Paleoclimate of Upper Oligocene-Lower Miocene Temburong Formation, Klias Peninsula, Sabah, Base on Planktonic Foraminifera Assemblage

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Abstract. Planktonic foraminifera assemblages were studied for biostratigraphy and paleoclimatic interpretation of the Upper Oligocene-Lower Miocene of Temburong Formation, Klias Peninsula, Sabah. The Temburong Formation is composed of mainly flysch-type argillaceous deposit intercalations of slightly calcareous pelagic shale. Recently we discovered abundance of moderate to well-preserved planktonic foraminifera at the measured section and its planktonic assemblages are useful for biostratigraphy and paleoclimatic studies of Temburong Formation. A total of nine samples of shale were collected from three outcrops and processed based on standard micropaleontology method. Twenty-eight species of planktonic foraminifera were identified and grouped into three zones, namely: P21-P22 Globorotalia opima opima-Globigerina angulisuturalis zone, N4 Globigerinoides primordius-Globigerinoides quadriloculatus zone, and N5-N6 Catapsydrax dissimilis-Globigerinoides altiapetura zone. For paleoclimate studies, the relative abundance of planktonic foraminifera was obtained and grouped into climatic indices namely cool, cool-temperate, warm, warm-temperate and none climatic diagnostic. The result shows the changes of planktonic foraminifera assemblages and the paleoclimatic indices through Oligocene-Miocene boundary. The cool climate indices were identified at the lower part of the study section of Upper Oligocene sediment and gradually shifted to warm climatic indices at Lower Miocene section.

1. Introduction
The Temburong Formation is widely exposed in Southern part of Klias Peninsula. This formation was deposited as turbidite facies in deep marine environment during Oligocene to Early Miocene. This formation has been examined since 1960. The latest data on planktonic foraminifera reported from the Menumbok, Klias Peninsula, Sabah [1]. Two assemblages of planktonic foraminifera have been identified namely, N4 Globigerinoides primordius zone and N5 Globoquadrina dehiscens-Globoquadrina praedehiscens zone indicating the Lower Miocene age. This foraminifera assemblage derived from thick shale facies of the Temburong Formation located at Kg. Assam, Menumbok. The earliest study on planktonic foraminifera of the Temburong Formation in Sabah was reported in Padas Valley at the southern part of Sabah and revealed the Oligocene-Miocene planktonic foraminifera assemblage [2]. Oligocene planktonic foraminifera have also been recorded at Tenom area, which is characterised by the presence of Globigerina ciperoensis P21/N3 zone [3].
A micropaleontology study of the Temburong Formation at the study area (Menumbok) was carried out to provide a biostratigraphic framework and paleoclimate interpretation. Recently we discovered some Late Oligocene Planktonic foraminifera at the southern part of Menumbok area which is significant to update the biostratigraphy of the area. Most of those studies only focused on sedimentological and biostratigraphy of the Temburong Formation [2][4-6] and the paleoclimate research based planktonic foraminifera was poorly studied. Hence this study is defined the important planktonic foraminifera assemblage for paleoclimate reconstruction.

2. Geological Setting

Klias Peninsula is located at the south-western part of Sabah (as shown in figure 1). The study area is underlain by Paleogene-Neogene sediment, namely, the Crocker Formation, Temburong Formation, Setap Shale and Belait Formation. The Temburong Formation could be concluded as a deep marine environment sediment deposited by turbidity current known as a flysch deposite [1-2][6-10]. The age of the formation ranged from Oligocene to Lower Miocene based on planktonic foraminifera assemblage. Previous researcher also suggested an age of Late Oligocene to Late Early Miocene derived from the Temburong Formation at the Tenom Area. The Temburong Formation is unconformably overlain by the Middle Miocene shallow marine, the Belait Formation. The Belait Formation is unconformably overlain by the Plio-Pleistocene Liang Formation. The Temburong Formation in Klias Peninsula shows some variations in lithology. At Batu Linting the thinly bedded turbidite sand is more dominant. At Menumbok and Batu Luang the argillaceous rocks are more dominant with isolated limestone lenticular beds. Some of the turbidite exhibits Bouma sequence from Tb to Te but mostly shows Tc to Te sequence. Thinly bedded sandstone is rarely observed in the shale dominated sequence. [3] reported some planktonic foraminifera in the Temburong Formation at the Tenom Area. This assemblage suggests an age ranges from Late Oligocene to late Early Miocene.

