. Primary branches are wide with the angles 20 – 30 degrees (Figure 5). This species occurred in a shallow, tropical reef environment. They were found on exposed upper reef slopes and reefs flats, intertidally and subtidally on reef tops. This species was considered to be a main reef-framework builder and was found in 5-11 meters depth (Gabioch et al., 1999). The location of the fossils is in the coordinate 7^0 21' 45" latitude and 106^0 24' 15" longitude.

Carbonate Standard Facies Belt

Carbonate standard facies belt is the terminology to describe a laterally continuous similar facies and characteristic of carbonate along a strike from shore to basin (Schlager, 2005). The succession of carbonate facies belt was published by Wilson (1975) (Figure 6) and widely used by many researchers in Indonesia. For example, Nugroho (2016) used this standard facies belt to explain the distribution and evolution of Rajamandala Carbonate evolution.

Belt	BASIN	OPEN SEA SHELF	DEEP SHELF MARGIN	FORESLOPE	ORGANIC BUILD UP	WINNOWED EDGE SANDS	SHELF LAGOON OPEN CIRCULATION	RESTRICTED CIRULATION SHELF & TIDAL FLATS	EVAPORITES ON SABKHAS - SALINAS
Diagrammatic cross section & Facies Number	1	2	3	4	5	6	7	8	9
Facies	a) Fine Clastics b) Carbonates c) Evaporites	a) Carbonates b) Shale	Toe of Slope carbonates	a) Bedded fine grain & slumps b) Foreset debris & lime sands c) Lime mud mases	a) Boundstone b) Crust on accumulations of debris lime mud; bindstone c) Bafflestone	a) Shoal lime sands b) Islands w. dune sands	a) Lime snad bodies b) Wackestone-mudstone areas, bioherms c) Areas of clastics	a) Bioclastic wackestone, lagoons and bays b) litho-bioclastic sands in tidal channels c) Lime mud-tide flats d) Fine clastic units	a) Nodular anhydirte & dolomite on salt flats. b) Laminated evaporites in ponds
Lithology	Dark shale or silt, thin limestones (starved basin); evaporite fill w. salt	Very fossiliferous lime-stone interbedded with marls; well segregated beds.	Fine grain limestone; cherty in some cases.	Variable, depending on water energy upslope; sedimentary breccia and lime sands	Massive limestone-dolomite	Calcarenitic-oolite lime sand or dolomite	Variable carbonate and clastics	Generally dolomite and dolomitic limestone	Irregularly laminated dolomite and anhydrite, may grade to red beds
Color	Dark brown, black, red	Gray, green, red, brown	Dark to light	Dark to light	Light	Light	Dark to light	Light	Red, yellow, brown
Grain type and depositoinal texture	Lime mudstone,; fine calcisiltites	Bioclastic and whole fossil wackestone; some calcisiltites	Mostly lime mudstone with some calcisiltites	Lime silt and bioclastic wackestone-packstone; lithoclastics of varying sizes	Boundstones and pockets of grainstone; packstone	Grainstones well sorted; rounded	Great variety of textures; grainstone to mudstone	Clotted, pelleted mudstone & grainstone; laminated mudstone; coarse lithoclastic wackestone in channels	
Bedding and sedimentary structure	Very even mm lami-nations; rhythmic bedding; ripple cross lamination	Thoroughly burrowed; thin to medium; wavy to nodular beds; bedding surfaces show diastems	Lamination may be minor; often massive beds; lenses of graded sediment; lithoclasts & exotic blocks. Rhythmic beds	Slump in soft sedi-ments; sofeset bedding; slope bioherms; exotic blocks	Massive org. structure or open framework with roofed cavities; Lamination contrary to gravity	Medium to large scale crossbedding; festoons common	Burrowing traces very prominent	Birdseye, stromatolites, mm lamination, graded bedding, dolomite crusts on flats. Cross-bedded sand in channels	Anhydrite after gypsum; nodular, rosettes, chickenwire, and blades; irregular lamination; carbonate caliche
Terrigenous clastics admixed or interbedded	Quartz silt & shale; fine grain siltstone; cherty	Quartz silt, siltstone, & shale; well segregated beds	Some shales, silt, & fine grained siltstone	Some shales, silt, & fine grained siltstone	None	Only some quartz sand admixed	Clastics and carbonates in well segregated beds	Clastics and carbonates in well segregated beds	Windblown, land derived admixtures; clastics may be very important units
Biota	Exclusively nektonic-pelagic fauna preserved in abundance on bedding planes	Very diverse shelly fauna preserving both infauna & epifauna	Bioclastic detritus derived principally from upslope	Colonies of whole fossil organisms & bioclastic debris	Major frame building colonies with ramose forms in pockets; in situ communities dwelling in certain niches	Worn and abraided coquinas of forms living at or on slope; few indigenous organisms	Open marine fauna lacking; mollusca, sponges, forams, algae abundant; patch reefs present	Very limited fauna, mainly gastropods, algae, certain foraminfirera & ostracods	Almost no indigenous fauna, except for stromatolitic algae

Figure 6. The carbonate standard facies belt of Wilson (1975 op cit. Alnaji, 2002).

