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Research Article

Porifera and Cnidaria Diversity and Paleoecology in Pleistocene Epoch at Sangiran, Indonesia

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ABSTRACT

The Kalibeng Formation of Sangiran Dome geological outcrop (Indonesia) in is an area where various fossils have been found, including ancient human fossils (*Homo erectus*), vertebrate fauna, and marine biota such as coral reefs. To date, the species diversity of fossil corals and sponges in Sangiran Dome and Indonesia, in general, is not widely known. The Sangiran stratigraphy is divided into several layers, with the lowest layer being the Kalibeng Formation, which was an ancient shallow sea, according to Brasseur et al. (2015). Further study can be conducted on the ancient corals and sponges' in Sangiran to reveal the past environmental conditions, particularly during the Pleistocene period in the Sangiran Dome area. Fossilised corals and sponges with well-preserved conditions can serve as a basis for identifying various genera member of the Phylum Porifera and Cnidaria, using specific morphological characteristics for identification. The objective of this study is to determine the genus diversity also to define diagnostic characteristics, and habitat of corals and sponges' fossils in the Plio-Pleistocene Period at Sangiran. The method used for identifying fossil samples was morphological comparison against type specimens and references. The results indicated that the identified corals and sponges were grouped into seven families that inhabits in the neritic zone. This study concludes that each coral genus (phylum Cnidaria) has distinctive corallite characteristics, while sponge genus (phylum Porifera) has distinctive spicules that are useful for identification.

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INTRODUCTION

The Sangiran Early Man Site is a location where various types of fossils have been discovered, including ancient human fossils (*Homo erectus*), vertebrate fauna, and marine biota such as corals and sponges. All fossils found in the Sangiran area and its surroundings were collected, described, and displayed in the Sangiran Early Man Site Museum exhibition room. The site is renowned worldwide as a paleontological research site and a scientific tourism destination. The Sangiran Dome area has been designated as a World Cultural Heritage Area protected by law due to its various geological and historical importance (Sukandarrumidi 2021).

The geological outcrop area of the Sangiran Dome, located in Solo, Central Java, has yielded several fossils of marine life, including foraminifera, mollusks, fish, shark teeth, corals and sponges (Yudha et al. 2013). Corals and sponges belong to the phylum Porifera and Cnidaria, they have been present on Earth since the Ediacaran period, over 600 million years ago until today. It is estimated that they first appeared molecularly around a billion years ago during the Cryogenian period and occur in nowadays Sangiran area during the Pio-Pleistocene Period (Morandini et al. 2016).

Research on identifying the characteristics of fossil corals and sponges (Porifera and Cnidaria) in Indonesia is limited. Therefore, it is necessary to conduct research on the diversity and morphology of corals and sponges' fossils in Indonesia, given the limited number of scientific publications on the subject. This research aims: 1) to identify the genus of corals and sponges' fossil collection of the Laboratory of Bioanthropology and Paleoanthropology, Faculty of Medicine, Public Health and Nursing UGM and Sangiran Early Man Site; 2) to examine morphological characteristics to compare with references and identify the genus of the collected samples; and 3) to provide additional references to the diversity of corals and sponges in Sangiran Dome.

MATERIALS AND METHODS

Materials

The study was carried out using comparative morphological method between present-day specimens with fossil collection. Present-day specimen of corals and sponges used was a collection of the Museum of Biology and Laboratory of Animal Systematics, Faculty of Biology, Universitas Gadjah Mada, and alive or in-situ specimen from Porok Beach, Gunung Kidul, Yogyakarta. Meanwhile corals and sponges' fossil analyzed were collection of the Laboratory Bioanthropology and Paleoanthropology, Faculty of Medicine, Public Health and Nursing UGM (abbreviated as LBP) and Sangiran Early Man Site (abbreviated as SEMS). There were three cnidarian fossil specimen collection of LBP; and twelve sponges and cnidarian fossil specimen collection of SEMS. We did not conduct the excavation to obtain the fossil, meanwhile, we only study fossil collection. Therefore, we were not preparing and processing anything also any geological information depends on specimen records from those institutions. Unfortunately, LBP and SEMS do not have any specific information or geological records on fossil corals and sponges of their collection; therefore, we cannot compare its stratigraphical position. The study focused on the hard parts of its morphological characteristics of the preserved fossils. We used identification guides for corals and sponges, i.e., Sponges of The New Caledonian Lagoon (Levi et al. 1998), *Jenis-Jenis Karang di Indonesia* (Suharsono 2008), and Coral Finder (Kelley 2012).

