The Preliminary Study of Late Oligocene to Early Miocene Calcareous Nannofossil in Klias Peninsula, Sabah

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Abstract. Klias Peninsula comprises of five different lithostratigraphic units which are, Temburong, West Crocker, Setup Shale, Belait, and Liang formations. The study area is one of the onshore outcrops of the western side of Sabah mainland which contributed to the high potential of hydrogen exploration within the Temburong Formation. There is still a lack of calcareous nannofossils study in terms of academic purposes, hence a systematic preliminary research study had been conducted to find the taxonomic diversity of the calcareous nannofossils within the age of late Oligocene to early Miocene. This study aims to identify the taxonomy classification of the calcareous nannofossil based on the morphology features. Coccosphere has been distinguished by two different taxonomic classifications of coccoliths and nannoliths. Coccoliths are the most discussed for their morphology and classified into two basic mode holococcoliths and heterococcoliths. Nannolith morphology feature is complex and classified as a heterogeneous group. Thirty-four samples from Kuala Penyu to Menumbok areas of Sabah were collected. A simple smear method used to prepare all the samples. Light microscope (LM) observations used to identify the taxonomy and calcareous nannofossil classification aided by plane-polarized (PPL) and cross-polarized (XPL) nicols with 800x magnification. Apart from that, there were diverse taxa that had been discovered such as, Braarudosphaera bigelowii, Discoaster deflandrei, Cyclicargolithus abisectus, Cyclicargolithus bukryi, Coccolithus pelagicus, Thoracosphaera saxea, Alisphaera sp. and Reticulofenestra bisecta.

1. Introduction

The research was conducted at the western part of the Klias Peninsula which was started from Kuala Penyu to the Menumbok area. The study area was located in the south-western part of the Sabah mainland. Generally, it is well-known as the Paleogene-Neogene sediments that comprise of five lithostratigraphic units, Temburong, West Crocker, Setup Shale, Belait and Liang Formations [1]. This paper is focused on the calcareous nannofossil assemblages from Temburong Formation. The distribution of the Temburong Formation dominated the study area. Stratigraphically, the formation is the same as the Crocker Formation and distinguished by three different lithofacies which are thin sandstone unit, the interbedded sandstone with thin shale unit and the interbedded thick shale with thin sandstone unit.

Previously, the calcareous nannofossil analysis had been dominated by the petroleum industry that carried out the onshore mapping projects for the paleontological analysis focused on correlating the
sedimentary facies at equivalent geological ages. However, this paper more discussed on the prospect of academic study. The significance is to identify the taxonomy assemblages of the calcareous nannofossil abundance within the age of late Oligocene to early Miocene. The correlation of the biostratigraphy to the formation, convincing the previous planktonic foraminifera analysis in Temburong Formation [2]. Besides, the calcareous nannofossil assemblages observed based on understanding specific morphology features and taxonomy classification.

2. Study Area

![Figure 1. The stratigraphy of Klias Peninsula [4]](image)

Generally, Sabah is known as East Malaysia and constructed by complicated geology elements which reflected the extreme kinematics complexity of the South China Sea region [3]. The main geological elements of Sabah categorized and demonstrated into four-phases which are pre-Tertiary core, Cretaceous-Early Palaeogene, Paleogene Basins and Neogene Basins.

Geologically, Sabah is located at the intersection of the two mega-TECTONIC trends which are NW–SE Sulu Trend and NE – NW Borneo Trend [5]. Klias Peninsula is the study area located in the south-western part of Sabah and it is comprised by five different types of rock units. The metamorphic and igneous complex (hornblende schists and gneisses; amphibolites, tonalities, granodiorites, and granites) dominated the pre-Tertiary core. The Sapulut, Trusmadi, and Crocker formations dominated the Cretaceous-Early Paleogene, and the chert-splite formation, The Madai-Baturong limestone. Based on Figure 1, the age of the rock units that been recognized according to the ascending order, started by the oldest Crocker formation, Temburong formation, Setup Shale formation, the Belait formation and the Liang formation [4]. Meanwhile, the samples of this research been collected at 33 stations along the Kuala Penyu to Menumbok area.

