

Radiolarian Biostratigraphy of Peninsular Malaysia — An update

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Abstract: Radiolarian cherts are common in the late Paleozoic and Early Mesozoic of the western belt of Peninsular Malaysia. The cherts were deposited in deep marine environment. Sixteen radiolarian assemblage zones were recognized. The oldest is *Trilonche minax* zone in the Frasnian, Late Devonian. Two zones were identified namely *Albaillella deflandrei* and *Albaillella indensis* zones of Late Tournaisian, Early Carboniferous. Eight zones were recognized in Permian namely *Pseudoalbaillella lomentaria*, *Pseudoalbaillella scalprata* m. *rhombothoracata* and *Pseudoalbaillella longtanensis* zones, Early Permian; *Pseudoalbaillella globosa*, *Follicucullus monacanthus*, and *Follicucullus porrectus* zones, Middle Permian; *Neoalbaillella ornithoformis* and *Neoalbaillella optima* zones, Late Permian. Five zones recorded in Triassic are *Entactinosphaera chiakensis*, *Triassocampe coronata*, *Triassocampe deweveri*, *Oertlispongus inaequispinosus* and *Capnodoce* zones. Most of the Permo-Triassic biozones were identified from the Semanggol Formation. The radiolarian biozones are very important for age determination of rocks which were deposited in deep marine environment where other fossils are very rare.

Keywords: radiolarians, biostratigraphy, biozones, chert, Peninsular Malaysia

INTRODUCTION

Studies of radiolarians in Peninsular Malaysia began in early 1990s. The early studies focused on the Semanggol Formation northwest Peninsular Malaysia where thick sequence radiolarian chert was well-exposed (Sashida *et al.*, 1993, 1995; Basir, 1994a; Metcalfe & Spiller, 1994; Spiller & Metcalfe, 1995a, 1995b; Basir, 1996, 1997, 2008; Spiller, 2002; Basir *et al.*, 2005a, 2005b). Subsequently, research on radiolarians was extended to other radiolarian bearing chert formations such as the Kubang Pasu Formation (Basir, 1995; Basir & Zaiton, 2001b), Kenny Hill Formation (Zaiton & Basir, 2003), Kodiang Limestone (Basir *et al.*, 1995b; Basir & Zaiton, 2001a), Pos Blau chert unit (Basir, 1994b; Metcalfe & Spiller, 1994; Spiller & Metcalfe, 1995b; Basir & Che Aziz, 1997b), siliceous rocks in Jengka, Pahang (Basir *et al.*, 1995a), Nenering, north Perak (Basir & Zaiton, 2006), Langkap, Negeri Sembilan and the chert block in the Bentong-Raub Suture Zone (Spiller & Metcalfe, 1995a, 1995b; Spiller, 2002; Basir & Che Aziz, 1997a; Basir *et al.*, 2004).

Sashida *et al.* (1995) recognised three biozones from the chert unit of the Semanggol Formation namely, *Follicucullus monacanthus*, *Neoalbaillella ornithoformis* and *Neoalbaillella opima* Zones. Spiller (2002) recognized 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.

We have also carried out research on the radiolarians of Peninsular Malaysia, and we discovered sixteen radiolarian assemblage zones. The biozones are very important for age determination of deep water sedimentary sequence where other fossils are lacking.

DISTRIBUTION OF CHERT

The bedded chert deposits of Peninsular Malaysia are present in the Setul Formation, Langkawi; Mahang Formation in Kedah; Bendang Riang Formation, eastern Kedah; Kubang Pasu Formation in Kedah and Perlis; Kenny Hill Formation in Selangor; Nenering area in north Perak; Semanggol Formation in north Perak and Kedah; Genting Serampang area, Jengka, Pahang; Langkap, Negeri Sembilan; Pos Blau, Kelantan and Bentong area, Pahang. The cherts from Langkap, Pos Blau and Bentong are located in the Bentong-Raub Suture Zone (Figure 1).

