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Radiolarian biostratigraphy of Malaysia

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Abstract: Cherts in Malaysia can be divided into two types namely bedded chert strata and chert blocks. The bedded radiolarian cherts in Peninsular Malaysia are mainly located in the Western Belt especially the Kubang Pasu, Kenny Hill and Semanggol Formations. Bedded cherts in Sabah are found in the Sabah Ophiolite Complex. In Sarawak, bedded cherts are exposed in the Serian Volcanic Formation, and at the basal part of the Pedawan Formation. Chert blocks are mainly distributed in the Bentong Raub Suture Zone of Peninsular Malaysia and in melanges of Sabah and Sarawak. Radiolarians from Peninsular Malaysia are older ranging from Late Devonian to Triassic. Sixteen biozones are identified namely, *Trilonche minax*, *Albaillella deflandrei*, *Albaillella indensis*, *Pseudoalbaillella lomentaria*, *Pseudoalbaillella scalprata* m. *rhombothoracata*, *Pseudoalbaillella longtanensis*, *Pseudoalbaillella globosa*, *Follicucullus monacanthus*, *Follicucullus porrectus*, *Neoalbaillella ornithoformis*, *Neoalbaillella optima*, *Entactinosphaera chiakensis*, *Triassocampe coronata*, *Triassocampe deweveri*, *Oertlispongus inaequispinosus* and *Capnodoce* Zones. Radiolarians from Sabah and Sarawak are younger compared to those of Peninsular Malaysia. They are ranging in age from early Jurassic to Cretaceous. Six biozones are recognised *viz. Trillus elkhornensis*, *Loopus primitivus*, *Pseudodictyomitra carpatica*, *Cecrops septemporatus*, *Dictyomitra communis* and *Pseudodictyomitra pseudomacrocephala* Zones. The radiolarian cherts in Malaysia are not continuous succession and their development is related to radiolarian productivity caused by volcanic activities which supply silica and nutrients to surface water.

Abstrak: Rijang di Malaysia boleh dibahagikan kepada dua jenis iaitu rijang berlapis berstrata dan bungkah rijang. Rijang berradiolaria berlapis di Semenanjung Malaysia terletak di Jalur Barat terutama Formasi Kubang Pasu, Formasi Kenny Hill dan Formasi Semanggol. Rijang berlapis di Sabah terdapat pada Kompleks Ofiolit Sabah. Di Sarawak rijang berlapis terdapat di Formasi Volkano Serian dan bahagian dasar Formasi Pedawan. Bungkah rijang pula tertabur di Zon Sutura Bentong-Raub di Semenanjung Malaysia dan di dalam melange di Sabah dan Sarawak. Radiolarian dari Semenanjung Malaysia lebih tua dan berjulat dari Devon Akhir hingga Trias. Enam belas biozon telah dikenal pasti iaitu Zon *Trilonche minax*, *Albailella deflandrei*, *Albaillella indensis*, *Pseudoalbaillella lomentaria*, *Pseudoalbaillella scalprata* m. *rhombothoracata*, *Pseudoalbaillella longtanensis*, *Pseudoalbaillella globosa*, *Follicucullus monacanthus*, *Follicucullus porrectus*, *Neoalbaillella ornithoformis*, *Neoalbaillella optima*, *Entactinosphaera chiakensis*, *Triassocampe coronata*, *Triassocampe deweveri*, *Oertlispongus inaequispinosus* dan *Capnodoce*. Radiolaria dari Sabah dan Sarawak berusia lebih muda berbanding dengan Semenanjung Malaysia. Ia berjulat dari Jura Awal hingga Kapur. Enam biozon telah dikenali iaitu Zon *Trillus elkhornensis*, *Loopus primitivus*, *Pseudodictyomitra carpatica*, *Cecrops septemporatus*, *Dictyomitra communis* dan *Pseudodictyomitra pseudomacrocephala.* Jujukan Rijang berradiolaria Malaysia tidak berterusan dan pembentukannya berkait dengan produktiviti radiolarian yang disebabkan oleh aktiviti volcano yang membekal bahan silika dan nutrien kepada jisim air di permukaan.

Keywords: Radiolarians, chert, biozones, Peninsular Malaysia, Sabah, Sarawak

INTRODUCTION

Research on Malaysian radiolarians was first carried out in the Lupar Valley, Sarawak by Hinde (1900). One hundred taxa were recognised. A. G. Davies of the British Museum of Natural History, London has identified a radiolarian assemblage representing Middle Jurassic to Early Cretaceous age from the same area (Haile, 1957). Wolfenden (1963) and Wilford (1965) have reported several genera of Jurassic-Cretaceous radiolarians from the Serabang and Sejingkat formations, Sarawak. G. F. Elliott of the British Museum of Natural History, London, identified 53 taxa from the Pedawan Formation (Wilford & Khoo, 1965). All identifications were based on thin sections.

A major development that enhanced the study of radiolarians in the siliceous rocks was of a new technique to retrieve whole radiolarian specimens from cherty rocks by using hydrofluoric acid (Pessagno & Newport, 1972). In Malaysia, the early studies based on whole specimens of radiolarians were carried out on the chert from Ulu Segama, Sabah by W. R. Riedel and A. Sanfillipo of the Scripps Institution of Oceanography, La Jolla, California (Leong, 1977) and on chert from the Lupar Valley by E. A. Pessagno Jr. from Texas University (Tan, 1979).

The study of radiolarian cherts rapidly developed in Malaysia since early 1990s. Radiolarians have proved very useful for biostratigraphic zonation of the Paleozoic and Mesozoic siliceous rocks in Malaysia. The study of radiolarian permits dating of rocks and also provides paleoecologic and sedimentologic data that are critical for understanding of the geology and tectonic history of Malaysia. This paper presents a revision of some taxa and reviews the development of radiolarian biostratigraphy of Malaysia.

PREVIOUS WORKS

Research on bedded radiolarian cherts in Peninsular Malaysia increased dramatically since early 1990s

particularly on the Semanggol Formation where chert is wide spread (Basir, 1994a, 1996a, 1997, 2008; Metcalfe & Spiller, 1994; Sashida *et al*., 1995; Spiller & Metcalfe, 1995a, 1995b; Basir *et al.*, 2005a, 2005b; Spiller, 2002). Studies were extended in parallel to chert blocks in the Bentong-Raub Suture Zone (Basir, 1994b; Metcalfe & Spiller, 1994; Spiller & Metcalfe, 1995a, 1995b; Basir & Che Aziz, 1997a, 1997b; Spiller, 2002; Basir *et al.*, 2004; Basir, 2013; Muhammad Ashahadi *et al.,* 2012). Additional studies on bedded siliceous rocks has been undertaken at Jengka Pass (Basir *et al*., 1995a), on bedded chert from the Kubang Pasu Formation (Basir, 1995; Basir & Zaiton, 2001b), the Kodiang Limestone (Basir *et al.*, 1995b; Basir & Zaiton, 2001a), the Kenny Hill Formation (Zaiton & Basir, 2003), and at Nenering, north Perak (Basir & Zaiton, 2006).

In East Malaysia on the Island of Borneo, research on radiolarians from bedded chert strata were carried out from Upper Segama (Leong, 1977; Junaidi & Basir, 2012), Kudat (Basir *et al*., 1985; Basir & Sanudin, 1988; Wan Nursaiedah *et al.,* 2014), Telupid (Basir, 1992) and Baliojong valley (Basir & Sanatulsalwa, 1992; Basir & Tongkul, 2000; Basir & Tongkul, 2013). The radiolarian chert in chert blocks were also studied particularly in the Ayer Melange (Aitchison, 1994), Wariu Melange (Basir *et al*., 1989; Basir, 2000) and Kuamut Melange (Junaidi & Basir, 2013).

Apart from the chert of the Lupar Valley (Tan, 1979) there were several radiolarian faunas recovered from the chert blocks in the Lubok Antu Melange (Basir & Haile, 1993; Basir, 1996b) and in the Serabang Melange (Basir & Aziman, 1996). Radiolarians from bedded chert strata were also discovered from the Serian Volcanic Formation (Basir *et al.,* 1996; Basir & Uyop, 1999a) and the Pedawan Formation (Basir & Uyop, 1999b).

OCCURRENCE AND DISTRIBUTION OF SILICEOUS ROCKS (CHERTS)

Cherts in Malaysia can be divided into two types, hemipelagic and pelagic cherts (Kamata *et al*., 2009). The radiolarian cherts in Peninsular Malaysia form thinly bedded cherts interbed with thinly bedded mudstone. They are usually associated with turbidites. The cherts are classified as hemipelagic cherts (Kamata *et al*., 2009) which are commonly exposed in the Western Belt of Peninsular Malaysia. The cherts represent a continental margin chert association (Jones & Murchey, 1986). Some pelagic cherts were observed in chert blocks in the Bentong- Raub Suture Zone (Spiller & Metcalfe, 1995b; Basir, 2013).

Tan (1980) has briefly described the distribution of cherts and siliceous rocks in Malaysia. Bedded chert strata were reported from the Setul Limestone, Langkawi; Mahang Formation, south Kedah; Karak Formation, Pahang; Kubang Pasu Formation, north Kedah and Perlis; Kenny Hill Formation, Selangor; Kodiang Limestone, north Kedah and Semanggol Formation, Kedah. Small isolated bedded cherts were also discovered from Genting Serampang, Jengka Pass, Pahang and Nenering, north Perak. Chert blocks are mainly distributed in the Bentong-Raub Suture Zone particularly in Pos Blau, Kelantan; Bentong, Pahang and Langkap, Negeri Sembilan (Figure 1). Radiolarians have yet to be discovered from the Lower Paleozoic rocks of the Setul and Mahang Formations.

Cherts in Sabah are associated with ophiolitic rocks which are included in the Sabah Complex (Basir, 1991). The chert represents ophiolitc chert association (Jones & Murchey, 1986) and forms upper part of oceanic crust. The chert layers are strongly folded and faulted. Bedded chert strata are exposed at Telupid, Kudat, Baliojong Valley, Upper Segama, Banggi Island, Pulau Timbun Mata and Darvel Bay (Figure 2). Some bedded cherts have undergone tectonic deformation and form blocks of chert embedded in mudstone matrix. The chert blocks combined with other fragments of sedimentary and basic igneous rocks to form ocean plate strairaphy (OPS) melange (Wakita, 2015). The chert blocks are widely distributed in the Wariu, Ayer and Kuamut Melanges (Figure 2).

The oldest bedded chert in Sarawak is located in the Serian Volcanics Formation. The chert is associated with dacitic tuff and well-exposed near Binong Pass. Bedded chert was also discovered from the Pedawan Formation exposed at Pang Bau near Bau town. The chert is associated with mudstone and is overlain by the Bau Limestone. The chert blocks are found in the Lubok Antu and Serabang Melanges (Figure 2).

BIOSTRATIGRAPHY OF RADIOLARIAN CHERT IN PENINSULAR MALAYSIA

Radiolarian cherts in Peninsular Malaysia are mainly of Late Paleozoic and Early Mesozoic age. The oldest radiolarians are discovered from a chert block in the Bentong-Raub Suture Zone and the youngest radiolarians are obtained from the Triassic Kodiang Limestone. Stratigraphic distribution of chert sequence is not continuous. The deposition of chert is punctuated by the influx of terrigenous material. Development of radiolarian chert is very much related to the radiolarian productivity which is controlled by many factors such as dissolved silica availability, nutrients, salinity, and temperature (Racki & Cordey, 2000).