3. Calcareous Nannofossil

Generally, the defined size of calcareous nannofossil is smaller than 30 microns (µm). They have been used in various ways to assist in the hydrocarbon exploration industry especially during drilling of the well site. They are exclusively known as the marine fossils and play a vital role in deep water exploration. However, this paper is focusing on understanding their morphology features and the taxonomy classification.
3.1 Coccolith Morphology Features.
Coccolith is mainly discussed for their morphology as it can be applied by a relatively consistent morphological plan with a coherent terminology [6]. However, nannolith has also been observed as it gave many preferences of their abundances through the samples. There are two basic modes of coccoliths morphology, which are holococcoliths and heterococcoliths. Its morphology is the base classification of both living and fossil members of the group. Holococcoliths constructed entirely by submicroscopic calcite crystals and mostly rhombohedra that arranged in regular order. Meanwhile, the heterococcoliths are larger and constructed by different submicroscopic elements, such as grains, rods, and plates. The three structures are combined to give a rigid formation of taxa. Heterococcoliths vary substantially in construction formation as it provides the bulk of the microfossil records. This consideration is not suitable for the holococcoliths as it eventually disintegrated after they are shed. Most of the coccolith specimens constituted by the discs of circular or elliptical outline constructed radially symmetrical plates, confined by a central area that may be empty, and also produce along the spine. Most of the calcareous nannofossil specimens from this research dominated by the coccolith as it is widely associated with formations.

3.2 Nannolith Morphology Features.
Nannoliths morphology is quite different from coccoliths as it appeared in various forms, such as complex crystal-unit shape, rotational symmetry, broadly plate-like shape or chirality. The modification of holococcoliths and heterococcoliths morphology from the ancestors (Discoaster, Nannotetra, Florisphaera, Ceratolithus) almost categorized nannoliths as an artificial group. Thus, it was defined as a heterogeneous group with a wide range of shapes. Most of the nannoliths morphology features have been used for taxonomy classification. For example, the family of Lithostromationaceae [7] with the age of Paleogene-Neogene, shows the formation of triangular, hexagonal or nearly circular nannofossils shape from small crystallites. The symmetrical arrangement of depressions covered it.

4. Methods
This section discussed the research method applied to distinguish the taxonomy of the calcareous nannofossil from 33 samples collected at the Klias Peninsula. A light microscope (LM) used in observation. Therefore, to accomplish the objectives of the research, a series of methods carried out started with the preliminary studies, fieldwork, laboratory works (smear preparation and light microscope) and classification observations.

4.1 Fieldwork
Fieldwork is the conducive work need to be done before analyzing in the laboratory. The preliminary study needs to be complete before going to the field. It was done by referring to the past researches that are related to the topic or related to the location. The micropaleontological sample collection is not as sophisticated as it undergoes several tasks in the field. The sample collection through the measuring section, bagging and logging information considered time-consuming. The samples have been collected along the Kuala Penyu to the Menumbok by referring to the stratigraphy and paleontological research.

4.2 Simple Smear Preparation
The raw sediment of samples that subsampled into 1cm² bulk of sediment been preserved with a special care. The precaution been used as avoiding them been contaminated to the surrounding, due to the small size of nannofossils. Plus, all the samples been trimmed and cleaned away all outer surfaces before the smear process been started. A simple smear slides preparation was done for light microscope observation. The preparation of the smear-slide for light-microscope analysis followed by the standard procedure that has been described by Blaj and Henderiks [8].
This method not undergo centrifuging and ultrasonic cleaning to keep the originality of the samples. The small fraction of sediment scraped by the toothpick and mix with a few drops of distilled water and spread evenly across the glass microscopic slide. A wooden toothpick is used to smear thinly across the surface of the glass slide until a thin layer of rippled material was obtained. It was a necessary technique as to get a clear recovery of the nannofossils specimen. The slide was then dried rapidly under the ultraviolet (U.V.) light or electric hotplate. Once it dries the coverslip inserted and glued by the mounting medium (Canada Balsam) to a slide, then cured under U.V. light or electric hotplate. Besides, the temperature of the electric hotplate used at the range of 60°C to 80°C, as to avoid reaching the boiling point of the mounting medium. Next, the smear slide was then observed under the polarized light microscope with x800 magnification. This method widely used by the oil and gas exploration industry and also for the research prospect. It was quick, easy to perform and low-cost compared to other methods used for coccolith analysis.