The Early Paleozoic cherts in Peninsular Malaysia were reported from the Setul Formation (Jones, 1981) and the Mahang Formation (Burton, 1970, Jones 1970). The chert of the Setul Formation is located in the Lower Detrital Member which contains graptolite and trilobites of Early Silurian age (Jones, 1981). It is well-exposed at the west coast of Pulau Langgun. The chert of the Mahang Formation is well exposed at new road cut along the Sungai Petani-Baling highway near a new township, Aman Jaya, central Kedah and at Sungai Air Hitam south Kedah (Burton, 1970). The chert was also reported from the Bendang Riang Formation, eastern Kedah (Jones, 1970). To date no radiolarians have been recovered from these formations.

Late Devonian chert was discovered as blocks in the Bentong-Raub Suture Zone, north of the Bentong town (Basir *et al.*, 2004). Early Carboniferous cherts were found in the

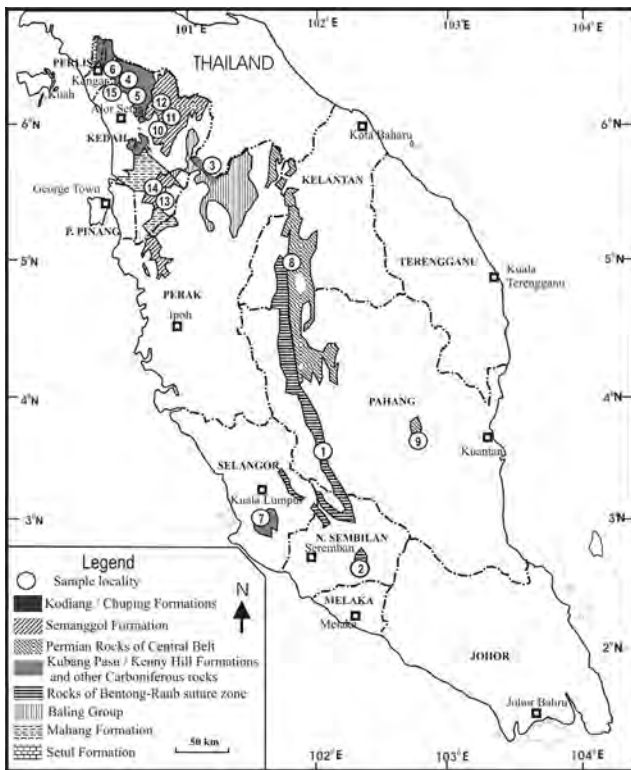


Figure 1: Geographic distribution of chert bearing rock formations and sample localities. 1: Bentong, 2: Langkap, 3: Nenering, 4: Bukit Binjal, 5: Bukit Kamelong, 6: Bukit Tuntung, 7: Dengkil, 8: Pos Blau, 9: Genting Serampang, 10: Bukit Yoi, 11: Bukit Larek, 12: Bukit Tembaga, 13: Kuala Ketil, 14: Merbau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

Kubang Pasu Formation (Basir, 1995), Kenny Hill Formation (Zaiton & Basir, 2003), Nenering area, north Perak (Basir & Zaiton, 2006), and a chert block from Langkap (Basir & Che Aziz, 1997b). Permian cherts were recorded from Pos Blau Kelantan (Basir & Che Aziz, 1997a), Genting Serampang, Pahang (Basir *et al.*, 1995a), and lower part of the Semanggol chert in north and central Kedah (Basir Jasin, 1996, 1997, 2008; Basir Jasin *et al.*, 2005a). Triassic cherts were discovered from the upper part of Semanggol chert (Basir, 1994a, 1997; Spiller & Metcalfe, 1995; Spiller, 2002; Basir *et al.*, 2005b) and Kodiang Formation (Basir & Zaiton, 2001a) (Figure 2).

RADIOLARIAN BIOSTRATIGRAPHY

More than 2000 chert samples were collected from various chert and siliceous rock localities in Peninsular Malaysia. The samples were processed to retrieve radiolarian by using hydrofluoric acid (Pessagno & Newport, 1972). More than 220 taxa of radiolarians were identified and sixteen radiolarian assemblage zones were recognized.