Methods

Qualitative data were obtained by inspecting morphological characteristics of each fossil coral and sponge samples with the references. Morphological characteristics data of corals obtained from present-day specimens, as well as

studying existing literature and compare original description of each genus using references from the World Register of Marine Species (WORMS) (Levi et al. 1998; Suharsono 2008; Kelley 2012). Present-day specimen used was from class Hexacorallia. The identified parts of corals include shape, surface pore distribution, surface ornamentation, texture, structure, system of waterways, size, and geometry of the inorganic skeleton. Meanwhile morphological characteristics data of sponges obtained from present-day specimens' member of the class Demospongiae. The identified parts of sponges include the colony shape, the present of osculum and ostium, and canal system structure.

RESULTS AND DISCUSSION

Summary of fossil specimens evaluated

There was a total of 15 fossil corals and sponges' specimens were identified from two sites (LBP and SEMS). Identified coral fossil consist of 8 genera, 5 families, 2 orders and 2 classes meanwhile there is only one genus of identified sponge fossil (Table 1). Both corals and sponges' fossil have a skeletal structure of limestone ($CaCO_3$) therefore well preserved.

Systematic Descriptions

Phylum Cnidaria Hatschek, 1888
Subphylum Anthozoa Ehrenberg, 1834
Class Hexacorallia Haeckel, 1896
Order Scleractinia Bourne, 1900
Family Agariciidae Gray, 1847
Pachyseris sp. Milne Edwards & Haime, 1849
Material examined: A corallum (Figure 1) collection of the Sangiran Early Man Site.
Diagnostic characters: The intact foliose colonies have sunken corallites with interconnected columella. The corallites are on one side and are immersed in indistinctly undulating walls. Septa are not visible due to erosion (Figure 1, A.2).

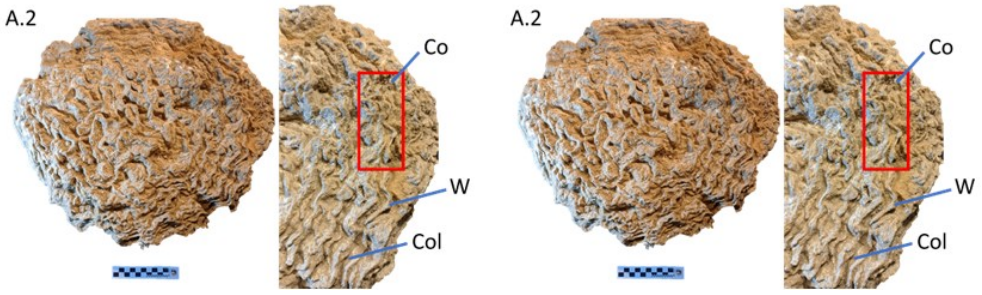

Figure 1. Fossil (A.2) corallum of *Pachyseris* sp., compared with recent specimen from Terraneo et al. (2014). Co = Corallite, Col = Columella, W = Wall.

Table 1. Classification of identified coral and sponge fossil studied.

Phylum	Subphylum	Class	Order	Family	Genus
Cnidaria	Anthozoa	Hexacorallia	Scleractinia	Agariciidae	Pachyseris
				Poritidae	Porites
				Cladocoridae	Cladocora
				Merulinidae	Favites
					Platygyra
				Oculinidae	Petrophyllia
					Oculina
Cnidaria	Anthozoa	Octocorallia	Malacalcyonacea	Tubiporidae	Tubipora
Porifera	–	Demospongiae	Indeterminate	Indeterminate	Indeterminate

Family Poritidae Gray, 1840
Porites sp. Link, 1807
Material examined: A corallum (Figure 2) collection of the LBP UGM, the fossil was found from Sangiran area (Sangiran's finding).
Diagnostic characters: The colonies are massive and the corallites are cerioid, less than 2mm in diameter, making the septa small. The surface appears smooth and hummocky (Figure 2).

