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Middle Miocene planktonic foraminifera and their implications in the geology of Sabah

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Abstract: Planktonic foraminifera flourished during Middle Miocene. They were recorded from the Ayer, Kuamut, Garinono mélanges, the Libong Tuffite, Tungku Formation, Tabanak Conglomerate, and Setap Shale Formation. Three assemblages of planktonic foraminifera were identified from the Libong Tuffite, the Garinono mélange, and the Setap Shale Formation. The assemblages indicate an age ranging from the early Middle Miocene *Globigerinoides sicanus-Globigerinatella insueta* Zone (N 8) to the middle Middle Miocene *Globorotalia fohsi fohsi* Zone (N12). The occurrence of the planktonic foraminifera suggests that a transgressive event caused the influx of the nutrient-rich water mass into the area. This event was probably related to the rifting of the Sulu Sea and the development of the eastern Sabah deep marine environment where the mélanges were deposited. The occurrence of tuff and tuffite indicates volcanic activity in the region. The age of the volcanic tuff is middle Middle Miocene as dated by planktonic foraminifera.

INTRODUCTION

Miocene planktonic foraminifera are very widespread in Sabah. Their occurrences have been recorded by many geologists especially from the Tanjung, Kapilit and Kalabakan Formations (Collenette, 1965), the Labang, Ayer, Libong Tuffite, Tungku and Sabahat Formations (Haile & Wong, 1965; Basir Jasin & Sanudin Tahir, 1987), the Kuamut and Tabanak formations (Leong, 1974), the Garinono and Sandakan Formations (Lee, 1970; Basir Jasin *et al.*, 1995) and Setap Shale (Basir Jasin *et al.*, 1993).

Planktonic foraminifera were obtained from three localities which represent the Libong Tuffite, Garinono and Setap Shale Formations (Fig.1). These formations are partly correlatable to the Kalumpang, Kuamut, Ayer, Labang, Tungku, Tabanak and Sandakan Formations. Most of these formations contain tuff, and tuffaceous material except the Sandakan Formation.

The aim of this paper is to study the planktonic foraminifera and their implications to the biostratigraphy, paleooceanography, and depositional environment.

GEOLOGICAL SETTING

The Garinono Formation is composed of slump breccia, and mudstone, boulder beds, sandstone, mudstone, conglomerate, tuff and tuffite (Haile & Wong, 1965; Leong, 1974). This formation is similar to the Kuamut and Ayer Formations. The Kuamut, Ayer and Garinono Formations are chaotic deposits and therefore considered as mélange. These formations were partly deposited by submarine slumping or debris flow (Basir Jasin *et al.*, 1995). In eastern Sabah, the Garinono mélange overlies the Gomantong Limestone.

The Libong Tuffite Formation comprises well-bedded tuffaceous conglomerate, sandstone and mudstone. It is very similar to the Tungku Formation except the latter has carbonaceous sandstone with conglomerate and mudstone (Haile & Wong, 1965). The Libong Tuffite Formation overlies the Ayer mélange. It is overlain by the Sebahat Formation (Wong, 1993).

The Setap Shale consists of predominantly thick dark grey mudstone with minor sandstone intercalations. The shale is occasionally calcareous, silty and may contain carbonaceous material. In Labuan Island the Setap Shale overlies the Temburung Formation. It is overlain by the Belait Formation.

PLANKTONIC FORAMINIFERA AND AGE

Age determination of the formations is based on the stratigraphic distribution of some selected index forms (Fig. 2). Basir Jasin *et al.* (1995) recorded two assemblages of planktonic foraminifera from the Garinono Formation in the Bidu-Bidu area. The first assemblage was retrieved from the matrix of mélange. The assemblage is composed of *Globigerinoides trilobus* (Reuss) *Praeorbulina transitoria* (Blow), *Globigerinoides diminutus* Bolli, *Globigerinoides sicanus* De Stefani, *Globoquadrina baroemoenensis* (LeRoy), *Dentoglobigerina altispira altispira* (Cushman & Jarvis) and *Dentoglobigerina altispira globosa* (Bolli). The occurrence of *Globigerinoides diminutus*, *Praeorbulina transitoria* and *Globigerinoides sicanus* is indicative of the early Middle Miocene *Globigerinoides sicanus-Globigerinatella insueta* Zone (N8).