***Trilonche minax* Zone**

The zone is characterised by the occurrence of *Trilonche minax* (Hinde), *Trilonche davidi* (Hinde), *Trilonche vetusta* Hinde, *Trilonche trectactinia* (Foreman), and *Stigmosphaerostylus herculea* (Foreman) (Plate 1). Other taxa recorded are *Trilonche cf. echinata* (Hinde), *Trilonche cf. parapalimbola*. *Trilonche minax* (Hinde) and *Stigmosphaerostylus herculea* (Foreman) are indicators of

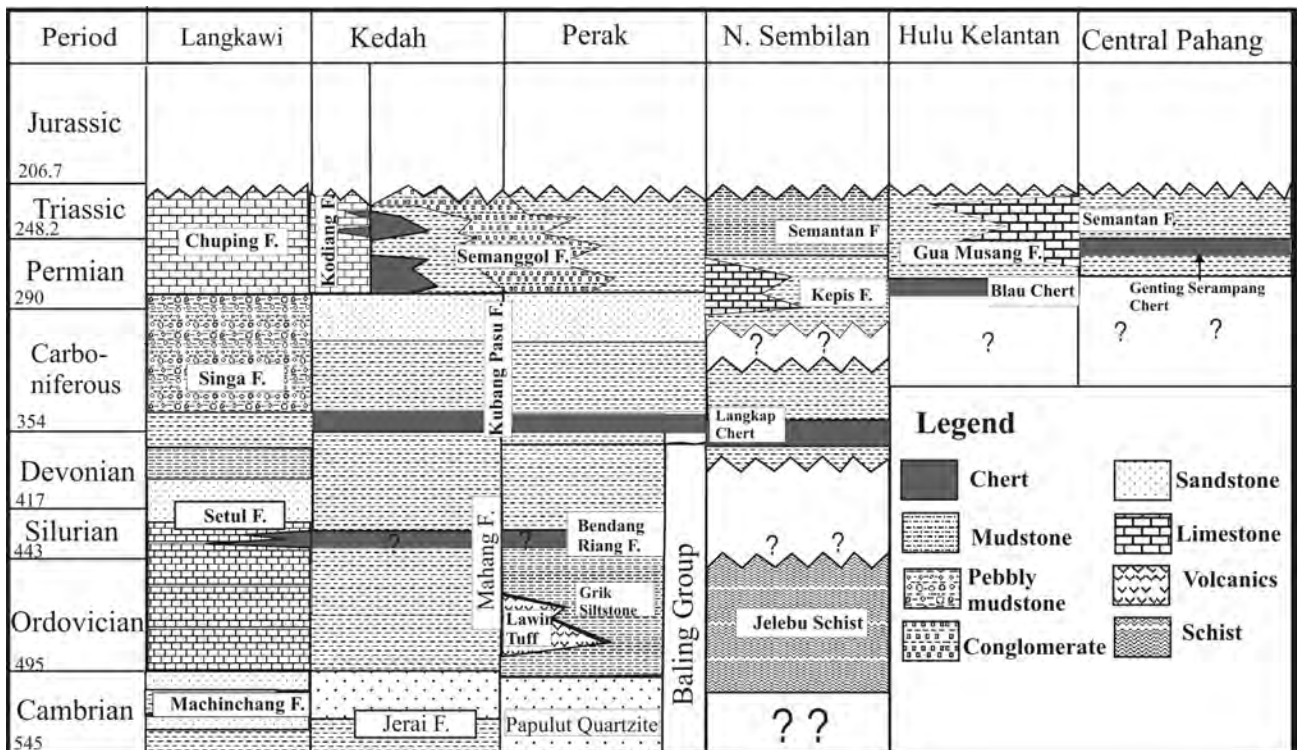


Figure 2: Stratigraphic distribution of chert in Peninsular Malaysia.