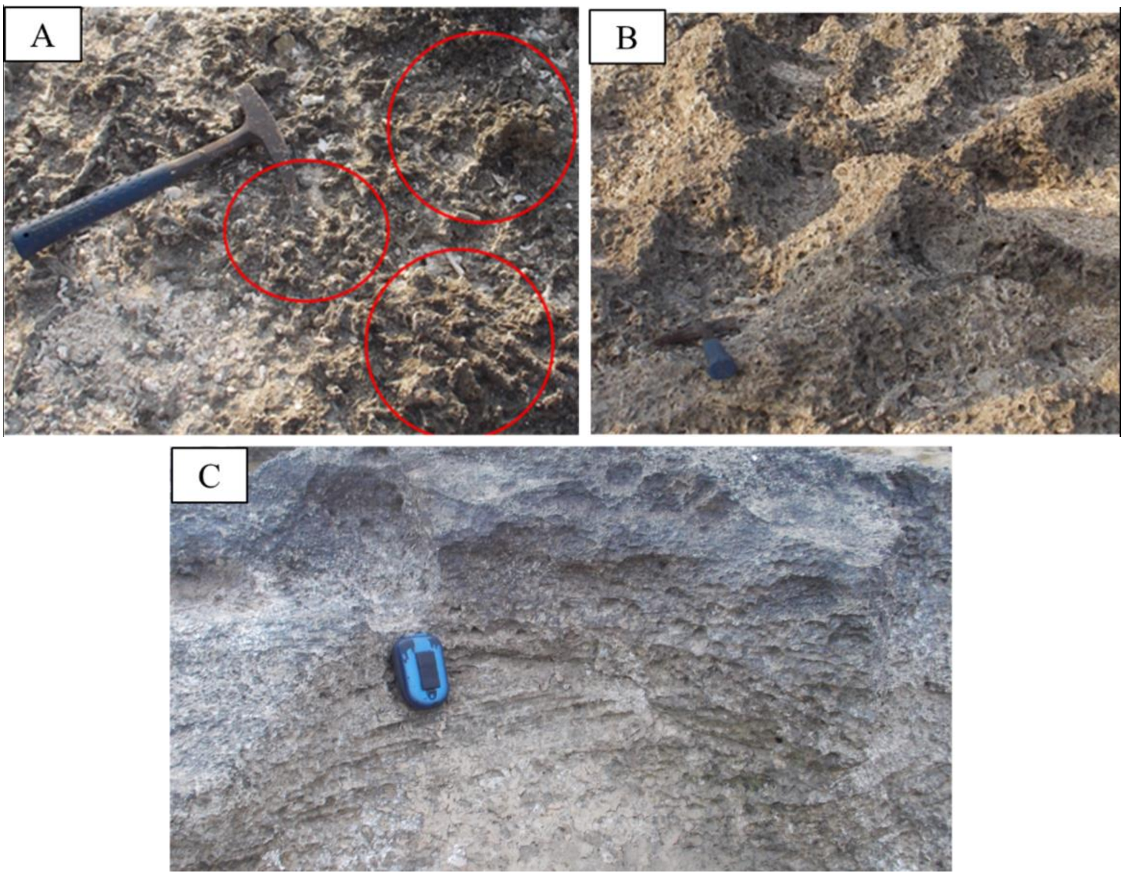


Figure 7. Shoreface - thanatocoenosis coral standard facies belt: (a) bioclastic limestone is composed by coral fragment (Santoso *et al.*, 2017). (b) Ripple structure, and (c) cross bedding are the main sedimentary structure in the shoreface sediment.

Wilson model (1975) was defined by lithology characteristic, sedimentary structure, and general biota. The dominant biota, which can be found in the carbonate, is coral. Coral was classified by Wilson (1975) into one standard facies belt called organic build-up. The occurrences of corals in the carbonate preserved in two conditions: build up and transported. Therefore, the coral can be classified into a more detailed standard facies belt based on taphonomy, with the position of fossils can be clearly observed.

