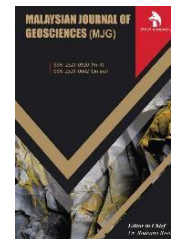


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## REVIEW ARTICLE

## LARGE FORAMINIFERA FROM LIMESTONE IN THE RAJAMANDALA FORMATION, SUKABUMI, WEST JAVA

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## ABSTRACT

Rajamandala Formation is a limestone reef formation that is exposed in the Rajamandala - Sukabumi area, West Java. Different from those in the Rajamandala area, this formation which is located in the Sukabumi area is still rarely analyzed, especially from its large foraminifera. This study aims to assess the content, age, and depositional environment of reef limestone from the Rajamandala Formation based on large foraminifera. Research method was carried out in several stages. Sampling was done by spot sampling as many as 6 samples. Then, thin section observations was carried out using Olympus CX-22 binocular microscope. Finally, age and environmental analysis were carried out using basic biostratigraphic methods and cluster analysis based on the fossil content of large foraminifera. Result, the limestone reefs of Rajamandala Formation in Sukabumi area have varied material content. These rock ages were found to be in the Late Oligocene range (Chattian). This rock depositional environment is in shallow marine environment which is divided into 3 main clusters. The first cluster is dominated by *Austrotrilina* and *Borelis* which shows the Backreef shelf environment. The second cluster is dominated by *Heterostegina* and *Cycloclypeus* which shows the Forereef shelf environment. Finally, the third cluster is dominated by all large foraminifera representing the Reef environment. When compared with previous studies, the limestone of Rajamandala Formation in Sukabumi and Rajamandala areas has the same age and depositional environment.

## KEYWORDS

Content, Rajamandala Formation, Large Foraminifera, Reef, Sukabumi.

## 1. INTRODUCTION

Indonesia is low latitude archipelagic country located in Southeast Asia with tropical climate (Schneider, 1998; Julismin, 2013; Hall, 2017). This condition makes Indonesia have complex atmosphere and sea circulation which is very important for the surrounding area (Song et al., 2006; Sprintall et al., 2014). From this, Indonesia is a country that has very high marine diversity, one of which is shown by the richness of coral reefs (Renema, 2007). Limestone is sedimentary rock resulting from organic, chemical, or mechanical processes associated with the development of coral reefs in an area (Natasia and Alfadli, 2018). The organic process occurs by the development of the carbonate skeleton and shell by various biota ( $\text{CaCO}_3$ ). These biota include protists, algae, and other animals that make up biogenic sediments (Hallock, 1997). Biota in limestone in the form of foraminifera can be used as indicator of how the condition of limestone grows and develops in an area. (Langer and Hottinger, 2000).

Foraminifera are marine organisms belonging to unicellular protists with shells mostly composed of  $\text{CaCO}_3$  (Hottinger, 1982; Terakado et al., 2010; Saraswati and Srinivasan, 2015). These creatures live in the intertidal region to the bottom of photic zone because the foraminifera are in symbiosis with the presence of algae to form additional energy. (Hohenegger et al., 1999). Large foraminifera is one of the divisions of foraminifera based on their size characteristics (3-300  $\mu$ ). These large

foraminifera can live in water environments with warm, shallow, and tropical characteristics in oligotrophic conditions (Saraswati and Srinivasan, 2015).

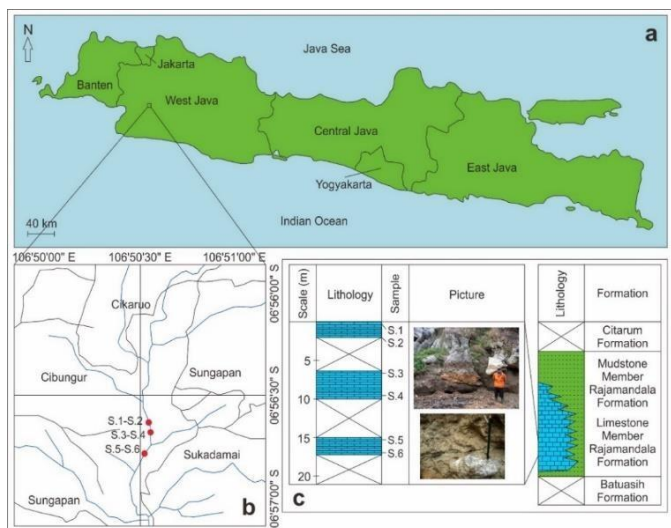
Rajamandala Formation is one of formations in the Bogor Basin which has an old limestone lithology. The overall thickness of this formation reaches 60 – 100 m (Hutabarat, 1971; Sudrajat, 1973). This formation is generally divided into 2 members, the Limestone Member at the bottom and the Mudstone Member at the top (younger) (Figure 1c). Rajamandala Formation extends in southwest-northeast direction from the Sukabumi area to the Rajamandala Padalarang area. Rajamandala Formation in the Padalarang area has been widely studied before (Siregar, 2005; Siregar and Mulyadi, 2007). Meanwhile, Rajamandala Formation in the Sukabumi area has not been studied much, especially from large foraminifera aspect. Based on previous studies that were analyzed using small foraminifera and nanofossils, Rajamandala Formation has Late Oligocene – Early Miocene age range. Furthermore, this formation is interpreted to have Shallow Sea depositional environment (Effendi et al., 1998; Martodjojo, 2003; Siregar, 2005; Wibowo and Kapid, 2014).