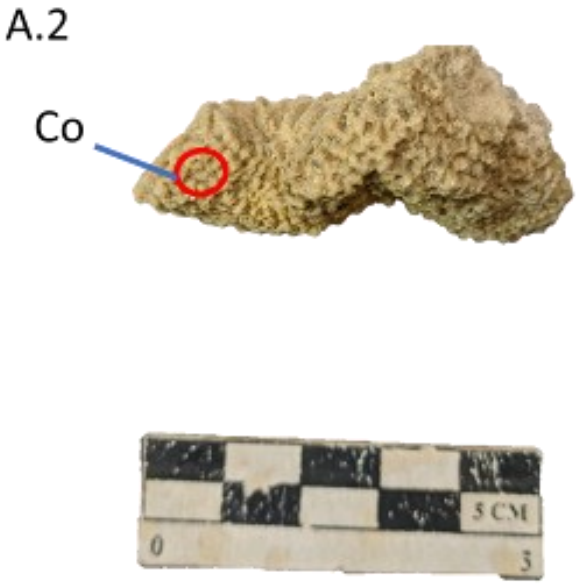

Figure 2. Fossil (A.2) corallum of *Porites* sp., compared with recent specimen from Samiei et al (2013). Co = Corallite

Family Cladocoridae Milne Edwards & Haime, 1857
Cladocora sp. Ehrenberg, 1834
Material examined: A corallum (Figure 3) collection of the Sangiran Early Man Site.
Diagnostic characters: The colonies are corymbose and form tight clumps. The corallites are tube-like and phaceloid in shape, with spacing between them. The septa and columella develop with the conesteum forming fine streaks. (Figure 3, A.2).

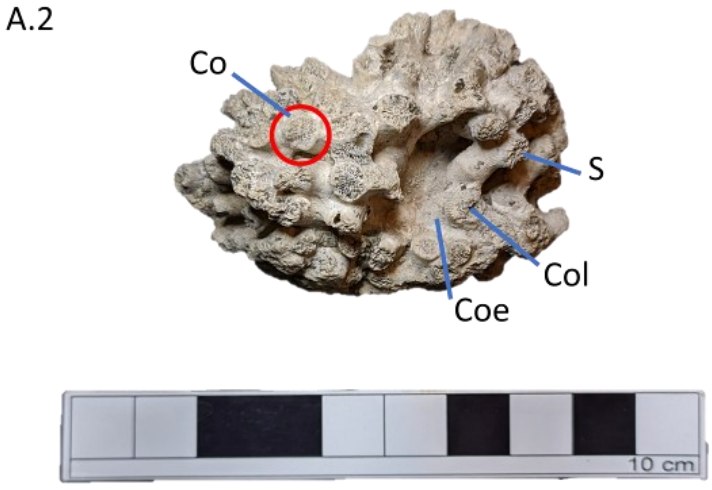

Figure 3. Fossil (A.2) corallum of *Cladocora* sp., compared with recent specimen from Hoeksema and Vicente (2014). Co = Corallite, Col= Columella, Coe = Conesteum , S= Septa.

Family Merulinidae Verrill, 1865
Favites sp. Link, 1807
Material examined: 4 specimens of corallum (Figure 4) collection of the Sangiran Early Man Site.
Diagnostic characters: Colonies are massive, cerioid corallites with smooth septa (Figure 4, B-D). Due to fossilisation, the septa appear to be lost (Figure 4, E) and there are no prominent paliform lobes.