The taphonomy of coral can be divided into biocoenosis and thanatocoenosis. Biocoenosis is an assemblage of fossils, which inhabited, perished, and fossilized in the similar ecology and depositional environment (Shrock and Twenhofel, 1953). The biocoenosis fossils are characterized by the undisturbed position of fossils, which represented the location when they were alive. The thanatocoenosis refers to a fossil assemblage, in which the fossil was clearly eroded and transported from their life habitat (Scrock and Twenhofel, 1953). As the excellent example, the biocoenosis fossils were a build up reef limestone and the thanatocoenosis would be a bioclastic limestone. Hence, we modified the organic build-up standard facies of Wilson (1975) into three standard facies belt based on taphonomy corals in the Ujunggenteng area: *shoreface - thanatocoenosis coral, open shelf - thanatocoenosis coral, and shelf margin – biocoenosis coral.*

(1) Shoreface - thanatocoenosis coral

This standard facies belt has the bioclastic coralline limestone and the shoreface sediment as the main characteristics (Figure 7). Broken corals from *Acropora cervicornis* were transported into small fragments, indicated the open contact and random orientation, which were exhibited the thanatocoenosis taphonomy (Figure 7a). The shoreface sediment is characterized by uniform medium sandstone with ripple and cross bedding structure (7b and 7c) (Clifton, 2006). The monotone coral variation, such as *Acropora cervicornis*, is another characteristic of this standard facies belt.

(2) Open shelf - thanatocoenosis coral

Open shelf - thanatocoenosis coral standard facies belt contains bioclastic limestone, which is composed of big and dense fragments of corals in the thanatocoenosis condition. High variation and close contact of coral fragments were found in the thanatocoenosis condition, such as *Acropora cervicornis*, *Montipora* sp., and *Merulinidae* corals (Figure 8). The primary indicators of this standard facies are big fragments (Figure 8A and 8B), close contacts (Figure 8A and 8B), uniform orientation (Figure 8C), and from different environments. *Merulinidae* corals from the upper reef slope environment, *Montipora* sp. from reef flat environment, and *Acropora cervicornis* from reef slope environment (Reza and Sancayaningsih, 2017) indicated that this standard facies belt revealed the transported coral fossils from different environments. The bioclastic limestone exhibits the close contact and uniform orientation of coral fossils. They indicated that the corals were transported by the wave energy to the shallower environment.

(3) Shelf margin – biocoenosis coral

Shelf margin – biocoenosis coral standard facies belt is characterized by high diversity corals and fossilized in the biocoenosis condition. The biocoenosis *Acropora cervicornis*, *Acropora palifera*, *Acropora humilis*, and *Acropora gemmifera* (Figure 9) were observed in the Ujunggenteng area and indicated the reef slope environment (Reza and Sancayaningsih, 2017).