Sashida *et al*. (1995) recognised three biozones from the chert unit of the Semanggol Formation, north Kedah namely, *Follicucullus monacanthus*, *Neoalbaillella ornithoformis* and *Neoalbaillella opima* Zones. Spiller (2002) identified thirteen radiolarian zones in Peninsular Malaysia, namely *Holoeciscus* 2 and *Holoeciscus* 3 assemblage Zones in Late Devonian; *Albaillella deflandrei* and *Albaillella cartalla* Zones (Early Carboniferous); *Pseudoalbaillella u-forma m.* II, *Pseudoalbaillella lomentaria, Pseudoalbaillella scalprata* m. *rhombothoracata, Albaillella sinuata, Albaillella longtanensis, Follicucullus porrectus, Neoalbaillella ornithoformis* Zones in Permian; and *Triassocampe coronata* and *Triassocampe deweveri* Zones in Middle Triassic.

Radiolarian zonation for Peninsular Malaysia has been revised and updated by Basir & Zaiton (2011a). Therefore, it is briefly mentioned in this paper. Sixteen biozones were identified.

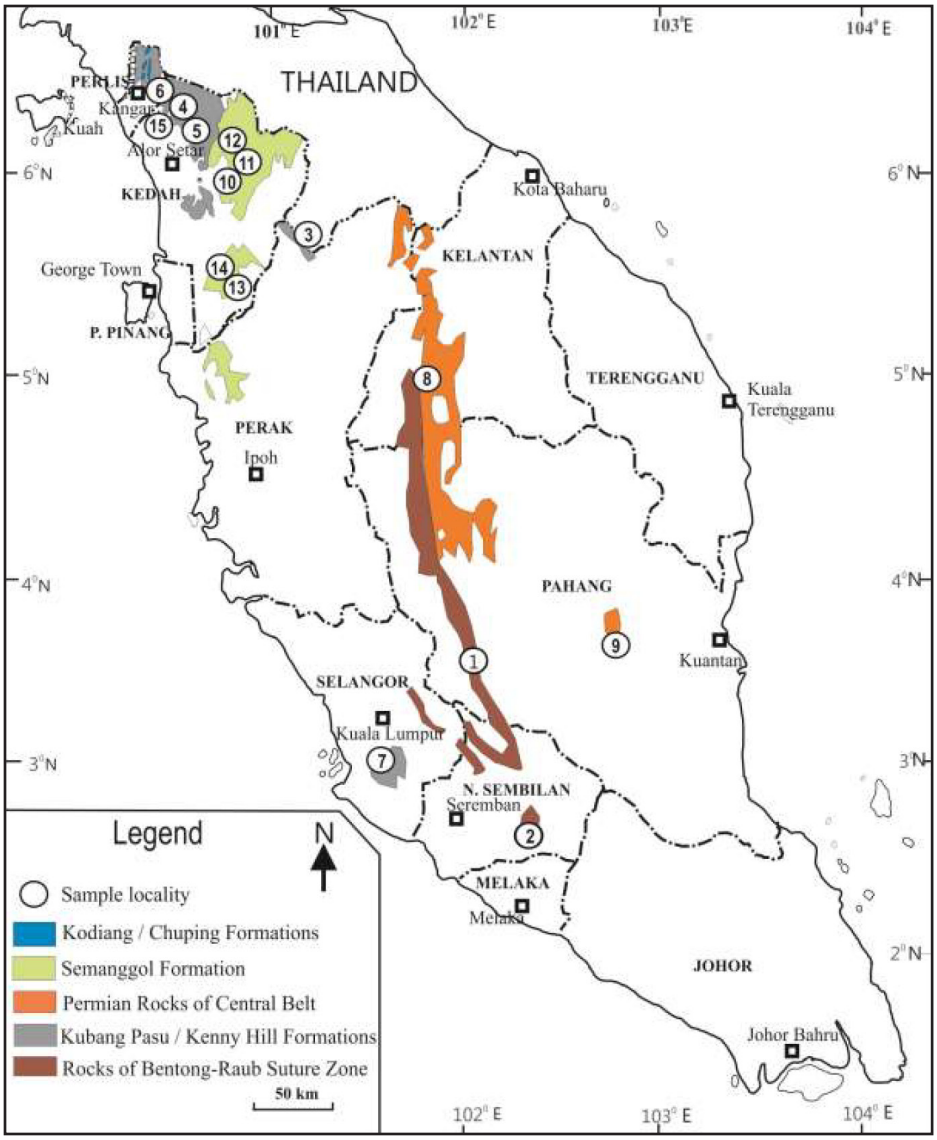

Figure 1: Distribution of radiolarian chert bearing formations in Peninsular Malaysia and sample localities.
1: Bentong, 2: Langkap, 3: Nenering, 4: Bukit Binjal, 5: Bukit Kamelong, 6: Bukit Tuntung, 7: Dengkil, 8: Pos Blau, 9: Genting Serampang, 10: Bukit Yoi, 11: Bukit Larek, 12: Bukit Tembaga, 13: Kuala Ketil, 14: Merbau Pulas, 15: Kodiang.

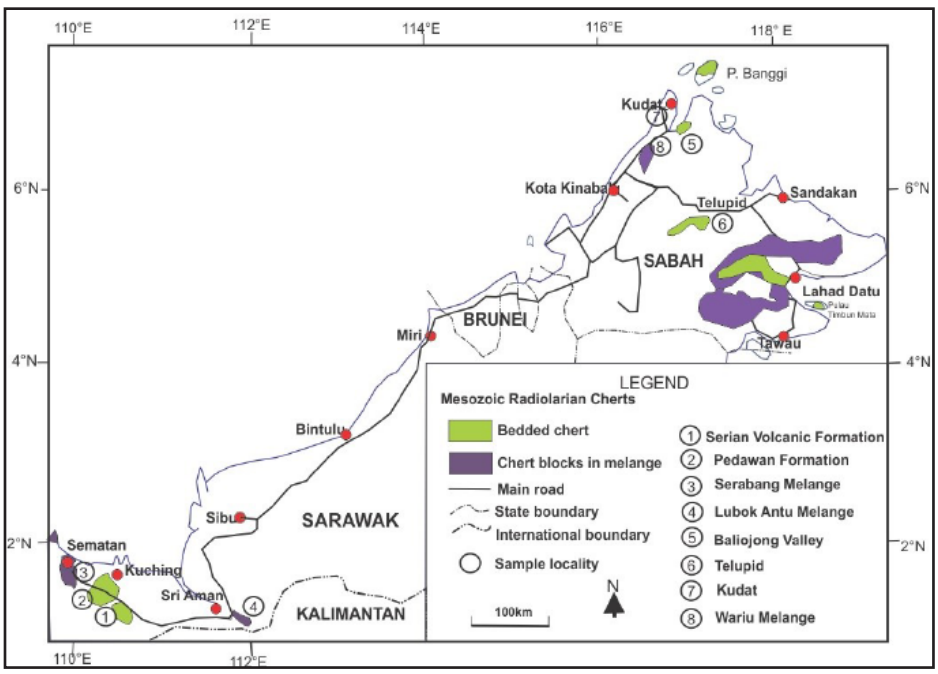

Figure 2: Distribution of radiolarian chert bearing formations in Sabah and Sarawak and sample localities.

Trilonche minax zone

This is the oldest radiolarian zone discovered in Peninsular Malaysia to date. The zone is characterised by the occurrence of the zonal marker *Trilonche minax* (Hinde) (Figure 3, nos. 1 and 2) together with *Trilonche davidi* (Hinde), *Trilonche vetusta* Hinde, *Trilonche tretactinia* (Foreman), and *Stigmosphaerostylus herculea* (Foreman) (Basir & Zaiton, 2011a). Among them, *Stigmosphaerostylus herculeus* (Foreman) and *Trilonche minax* (Hinde) are indicators of lower Frasnian, early Late Devonian (Aitchison *et al*., 1999). The assemblage was found in a chert block in the Bentong-Raub Suture Zone north of Bentong town (Basir *et al.,* 2004).

Albaillella deflandrei zone

The occurrence of *Albailella deflandrei* Gourmelon (Figure 3, no. 3), *Albaillella indensis ambigua* Deflandre, *Albaillella paradoxa* Deflandre, *Albaillella undulata* Deflandre, *Ceratoikiscum avimexpectans* Deflandre, *Ceratoikiscum berggreni* Gourmelon and *Ceratoikiscum jacundum* Noble, Tekin, Gedik & Pehlivan is indicative of the *Albaillella deflandrei* Zone, Tournaisian, Early Carboniferous (Noble *et al*., 2008). The assemblage was discovered from several chert samples collected from Langkap, Negeri Sembilan (Basir & Che Aziz, 1997b). The chert from Nenering, north Perak yielded 20 species of radiolarians. The presence of *Archocyrtium lagabreillei* Gourmelon, *Archocyrtium pulchrun* Braun, *Archocyrtium venustum* Cheng, *Astroentactinia biaciculata* Nazarov, *Stigmosphaerostylus vulgaris* (Won), *Astroentactinia mirousi* Gourmelon, *Astroentactinia multispinosa* Won, *Ceratoikiscum berggreni* Gourmelon, *Stigmosphaerostylus tortispina* (Ormiston & Lane), and *Pylentonema antiqua* Deflandre indicates similar age (Basir & Zaiton, 2006, 2011a).