Figure 1. Location of samples at Klias Peninsula. Geological map modified from Wilson (1960).
3. Materials and Methods
Three outcrops have been examined for micropaleontology study located at the Jalan Kuburan Cina, Kg. Assam respectively. A total of nine samples of shale collected for planktonic foraminifera analysis. Three samples (M101, M102, M103) from Jalan Kuburan Cina, four samples (M201-M204) from Kg. Maulu, and two samples (M301 and M302) from Kg Assam. All shale samples were processed based on standard micropaleontology method by the using Na\textsubscript{2}CO\textsubscript{3} method. The shale samples were weighed and crushed into small pieces (1-2cmm) and put in 1000ml beaker. Distilled water was pour into beaker, then boiled it for several hours and one small spoon of Na\textsubscript{2}CO\textsubscript{3} was added. The samples were washed and sieved through sieve fraction with different sizes (500m-65um). The residue then dried and examined for planktonic classification by using binocular microscope. The 125um fraction was chosen for this study and approximately 1000 individual specimen of planktonic foraminifera were analysed for biostratigraphy and paleoclimate [11]. The identification of taxonomy of planktic foraminifera are based on standard classification [12-14].

For the paleoclimatic purpose, the relative abundance or percentages of a certain planktonic foraminiferal species or groups with similar paleoecological affinities is represented by the number of specimens of the selected species (or group) to the total of specimen in the samples. A summary of paleoecological preferences of oligocene-miocene planktonic foraminifera with respect to surface water temperature and productivity were listed in (table 1). In principle, the scheme proposed by previous researcher [15-17]. The planktonic foraminifera in studied section were grouped into cool; cool+Temperate; Warm, warm+temperate and none climate diagnostic. The graphs were constructed to show the changes of cumulative curve of the planktonic foraminifera climate indices through-out study section.

| Table 1. Division of planktonic foraminifera based on paleoclimatic indices. |
|--------------------------------|-----------------------------------------------|
| Species                        | Climatic Indices                             |
| Catapsydrax dissimilis, Catapsydrax unicava, Globigerina officinalis, Globigerina praebulloides, Globigerina spp. | Cool                                          |
| Globigerina brazier, Globigerina woodi, Globorotalia nana, Globorotalia opima | Cool-temperate                                |
| Globigerina prasaepis, Globigerinella praesiphonifera, Globigerinita uvula, Globoquadrina venezuelana, Globorotalia obesa | Non-climate diagnostic                        |
| Dentogloborotalia altispira altispira, Globigerina angulisuturalis, Globigerinoides altiapetura, Globigerinoides primordius, Globigerinoides trilobus, Gs. trilobus bullatus, Globorotalia spp. | Warm                                          |
| Globigerina binaiensis, Globigerina selli, Globoquadrina baroemoenensis, Globoquadrina dehiscens, Globoquadrina praeheiscens, Globorotalia mayeri, Globorotalia semivera | Warm-temperate                                |
4. Results and Discussions

Table 2. Occurrence of planktonic foraminifera in the samples of section M1-M3.

| Species                                | M101 | M102 | M103 | M201 | M202 | M203 | M204 | M301 | M302 |
|-----------------------------------------|------|------|------|------|------|------|------|------|------|
| Catapsydrax dissimilis                 | 2    | 0    | 0    | 0    | 5    | 7    | 0    | 1    | 0    |
| Catapsydrax unicava                    | 7    | 0    | 0    | 4    | 0    | 0    | 1    | 0    | 2    |
| Dentoglobodreina altispira altispira   | 3    | 1    | 4    | 9    | 5    | 4    | 2    | 5    |      |
| Globigerina angulisuturalis            | 3    | 0    | 0    | 5    | 4    | 0    | 0    | 0    |      |
| Globigerina binaensis                  | 0    | 0    | 0    | 1    | 1    | 0    | 1    | 0    |      |
| Globigerina brazieri                   | 0    | 0    | 0    | 13   | 1    | 0    | 0    | 0    |      |
| Globigerina officinalis                | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |      |
| Globigerina praebulloides              | 66   | 2    | 6    | 15   | 24   | 54   | 13   | 12   | 1    |
| Globigerina prasaepis                  | 25   | 0    | 0    | 0    | 0    | 0    | 0    | 0    |      |
| Globigerina selli                      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1    |
| Globigerina spp.                       | 20   | 1    | 3    | 25   | 13   | 12   | 15   | 19   | 1    |
| Globigerina woodi                      | 23   | 0    | 5    | 1    | 19   | 21   | 8    | 5    | 0    |
| Globigerinella praesiphonifera         | 2    | 0    | 0    | 0    | 6    | 3    | 0    | 0    |      |
| Globigerinita uva                      | 0    | 0    | 0    | 0    | 1    | 0    | 0    | 0    |      |
| Globigerinoides altiapetura            | 0    | 0    | 0    | 0    | 6    | 4    | 5    | 2    |      |
| Globigerinoides primordius             | 0    | 0    | 0    | 41   | 24   | 34   | 31   | 8    | 1    |
| Globigerinoides trilobus               | 0    | 0    | 0    | 16   | 7    | 19   | 5    | 9    | 2    |
| Globigerinoides trilobus bullatus      | 0    | 0    | 0    | 0    | 9    | 6    | 0    | 0    |      |
| Globoquadrina baroemoenensis           | 11   | 0    | 0    | 5    | 6    | 8    | 6    | 0    | 0    |
| Globoquadrina dehiscens                | 0    | 0    | 0    | 0    | 17   | 7    | 2    | 0    |      |
| Globoquadrina praehisicenesis          | 0    | 0    | 0    | 0    | 9    | 8    | 3    | 1    | 2    |
| Globoquadrina venezuelana              | 0    | 1    | 0    | 0    | 19   | 2    | 0    | 0    |      |
| Globorotalia mayeri                    | 11   | 0    | 0    | 8    | 7    | 17   | 6    | 0    | 0    |
| Globorotalia obesa                     | 2    | 0    | 1    | 5    | 15   | 9    | 9    | 7    | 1    |
| Globorotalia nana                      | 8    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |      |
| Globorotalia opima                     | 17   | 0    | 4    | 0    | 0    | 0    | 0    | 0    |      |
| Globorotalia semivera                  | 0    | 0    | 0    | 0    | 5    | 0    | 0    | 0    |      |
| Globorotalia spp.                      | 7    | 0    | 1    | 10   | 14   | 8    | 8    | 9    | 1    |