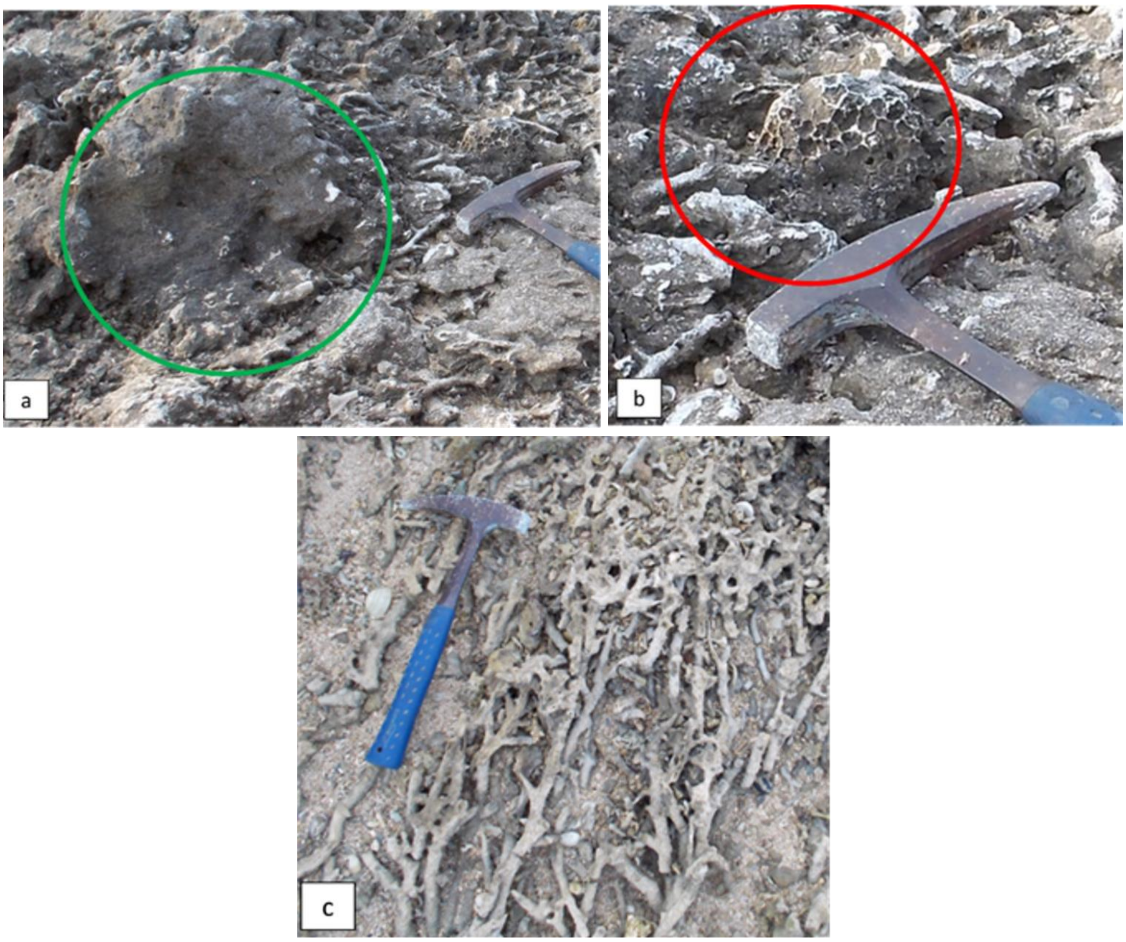


Figure 8. Open shelf - thanatocoenosis coral standard facies belt is characterized by many corals in thanatocoenosis condition: (a) *Montipora* sp. patch to *Acropora cervicornis* fragment, (b) *Merulinidae* coral shows close contact with *Acropora cervicornis* fragment (red circle), and (c) *Acropora cervicornis* with uniform orientation.

Figure 9. Shelf margin – biocoenosis coral shows the build up coral in the biocoenosis condition

Table 1. The Comparison between the standard facies in this study with Wilson (1975).

	This study (Santoso et al., 2018)	**Previous study (Wilson, 1975)**
Group of standard facies belt based on occurrence of corals	Three (Shoreface - thanatocoenosis coral, Open shelf - thanatocoenosis coral, and Shelf margin – biocoenosis coral).	One (Organic build up)
Main classification	Taphonomy	Lithology
Advantages	More detail in the coral and fossil region which consist by coral fossil	More detail in the platform environment
Organism identification	Detail in coral paleontology into species identification: *Acropora cervicornis*, *Acropora palifera*, *Acropora humilis*, *Acropora gemmifera Montipora*, and *Merulinidae*	Not too detail (foraminifera, coral, sponge, ostracods, algae); maximum into class (gastropoda)

The summary of the standard facies belt in the Ujunggenteng area can be seen in the Figure 10 and the comparison with previous standard by Wilson (1975) can be observed in the Table 1.

CONCLUSIONS

The detailed taxonomy and taphonomy approaches had distinguished the *Acropora* corals in Ujunggenteng area into four species, namely *Acropora cervicornis*, *Acropora palifera*, *Acropora gemmifera*, and *Acropora humilis*. Based on the distribution and characteristics of the fossils, a new standard facies in Ujunggenteng Area is proposed. The facies can be classified into shoreface - thanatocoenosis coral, open shelf - thanatocoenosis coral, and shelf margin – biocoenosis coral.

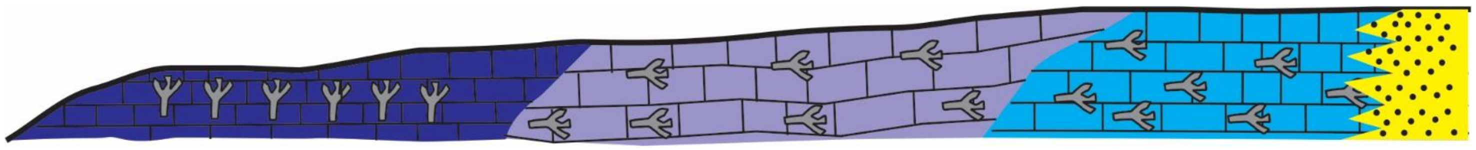
Standard Facies Belt	(Shelf margin - biocoenosis coral)	(Open shelf -thanatocoenosis coral)	(Shoreface - thanatocoenosis coral)
Cross section sketch			
Lithology characteristic	Reef build up limestone	a. Bioclastic limestone. b. Big and dense of coral fragment. c. Close contact between coral fragment	a. Bioclastic limestone b. Shoreface sandstone c. Small fragments, open contact, and random orientation of coral fragments
Sedimentary structures	Build up reef	Interbedding bioclastic limestones contain of corals fragment.	Ripple and cross bedding in the shoreface sandstone
Organism	*Acropora cervicornis*, *Acropora palifera*, *Acropora humilis*, and *Acropora gemmifera* in biocoenosis condition.	*Acropora cervicornis*, *Montipora*, and *Merulinidae* in thanatocoenosis condition.	*Acropora cervicornis* in thanatocoenosis condition. .

Figure 10. The carbonate standard facies belt in the Ujunggenteng area**.**

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