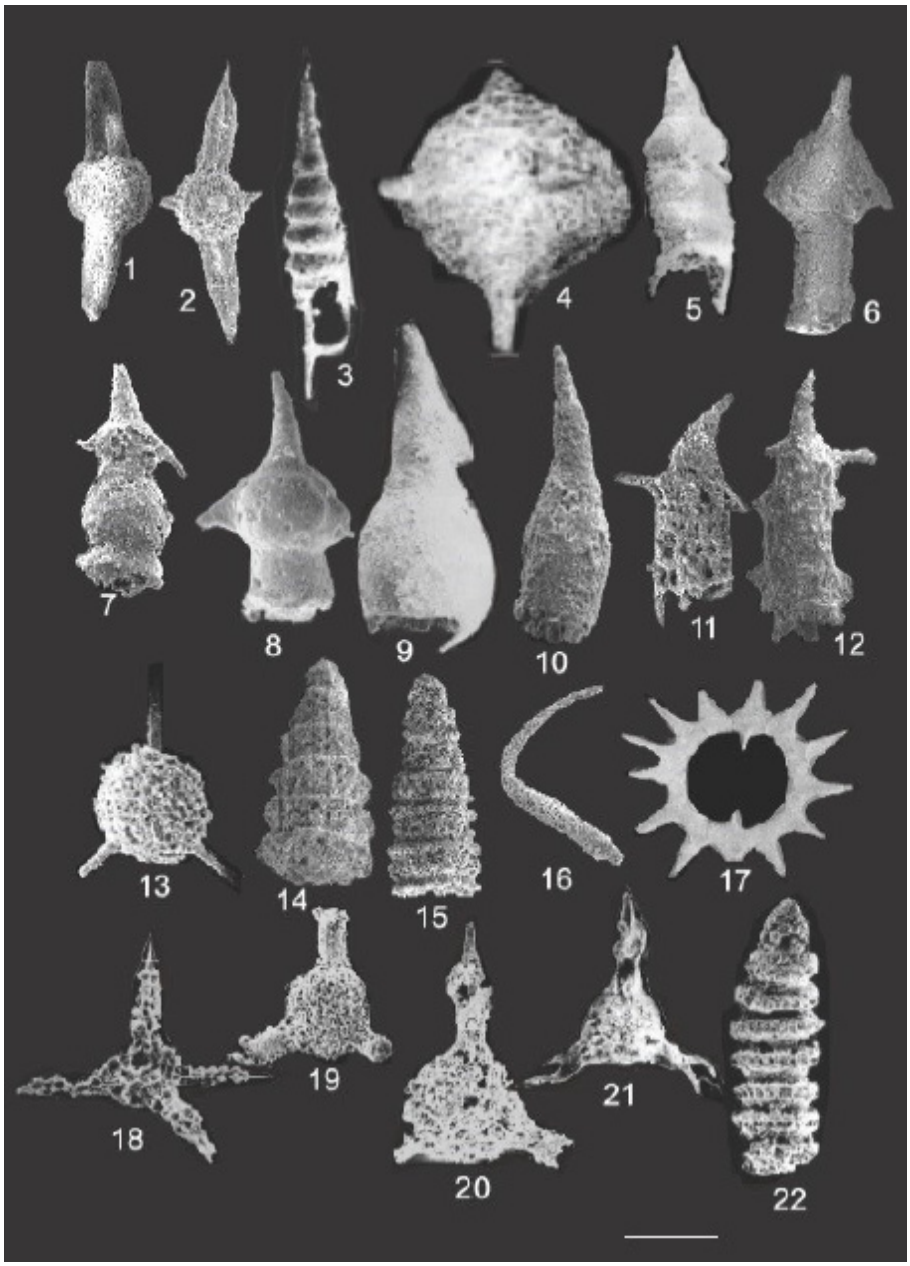

Figure 3: Zonal markers for Late Paleozoic and some selected taxa from Early Mesozoic radiolarians. (Scale bar is indicated in parentheses).
1, 2. *Trilonche minax* (Hinde) (100µm)
3. *Albaillella deflandrei* Gourmelon (100µm)
4. *Cubaxonium* ? *octaedrospongiosum* Won (100µm)
5. *Pseudoalbaillella lomentaria* Ishiga & Imoto (100µm)
6. *Pseudoalbaillella scalprata* m. *rhombothoracata* Ishiga (100µm)
7. *Pseudoalbaillella longtanensis* Sheng & Wang (100µm)
8. *Pseudoalbaillella globosa* Ishiga, Kito & Imoto (100µm)
9. *Follicucullus monacanthus* Ishiga & Imoto (100µm)
10. *Follicucullus porrectus* Rudenko (120µm)
11. *Neoalbaillella ornithoformis* Takemura & Nakaseko (100µm)
12. *Neoalbaillella optima* Ishiga, Kito & Imoto (100µm)
13. *Entactinosphaera chiakensis* Sashida & Igo (100µm)
14. *Triassocampe coronata* Bragin (100µm)
15. *Triassocampe deweveri* (Nakaseko & Nishimura) (100µm)
16. *Oertlispongus inaequispinosus* Dumitrica, Kozur & Mostler (100µm)
17. *Palaeosaturnalis triassicus* (Kozur & Mostler) (100µm)
18. *Tetraporobrachia asymmetrica* Kozur & Mostler (94µm)
19. *Capnuchosphaera triassica* De Wever (67µm)
20. *Capnuchosphaera deweveri* Kozur & Mostler (100µm)
21. *Sarla vizcainoensis* Pessagno (60µm)
22. *Annulotriassocampe sulovensis* (Kozur & Mock) (61µm)

Albailella indensis zone

Eight Radiolarian taxa discovered from the Kubang Pasu Formation, Kedah, consists of *Stigmosphaerostylus variospina* (Won), *Entactinia inaequoporosa* Won, *Callela hexatinia* Won, *Callella* cf. *parvispinosa* Won, *Treanosphaera hebes* Won, *Cubaxonium? octaedrospongiosum* Won *Duplexia foremanae* (Ormiston & Lane) and *Duplexia parviperforata* Won (Basir & Zaiton, 2001b). The zonal marker *Albailella indensis* is absent but the presence of *Cubaxonium? octaedrospongiosum* Won (Figure 3, no. 4), *Stigmosphaerostylus variospina* (Won), *Callela hexatinia* Won, *Entactinia inaequoporosa* Won is indicative of *Albaillella indensis* Zone, late Tournaisian, or early Visean, Early Carboniferous (Won, 1990).

Pseudoalbaillella lomentaria zone

The assemblage was found in a chert block at Pos Blau, Ulu Kelantan. Twenty two species of Radiolarians were identified (Basir & Che Aziz, 1997a). The zone is characterized by the occurrence of the zonal marker *Pseudoalbaillella lomentaria* Ishiga & Imoto (Figure 3, no. 5), *Pseudoalbaillella ornata* Ishiga & Imoto, *Pseudoalbaillella sakmarensis* Kozur, *Pseudoalbaillella scalprata scalprata* Ishiga and *Pseudoalbaillella scalprata postscalprata* Ishiga. The assemblage is indicative of late Asselian-early Sakmarian, Early Permian.

Pseudoalbaillella scalprata m. *rhombothoracata* zone

The assemblage zone is defined by the presence of zonal maker *Pseudoalbaillella scalprata* m. *rhombothoracata* Ishiga (Figure 3, no. 6), *Pseudoalbaillella scalprata* m. *scalprata* Ishiga, *Pseudoalbaillella scalprata* m. *postscalprata* Ishiga and *Pseudoalbaillella elongata* Ishiga & Imoto. This is the oldest radiolarian assemblage recorded in the Semanggol Formation of north and south Kedah. The zone was first reported from Bukit Larek (Basir, 1997) and Bukit Yoi, north Kedah (Basir, 2008) and subsequently was also recorded from Bukit Kukus, south Kedah (Basir *et al.*, 2005a). The assemblage contains very low specific diversity. The stratigraphically important species in the zone is *Pseudoalbaillella elongata*, which has very short range and restricted to *Pseudoalbaillella scalprata* m *rhombothoracata* Zone (Ishiga, 1990). The zone is assignable to late Sakmarian age, late Early Permian.

Pseudoalbaillella longtanensis zone

The radiolarian assemblage representing this zone exhibits very low specific diversity and consists of *Pseudoalbaillella longtanensis* Sheng & Wang (Figure 3, no. 7), *Pseudoalbaillella aidensis* Nishimura & Ishiga and, *Pseudoalbaillella fusiformis* (Holdsworth & Jones). Nishimura & Ishiga (1987) reported the occurrence of short ranging species of *Pseudoalbaillella aidensis* corresponds to the *Pseudoalbaillella longtanensis* Zone. The assemblage was discovered from the Semanggol Formation exposed at Bukit Yoi, Pokok Sena, Kedah (Basir, 2008). The zone is of Kungurian, Middle Permian age.

Pseudoalbaillella globosa zone

The zone is characterized by the abundance of the zonal marker, *Pseudoalbaillella globosa* Ishiga, Kito & Imoto (Figure 3, no. 8) together with *Pseudoalbaillella yanaharensis* Nishimura & Ishiga, *Pseudoalbaillella fusiformis* (Holdsworth & Jones), *Latentifistula texana* Nazarov & Ormiston, and *Raciditor inflata* (Sashida & Tonishi). *Pseudoalbaillella globosa* has longer stratigraphic range. It occurs from the late *Pseudoalbaillella longtanensis* Zone to the *Follicucullus monacanthus* Zone. *Pseudoalbaillella yanaharensis* is a good indicator for the zone (Jin *et al*., 1994). The assemblage is found in the chert samples of the Semanggol Formation exposed at Bukit Yoi, Pokok Sena, Kedah (Basir, 2008). The zone is of Roadian, Middle Permian age.

Follicucullus monacanthus zone

The zone is dominated by occurrence of *Follicucullus monacanthus* Ishiga and Imoto (Figure 3, no. 9) with *Follicucullus scholasticus* Ormiston & Babcock, *Entactinia itsukaitchiensis* Sashida & Tonishi, and *Hagleria mammilla* Sheng & Wang. This zone exhibits very low specific diversity. Six taxa were recovered from Genting Serampang (Basir *et al*., 1995a), and four taxa are recorded from Kuala Ketil area (Basir *et al*., 2005a) and six taxa were recorded from a chert block in Pos Blau, Kelantan (Basir *et al*., 2013). This zone is assigned to Wordian, Middle Permian (Sashida & Salyapongse, 2002).

Follicucullus porrectus zone

The assemblage was discovered from the Semanggol Formation exposed at Bukit Kukus, Kuala Ketil, Kedah (Basir *et al*., 2005a). The assemblage exhibits very low specific diversity and contains zonal marker *Follicucullus porrectus* Rudenko (Figure 3. No. 10), *Follicucullus scholasticus* Ormiston & Babcock, *Follicucullus elongata* Spiller. Other species are *Quinqueremis* sp. and *Entactinia* sp. The zone indicates a Capitanian, late Middle Permian to early Late Permian age.

Neoalbaillella ornithoformis zone

The zone is recognized based on the occurrence of *Neoalbaillella ornithoformis* Takemura & Nakaseko (Figure 3, no. 11), *Albaillella protolevis* Kuwahara, *Albaillella levis* Ishiga, Kito & Imoto, *Albaillella lauta* Kuwahara, *Albaillella excelsa* Ishiga, Kito & Imoto, *Neoalbaillella grypus* Ishiga, Kito & Imoto, *Entactinosphaera pseudocimelia* Sashida & Tonishi and *Octatormentum floriferum* Sashida & Tonishi (Basir, 1997; Basir *et al*., 2005a). *Albaillella lauta* Kuwahara and *Albaillella excelsa* Ishiga, Kito & Imoto appeared at the top of *Neoalbaillella ornithoformis* Assemblage Zone (Kuwahara, 1999). This assemblage is indicative of Wuchiapingian, Late Permian (Sashida & Salyapongse, 2002). The assemblage zone was identified from chert sequence at Kuala Ketil, Kampung Lanjut Malau and Merbau Pulas, Kedah. Twenty taxa were recorded from chert sequence exposed at Bukit Kukus, Kuala Ketil (Basir

et al., 2005a), five taxa from Kampung Lanjut Malau and twelve taxa from Merbau Pulas area (Basir, 1997).

Neoalbaillella optima zone

The zone contains zonal marker *Neoalbaillella optima* Ishiga, Kito & Imoto (Figure 3, no. 12), *Albaillella triangularis* Ishiga, Kito & Imoto, *Albaillella flexa* Kuwahara, *Albaillella excelsa* Ishiga, Kito & Imoto, *Albailella levis* Ishiga, Kito & Imoto, *Copiellintra fontainei* (Sashida), *Copicyntra akikawaensis* Sashida & Tonishi, and *Foremanhelena triangula* De Wever & Caridroit. This assemblage is recovered from chert samples of the Kuala Ketil area, Kedah (Basir *et al*., 2005a; Basir & Zaiton, 2011a). The assemblage indicates Changxingian, Late Permian (Kuwahara, 1999).

Entactinia chiakensis zone

The zone is characterized by the occurrence of *Entactinosphaera chiakensis* Sashida & Igo (Figure 3, no. 13), *Cenosphaera andoi* Sugiyama, *Archaeosemantis cristianensis* Dumitrica, *Entactinia nikorni* Sashida & Igo, and *Thaisphaera minuta* Sashida & Igo (Basir & Zaiton, 2001a). *Entactinosphaera chiakensis, Entactinia nikorni* and *Thaisphaera minuta* were recorded from the latest Spathian of Southern Thailand (Sashida & Igo, 1992). The assemblage zone is comparable to the *Parentactinia nakatsugawaensis* Zone, Spathian, Early Triassic (Sugiyama, 1992; Kamata, 1999). The assemblage zone has been reported from the Kodiang Limestone (Basir & Zaiton, 2001a) and the Semanggol Formation (Basir *et al*., 2005b).

Triassocampe coronata zone

The zone is based on the presence of zonal marker *Triassocampe coronata* Bragin (Figure 3, no. 14) together with *Pseudostylosphaera japonica* (Nakaseko & Nishimura), *Eptingium manfredi* Dumitrica and *Acanthosphaera awaensis* Nakaseko & Nishimura. *Triassocampe coronata* has very short stratigraphic range and restricted to the zone (Sugiyama, 1992). The assemblage is indicative of middle Anisian, Middle Triassic. The assemblage was discovered from the Semanggol Formation in south Kedah (Basir *et al*., 2005b).