4.3 Light Microscope Observation

High-quality optics and magnification polarized light microscope used as the nannofossil size is limited by the LM resolution. The basic magnification used for this technique is in the range of x2500 to x5000. However, Leica ICC50 E polarizing light-microscope with x800 magnification has been used for this research and it resulted in the perfect images of varies types of nannofossils. Plus, the x100 immersion oil objective lens not been aided during the light microscopy analysis. Both cross-polarized light (XPL) and plane-polarized (PPL) used to get the composition, structure, preservation, and size of the coccoliths. The XPL used to get a particular feature of the holococcoliths and nannoliths. Hence, it helped in identifying and finding them in a low abundance sample.

5. Results

5.1 Systematic Taxonomy

The images of the principal taxa from the samples were illustrated into two different plates. The images are captured at a constant magnification of 50µm in both plane-polarized (PPL) and cross-polarized (XPL) observations. The descriptive morphology features and terminology of the calcareous nannofossil been discussed based on Young and Bown [9]. The higher taxonomic classification referred to the Young and Bown [9] and Young et al. [10]. They were placolith coccoliths, nannoliths and Mesozoic non-coccoliths. The further discussion of the morphology-based on the taxa ranging from upper Pleistocene to lower Eocene [11].

5.2 Placolith Coccoliths

**Order** Isochrysidales *Pascher, 1910.*
**Family** NOELAERHABDACEAE Jerkovic,1970 emend Young & Bown,1997.
Coccoliths with *Reticulonefestra*-type structure.

*Cyclicargolithus abisectus*
(Roth & Hay, in Hay et al., 1967) Bukry, 1971
Pl. 1, fig.10

Remarks: The species is quite similar to the *C. bukryi* in the shape of sub-circular formation but the size is much bigger and large (11µm). This is the most common species that could be discovered from this research. The large triangle central area also covered and partially covered by lath-shaped plates on the distal side. It is relatively stratified at the consistent range of equatorial Pacific (NP24-NP25) (Bown & Dunkley Jones, 2012).

*Cyclicargolithus bukryi* (Wise, 1973)
Pl. 1, fig.11

Remarks: This species is known as the small size (3-6µm) to medium, sub-circular placolith of two shields bright in XPL. It is exhibiting a moderate to broad central covered or partially covered by lath-
shaped plates on the distal side (approximate calcium content in between 20-25% of coccolith width). Some research suggested that this taxon has not widely used. However, five abundance events were being used and recorded as the valuable CN marker in the Gulf of Mexico. 

**Remarks:** The species is known as medium-sized (<10µm) elliptical reticulofenestrid coccolith with a holotype length of 9µm. It constructed by the central plug area and been applied differently based on the species concept of the size ranges. This image shows that, R. bisecta is attached until it formed a new anhedral shape of specimens.

**Order** Coccolithales *Schwarz, 1932.*

**Family** COCCOLITHACEAE Poche, 1931 emend. Young & Bown, 1997

**Genus** COCCOLITHUS Schwarz, 1894

*Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930

**Remarks:** It is elliptical placolith coccolith with an open central area or spanned by a disjunct bar. It is a very long-ranging, widespread and diverse species that useful classified. Two different morphotypes of *C. pelagicus* recorded in the modern nannoflora for molecular genetics and culture studies. The species have showed these are genotypically different but very closely related. Some researchers classified them into sub-species or species.

5.3 *Nannoliths*

**Family** BRAARARUDOSPHAERACEAE Deflandre, 1947

**Genus** Braararudosphaera Deflandre, 1947

*Braararudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947

**Remarks:** This nannolith constructed by a regular pentagonal dodecahedron with a closely butting plate to form a continuous cover. It sizes approximately at the range of 10-20µm with a smooth surface pentagonal shape and gently concave edges. Its sutures are running from center to approximate 3/8 alongside the pentalith with clockwise obliquity in distal view. Several pseudo-cryptic species have the same morphology with the modern *B. bigelowii* (Takano et al. 2006).