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**Figure 1:** Location and Stratigraphy of Research Area; a. Research location in relation to Java; b. Research location in relation to Base Map; c. Results of Stratigraphy and Lithology

Research location is on the Cibatu River, Sukadamai Village, Cicantayan District, Sukabumi Regency, West Java with coordinates 06° 56' 36,57" – 06° 56' 56,13" S to 106° 50' 30,85" – 106° 50' 32,10" E (Figure 1a – 1b). From this description, it can be seen that it is interesting to analyze the limestone content of Rajamandala Formation in Sukabumi area. In addition, further analysis of large foraminifera was also carried out to determine the condition of age and depositional environment from this Rajamandala Formation limestone.

**2. MATERIAL AND METHODS**

This research was conducted in several stages. First, the rocks were taken by spot sampling on several limestone outcrops of Rajamandala Formation on the Cibatu River, Sukabumi Regency, West Java (Liu et al., 2014). As a result, 6 rock samples were obtained at several points from the Rajamandala Formation. Rock samples were described in the field megascopically with the help of rock parameters. After that, the sample is prepared by making a thin section. Then the samples were described, identified, and determined using an Olympus CX-22 binocular microscope to find out the content of each research sample. Next, analysis is carried out on limestone content in the research sample which is compared with the previous reference (Adams, 1984; BouDagher-Fadel, 2018). The results of the limestone content are then analyzed by grouping and drawing ranges based on biostratigraphic principles, both age and depositional environment of each biota, especially from large foraminifera.

In addition, cluster analysis was also carried out to confirm the results of analysis. Cluster analysis is a multivariate technique that aims to classify objects into different groups. It is used to identify the similarities in the characteristics of objects that indicate certain conditions of influence (Romesburg, 2004). All of these steps are carried out to be able to interpret the conditions of Rajamandala Formation when these limestones grow and develop (Jambak et al., 2014; Patriani et al., 2016). After all interpretation and analysis is done. This research was compared with those in the Rajamandala Formation in the Padalarang area from previous studies. The results of the comparison are then concluded to determine the similarities and differences that occur from the Rajamandala Formation of these two regions.

**3. RESULTS**

**3.1 Limestone Content**

Reef limestone outcrops were found to be located on the Cibatu River. This limestone has light white to yellowish color characteristic with a lot of coral and foraminifera content. Moreover, this limestone looks massive with 7.2 meters thickness. From these outcrops, 6 samples were taken sequentially (S.1 – S.6) which represented each of the rock outcrops in study area (Figure 1c).

**Table 1: Large Foraminifera Rajamandala Formation**

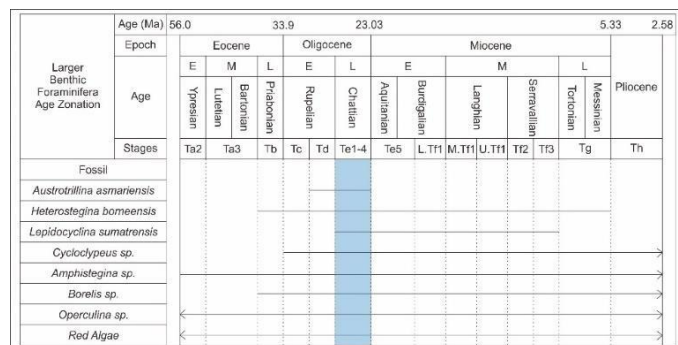
Large Foraminifera	S.1	S.2	S.3	S.4	S.5	S.6
<i>Austrorillina asmariensis</i>			1	4	1	
<i>Heterostegina borneensis</i>	11	4				2
<i>Lepidocyclus sumatrensis</i>	5	3				11
<i>Cycloclypeus sp.</i>	18	3				3
<i>Amphistegina sp.</i>	1	3				1
<i>Borelis sp.</i>		2	5	6		
<i>Operculina sp.</i>		4				
Red Algae	1	3	2			
Total	36	22	8	10	1	17