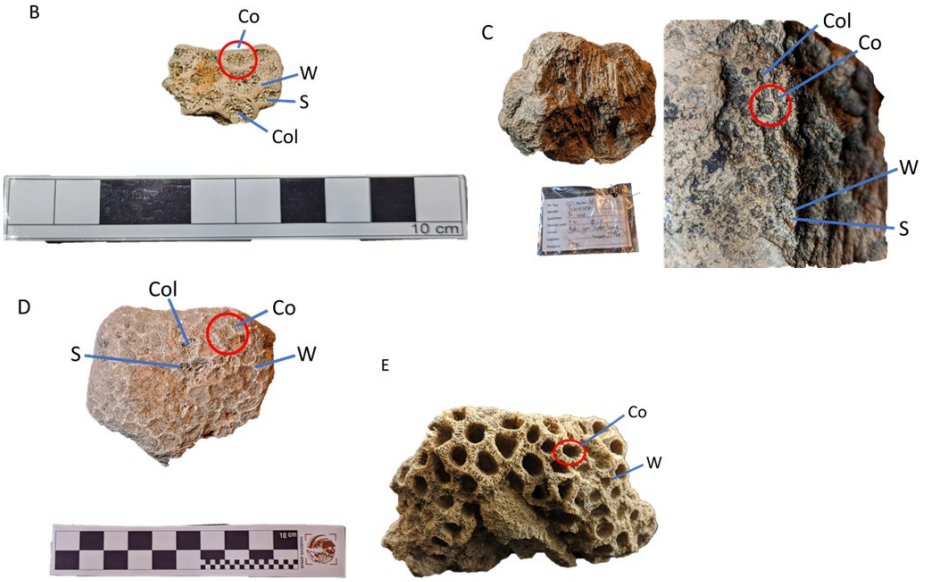

Figure 4. Fossils (B-E) corallum of *Favites* sp., compared with recent specimen from Khalil et al (2021). Co = Corallite, Col= Columella, W= Wall, S= Septa.

Platygyra sp. Ehrenberg, 1834
Material examined: 3 specimens of corallum (Figure 5) collection of the Sangiran Early Man Site.
Diagnostic characters: The colonies are massive and consist of corallites of the meandroid (Figure 5, B-C) and subcerioid to submeandroid (Figure 5, D). The columella appears to be interconnected and the septa are thinly developed with the absence of paliform lobes.

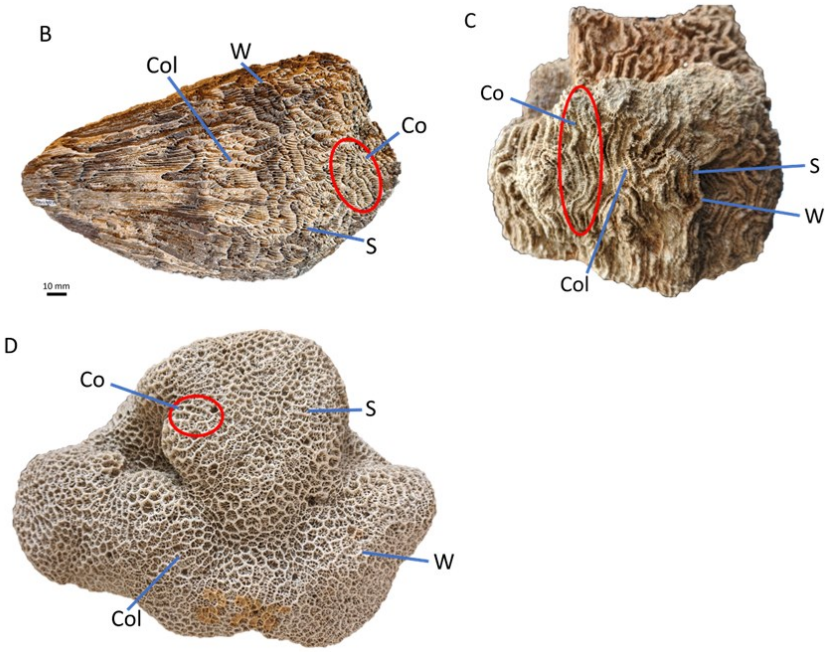

Figure 5. Fossils (B-D) corallum of *Platygyra* sp., compared with recent specimen from Khalil et al (2021). Co = Corallite, Col= Columella, W= Wall, S= Septa.

Family Oculinidae Gray, 1847
Petrophyllia Conrad, 1855
Material examined: A corallum (Figure 6) collection of the Sangiran Early Man Site.
Diagnostic characters: The colonies have a ramose growth form with plocoid-type corallites and irregular branching. The septa and columella develop with a smooth conesteum, particularly when maturing. This coral has both radial corallites and axial corallites (Figure 6).