The second assemblage were retrieved from tuffaceous mudstone layer above the mélange. Nine species were identified; *Orbulina universa* d'Orbigny, *Orbulina*

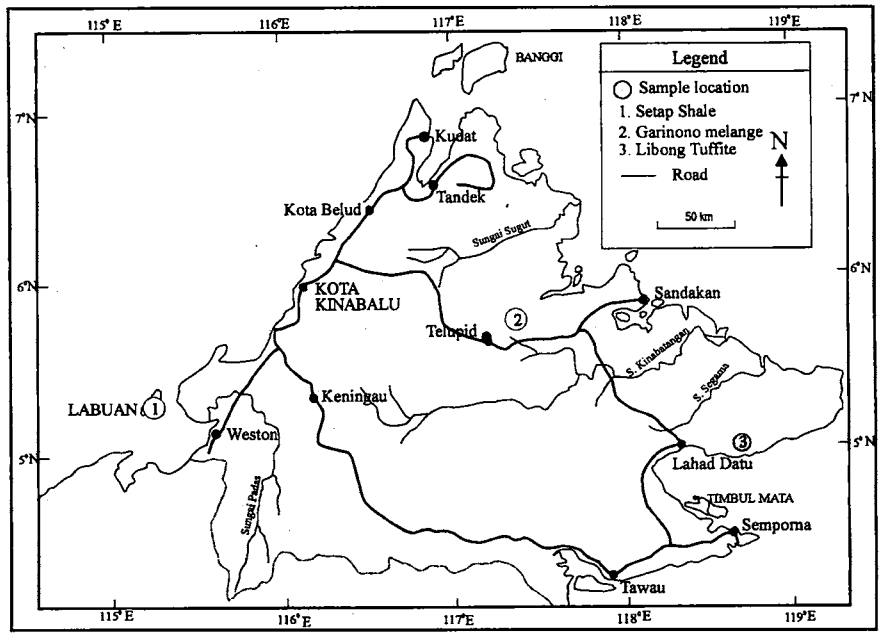

Figure 1. Map of Sabah showing the fossil localities.