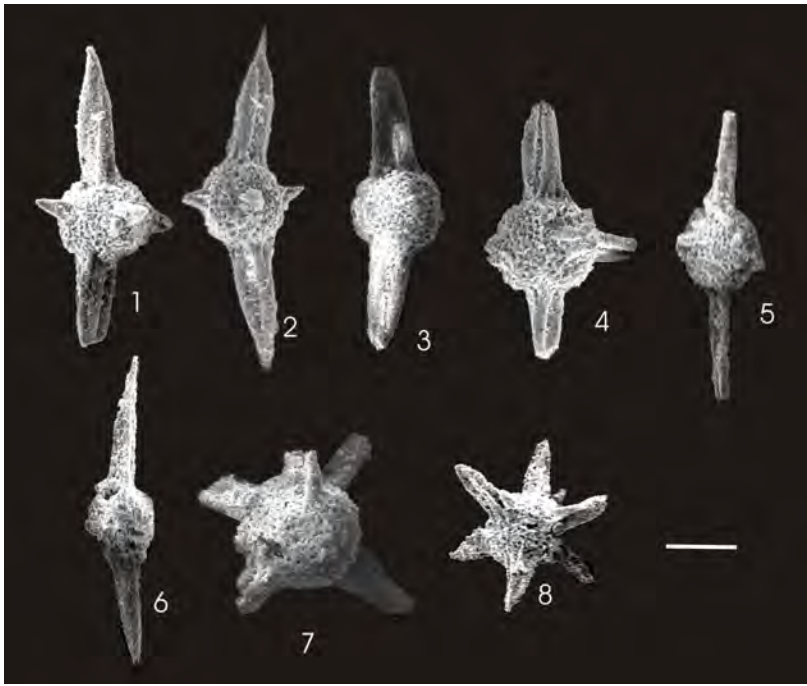


Plate 1: *Trilonche minax* assemblage zone, Early Frasnian, Late Devonian. (Scale bar is indicated in parentheses)

- 1.,2.,3., *Trilonche minax* (Hinde) (100µm, 100µm and 75µm respectively)
 4. *Trilonche davidi* (Hinde) (75µm)
 5.,6. *Trilonche vitusta* (Hinde) (100µm)
 7. *Trilonche tretactinia* (Foreman) (100µm)
 8. *Stigmosphaerostylus herculean* (Foreman) (75µm)

Frasnian, early Late Devonian (Aitchison *et al.*, 1999). The assemblage was discovered from a chert block in the Bentong-Raub Melange (Basir *et al.*, 2004). This is the oldest radiolarian assemblage discovered in Peninsular Malaysia.

***Albaillella deflandrei* Zone**

The occurrence of *Albaillella deflandrei* Gourmelon, *Albaillella indensis ambigua* Deflandre, *Albaillella paradoxa* Deflandre, *Albaillella undulata* Deflandre, *Ceratoikiscum avimexpectans* Deflandre, *Ceratoikiscum berggreni* Gourmelon and *Ceratoikiscum jacundum* Noble, Tekin, Gedik and Pehlivan (Plate 2, figures 1-8) 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 and Nening area, north Perak. Thirty four taxa were identified from Langkap (Basir & Che Aziz, 1997b).

The chert from north Perak yielded 20 species of radiolarians (Basir & Zaiton, 2006). The presence of *Archocyrtium lagabreillei* Gourmelon, *Archocyrtium pulchrum* Braun, *Archocyrtium venustum* Cheng, *Astroentactinia biaciculata* Nazarov, *Stigmosphaerostylus vulgaris* (Won), *Astroentactinia mirousi* Gourmelon, *Astroentactinia multispinosa* Won, *Ceratoikiscum berggreni* Gourmelon, *Stigmosphaerostylus tortispina* (Ormiston and Lane), and *Pylentonema antiqua* Deflandre (Plate 2, figs. 9-18) suggests this assemblage belongs to *Albaillella deflandrei* Zone (Noble *et al.*, 2008). The radiolarian assemblage from north Perak is very much similar to those described from the Early Carboniferous of Germany (Won, 1983; Braun, 1990), France (Gourmelon, 1987), Spain (O'Dogherty *et al.*, 2000) and Turkey (Noble *et al.*, 2008) with the exception

that the present material lacks the zonal marker *Albaillella deflandrei* and other species of *Albaillella* which are widely used in the radiolarian biostratigraphy.