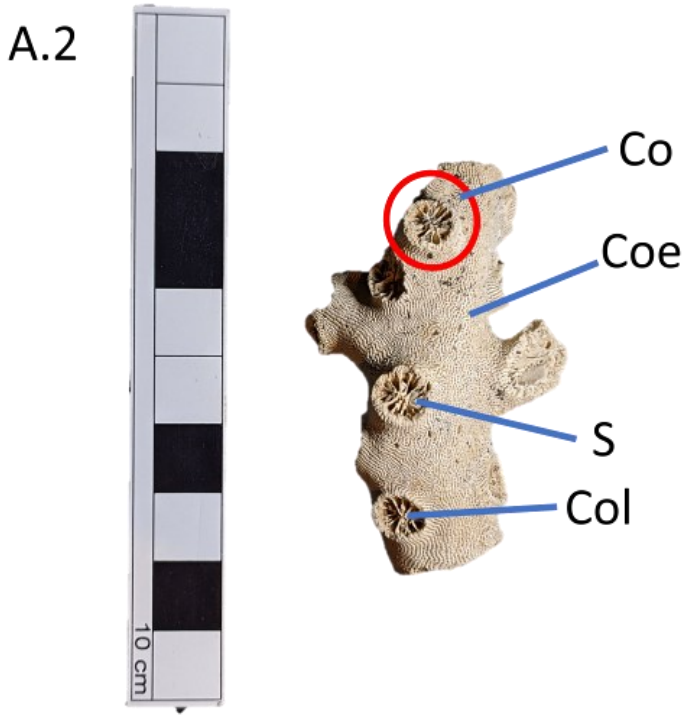

Figure 6. Fossil (A.2) corallum of *Petrophyllia* sp., compared with recent specimen from Cairns and Kitahara (2012). Co = Corallite, Col= Columella, Coe = Conesteum, S= Septa.

Oculina sp. Lamark, 1816
Material examined: A corallum (Figure 7) collection of the Sangiran Early Man Site.
Diagnostic characters: The coral consists of branching colonies of radial corallites with a distance between each corallite. The corallites sink with fine septa and the surface of the conesteum is textured with fine strokes. this coral has only radial corallites (Figure 7).

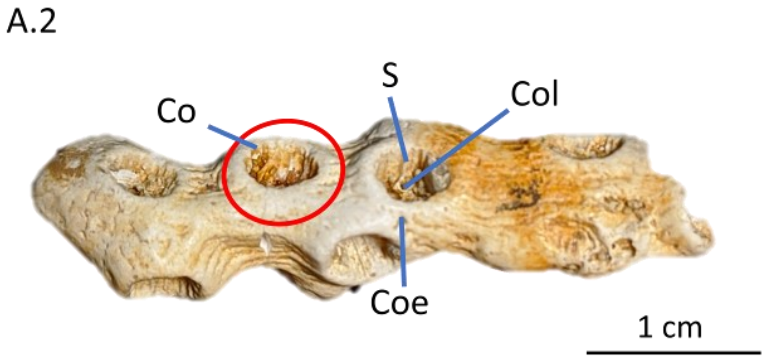

Figure 7. Fossil (A.2) corallum of *Oculina* sp. compared with recent specimen from Hoeksema and Vicente (2014). Co = Corallite, Col= Columella, Coe = Conesteum, S= Septa.

Phylum Cnidaria Hatschek, 1888
Subphylum Anthozoa Ehrenberg, 1834
Class Octocorallia Haeckel, 1866
Order Malacalcyonacea McFadden, van Ofwegen & Quattrini, 2022
Family Tubiporidae Ehrenberg, 1828
Tubipora sp. Linnaeus, 1758
Material examined: 3 specimens of corallum (Figure 8) collection of the LBP UGM, the fossil was found from Sangiran area (Sangiran's finding).
Diagnostic characters: The colonies consist of tubular, towering pipes with phaceloid-type corallites. The walls of the corallites have a porous structure (Figure 8, B-C).

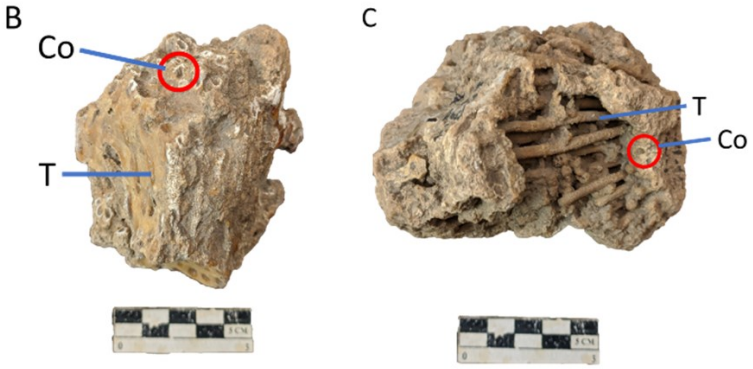

Figure 8. Fossils (B-C) corallum of *Tubipora* sp. compared with description from Richards (2018). Co = Corallite, T= Tabulae.

There was one fragment fossil which was a little bit difficult to identify (Figure 9). First, we identified as *Callyspongia* Duchassaing & Michelotti, 1864 but then, there is a suggestion that the fossil can also be *Clathria basilana* Lévi, 1961. Those two genus were possible due to the similarity of their morphological characters. To identify present-day sponges is by molecular analysis or analyze its spicules or skeleton, therefore we only determine this sponge fossil until class rank which is Class Demospongiae.