**Table 2: Material Content Rajamandala Formation**

Content (%)	S.1	S.2	S.3	S.4	S.5	S.6
Calcite	50	20	10	15	60	25
Coral	0	5	15	0	5	5
Large Foraminifera	30	20	20	30	5	45
Small Foraminifera	5	15	20	15	10	5
Algae	5	25	10	0	5	10
Other Fragments	5	10	15	30	10	5
Matrix	5	5	10	10	5	5
Total	100	100	100	100	100	100

In general, Rajamandala Formation has quite diverse limestone content, some samples are dominated by large amounts of calcite (S.1 and S.2), other sample are dominated by large foraminifera (S.6), and the other samples have a wide variety of limestone content. When viewed from the large foraminifera content, at least 95 individual foraminifera which are divided into 7 species were identified. The most dominant foraminifera were obtained from the *Cycloclypeus sp* as many as 24 individuals. While the least identified foraminifera came from the *Operculina sp* as many as 4 individuals. When viewed from the sample, sample S.1 has the most identified foraminifera as many as 36 individuals and sample S.5 has the least identified foraminifera as many as 1 individual (Table 1 - 2).

**3.2 Age Analysis**



**Figure 2:** Age Range of Rajamandala Formation from Large Foraminifera Analysis (Adams, 1976; BouDagher-Fadel, 2018)

Age analysis was carried out by drawing the biostratigraphic zone from all research samples. As a result, Rajamandala Formation was deposited at Late Oligocene (Chattian) age which belongs to the large foraminiferal zone Te1-4. This age was drawn based on interval zone between the early appearance of *Lepidocyclus sumatrensis* and the late appearance of *Austrorillina asmariensis* (Figure 2). Basically, *Lepidocyclus sumatrensis* was only present and developed in Southeast Asia starting in Late Oligocene as a result from evolution of *Lepidocyclus isolepidinoides* species. This *L. sumatrensis* then evolved into *L. verbeeki* with changes influenced by the nepionic chamber conditions of each of these large foraminifera (Adams, 1976; BouDagher-Fadel, 2018). While *Austrorillina asmariensis* is species that developed until the Late Te which then evolved into *Austrorillina howchini* in Tf1 and became extinct throughout the *Austrorillina* genus in Indonesian territory at Early Miocene age (Tf1). In addition, the development of large foraminifera from *Heterostegina borneensis* and *Cycloclypeus sp* that were present in the study sample showed that the study sample has age not far from Oligocene. (Adams, 1976; BouDagher-Fadel, 2018).

3.3 Depositional Environmental Analysis

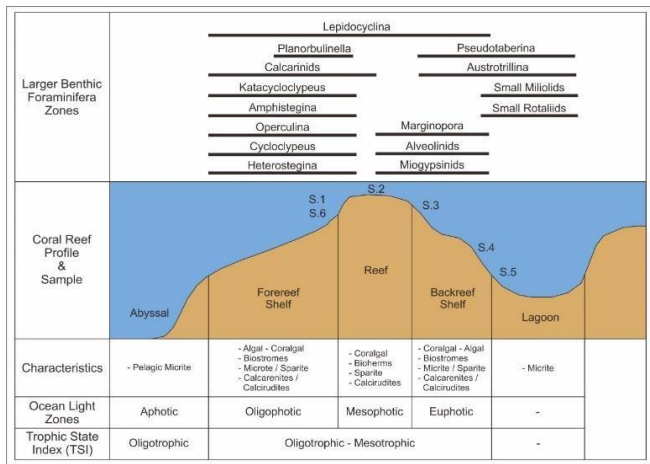


Figure 3: Depositional Environments Range of Rajamandala Formation from Large Foraminifera Analysis (BouDagher-Fadel, 2018)

The analysis of depositional environment was interpreted based on foraminifera content in research sample. Result, Rajamandala Formation in this study can be divided into 3 depositional environments. First, samples S.3, S.4, and S.5 showed that these three samples were formed in Backreef shelf environment. This can be seen by the large number of large foraminifera from *Austrorillina* and *Borelis* species (Alveolinids). These two large foraminifera basically developed well in Backreef shelf environment compared to other foraminifera. In addition, the abundance of calcite, small foraminifera, large foraminifera, and coral growth in sample S.3 indicates that this sample has very close formation site to the main reef. Meanwhile, in samples S.4 and S.5, large amounts of calcite, algae, and other fragments indicate that these samples have site of formation that is further away from the presence to the main reef. Therefore, it can be interpreted that these three samples were formed in Backreef shelf depositional environment with tendency for S.3 samples to be closer to the main reef development.