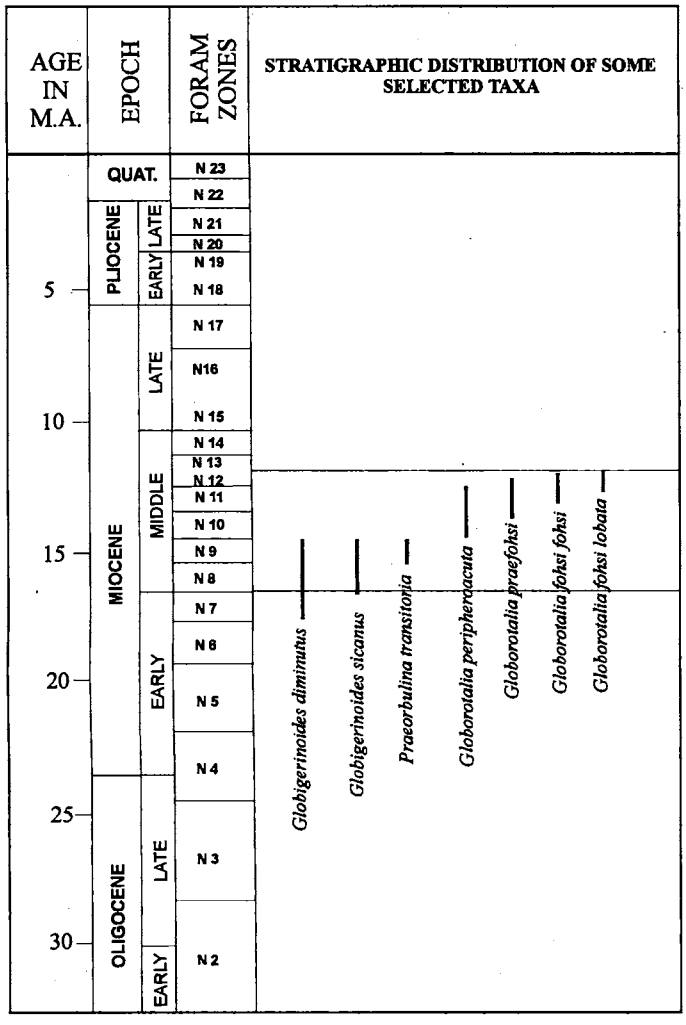

Figure 2. Stratigraphic distribution of index plantonic foraminifera.

suturalis Bronnimann, *Globigerinoides trilobus* (Reuss), *Globigerinoides immaturus* LeRoy, *Globigerina woodi* Jenkins, *Dentiglobigerina altispira altispira* (Cushman and Jarvis), *Globorotalia praescitula* Blow, *Globorotalia peripheroacuta* Blow and Banner and *Sphaerodenellopsis disjuncta* (Finlay). This assemblage indicates the early Middle Miocene *Globorotalia peripheroacuta* Zone (N10).

Sixteen taxa of planktonic foraminmifera were retrieved from the tuffaceous shale of the Libong Tuffite Formation exposed at the headwater of Sungai Sabahat, Dent Peninsula (Basir Jasin & Sanudin Tahir, 1987). The assemblage consists of *Globigerinoides immaturus* (LeRoy), *Globigerinoides trilobus* (Reuss), *Globigerinoides quadrilobatus* (d'Orbigny), *Orbulina bilobata* (d'Orbigny), *Orbulina suturalis* Bronnimann, *Orbulina universa* d'Orbigny, *Globoratalia praefohsi* Blow and Banner, *Globorotalia fohsi fohsi* Cushman and Ellisor, *Globorotalia fohsi lobata* Bermudez, *Globorotalia mayeri* Cushman and Ellisor, *Dentoglobigerina altispira altispira* Cushman and Jarvish, *Globoquadrina baroemoenensis* LeRoy, *Neogloboquadrina dehisens* (Chapman, Parr & Collins), *Sphaeroidinellopsis disjuncta* (Finlay), *Sphaeroidinellopsis seminulina* (Schwager), and *Globigerinella obesa* (Bolli). The occurrence of *Globoratalia praefohsi, Globorotalia fohsi fohsi, Globorotalia fohsi lobata*, suggests the middle Middle Miocene.*Globorotalia fohsi fohsi* Zone (N12).

Twelve taxa were identified from the Setap Shale exposed at Kampung Sungai Berdaun, Labuan (Basir Jasin *et al.*, 1993). The faunas consists of

Globigerinoides immaturus (LeRoy), *Globigerinoides trilobus* (Reuss), *Globigerinoides quadrilobatus* (d'Orbigny), *Globigerinoides diminutus* Bolli, *Globigerinoides sicanus* De Stefani, *Praeorbulina transitoria* (Blow), *Globorotalia bella* Jenkins, *Globoquadrina baroemoenensis* LeRoy, *Neogloboquadrina dehiscens* (Chapman, Parr & Collins), *Dentoglobigerina altispira altispira* (Cushman & Jarvis), *Dentoglobigerina altispira conica* (Bronnimann & Resig) and *Dentoglobigerina altispira globosa*. The occurrence of *Globigerinoides diminutus, Praeorbulina transitoria* and *Globigerinoides sicanus* is indicative of the early Middle Miocene *Globigerinoides sicanus-Globigerinatella insueta* Zone (N8).