Triassocampe deweveri zone

The assemblage consists of *Triassocampe deweveri* (Nakaseko & Nishimura) (Figure 3, no. 15), *Triassocampe scalaris* Dumitrica, Kozur & Mostler, *Pseudostylosphaera tenue* (Nakaseko & Nishimura), *Pseudostylosphaera japonica* (Nakaseko & Nishimura), *Pseudostylosphaera coccostyla* (Rüst), and *Eptingium manfredi* Dumitrica (Basir, 1997). This assemblage indicates an age of late Anisian, Middle Triassic. This assemblage zone is found in the Semanggol Formation exposed at Bukit Tembaga (Basir, 1994a, 1997; Spiller & Metcalfe, 1995b; Spiller, 2002), Pokok Pauh and Merbau Pulas, Kedah (Basir, 1994a, 1997).

Oertlispongus inaequispinosus zone

The assemblage is composed of zonal marker *Oertlispongus inaequispinosus* Dumitrica, Kozur & Mostler (Figure 3, no. 16), *Muelleritortis cochleata* (Nakaseko & Nishimura), *Triassocampe annulata* (Nakaseko & Nishimura), *Baumgartneria retrospina* Dumitrica, *Baumgartneria lata* Kozur & Mostler and *Acanthosphaera awaensis* (Nakaseko & Nishimura) (Basir *et al*., 2005a). Kozur & Mostler (1994) reported the assemblage as *Oertlispongus inaequispinosus* subzone of the *Silicarmiger italicus* Zone. In the present material, *Silicarmiger italicus* is not found. The zone is indicative of Ladinian, Middle Triassic. The zone was identified from the chert sequence exposed at Bukit Kukus, Kuala Ketil, Kedah (Basir *et al*., 2005b).

Capnodoce zone

The zone is recovered from the Kodiang Limestone exposed at Bukit Kodiang, north Kedah (Basir *et al*., 1995b). The zone is characterized by the occurrence of *Palaeosaturnalis triassica* Kozur and Mostler (Figure 3, no. 17), *Tetraporobrachia asymmetrica* Kozur & Mostler (Figure 3, no. 18), *Capnuchosphaera triassica* De Wever (Figure 3, no. 19) *Capnuchosphaera deweveri* Kozur & Mostler (Figure 3, no. 20), *Sarla viscainoensis* Pessagno (Figure 3, no. 21), and *Annulotriasocampe sulovensis* (Kozur & Mock) (Figure 3, no. 22). Most of the species have the stratigraphic range from Middle Carnian to Early Norian (Tekin, 1999). This assemblage is comparable to the *Capnodoce* Zone of Blome (1984), late Carnian-early Norian, Late Triassic. The genus *Capnodoce* was not found in the present material.

The radiolarian biozones provide the age for the chert bearing formations. The chert blocks in the Bentong-Raub Suture Zone are ranging in age from Frasnian, Late Devonian, Early Permian and Middle Permian. The chert of the Kubang Pasu and the Kenny Hill Formation is Tournaisian-early Visean, Early Carboniferous. The age of the Semanggol chert ranges from Early Permian to Middle Triassic. The chert from Kodiang Limestone is of Early and Late Triassic age. Middle Permian radiaolarian chert was also discovered from Genting Serampang, Pahang (Figure 4). Radiolarians are also very important to enhance the tectonic of Peninsular Malaysia (Basir, 2013).

RADIOLARIAN BIOSTRATIGRAPHY OF SABAH AND SARAWAK

The synthesis on radiolarian biostratigraphy from Sabah and Sarawak is based on research carried out by Basir *et al*. (1985), Basir & Sanudin (1988), Basir *et al.* (1989), Basir (1991), Basir & Sanatulsalwa (1992), Basir (1992), Basir & Haile (1993), Basir & Aziman (1996), Basir *et al*. (1995), Basir (1996), Basir & Uyop (1999a, 1999b), Basir (2000a, 2000b), Junaidi & Basir (2012, 2013), and Basir & Tongkul (2000, 2013). Early research was mainly on identification of the radiolarian species and possible stratigraphic range of radiolarian assemblages. No detailed

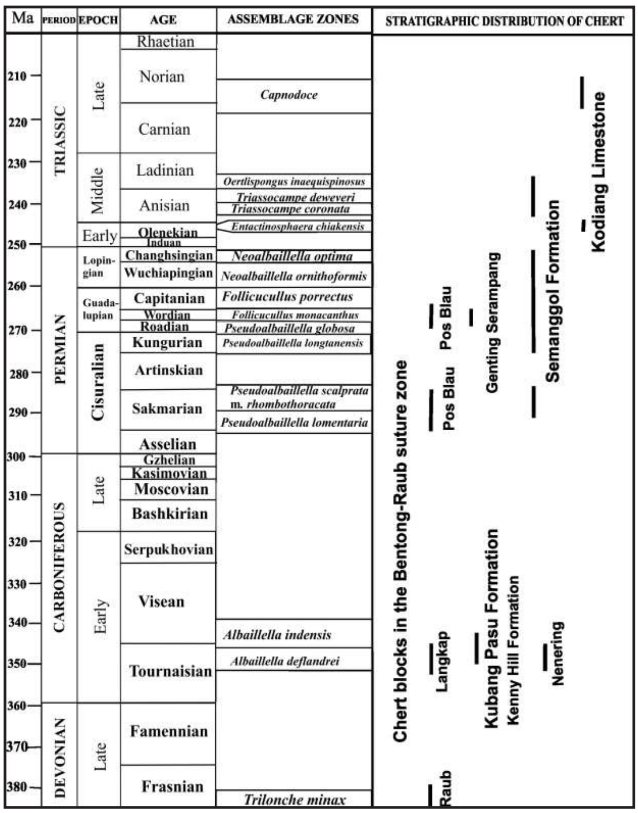

Figure 4: Radiolarian biozones and stratigraphic distribution of cherts for Peninsular Malaysia.

work on the biozonation has been carried out. In this paper the author propose biozones for Sabah and Sarawak with revision on the name of some species according to up to date literature (Baumgartner *et al*., 1995a; Gorican *et al*., 2006). The biozonation is based on those of Matsouka (1995), Sanfilippo & Riedel (1985) and Vishnevskaya (1993). A complete biozonation cannot be erected due to patchy stratigrahic distribution of radiolarian chert.

Trillus elkhornensis zone

The zone is characterized by the occurrence of the zonal marker *Trillus elkhornensis* Pessagno & Blome (Figure 5, no.1), and other species such as *Parahsuum simplum* Yao (Figure 5, no. 2), *Parahsuum ovale* Hori & Yao (Figure 5, no. 3), *Canoptum anulatum* Pessagno & Poisson (Figure 5, no. 4), *Canoptum artum* Yeh (Figure 5, no. 5), *Lantus obesus* (Yeh) (Figure 5, no. 6), *Pantanellium carlense* Whalen & Carter (Figure 5, no. 7), *Praeconocaryomma parvimamma* Pessagno & Poisson (Figure 5, no. 8), *Praeconocaryomma immodica* Pessagno & Poisson (Figure 5, no. 9), *Praeconocaryomma bajaensis* Whalen (Figure 5, no. 10), and *Praeconocaryomma sarahae* Carter (Figure 5, no. 11). Basir & Uyop (1999a) assigned this assemblage to the *Parahsuum directiporatum* Zone (Nishizono *et al*., 1997). The co-occurrence of *Trillus elkhornensis* and *Parahsuum simplum* is indicative of the late Plienbachian to Toarcian (Matsuoka, 1995). Hori (1990) placed the

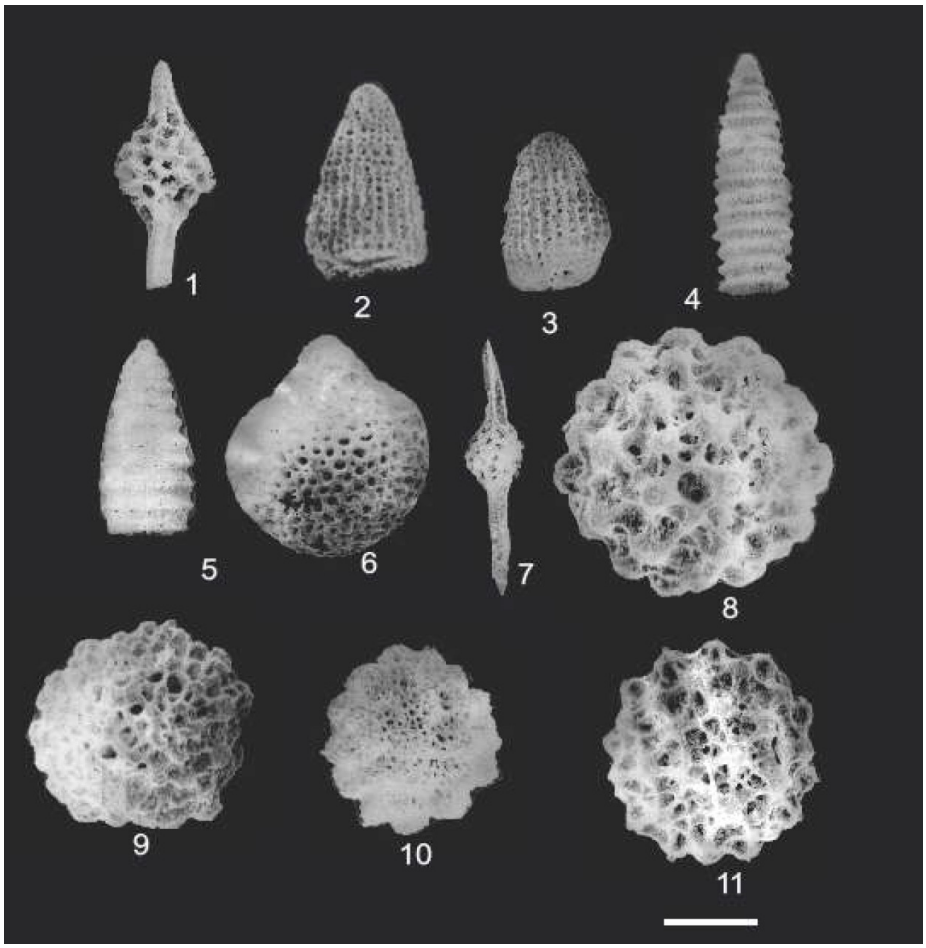

Figure 5: Some selected radiolarians from the Serian Volcanic Formation.
1. *Trillus elkhornensis* Pessagno & Blome (100µm)
2. *Parahsuum simplum* Yao (80µm)
3. *Parahsuum ovale* Hori & Yao (100µm)
4. *Canoptum anulatum* Pessagno & Poisson (100µm)
5. *Canoptum artum* Yeh (100µm)
6. *Lantus obesus* (Yeh) (100µm)
7. *Pantanellium carlense* Whalen & Carter (100µm)
8. *Praeconocaryomma parvimamma* Pessagno & Poisson (100µm)
9. *Praeconocaryomma immodica* Pessagno & Poisson (100µm)
10. *Praeconocaryomma bajaensis* Whalen (100µm)
11. *Praeconocaryomma sarahae* Carter (100µm)

Trillus elkhornensis Zone as a subzone of the *Parahsuum simplum* Zone.

Loopus primitivus zone

The occurrence of the zonal marker *Loopus primitivus* (Matsuoka & Yao) (Figure 6, no. 1), and other species namely, *Angulobacchia* (?) *rugosa* Jud (Figure 6, no. 2), *Cinguloturis cylindrical* Kemkin & Rudenko (Figure 6, no. 3), *Artocapsa* (?) *amphorella* Jud (Figure 6, no. 4), *Obesacapsula rusconensis umbriensis* Jud (Figure 6, no. 5), *Hsuum raricostum* Jud (Figure 6, no. 6), *Mirifusus dianae baileyi* Baumgartner (Figure 6, no. 7), and *Syringocapsa longitubus* Jud (Figure 6. No. 8), at the lower part of the outcrop at Pang Bau, Sarawak is indicative of the *Loopus primitivus* Zone which is equivalent to Zone 12 Unitary Association of Baumgartner *et al*. (1995b). The zone is Tithonian (Late Jurassic) in age.