**Family** DISCOASTERACEAE Tan, 1927

**Genus** DISCOASTER Deflandre Tan, 1927

*Discoaster deflandrei* (Bramlette & Riedel, 1954)

**Remarks:** This is the most abundant species that could be discovered from this research. It is known as the 6-rayed discoaster that end the rays in strong short wide bifurcations, with a well-developed central area. There is a featureless proximal side, although the sutures may be incised. Sometimes the species has weak distal ridges on the rays and usually has a distal knob. Generally, this species is considerably diverse in size, the number of rays, degree of development of the ray bifurcations and relative size of the central area (Hay et al.,1967). It sizes approximately at the range of 10-15µm. There are five different species that originated from early Miocene to Trinidad. *D. nonaradiatus* has nine rays (includes 10-12 rays), *D. septemradiatus* has 7-8 rays and lastly *D. deflandrei* has 5-6 rays. However, it had been not very useful in calcareous nannofossil marker as it been separated or intergrade the formation. *D. aulakos* and *D. saundersii* and possible exceptions formed with small central areas. These two species originated from the end of early Miocene classified as an intermediate variety between *D. deflandrei* and *D. exilis.*
5.4 Mesozoic Non-coccoliths

Family **THORACOSPHAERCEAE** Schiller, 1930 emend. Tangen, in Tangen et al., 1982

*Thoracosphaera saxea* (Stradner, 1961)

Remarks: This species originated from the family of Thoracosphaercaceae subsequently which classified as Mesozoic non-coccoliths. This species is specified as the extant calcifying dinoflagellates which belong to a single clade. Most of the fossil calcispheres are directly related to the family of Toracosphaercaceae as suggested by the palaeontologist. The calcification evolved only once in a group, as in the haptophytes.

Family **ALISPHAERACEAE** (Young et al., 2003)

*Alisphaera* sp.

Remarks: It came from the diversity of the Alisphaeraceae family of extant coccolithophores. It is placolith-like coccoliths with asymmetrical distal flange. However, it is low abundance and produced very small coccoliths This fossil not been documented of their morphology yet but usually found in well-preserved sediments.

Plate 1. Images of selected calcareous nanofossil taxa from samples of Klias Peninsula lithostratigraphy formations. Scale bar 0.05mm. 1-6 *Braarudosphaera bigelowii* (Grand & Braarud, 1935). Parallel nicols (1,3,5) and cross nicols (2,4,6) of sample No.33 Sempadan. 7-9 *Discoaster deflandrei* (Bramlette & Riedel, 1954). Parallel nicols (7) and cross nicols (8,9) of sample No.33 Sempadan. 10. *Cyclicargolithus abisectus* (Muller, 1970). Parallel nicols of sample Te01-01. 11. *Cyclicargolithus bukryi* (Wise, 1973). Parallel nicols of sample Te01-01. 12. *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930. Parallel nicols of sample Be05-02. 13-14 *Thoracosphaera saxea* (Stradner, 1961). Parallel nicols of sample No.33 Sempadan. 15. *Alisphaera* sp. Parallel nicols
of sample No.33 Sempadan. **16. Reticulofenestra bisecta** (Hay, Mohler and Wade, 1966) Roth, 1970. Parallel nicols of sample Be05-02.

6. **Summary & Conclusions**

A total of eight different species had been discussed in the finding included their taxonomic remarks based on the light microscope observation. There are *Braarudosphaera bigelowii*, *Discoaster deflandrei*, *Cyclicargolithus abisectus*, *Cyclicargolithus bukryi*, *Coccolithus pelagicus*, *Thoracosphaera saxea*, *Alisphaera* sp. and *Reticulofenestra bisecta*. Each of the species distinguished by diverse specific morphology features and appearances. Their records show that the samples originated at the range of late Oligocene to early Miocene. However, there is Mesozoic non-coccolith at the age of Danian been observed by *Thoracosphaera saxea* and *Alisphaera* sp. which indicates the last occurrence of this species within the formation at the lower Paleogene. The correlation of the biostratigraphy to the Temburong Formation, convincing the previous stratigraphy. The light microscope observation had achieving to admirable preservation, summarizing the state of biostratigraphy for the major of the calcareous nannofossil within the range of late Oligocene to early Miocene of Klias Peninsula. Thus, the calcareous nannofossil has proven and very useful in the paleontological study. This research can be a reference for biostratigraphy and botanist that may have a plan to develop a new finding of the calcareous nannofossil species.

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