The planktonic foraminifera assemblage from the Setap Shale is similar to the assemblage recovered from the matrix of the Garinono mélange. The planktonic foraminifera of Sabah ranges from N8 (early Middle Miocene) to N12 (middle Middle Miocene). Similar planktonic foraminifera assemblage was recorded from the Ayer mélange (Haile & Wong, 1965) and Kuamut mélange (Leong, 1974). Some selected taxa are illustrated in Plate 1 to Plate 3.

The Middle Miocene palnktonic foraminifera were also recorded from the Tabanak Conglomerate (Leong, 1974), Sebahat (Haile & Leong, 1965), Tungku (Haile & Leong, 1965), Tanjung (Collenette, 1965) and Sandakan Formations (Lee, 1970).

DEPOSITIONAL ENVIRONMENT

Planktonic foraminifera are usually found living near the surface of the ocean especially in the top 100 m of the water column. They are abundant in the open ocean. Most of the well-preserved planktonic foraminiferal fossils are commonly found in the deep-sea sediments above the calcite compensation depth. Preservation of the foraminiferal tests is very much related to planktonic productivity. The productivity is controlled by the nutrient supply and the availability of dissolved carbonate in the sea-water.

The occurrence of abundant Middle Miocene planktonic foraminifera in the formations indicates that productivity was high and was likely related to the upwelling of deep nutrient-rich water mass near the continental margin of the western Pacific. All the planktonic foraminifera bearing rock formations in Sabah were deposited in a deep water environment. During the Middle Miocene most of the eastern Sabah and Labuan Island were deep water environment (Fig. 3).

DEPOSITIONAL HISTORY

The Garinono mélange overlies the Gomantong Limestone, the Kulapis and the Labang Formations. Both the Kulapis and the Labang Formations were deposited in deep marine environment. The Gomantong Limestone is

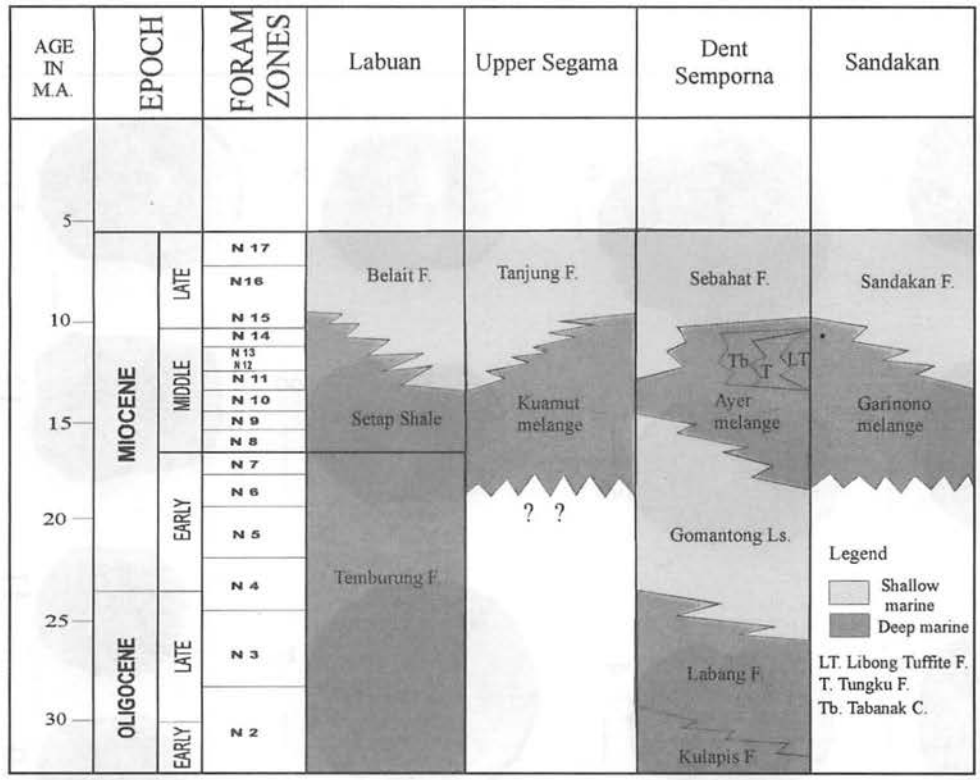

Figure 3. Depositional environment of the rock formations in eastern Sabah and Labuan Island during Oligocen-Miocene.