A similar fauna was recovered from a chert block from the Lubok Antu Melange. The radiolarian assemblage is slightly different in species composition, comprising of *Homoeoparonaella gigantea* Baumgartner (Figure 7, no. 1), *Acanthocircus suboblongus suboblongus* (Yao) (Figure 7, no. 2), *Archaeodictyomitra excellens* (Tan) (Figure 7, no. 3), *Ristola altissima* (Rüst) (Figure 7, no. 4), *Mirifusus dianae baileyi* Pessagno (Figure 7, no. 5), *Mirifusus dianae minor* Baumgartner (Figure 7 no. 6), *Tritrabs exotica* (Pessagno) (Figure 7, no. 7), *Pantanellium squinaboli* (Tan) (Figure 7, no. 8). The *Loopus primitivus* zonal marker was not however discovered.

Pseudodictyomitra carpatica zone

This zone is characterized by the occurrence of the zonal marker *Pseudodictyomitra carpatica* (Lozyniak) (Figure 6, no. 9) *Pantanellium squinaboli* (Tan) (Figure 6, no. 10), *Archaeodictyomitra excellens* (Tan) (Figure 6, no. 11), *Archaeospongoprunun patricki* Jud Figure 6, no. 12), *Archaeodictyomitra apiarium* (Rüst) (Figure 6, no. 13)

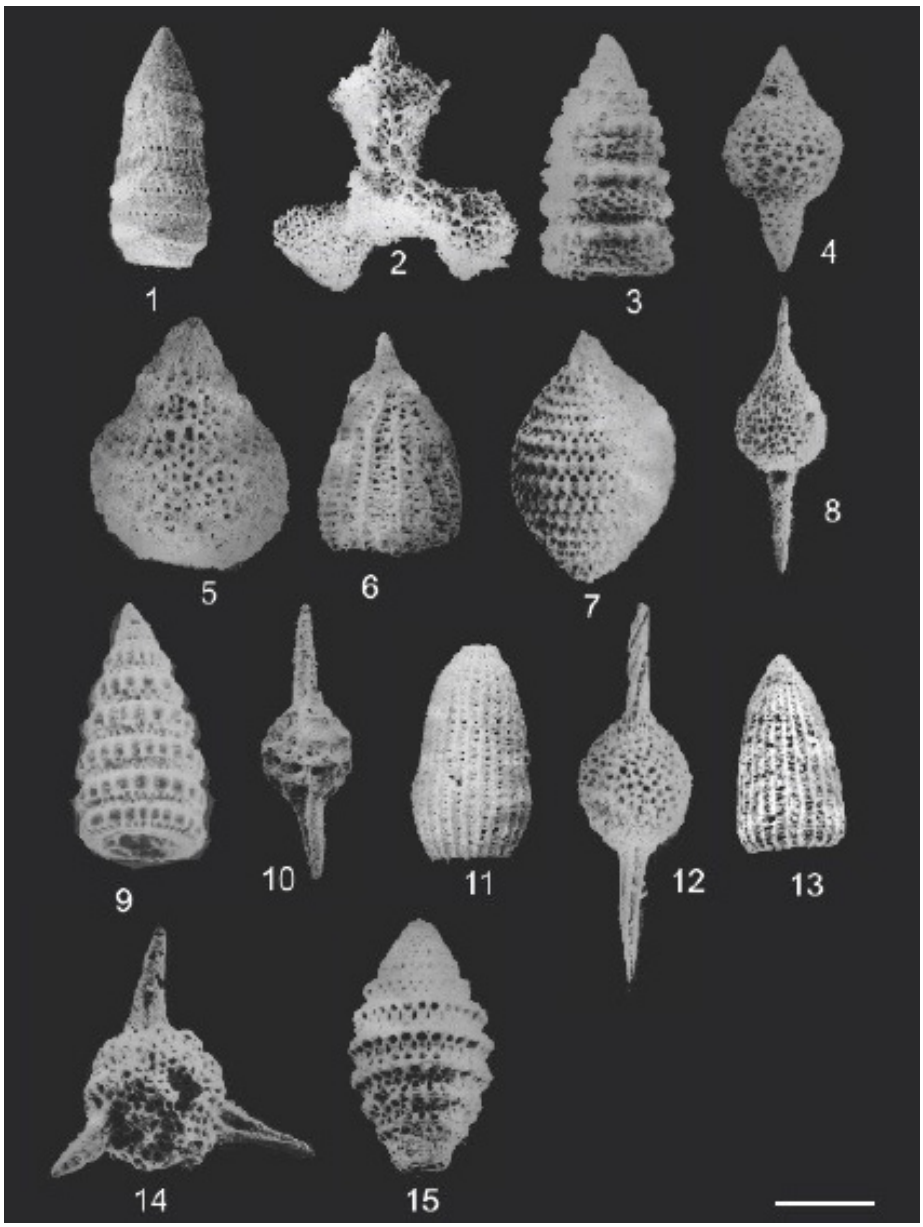

Figure 6: Some selected radiolarians from the Pedawan Formation.
1. *Loopus primitivus* (Matsuoka & Yao) (100 µm)
2. *Angulobracchia* (?) *rugosa* Jud (133 pm)
3. *Cinguloturris cylindrica* Kemkin & Rudenko (133 µm)
4. *Artocapsa* (?) *amphorella* Jud (100 µm)
5. *Obesacapsula rusconensis umbriensis* Jud (133 µm)
6. *Hsuum raricostatum* Jud (80 µm)
7. *Mirifusus dianae baileyi* Baumgartner (200 µm)
8. *Syringocapsa longitubus* Jud (200 µm)
9. *Pseudodictyomitra carpatica* (Lozyniak) (100 µm)
10. *Pantanellium squinaboli* (Tan) (100 µm)
11. *Archaeodictyomitra excellens* (Tan) (100 µm)
12. *Archaeospongoprunum patricki* Jud (114 µm)
13. *Archaeodictyomitra apiarum* (Rüst) (100µm)
14. *Acaeniotyle diaphorogona* Foreman (100 µm)
15. *Parvicingula boesii* (Parona) (100 µm)

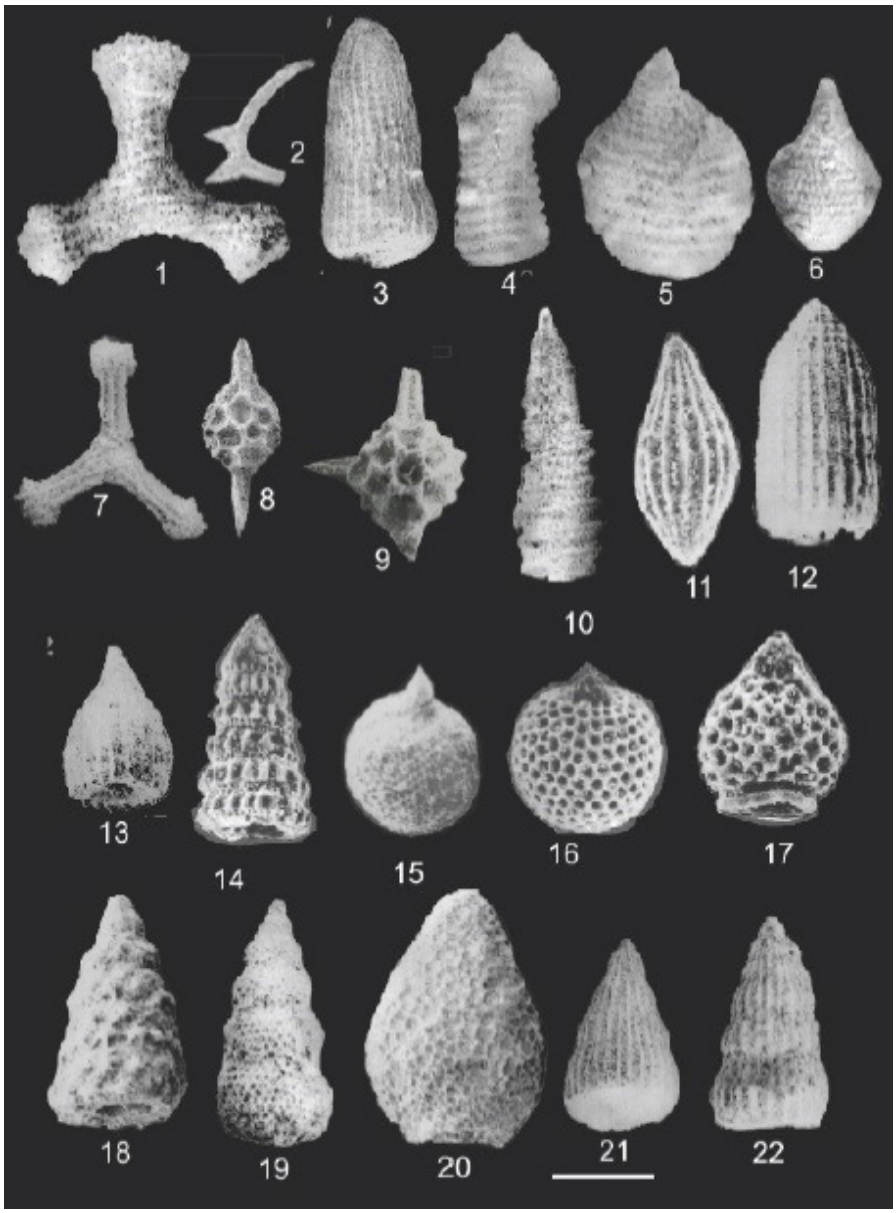

Figure 7: Some selected radiolarians from the chert blocks of the Lubok Antu Melange.
1. *Homoeoparonaella gigantea* Baumgartner (100 µm)
2. *Acanthocircus suboblongus suboblongus* (Yao)(130µm)
3. *Archaeodictyomitra excellens* (Tan) (90µm)
4. *Ristola altissima* (Rüst) (130µm)
5. *Mirifusus dianae baileyi* Pessagno (200µm)
6. *Mirifusus dianae minor* Baumgartner (200µm)
7. *Tritrabs exotica* (Pessagno) (200µm)
8. *Pantanellium squinaboli* (Tan) (100µm)
9. *Cecrops septemporatus* (Parona) (135µm)
10. *Parvicingula excelsa* Pessagno & Blome (110µm)
11. *Archaeodictyomitra lacrimula* (Foreman) (100µm)
12. *Archaeodictyomitra excellens* (Tan) (90µm)
13. *Thanarla pacifica* Nakaseko & Nishimura (100µm)
14. *Pseudodictyomitra pseudomacrocephala* (Squinabol) (80µm)
15. *Squinabollum fossilis* (Squinabol) (100µm)
16. *Cryptamphorella conara* (Foreman) (100µm)
17. *Rhopalosyringium majuroensis* Schaaf (70µm)
18. *Xitus mclaughlini* Pessagno (100µm)
19. *Stichomitra communis* Squinabol (100µm)
20. *Obesacapsula somphedia* Foreman (130µm)
21. *Thanarla praeveneta* Pessagno (100µm)
22. *Archaeodictyomitra vulgaris* Pessagno (100µm)

Acaeniotyle diaphorogona Foreman (Figure 6, no. 14), and *Parvicingula boesii* (Parona) (Figure 6, no. 15) in the top part of the Pang Bau section and indicates the *Pseudodictyomitra carpatica* Zone (Matsouka, 1995). The zone is equivalent to Zone 13 to Zone 15 of Unitary Association of Baumgartner *et al*. (1995b) which is Berriasian (Lowermost Cretaceous).

Many radiolarian taxa are common to both the *Loopus primitivus* and *Pseudodcityomitra carpatica* Zones. The zone can only be distinguished by the occurrence *Loopus primitivus* in the former. Both zones are recorded in at the basal part of the Pedawan Formation.