Second, samples S.1 and S.6 showed that they were formed in Forereef shelf environment. This can be seen by the presence of large foraminifera from *Heterostegina* and *Cycloclypeus* types. Basically, these two types of large foraminifera can develop well in Forereef shelf environment. In addition, the large number of *Lepidocyclus* that can live in wider environmental range also shows that samples S.1 and S.6 have depositional environment in the Forereef shelf region. When viewed from the composition, large amount of foraminifera in this sample indicates the formation area is very close to the main reef. Therefore, these two samples are interpreted to have formed in Forereef shelf depositional environment close to the main reef growth.

Last, sample S.2 shows that it was formed in Reef environment. This can be seen with the same number of large foraminifera originating from the Forereef and Backreef environment in this sample. Furthermore, when viewed from the sample content, the large number of calcite, small foraminifera, large foraminifera, and the growth of coral in this sample also indicate the conditions for main reef. Therefore, this sample is interpreted to have formed in main Reef depositional environment.

4. DISCUSSION

The analysis carried out in previous studies was mostly carried out on the Rajamandala Formation in Rajamandala area. Age of this formation is found to be in Late Oligocene - Early Miocene range (Effendi et al., 1998; Martodjo, 2003). When compared with this study, rock from Rajamandala Formation in Sukabumi area were formed at the same time as those in the Rajamandala area. This can be seen from large foraminifera analysis which shows that these rocks were formed at Late Oligocene age ( Chattian).

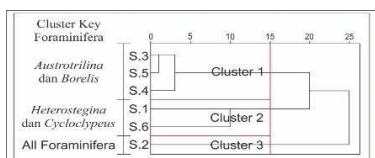


Figure 4: Cluster Analysis Results of Research Samples

Results from cluster analysis show that the research sample can be divided into three main clusters. The first cluster is cluster that shows the Backreef shelf environment. This cluster consists of 3 samples (S.3, S.4, and S.5). In this first cluster, foraminifera from *Austrorillina* and *Borelis* types (Alveolinids) show that this limestone formed in shallow marine environment with very low current conditions. These current conditions can occur in Backreef shelf environment because the currents that occur in this environment are blocked by the presence of main Reef. These two types of foraminifera are associated with each other at the rear of main Reef. When viewed based on its classification, this environmental area is in Euphotic lighting zone with a tropical index that is classified as Oligotrophic - Mesotrophic. (BouDagher-Fadel, 2018). Therefore, this first cluster is interpreted to have environment on Backreef shelf when viewed from the association of large foraminifera.

The second cluster is cluster that shows the Forereef depositional environment. This second cluster consists of 2 main samples (S.1 and S.6). In this second cluster, the large number of foraminifera from *Heterostegina* and *Cycloclypeus* types indicate that the limestones in this cluster were formed in very shallow environment (< 30 m) with soft sediments or hard sediments substrate conditions. This is interpreted because genus *Cycloclypeus* has low tolerance for lack of light and changes in temperature in shallow sea areas. In addition, the presence of *Heterostegina* and *Lepidocyclus* indicates that limestone was formed in high energy environment. When viewed based on its classification, this environmental area is in Oligophotic lighting zone with tropical index that is classified as Oligotrophic - Mesotrophic. (BouDagher-Fadel, 2018). Therefore, this second cluster is interpreted to have an environment formed on Forereef shelf with conditions close to the main Reef body which has shallow depth.

Last, the third cluster is cluster formed in the Reef environment which consists of only one sample (S.2). In this last cluster, all foraminifera dominated the research sample, both those in the Forereef shelf and Backreef shelf environments. When viewed based on its classification, this environmental area is in Mesophotic lighting zone with tropical index that is classified as Oligotrophic - Mesotrophic (BouDagher-Fadel, 2018). Due to the abundance of foraminifera with various types, it is interpreted that this cluster formed on the main Reef of Rajamandala Formation.