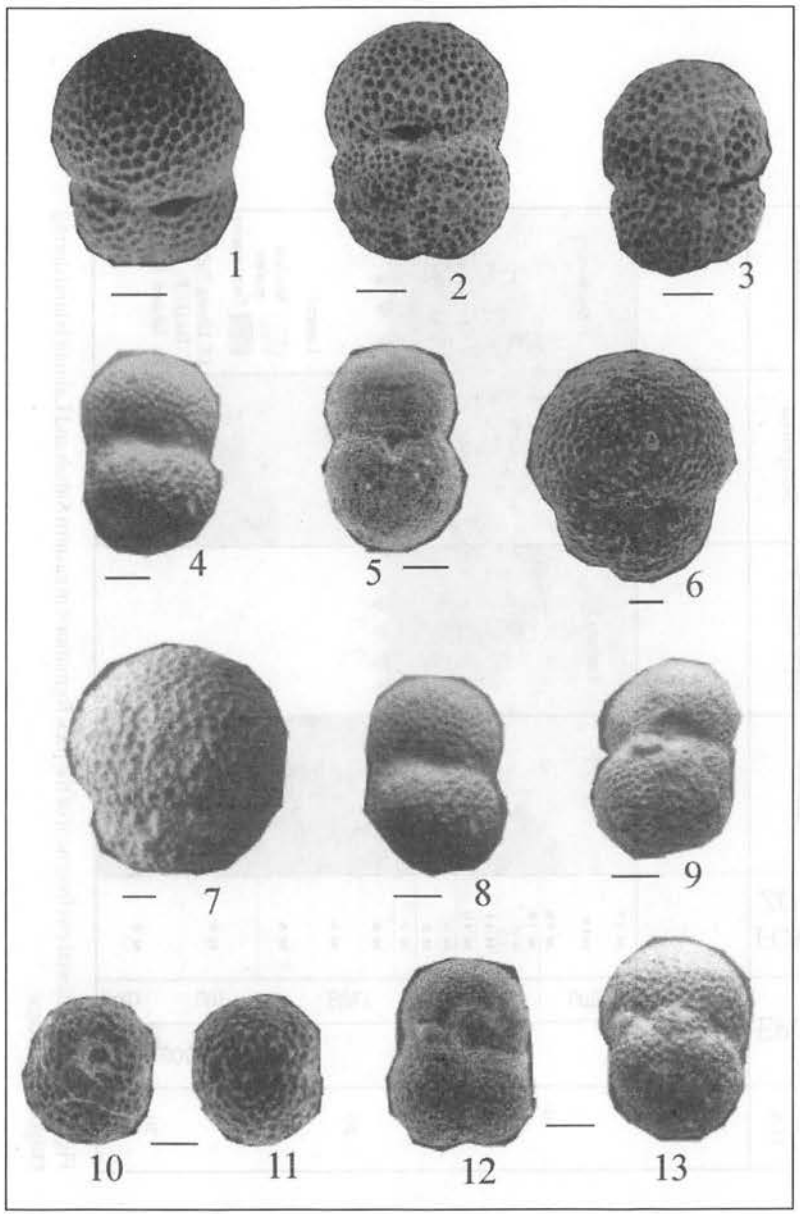

Plate 1. (Bar scale = 100 μm) 1, 2, & 3. *Globigerinoides triloba* (Reuss); 1, 3. Umbilical view; 2. Spiral view; 4, 5. *Praeorbulina transitoria* (Blow); 4. Umbilical view; 5. Spiral view; 6, 7. *Globigerinoides sicanus* De Stefani; 6. Umbilical view; 7. Spiral view; 8, 9. *Globigerimoides immaturus* LeRoy; 8. Umbilical view; 9. Spiral view; 10, 11. *Globigerinoides diminutus* Bolli; 10. Umbilical view; 11. Spiral view; 12, 13. *Globigerinoides subquadratus* Bronnimann; 12. Umbilical view; 13. Spiral view.