Cecrops septemporatus zone

The radiolarian assemblage in the Lubok Antu Melange contains the zonal marker *Cecrops septemporatus* (Parona) (Figure 7, no. 9) with other taxa namely *Parvicingula excelsa* Pessagno & Blome (Figure 7,no. 10), *Archaeodictyomitra lacrimula* (Foreman) (Figure 7, no 11), *Archaeodictyomitra excellens* (Tan) (Figure 7, no. 12), and *Thanarla pacifica* Nakaseko & Nishimura (Figure 7, no. 13).

The assemblage from Telupid contains *Cecrops septemporatus* (Parona) (Figure 8, no. 1), *Archaeodictyomitra lacrimula* (Foreman) (Figure 8, no. 2), *Dictyomitra pseudoscalaris* (Tan) (Figure 8, no. 3), *Pantanellium squinaboli* (Tan) (Figure 8, no, 4), and *Pseudodictyomitra carpatica* (Lozyniak) (Figure 8, no. 5). The zone is indicative a Valanginian to Hauterivian age (Matsouka, 1995).

The occurrence of *Archaeodictyomitra lacrimula* (Foreman), *Thanarla conica* (Aliev), and *Archaeodictyomitra vulgaris* (Pessagno) in the Serabang Complex indicates the same age.

The chert in Telupid exhibits slightly different species composition compared to that of Lubok Antu. The zone is recorded from a chert block in the Lubok Antu Melange, Sarawak and the chert sequence in Telupid, Sabah.

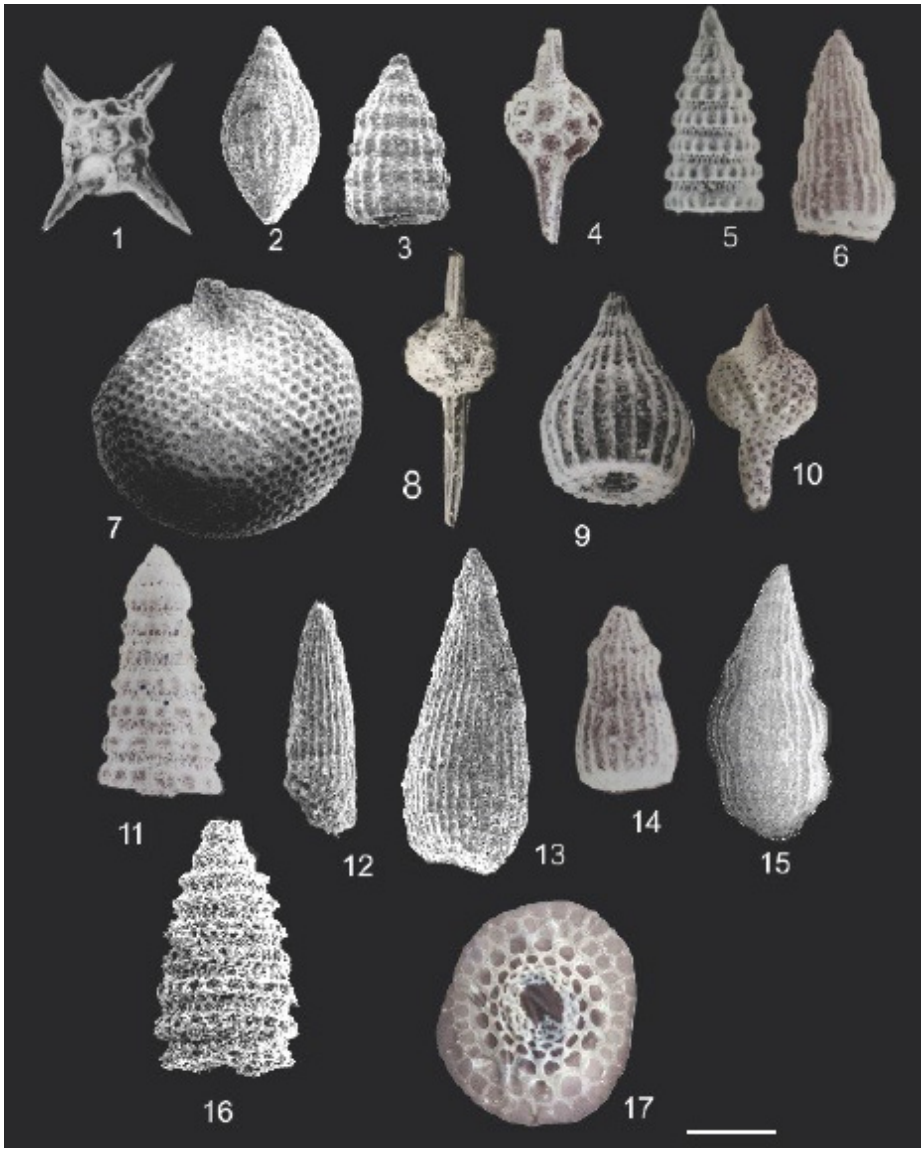

Figure 8: Some selected radiolarians from Sabah Complex and melanges. (Scale bar = 100µm)
1. *Cecrops septemporatus* (Parona)
2. *Archaeodictyomitra lacrimula* (Foreman)
3. *Dictyomitra pseudoscalaris* (Tan)
4. *Pantanellium squinaboli* (Tan)
5. *Pseudodictyomitra carpatica* (Lozyniak)
6. *Dictyomitra communis* (Squinabol)
7. *Sethocapsa* (?) *orca* Foreman
8. *Acaeniotyle umbilicata* (Rüst)
9. *Thanarla pacifica* Nakaseko & Nishimura
10. *Podobursa typical* (Rüst)
11. *Pseudodictyomitra pseudomacrocephala* (Squinabol)
12. *Dictyomitra montisserei* (Squinabol)
13. *Dictyomitra gracilis* (Squinabol)
14. *Dictyomitra formosa* Squinabol
15. *Dictyomitra obesa* (Squinabol)
16. *Pseudodictyomitra tiara* (Holmes)
17. *Scadiocapsa speciosa* (Squinabol)

Dictyomitra communis zone

The zone is characterised by the occurrence of the zonal marker *Dictyomitra communis* (Squinabol) (Figure 8, no. 6), together with *Sethocapsa* (?) *orca* Foreman (Figure 8, no. 7), *Acaeniotyle umbilicata* (Rüst) (Figure 8, no. 8), *Thanarla pacifica* Nakaseko & Nishimura (Figure 8, no. 9), and *Podobursa typical* (Rüst) (Figure 8, no. 10). The zone has been described by Basir & Tongkul (2013) and was discovered from the Baliojong ophiolite sequence, Sabah which ranges from late Barremian to Aptian in age.

Pseudodictyomitra pseudomacrocephala zone

The zone has been recorded from a chert block in the Lubok Antu Melange, Sarawak and in chert from Sabah. The zone is characterised by the occurrence of the zonal marker *Pseudodictyomitra pseudomacrocephala* (Squinabol) (Figure 7, no. 14). The assemblage in the chert block of Lubok Antu contains *Squinabollum fossilis* (Squinabol) (Figure 7, no. 15), *Cryptamphorella conara* (Foreman) (Figure 7, no. 16), *Rhopalosyringium majuroensis* Schaaf (Figure 7, no. 17), *Xitus mclaughlini* Pessagno (Figure 7, no. 18), *Stichomitra communis* Squinabol (Figure 7, no. 19), *Obesacapsula somphedia* Foreman (Figure 7, no. 20), *Thanarla praeveneta* Pessagno (Figure 7, no. 21), and *Archaeodictyomitra vulgaris* Pessagno (Figure 7, no. 22).

The radiolarian assemblage from chert in Sabah consists of *Pseudodictyomitra pseudomacrocephala* (Squinabol) (Figure 8, no. 11), *Dictyomitra montisserei* (Squinabol) (Figure 8, no. 12), *Dictyomitra gracilis* (Squinabol) (Figure 8, no. 13), *Dictyomitra formosa* Squinabol (Figure 8, no. 14), *Dictyomitra obesa* (Squinabol) (Figure 8, no. 15), *Pseudodictyomitra tiara* (Holmes) (Figure 8, no. 16) and *Scadiocapsa speciosa* (Squinabol) (Figure 8, no. 17).

The zone is equivalent to the *Obesacapsula somphedia* Zone of Sanfilippo & Riedel (1985). The zone ranges from Albian to Turonian.

A total of six assemblage zones were recognised in Sabah and Sarawak. The chert from the Serian Volcanic Formation is Plienbachian-Taorcian in age. The age of the chert from the Pedawan Formation is Late Jurassic- Early

Cretaceous. The chert blocks from Lubok Antu Melange is ranging from Late Jurassic to early Late Cretaceous. The age of Serabang Melange chert blocks is Early Cretaceous. Bedded chert and chert blocks from Sabah are of the same age, Early to early Late Cretaceous (Figure 9). The chert blocks are derived from the cherts of the Sabah ophiolite Complex.

DISTRIBUTION OF RADIOLARIAN CHERTS AND PALEOOCEANOGRAPHY

Radiolarian cherts are generally deposited in a deep-marine environment which lacks of supply of terrigenous material. Absence of limestone in the chert sequence suggests the chert was deposited below the calcite compensation depth where the calcareous material dissolved. Radiolarians provide vital information on the age of sediments where other fossils are lacking.

The distribution of radiolarian cherts in the sedimentary sequence in Malaysia is not continuous. Their occurrence is punctuated by the influx of clastic sediments. Development of chert very much depends on the plankton productivity and the supply of clastic material. Higher productivity causes the widespread depositional of chert and an increase in clastic supply reduces chert formation. The productivity of radioalarians is usually associated with concentration of silica in the sea-water, nutrients and oxygen which are vital for development of radiolarian chert. The concentration of silica was very high in Paleozoic ocean about 60ml/l, decreases in the Mesozoic and became less in the Cenozoic (Racki & Cordey, 2000).

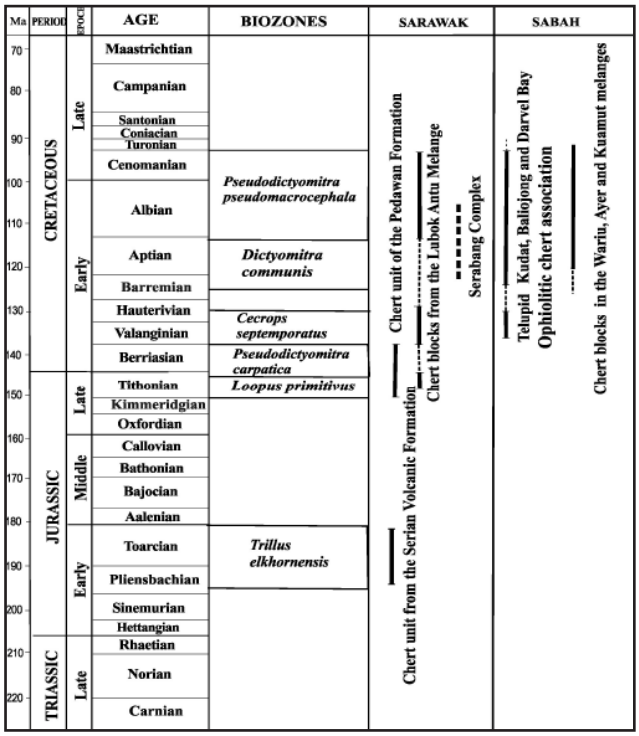

Figure 9: Radiolarian biozones and stratigraphic position of chert in Sabah and Sarawak.

The occurrence of radiolarian chert and radiolarian biozones can be correlated to productivity. There are five periods of chert (Hypersiliceous) depositions (Figure 10).