***Albaillella indensis* Zone**

Eight Radiolarian taxa discovered from the Kubang Pasu Formation at Bukit Binjal, Kedah, consists of *Stigmosphaerostylus variospina* (Won), *Entactinia inaequopora* Won, *Callela hexatinia* Won, *Callela* cf. *parvispinosa* Won, *Treanosphaera hebes* Won, *Cubaxonium? octaedrospongiosum* Won *Duplexia foremanae* (Ormiston dan Lane) and *Duplexia parviporata* Won (Basir & Zaiton, 2001b). The zonal marker *Albaillella indensis* is absent but the presence of *Stigmosphaerostylus variospina*, *Callela hexatinia*, *Entactinia inaequopora* and *Cubaxonium? Octaedrospongiosum* (Plate 3) is indicative of *Albaillella indensis* Zone, late Tournaisian, early Viséan, Early Carboniferous (Won, 1990). *Stigmosphaerostylus variospina* (Won) and *Callela hexatinia* Won were also found at outcrops at Bukit Kamelong, Kedah and Bukit Tunting, Perlis. This assemblage may represent the same age.

***Pseudoalbaillella lomentaria* Zone**

The assemblage was found from chert blocks at Pos Blau, Ulu Kelantan. Twenty-two species of Radiolarians were identified (Basir & Che Aziz, 1997a). The zone is characterized by the occurrence of zonal marker *Pseudoalbaillella lomentaria* Ishiga and Imoto, *Pseudoalbaillella ornata* Ishiga and Imoto, *Pseudoalbaillella sakmarensis* Kozur, *Pseudoalbaillella scalprata scalprata* Ishiga and *Pseudoalbaillella scalprata postscalprata* Ishiga (Plate 4, figs.1-6). The assemblage is indicative of late Asselian-early Sakmarian, Early Permian.