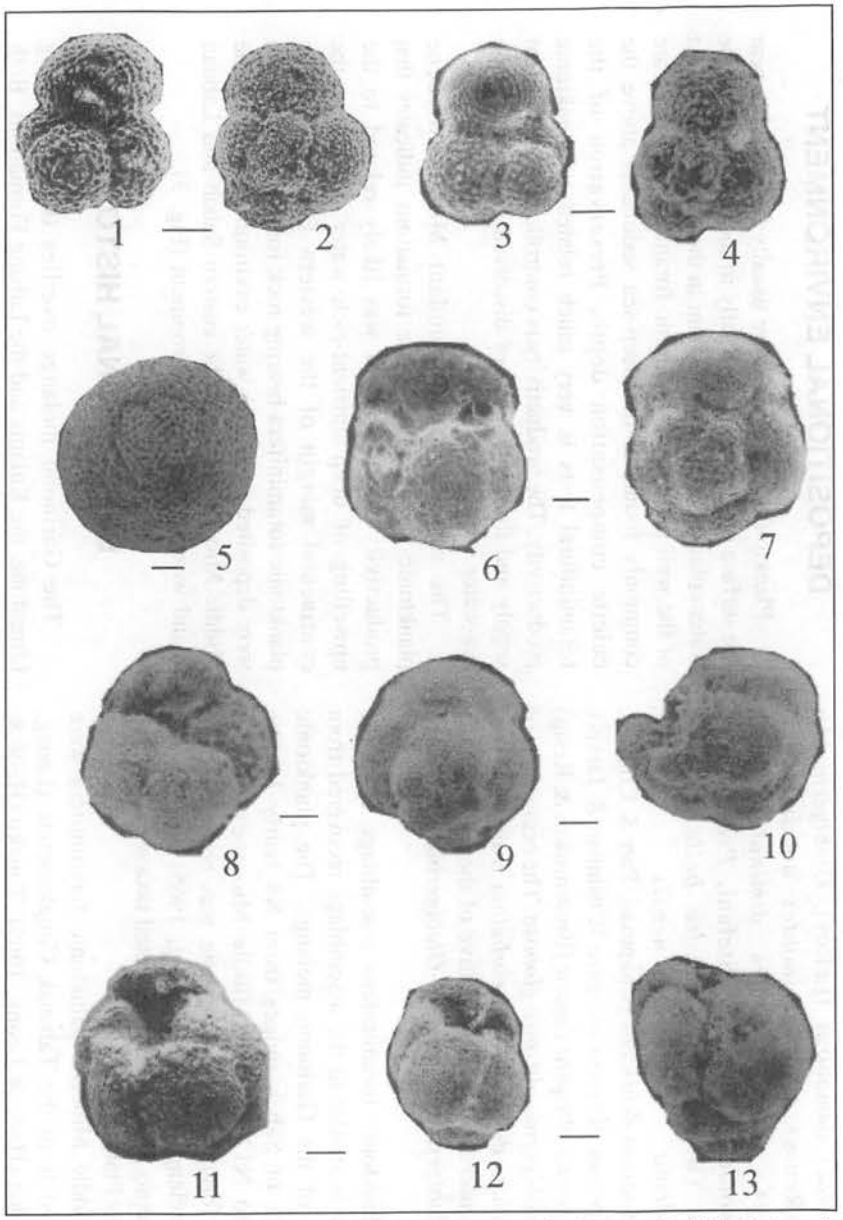

Plate 2. (Bar scale = 100 μm) 1, 2. *Globigerina woodi* Jenkins; 1. Umbilical view; 2. Spiral view; 3, 4. *Globigerina praebulloides* Blow; 3. Umbilical view; 4. Spiral view; 5. *Orbulina universa* d'Orbigny; 6, 7. *Globoquadrina baroemoenensis* (LeRoy); 6. Umbilical view; 7. Spiral view; 8, 9, 10. *Dentoglobigerina altispira globosa* (Bolli); 8. Umbilical view; 9. Spiral view; 10. Side view; 11, 12. *Dentoglobigerina altispira altispira* (Cushman & Jarvis); 11. Umbilical view; 12. Side view; 13. *Dentoglobigerina altispira conica* (Bronnimann & Resig); 13. Side view.