1. Late Devonian-Early Carboniferous
2. Permian
3. Early-Middle Triassic
4. Early Jurassic
5. Late Jurassic- Cretaceous

Development of radiolarian chert in Late Devonian-Early Carboniferous period is related to the supply of silica as a result of opening of the Paleo-Tethys. The opening of an ocean caused submarine volcanism and hydrothermal plumes which increases supply of silica and nutrient (Racki & Cordey, 2000) to the surface of an ocean. The event contributed to the radiolarian blooms and resulted in the formation thick radiolarian chert.

Permian radiolarian cherts are widespread in the Semanggol Formation, bedded chert in Jengka Pass and chert blocks in Pos Blau. The cherts are also associated with tuffaceous mudstone. This suggests that radiolarian productivity during the Permian was related to the supply of silica and nutrients from tuff as a result of volcanic activity in the Central Belt.

Early and Middle Triassic cherts are widespread in the Kodiang and Semanggol Formations. The occurrence of tuffaceous sediments in the Semanggol Formation was also the result of massive volcanism in the Central Belt of Peninsular Malaysia (Azman, 2009).

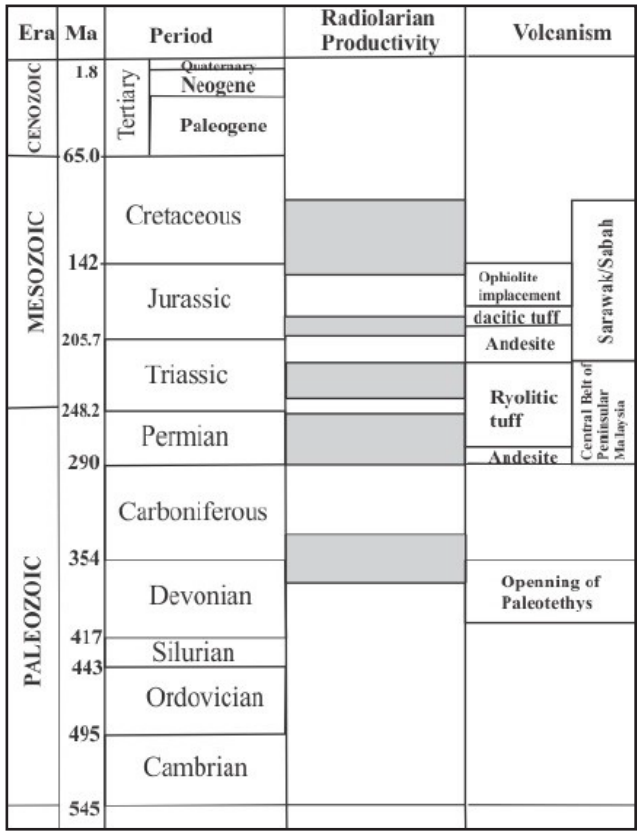

Figure 10: Radiolarian biostratigrahy and hypersilicoeus development in Malaysia.

Early Jurassic chert in Sarawak is associated with dacitic tuff of the Serian Volcanic Formation which is well-exposed at the road-cut near Binong Pass near Piching (Basir *et al*., 1996; Basir & Uyop, 1999a). The productivity of radiolarian chert was related to volcanic activity in the area.

Development of Cretaceous radiolarian cherts in Sabah and Sarawak is also related to high concentration of silica as a result of weathering of the oceanic basement ophiolitic rocks in Sabah and Sarawak. In Sabah, the silica is derived from the Sabah ophiolite and in Sarawak the siliceous material derived from the ophiolite suite formed prior to the formation of Serabang Complex (Hutchison, 2005).

Generally, the development and deposition of radiolarian chert in Malaysia partly corresponds to global hypersiliceous periods particularly in the Early Carboniferous, middle Permian, Middle Triassic, and Cretaceous (Racki & Cordey, 2000). Other radiolarian chert formations are related to local events such as volcanism. The enrichment of silica and nutrient to surface water was caused by the supply of tuffaceous material or upwelling currents which brought weathered material to the surface of the ocean and caused radiolarian blooms. As a result, radiolarian chert was well developed.

CONCLUSIONS

Radiolarians are very important microfossils for dating siliceous rocks (chert) in Malaysia. Radiolarian biozones provide biochronology for rock sequences devoid of other fossils especially deep-sea sediments where calcareous fossils dissolve below the Calcite Compensation Depth. A total of twenty two biozones were identified from the radiolarian cherts through out Malaysia. Sixteen radiolarian biozones are identified in Peninsular Malaysia and six biozones in Sabah and Sarawak. The zones are assemblage zones based on the occurrence zonal markers and index taxa. The oldest radiolarian chert in Peninsular Malaysia is Frasnian, Late Devonian. Two biozones are identified from the Early Carboniferous, eight biozones from the Permian and five bioznes from the Triassic.

In Sabah and Sarawak, six biozones are recognised, one in the Pliesbachian-Toarcian, (Early Jurassic), one in the Tithonian (Late Jurassic) and four in the Early and early Late Cretaceous. There are five hypersiliceous period; Late Devonian-Early Carboniferous. Permian, Triassic, Early Jurassic, and Late Jurassic-Cretaceous. The hypersiliceous developments were related to local volcanism.

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REFERENCES

Aitchison, J.C., 1994. Early Cretaceous (pre-Albian) radiolarians from blocks in Ayer Complex melange, eastern Sabah, Malaysia, with comments on their regional tectonic significance and the origins of enveloping melanges. J. SE Asian Earth Sci., 9(3), 255-262.

Aitchison, J.C., Davis, A.M., Stratford, J.M.C. & Spiller, F.C.P., 1999. Lower and Middle Devonian radiolarian biozonation of the Gamilaroi terrane New England Orogen, eastern Australia. Micropaleontology, 45(2), 138-162.

Azman, A.G., 2009. Volcanism, In: Hutchison S.C. & Tan D.N.K. (Eds.), Geology of Peninsular Malaysia. Geological Society of Malaysia, Kuala Lumpur, 197-210.

Basir Jasin, 1991. The Sabah Complex- a lithodemic unit (a new name for the Chert-Spilite Formation and its ultramafic association). Warta Geologi, 17(6), 253-259.

Basir Jasin, 1992. Significance of radiolarian cherts from the Chert-Spilite Formation, Telupid, Sabah. Bulletin of the Geological Society of Malaysia, 31, 67-83.

Basir Jasin, 1994a. Middle Triassic Radiolaria from the Semanggol Formation, northwest Peninsular Malaysia. Warta Geologi, 20(4), 279-284.

Basir Jasin, 1994b. Early Permian radiolaria from Ulu Kelantan, Malaysia. Seminar on Permo-Triassic of Peninsular Malaysia and associated mineralization-Abstract of papers. Warta Geologi, 20(2), 96.

Basir Jasin, 1995. Occurrence of bedded radiolarian chert in the Kubang Pasu Formation, North Kedah, Peninsular Malaysia. Warta Geologi, 21(2), 73-79.

Basir Jasin, 1996a. Discovery of Early Permian Radiolaria from the Semanggol Formation, northwest Peninsular Malaysia. Warta Geologi, 22(4), 283-287.

Basir Jasin, 1996b. Late Jurassic to Early Cretaceous Radiolaria from chert blocks in the Lubok Antu melange, Sarawak. Journal Southeast Asian Earth Sci., 13(1), 1-11.

Basir Jasin, 1997. Permo-Triassic radiolaria from the Semanggol Formation, northwest Peninsular Malaysia. Journal of Asian Earth Sciences, 15(1), 43-53.

Basir Jasin, 2000a. Geological significance of radiolarian chert in Sabah. Geol. Soc. Malaysia Bull., 44, 35-43.

Basir Jasin, 2000b. Significance of Mesozoic Radiolarian Chert in Sabah and Sarawak. In: Teh, G.H., Pereira, J. J. & Ng, T. F. (Eds.), Proceedings Annual Geological Conference 2000, 123-130.

Basir Jasin, 2008. Some Permian Radiolarians from Bukit Yoi, Pokok Sena, Kedah. Bulletin of the Geological Society of Malaysia, 54, 53-58.

Basir Jasin, 2013. Chert blocks in Bentong-Raub Suture Zone: a heritage of Paleo-Tethys. Bulletin of the Geological Society of Malaysia, 59, 85 – 91.

Basir Jasin & Aziman Madun, 1996. Some Lower Cretaceous Radiolaria from the Serabang Complex, Sarawak. Warta Geologi, 22(2), 61-65.

Basir Jasin & Che Aziz Ali, 1997a. Lower Permian Radiolaria from the Pos Blau area, Ulu Kelantan, Malaysia. Journal of Asian Earth Sciences, 15(4/5), 327-339.

Basir Jasin & Che Aziz Ali, 1997b. Significance of Early Carboniferous Radiolaria from Langkap, Negeri Sembilan, Malaysia. Bulletin of the Geological Society of Malaysia, 41, 109-125.

Basir Jasin & Haile, N.S., 1993. Some radiolaria from the chert block of the Lubok Antu Melange, Sarawak. Warta Geologi, 19(5), 205-209.

Basir Jasin & Sanatulsalwa Hasan, 1992. Some Early Cretaceous Radiolaria from the chert sequence in the Mandurian area, Sabah. Sains Malaysiana, 21(1), 55-67.

Basir Jasin & Sanudin Tahir, 1988. Barremian Radiolaria from the Chert-Spilite Formation, Kudat, Sabah. Sains Malaysiana,

17(1), 67-79.

Basir Jasin & Tongkul, F., 2000. Fosil radiolaria daripada jujukan ofiolit Lembah Baliojong, Tandek, Sabah. Warisan Geologi Malaysia, 3, 219-230.

Basir Jasin & Tongkul F., 2013. Cretaceous radiolarians from Baliojong ophiolite sequence, Sabah, Malaysia. Journal of Asian Earth Sciences, 76, 258–265.

Basir Jasin & Uyop Said, 1999a. Significance of Early Jurassic radiolarian from west Sarawak, Malaysia. GEOSEA '98 Proceeding, Bulletin of the Geological Society of Malaysia, 43, 491-502.

Basir Jasin & Uyop Said, 1999b. Some Late Jurassic-Early Cretaceous radiolarian faunas from the Pedawan Formation. GEOSEA '98 Proceeding, Bulletin of the Geological Society of Malaysia, 43, 611-620.

Basir Jasin & Zaiton Harun, 2001a. Some Triassic radiolarians from the Kodiang Limestone, northwest Peninsular Malaysia, In: Teh, G.H., Pereira, J. J. & Ng, T. F. (Eds.), Proceedings Annual Geological Conference 2001, 105-109.

Basir Jasin & Zaiton Harun, 2001b. Some radiolarians from the Kubang Pasu Formation. In: Teh, G.H., Pereira, J.J. & Ng, T.F. (Eds.), Proceedings Annual Geological Conference 2001, 110-114.

Basir Jasin & Zaiton Harun, 2006. Discovery of some Early Carboniferous Radiolarians from North Perak and their significance. Bulletin of the Geological Society of Malaysia, 49, 19-24.

Basir Jasin & Zaiton Harun, 2011a. Radiolarian biostratigraphy of Peninsular Malaysia; an update. Bulletin of the Geological Society of Malaysia, 57, 27-38.

Basir Jasin & Zaiton Harun, 2011b. Lower Carboniferous (Tournaisian) radiolarians from Peninsular Malaysia and their significance. Bulletin of the Geological Society of Malaysia, 57, 47-54.

Basir Jasin, Atilia Bashardin & Zaiton Harun, 2013. Middle Permian radiolarians from siliceous mudstone block near Pos Blau, Ulu Kelantan and their significance. Bulletin of the Geological Society of Malaysia, 59, 33-38.

Basir Jasin, Uyop Said & Rosmah Abd. Rahman, 1995a. Late Middle Permian Radiolaria from the Jengka area, central Pahang. Journal of Southeast Asian Earth Sciences, 12(1/2), 79-83.