4.1. Biostratigraphy

A total of 28 species of planktonic foraminifera and their relative abundance were listed in table 2 in alphabetic order. The stratigraphic distribution of foraminiferal species is based on [12-14]. The foraminifera assemblages are also compared to foraminiferal zones of Blow Zone [18].

Shale Sample M1 (M101, M102, M103) is located at Kuburan Cina road at South of Klias Peninsula. This sample consists of *Catapsydrax dissimilis* (Cushman & Bermudez), *Catapsydrax unicava* Bolli, Leoblich & Tappan, *Globigerina praebulloides* Blow, *Globigerina prasaepis* Blow & Banner, *Globigerina sp.*, *Globigerina angulisuturalis* Bolli, *Globoquadridna baroemoenensis* (Leroy), *Globoquadridna venezuelana* (Hedberg), *Globigerina woodi* Jenkins, *Globigerina officinalis* Subbotina, *Globigerinella praesipohonifera* (Blow), *Globorotalia mayeri* Cushman & Ellisor, *Globorotalia obesa* (Bolli), *Globorotalia opima nana* Bolli, *Globorotalia opima opima* Bolli and *Dentoglobodreina altispira altispira* Cushman & Jarvis. The occurrence of *Globorotalia opima opima* and *Globigerina angulisuturalis* indicated P21/P22 zone of Blow Zone.
M2 section consists of four samples (M201, M202, M203, M204) collected from Kg. Bakarang. Sample M201 and M202 collected at the lower part of M2 section. The planktonic foraminifera are *Catapsydrax dissimilis* (Cushman & Bermudez), *Catapsydrax unicava* Bolli, Leoblich & Tappan, *Globigerina praebulloides* Blow, *Globigerina sp.*, *Globigerina angulisuturalis* Bolli, *Globigerina binaiensis* Koch, *Globigerina brazieri* Jenkins, *Globigerina woodi* Jenkins, *Globigerinoides primordius* Blow & Banner, *Globoquadra praebulloides* (Leroy), *Globoquadra praedeheiscens* Blow & Banner, *Globorotalia mayeri* Cushman & Ellisor, *Globorotalia obesa* (Bolli), *Globorotalia semivera* (Hornibrook), *Dentoglobiquadrina altispira altispira* Cushman & Jarvis and *Globorotalia spp.* The planktonic foraminifera assemblage from samples M201 and M202 are within the N4 zone of Blow zone by the present of *Globigerinoides primordius* and *Globigerina angulisuturalis*.