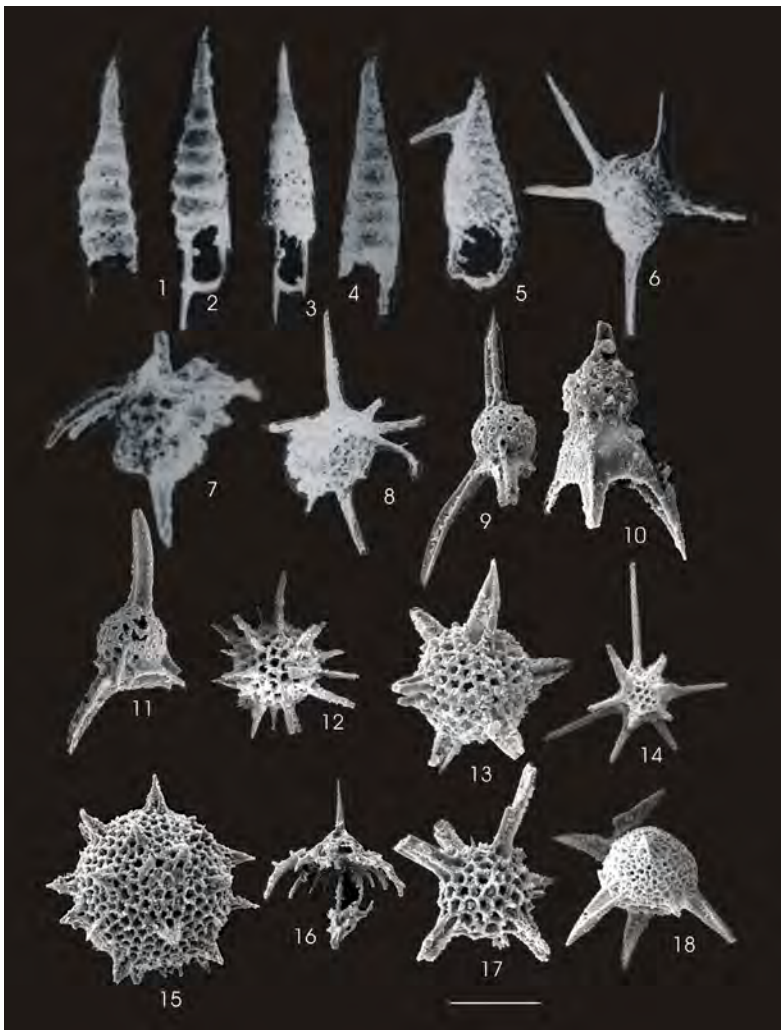


Plate 2: *Alibaillella deflandrei* assemblage zone, Tournaisian, Early Carboniferous. (Scale bar is indicated in parentheses)

- 1., 2. *Alibaillella deflandrei* Gourmelon (100µm)
3. *Alibaillella paradoxa* Deflandre (200µm)
4. *Alibaillella undulata* Deflandre (133µm)
5. *Alibaillella indensis ambigua* Braun (100µm)
6. *Ceratoikiscum avimexpectans* Deflandre (133µm)
7. *Ceratoikiscum berggreni* Gourmelon (100µm)
8. *Ceratoikiscum jacundum* Noble, Tekin, Gedik and Pehlivan (100µm)
9. *Archocyrtium lagabrielei* Gourmelon (100µm)
10. *Archocyrtium pulchrum* Braun (50µm)
11. *Archocyrtium venustum* Cheng (100µm)
12. *Astroentactinia biaciculata* Nazarov (100µm)
13. *Stigmosphaerostylus vulgaris* (Won) (75µm)
14. *Astroentactinia mirousi* Gourmelon (100µm)
15. *Astroentactinia multispinosa* Won (75µm)
16. *Ceratoikiscum berggreni* Gourmelon (100µm)
17. *Stigmosphaerostylus tortispina* (Ormiston and Lane) (75µm)
18. *Pylentonema antiqua* Deflandre (100µm).

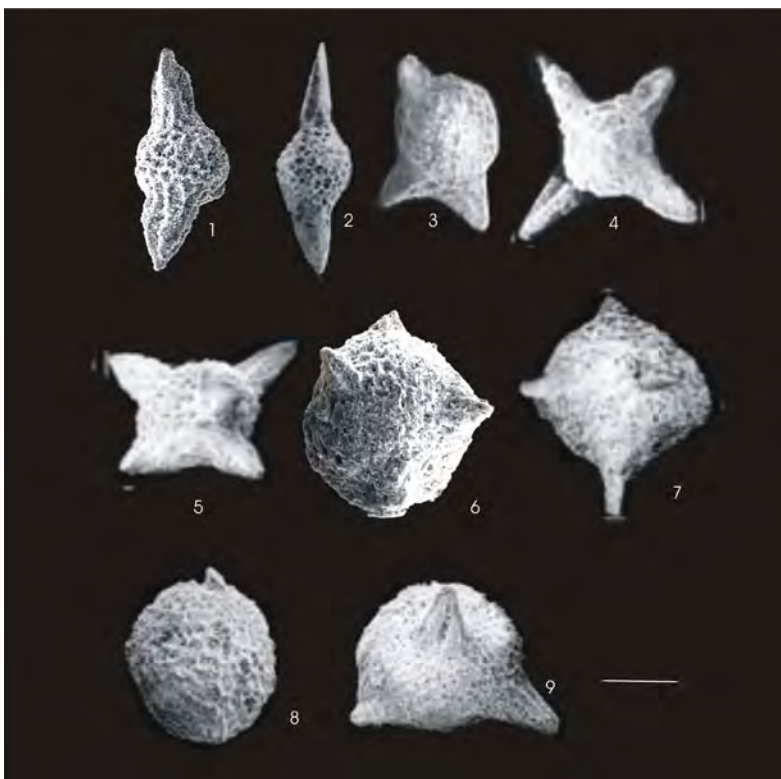


Plate 3: *Alibaillella indensis* assemblage zone, Early Carboniferous. (Scale bar is indicated in parentheses)