From all these explanations, it can be seen that the results of cluster analysis confirm the results of analysis of depositional environment based on large foraminifera. The research sample can be divided into 3 main environments, namely Forereef shelf, Backreef shelf, and Reef. The results of this study are in line with previous studies which stated that the Rajamandala Formation was formed in shallow marine environment which was divided into several facies, namely Reef facies, Forereef shelf, and also Backreef shelf (Siregar, 2005; Wibowo & Kapid, 2014). However, it is true that the Rajamandala Formation located in Sukabumi region contains foraminifera and coral that are not as abundant as those found in Rajamandala area.

From this description, it can be interpreted that the reef limestones in Sukabumi and Rajamandala areas are continuous reef limestones and are formed at the same age and environment. This reef limestone was formed at Late Oligocene age with Shallow Sea depositional environment on the Reef, Forereef shelf, and Backreef shelf. These limestones were formed when the Bogor Basin began to develop and became more visible due to the changing of northern and southern parts of Java into higher elevations. This elevation is caused by development of volcanoes associated with the Jampang Formation (Martodjo, 2003).

5. CONCLUSIONS

From the results of this study, several conclusions can be drawn. Reef limestones of Rajamandala Formation in Sukabumi region contain both calcite, coral, large foraminifera, small foraminifera, algae, and other fragments. From the age of the formation, these rocks of Rajamandala Formation has Late Oligocene ( Chattian) age. This age was drawn based on interval zone between the early appearance of *Lepidocyclus sumatrensis* and the late appearance of *Austrorillina asmariensis*. Meanwhile, from the depositional environment, this formation has shallow marine depositional environment which is divided into 3 clusters. The first cluster is dominated by foraminifera from *Austrorillina* and *Borelis* types which show Backreef shelf environment. The second cluster is dominated by *Heterostegina* and *Cycloclypeus* which shows Forereef shelf environment. Finally, the third cluster is dominated by all large foraminifera that represent Reef environment. When compared with previous studies, the limestones of Rajamandala Formation in Sukabumi



and Rajamandala regions have the same age and depositional environment.

## ACKNOWLEDGEMENT

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## APPENDICES

### Plate 1

- Sample S.1
- a. *Amphistegina* sp.; Vertical Incision
- b – d, f. *Cycloclypeus* sp.; Vertical Incision
- e, h – j. *Heterostegina borneensis*; Vertical Incision
- g. Red algae
- k. *Lepidocyclusina sumatrensis*; Horizontal incision

### Plate 2

- Sample S.4
- a. *Austrorillina asmariensis*; Vertical Incision
- b – c. *Borelis* sp.; Vertical – Horizontal incision
- Sample S.3
- d – h. *Borelis* sp.; Vertical – Horizontal incision
- i. Red algae
- Sample S.2
- j. *Amphistegina* sp.; Vertical Incision
- k. *Borelis* sp.; Horizontal incision
- l. *Operculina* sp.; Horizontal incision
- m. *Lepidocyclusina sumatrensis*; Vertical Incision
- n. *Cycloclypeus* sp.; Vertical Incision
- o. Red algae
- p. *Heterostegina borneensis*; Vertical Incision

### Plate 3

- Sample S.5
- a. *Austrorillina asmariensis*; Vertical Incision
- Sample S.6
- b. *Amphistegina* sp.; Vertical Incision
- c – e. *Cycloclypeus* sp.; Vertical Incision
- f. *Heterostegina borneensis*; Vertical Incision
- g – m. *Lepidocyclusina sumatrensis*; Vertical – Oblique Incision