Shale samples M203 and M204 collected from the upper part of M2 section contain of *Catapsydrax dissimilis* (Cushman & Bermudez), *Catapsydrax unicava* Bolli, Leoblich & Tappan, *Dentoglobiquadrina altispira altispira* Cushman & Jarvis, *Globigerina binaensis* Koch, *Globigerina woodi* Jenkins, *Globigerinita uvula* (Ehrenberg), *Globigerina praebulloides* Blow, *Globigerinella praesiphonifera* (Blow), *Globigerinoides altiaperturus* Bolli, *Globigerinoides primordius* Blow & Banner, *Globigerinoides trilobus* (Reuss), *Globigerinoides trilobus bullatus* Chang & Chang, *Globoquadra praebulloides* (Leroy), *Globoquadra dehiscens* Chapman, Parr & Collins, *Globoquadra praedeheiscens* Blow & Banner, *Globoquadra venezuelana* (Hedberg), *Globorotalia mayeri* Cushman & Ellisor, *Globorotalia obesa* (Bolli), and *Globorotalia spp.* The present of *Catapsydrax dissimilis*, *Globigerinoides altiaperturus*, *Globoquadra praedeheiscens* and *Globoquadra dehiscens* are within the N5-N6 zone of Blow zone. The same assemblage was identified from the M3 section at Kg. Sinapokan. Two samples were collected and the planktonic foraminifera assemblage is indicative of N5-N6 zone.

Hence based on the biostratigraphy study, the Temburong Formation in study area range from Late Oligocene to Early Miocene (P21-P22, N4, and N5-N6) (figure 4).

### 4.2. Paleoclimate

Samples M101-M103 of Upper Oligocene dominated by cool-water and cool-temperate indicators based on the sum of percentage cool and cool-temperate indices up to 70% compared to warm indicators (figure 2). The high percentage of cool-water indicator is *Globigerina praebulloides* which are present in all samples. Other cool-water indices present in the M1 section are *Catapsydrax dissimilis*, *Catapsydrax unicava* and *Globigerina officinalis*. The high percentage of cool-temperate indicators is *Globigerina woodi* and *Globorotalia opima opima*.

![Figure 2. Planktonic foraminifera climatic indicator (cool and cool-temperate).](image)
Sample M201 and M202 of N4 zone, contain of high abundance of warm and warm-temperate indicator about 59.87% and 51.57% respectively (figure 3). The warm-water indicator is marked by the high percentage of *Globigerinoides primordius* in the samples. *Dentogloborquadrina altispira altispira*, *Globigerina angulisuturalis* and *Globigerinoides trilobus* are categorized as warm-water indicator also can be found in the sample. The warm-temperate indices were characterised by the presence of *Globoquadrina baroemoenensis*, *Globoquadrina praedehiscens*, *Globorotalia mayeri* and *Globorotalia semivera*. *Globoquadrina baroemoenensis* is the high percentage of warm-temperate indices in the samples.

Sample M203, M204, M301 and M302 were within the N5-N6 zone of Lower Miocene. The warm and warm-temperate indicator are dominant in all samples. Samples M203-M204 contain of high percentage of *Globigerinoides primordius* of warm-water indicator and for the samples M301-M302 the high percentage of warm indicator is *Globigerinoides trilobus*. Other warm indicator present in the samples are *Dentogloborquadrina altispira altispira*, *Globigerinoides altiapetura* and *Gs. trilobus bullatus*. The warm-temperate indicator only contributed a low percentage of species appearence in sample M301 and M302 compared to the samples in M2 section (M203-M204).

The paleoclimate analysis shows that the Planktonic foraminiferal assemblages of Upper Oligocene P22/P21 (M101-M103) mainly dominated by globigerinids and tenuitellids indicating cool surface waters, while warm-water indicators are rather scarce. The Lower Miocene planktonic foraminifera assemblage dominated by warm surface water Indicates by globigerinoides group. This result support the global paleoclimate proposed by [19] which suggested cooling event during P21 zone of earliest Upper Oligocene age. Then during the earliest Lower Miocene age, the global paleoclimate was shifted to warm climate starting from N4 to the middle part of N5 zone. The temporary cooling event was detected by [19] during upper part of N5 zone probably resemble by the sample M301 which are show the increasing of percentage *Globigerina praebulloides* of cool-water indicator (figure 4 and figure 5).
Figure 4. Planktonic foraminifera climatic indicator and none climatic diagnostic indicator.

Figure 5. Comparison of stacked graph of planktonic foraminifera climatic indicator of the study area with the global paleoclimate.

5. Conclusion
Planktonic foraminifera assemblage of the Temburong Formation from the study area ranges from Upper Oligocene to Lower Miocene and categorises intro three zones namely P21/P22 zone (M101-M103), N4 zone (M201-M202), and N5-N6 zone (M203-M204 and M301-M302). The paleoclimate studies show that the Upper Oligocene planktonic foraminifera assemblage was dominated by cool surface water. Then, transition was observed from cool to warm surface water during Lower Miocene stage.
6. References

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