Basir Jasin, Che Aziz Ali & Kamal Roslan Mohamed, 1995b. Late Triassic Radiolaria from the Kodiang Limestone, northwest Peninsular Malaysia. Journal of Southeast Asian Earth Sciences, 12(1/2), 31-39.

Basir Jasin, Sanudin Tahir & Abd. Rahim Samsudin, 1985. Lower Cretaceous Radiolaria from the Chert-Spilite Formation, Kudat, Sabah. Warta Geologi, 11(4), 161-162.

Basir Jasin, Uyop Said & Ang Duen Woei, 1996. Discovery of Early Jurassic Radiolaria from the tuff sequence near Piching, west Sarawak. Warta Geologi, 22(5), 343-347.

Basir Jasin, Zaiton Harun & Uyop Said, 2004. Some Devonian radiolarians from chert blocks In the Bentong-Raub Suture Zone, Pahang. Bulletin of the Geological Society of Malaysia, 48, 81-84.

Basir Jasin, Zaiton Harun, Uyop Said & Sulaiman Saad, 2005a. Permian radiolarian biostratigraphy of the Semanggol Formation, south Kedah, Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 51, 19-30.

Basir Jasin, Zaiton Harun & Uyop Said, 2005b. Triassic radiolarian biostratigraphy of the Semanggol Formation, south Kedah, Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 51, 31-39.

Basir Jasin, Ahmad Jantan, Lim Peng Seng & Mat Niza Abd. Rahman, 1989. Some Microfossils from the Wariu Formation. Sains Malaysiana, 18(1), 57-75.

Baumgartner, P.O., O'Dogherty, L., Gorican, S., Urquhart, E., Pillevuit, A. & De Wever, P., 1995a. Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: ocurcrence, systematics, biochronology. Memoires de geologie (Lausanne), 23, 1172 p.

Baumgartner, P.O., Bartolini, A., Carter, E.S., Conti, M., Corteses, G., Danelian, T., De Wever. P., Dumitrical P., Dumitrica-Jud, R., Gorican, S., Guex, J., Hull, D.M., Kitol, N., Marcuci, M., Matsouka, A., Murchey, B., O'Dogherty, L., Savary, J., Vishnevkaya, V., Widz, D. & Yao, A., 1995b. Middle Jurassic to Early Cretaceous Radiolarian Biochronology of Tethys Based on Unitary Associations. Memoires de geologie (Lausanne), 23, 1013-1048.

Blome, C.D., 1984. Upper Triassic radiolaria and radiolarian zonation from western North America. Bulletin of American Paleontology, 85(318), 88 p.

Braun, A. & Schmidt-Effing, R., 1993. Biozonation, diagenesis and evolution of radiolarians in the Lower Carboniferous of Germany. Marine Micropaleontology, 21, 369-383.

Goričan, S,. Carter, E.S. Dumitrică, P., Whalen, P.A., Hori, R.S., De Wever, P., O'Dogherty, L., Matsuoka, S. & Guex, J., 2006. Catalogue and systematics of Pliensbachian, Toarcian and Aalenian radiolarian genera and species. ZRC Publishing, Ljubljana. 446 p.

Haile, N.S., 1957. The geology and mineral resources of the Lupar and Saribas Valleys, west Sarawak. Brit. Borneo Geol. Surv. Mem. 7.

Hinde, G.J., 1900. Description of fossils Radiolaria from the rocks of central Borneo. In: Molengraaff, G.A.F. (Ed.), Borneo-Expeditie: geologische verkenningstochten in Centraal Borneo (1893-1894), Brill Leiden, 1-51.

Hori, R., 1990: Lower Jurassic radiolarian zones of SW Japan. Transactions and Proceedings of the Palaeontological Society of Japan, New Series 159, 562-586.

Hutchison, C.S., 2005. Geology of North-West Borneo Sarawak, Brunei and Sabah. Elsevier, Amsterdam. 421 p.

Ishiga, H., 1990. Paleozoic Radiolarians. In: Ichikawa, K., Mizutani, S., Hara, I., Hada, S. Yao, A. (Eds.), Pre-Cretaceous terranes of Japan. Publication of IGCP Project No. 224: Pre-Jurassic Evolution of Eastern Asia. Nippon Insatsu Shuppan Co. Ltd. Osaka, 285-295.

Jin Yugan, Utting, J. & Wardlaw, B.R., 1994. Biostratigraphy and systematics of Permian Radiolarians in China. Palaeoworld, 4, 172-202.

Jones, D.L. & Murchey, B., 1986 Geological significance of Paleozoic and Mesozoic radiolarian chert. Ann. Rev. Earth Planet. Sci., 14, 455-492.

Junaidi Asis & Basir Jasin, 2012. Aptian to Turonian Radiolaria from the Darvel Bay Ophiolite Complex, Kunak, Lahat Datu, Sabah. Bulletin of the Geological Society of Malaysia, 58, 89-96.

Junaidi Asis & Basir Jasin, 2013. Aptian to Turonian radiolarians from Chert Blocks in the Kuanut Melange, Sabah, Malaysia. Sains Malaysiana, 42(5), 561–570.

Kamata, Y., 1999. Lower Triassic (Spathian) radiolarians from the Kuzu area (Tochigi Prefecture, central Japan). Geodiversitas, 21(4), 657-673.

Kamata, Y.,Ueno, K., Hara, H., Ichise, M., Charoentitirat, T., Charusiri, P., Sardsud, A. & Hisada, K-I., 2009. Classification of the Sibumasu and Paleo-Tethys tectonic division in Thailand using chert lithofacies. Island Arc, 18, 21-31.

Kozur, H. & Mostler, H., 1994. Anisian to Middle Carnian radiolarian

zonation and description of some stratigraphically important radiolarians. Geologisch-Palaeontologische Mitteilungen Innsbruck, Sonderband, 3, 39-199.

Kuwahara, K., 1999. Phylogenetic lineage of the Late Permian Albaillella (Albaillellaria, Radiolaria). Journal of Geoscience, Osaka City University, 42(6), 85-101.

Leong, K.M., 1977. New ages from radiolarian cherts of the Chert-Spilite Formation, Sabah. Bulletin of the Geological Society of Malaysia, 8, 109-111.

Matsuoka, A., 1995. Jurassic and Lower Cretaceous radiolarian zonation in Japan and in the western Pacific. The Island Arc, 4 (2), 140-153.

Metcalfe, I. & Spiller, F.C.P., 1994. Correlation of the Permian and Triassic in Peninsular Malaysia: new data from conodont and radiolarian studies. Proceedings of the International symposium on stratigraphic correlation of Southeast Asia (abstract), 129.

Muhammad Ashahadi Dzulkafli, Basir Jasin & Mohd Shafeea Leman, 2012. Early Permian (Sakmarian) radiolarian from a new outcrop at Pos Blau, Ulu Kelentan and their importance. Bulletin of the Geological Society of Malaysia, 58, 67-73 (in Malay with English abstract).

Noble, P.J., Tekin, U.K., Gedik, I. & Pehlivan, S., 2008. Middle to Upper Tournasian Radiolaria of the Baltalimani Formation, Istanbul, Turkey. J. Paleont., 82(1), 37-56.

Nishimura, K. & Ishiga, H., 1987. Radiolarian biostratigraphy of the Maizuru Group in Yanahara area, southwest Japan. Mem. Fac. Sci. Shimane Univ., 21, 169-188.

Nishizono, Y., Sato, T. & Murata, M., 1997. A revised Jurassic radiolarian zonation for the South Belt of the Chichibu terrane, western Kyushu, Southwest Japan. Marine Micropaleontology, 30, 117-138.

Pessagno, E.A. & Newport, R.L., 1972. A technique for extracting Radiolaria from radiolarian cherts. Micropaleontology, 18(2), 231-234.

Racki, G. & Cordey, F., 2000. Radiolarian paleoecology and radiolarites: is the present the key to the past? Earth-Science Reviews, 52, 83-120.

Sanfilippo, A. & Riedel, W.R., 1985. Cretaceous radiolaria. In: Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K. (Eds.), Plankton Stratigraphy. Cambridge University Press, Cambridge, 573-630.

Sashida, K. & Igo, H., 1992. Triassic radiolarians from a limestone exposed at Khao Chiak near Patthalung, southern Thailand. Transaction and Proceedings of the Paleontological Society of Japan, New Series 168, 1296-1310.

Sashida, K. & Salyapongse, S., 2002. Permian radiolarian faunas from Thailand and their paleogeographic significance. Journal of Asian Earth Sciences, 20, 691-701.

Sashida, K. Adachi, S., Igo, H., Koike, T. & Ibrahim Amnan, 1995. Middle and Late Permian radiolarians from the Semanggol Formation, Northwest Peninsular Malaysia. Trans. Proc. Palaeont. Soc. Japan, 177, 43-58.

Spiller, F.C.P., 2002. Radiolarian Biostratigraphy of Peninsular Malaysia and Implications for Regional Palaeotectonics and Palaeogeography. Palaeontographica Abt. *A*., 266, 1-91.

Spiller, F.C.P. & Metcalfe, I., 1995a. Late Paleozoic radiolarians from the Bentong-Raub suture and the Semanggol Formation of Peninsular Malaysia- initial results. J. Southeast Asian Earth Sci., 11(3), 217-224.

Spiller, F.C.P. & Metcalfe, I., 1995b. Paleozoic and Mesozoic radiolarian biostratigraphy of Peninsular Malaysia. Proceedings of IGCP Symposium on Geology of SE Asia,Journal of Geology ser. B, Hanoi 5/6, 75-93.

Sugiyama, K., 1992. Lower and Middle Triassic radiolarians from Mt. Kinkazan, Gifu Prefecture, Central Japan. Trans. Proc. Palaeont. Soc. Japan, N.S. 167, 1180-1223.

Tan, D.N.K., 1979. Lupar valley, west Sarawak, Malaysia: explanation of sheets 1-111-14, 1-111-15 and part of 1-111-16. Geol. Surv. Malaysia Rept. 13.

Tan, D.N.K., 1980. Siliceous deposits (Chert) of Malaysia. Geol. Surv. Malaysia Geol. Papers 3, 100-113.

Tekin, U.K., 1999. Biostratigraphy and systematics of late Middle to Late Triassic radiolarians from the Taurus Mountains and Ankara region, Turkey. Geologisch-Paläontologische Mitteilungen Innsbruck, Sonderband 5, 1-296.

Vishnevskaya, V.S., 1993. Jurassic and Cretaceous radiolarian stratigraphy in Russia, In: Blueford, J. and Murchey, B. (Eds.), Radiolarian of the giant and subgiant oilfield in Asia. Micropaleontology Spec. Publ., 6, 175-200.

Wakita, K., 2015. OPS mélange: a new term for mélanges of convergent margins of the world. International Geology Review, 57 (5–8), 529–539.

Wan Nursaiedah Wan Ismail, Sanudin Tahir & Basir Jasin, 2014. Barremian-Aptian radiolarian from Chert-Spilite Formation, Kudat, Sabah. Warta Geologi, 40(3-4), 59-61.

Wilford, G.E., 1965. Geology of the Bako National Park area, west Sarawak. Borneo region Malaysia Geol. Surv. Ann. Rept., 147-152.

Wilford, G.E. & Khoo, C.H., 1965. Penrissen area, west Sarawak, Malaysia. Geol. Surv. Malaysia Borneo Reg. Rept. 2.

Wolfenden, E.B., 1963. Sematan and Lundu area, west Sarawak, Malaysia: explanation of sheets 1-109-3,4,7 and 8 and 2-109-15. Borneo region Malaysia Geol. Surv. Rept. 1.

Won, M.-Z., 1990. Lower Carboniferous radiolarian fauna from Riescheid, Germany. Journal Paleontological Society of Korea, 6(2), 111-146.

Zaiton Harun & Basir Jasin, 2003. Some Radiolarians from Dengkil, Selangor. Bulletin of the Geological Society of Malaysia, 46, 133-136.

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