Class Demospongiae Sollas, 1885
Material examined: A fragment (Figure 9) collection of the Sangiran Early Man Site.
Diagnostic characters: The upper part features a water outlet (Osc) and the outer side serves as a porous water inlet (Os). The sponge of the tube group has a broad spongocoel with an asconoid water flow type (Figure 9).

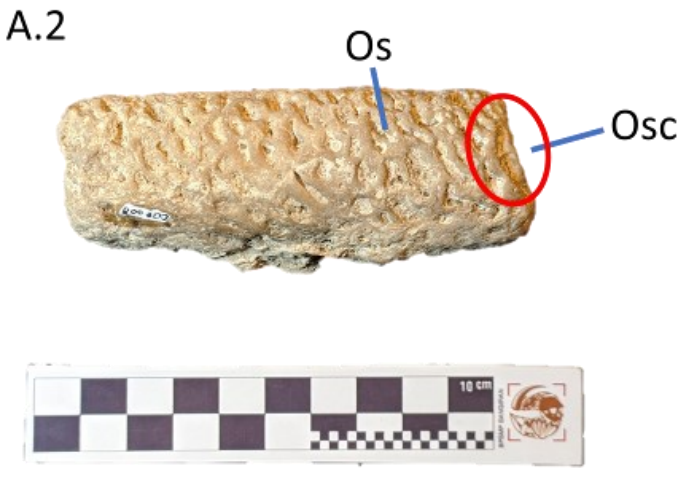

Figure 9. Fossils (A.2) fragment fossil of Demospongiae. Osc= Osculum, Os = Ostia.

Paleo-Environmental Implications

The discovery of coral and sponge fossils in the Kalibeng Formation of the Sangiran Dome provides information about marine condition in the past. Kalibeng Formation of the Sangiran Dome is the oldest layer, found in the center, and aged about 2 million years based on the study of magnetic polarity in the Sangiran area (Sémah et al. 2000).

Understanding the paleoecology of an area based on coral and sponge fossil is based on comparison with recent species or genus, therefore correct determination of coral and sponge's species or genus is a crucial. The ecological niche of these fossil species or genus then compare to the same species or genus which can still be found in the present time (Holocene Period).

Presence of these eight-coral genus and sponge fossils indicates a marine environment, with warm and clear water. A clear environment is required to prevent the callus from being infiltrated and covered by fine-grained sediments. Cnidarians requires sunlight during its life. Presence of cnidarians fossil indicates that in Sangiran during the Lower Pleistocene was shallow marine environment which far from river mouth (delta). These cnidarian fossils can only live in normal marine conditions; therefore, presence of cnidarians fossil also indicate normal salinity. Most corals and sponges tend to live and develop on hard, non-muddy seabed; therefore, these fossils can also be a substrate indicator. Seawater circulation is very important for coral reefs to receive nutrients (Sukandarrumidi 2021).

A total of eight fossil coral genera and one sponge genus were identified from the Kalibeng Formation. The fossil corals and sponge genus identified indicate that the Kalibeng Formation was a shallow marine environment. The upper Kalibeng layer consists of bluish-grey clays and mudstones and also contains marine mollusks (*Arca*, *Chione*, *Nassarius*, *Turritella*), foraminifers, and diatoms deposited during the Early Pleistocene transitions. These mollusks habitats characterize the coastal marine habitats (Faylona 2019).

CONCLUSIONS

There were eight genera of identified coral fossils and one fragment of sponge fossil which indeterminate. The eight genera of coral fossil were *Pachyeseris*, *Porites*, *Cladocora*, *Favites*, *Platygyra*, *Petrophyllia*, *Oculina*, and *Tubipora*. The indeterminate genus of sponge fossil was classified as Class Demospongiae. Palaeoecological reconstruction of the Kalibeng Formation in Sangiran Dome based on the coral and sponges' fossils indicated a shallow marine environment of the neritic zone based on habitat comparisons with present-day similar genus of corals and sponges.

AUTHOR CONTRIBUTION

F.A.A. collected, analysed the data, and wrote the manuscript. D.S.Y. validated data, reviewed, and wrote manuscript. All authors have read and approved the manuscript for publication.

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CONFLICT OF INTEREST

There are no competing interests.

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