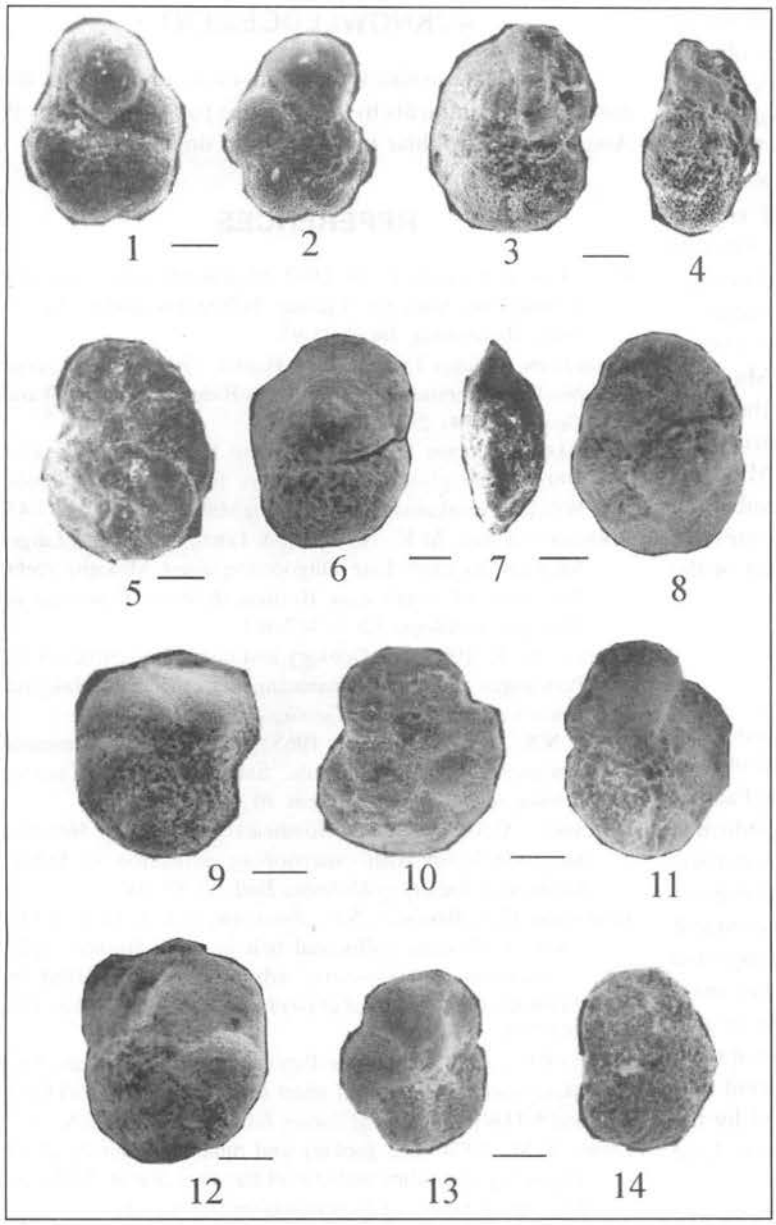

Plate 3. (Bar scale = 100 μm) 1, 2. *Globorotalia bella* Jenkins; 1. Umbilical view; 2. Spiral view; 3, 4, 5. *Globorotalia peripheroacuta* Blow and Benner; 3. Umbilical view; 4. Side view; 5. Spiral view; 6, 7, 8. *Globorotalia praefohsi* Blow and Banner; 6. Umbilical view; 7. Side view; 8. Spiral view; 9, 10. *Globorotalia fohsi fohsi* Cushman and Ellisor; 9. Umbilical view; 10. Spiral view; 11, 12. *Globorotalia fohsi lobata* Bermudez; 11. Umbilical View; 12. Spiral view; 13, 14. *Globorotalia praescitula* Blow; 13. Umbilical view; 14. Spiral view.

a shallow marine reefal limestone containing abundant larger foraminifera and clasts of the underlying Labang Formation (Boudagher-Fadel *et al*, 2000). The change from the deep marine Labang Formation to the shallow marine Gomantong Limestone suggests a regressive event during the Late Oligocene. This regression was related to either a lowering of sea-level or tectonic uplift. The Gomantong Limestone unconformably overlies the Labang Formation. The shallow marine environment prevailed until Early Miocene.

The presence of planktonic foraminifera in the matrix of the Garinono, Ayer, and Kuamut mélanges suggests that these mélanges were deposited as submarine debris flows during the major rifting event of the opening of the southeast Sulu Sea marginal basin (Hutchison, 1992; Hutchison *et al*., 2000). According to Hutchison *et al.* (2000) the clasts of the mélange were derived from the older formations *i.e.* the Kulapis, the Labang and the ophiolite association.

During the early Middle Miocene, there was a transgression episode related to the major rifting event resulting in the subsidence and the development of graben and horst. This deepening event was also observed from drowning of the Gomantong Limestone during the late Early Miocene (Noad, 2001). The development of deep marine environment allowed the ocean currents to transport the planktonic foraminifera into this region.

The mélanges were probably deposited as result of