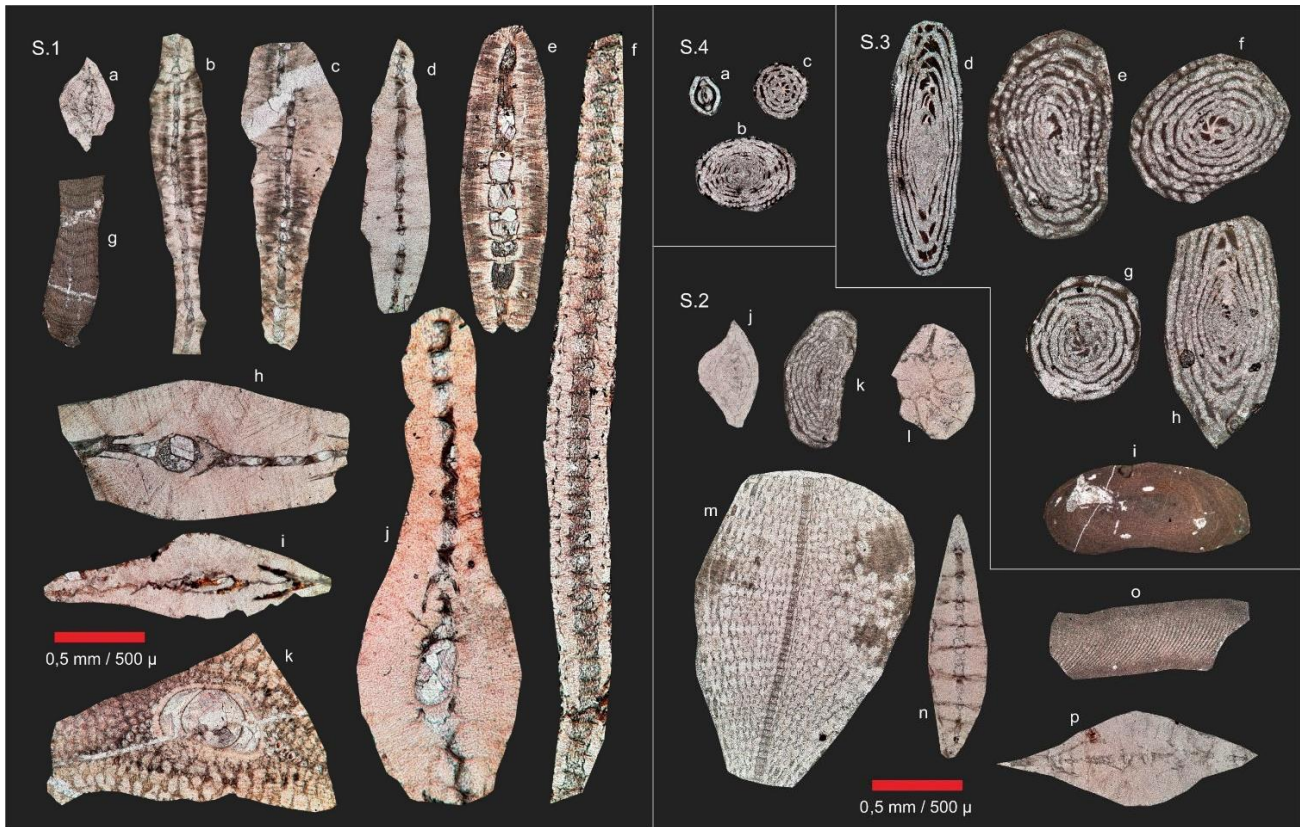


Plate 1

Plate 2

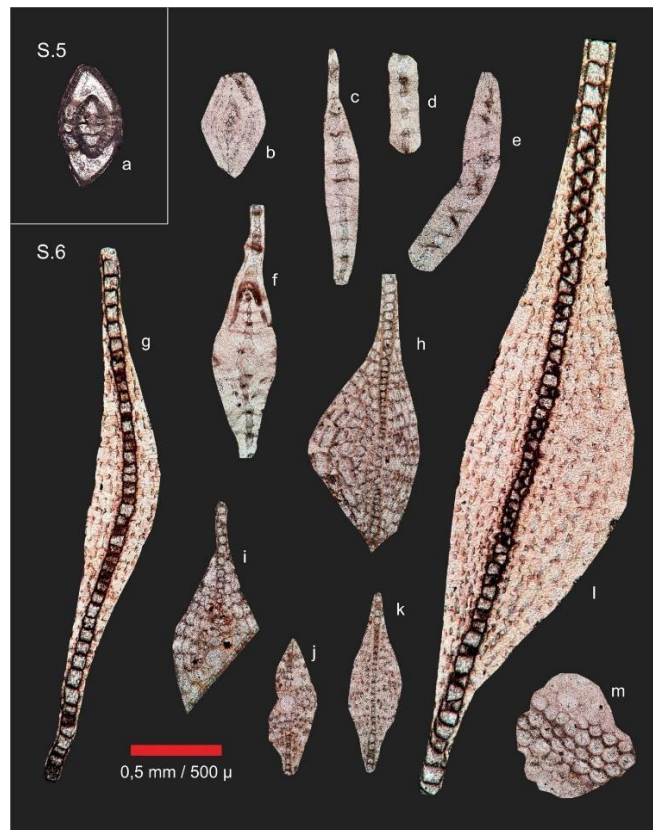


Plate 3