submarine slumping or debris flows. Submarine slumping was triggered by earthquake as a result of the volcanic eruption in the Dent and Semporna peninsulas. Volcanic tuff are widely distributed in the Libong Tuffite Formation, the Ayer, Garinono and Kuamut mélanges, the Tabanak Conglomerate and the Tungku Formation (Haile & Wong, 1965; Leong, 1974; Lee, 1970). Most of the tuff yielded some Middle Miocene planktonic formaminifera. The tuff and tuffite were deposited at the same time. The occurrence of planktonic foraminifera in the tuff can be used to determine the age of the volcanic activity in the eastern Sabah. The age of the tuffite is middle Middle Miocene.

The occurrence of planktonic foraminifera in the Setap Shale in Labuan Island indicates the development of a deep marine environment during the Middle Miocene. The change in lithology from the turbiditic Temburung Formation to the Setap Shale suggests the transgressive event which was related either to rise of sea-level or the basin subsidence.

CONCLUSION

Planktonic foraminifera were abundant during the Middle Miocene of Sabah. This biological event was related to the paleoceanography of the western Pacific. Transgressive event during the Middle Miocene is indicated by the lithologic change from the shallow marine Gomantong Limestone to the deep marine Garinono mélange. The development of deep marine environment allowed the incursion of ocean current which transported in planktonic foraminifera and nutrient rich water mass into this region. This transgression was probably related to the rifting of the Sulu Sea, which caused the development of the eastern Sabah deep marine basin. This event was followed by another regressive event as indicated by the deposition of shallow marine sediment during Late Miocene.

Planktonic foraminifera are good index fossils for age determination of the rock formations in Sabah. The mélanges (Kuamut, Garinono and Ayer), the Libong Tuffite, Tabanak Conglomerate, and part of the Setap Shale were deposited during Middle Miocene. The tuff and tuffite found in the those formations are dated as middle Middle Miocene.

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