- 1.,2. *Stigmostylosphaera variospina* (Won) with two spines (100µm)
3. *Stigmostylosphaera variospina* (Won) with three spines (100µm)
4. *Stigmostylosphaera variospina* (Won) with four spines (80µm)
5. *Stigmostylosphaera variospina* (Won) with five spines (100µm)
6. *Callella hexactinia* Won (100µm)
7. *Cubaxonium? octaedrospongiosum* Won (100µm)
8. *Entactinia? inaequoporosa* Won (100µm)
9. *Traenistaera hebes* Won (100µm)

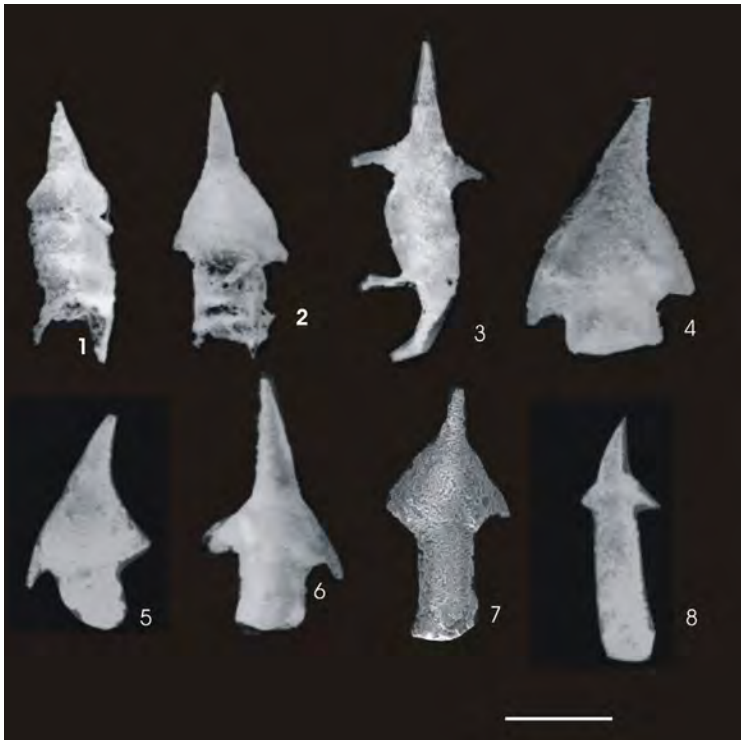


Plate 4: *Pseudoalbaillella lomentaria* and *Pseudoalbaillella scalprata* m. *rhombothoracata* zones, Early Permian (Scale bar is indicated in parentheses).

1. *Pseudoalbaillella lomentaria* Ishiga and Imoto (166 μm).
2. *Pseudoalbaillella ornata* Ishiga and Imoto (133 μm).
3. *Pseudoalbaillella sakmarensis* (Kozur) (133 μm).
- 4., 5. *Pseudoalbaillella scalprata* m. *scalprata* Ishiga (80 μm and 100 μm respectively).
6. *Pseudoalbaillella scalprata* m. *postscalprata* Ishiga (133 μm).
7. *Pseudoalbaillella scalprata* m. *rhombothoracata* Ishiga. (140 μm)
8. *Pseudoalbaillella elongata* Ishiga and Imoto (116 μm).

***Pseudoalbaillella scalprata* m. *rhombothoracata* Zone**

The assemblage zone is defined by the presence of zonal marker *Pseudoalbaillella scalprata* m. *rhombothoracata* Ishiga, *Pseudoalbaillella scalprata* m. *scalprata* Ishiga, *Pseudoalbaillella scalprata* m. *postscalprata* Ishiga and *Pseudoalbaillella elongata* Ishiga and Imoto (Plate 4, figs. 4-8). This is the oldest radiolarian assemblage recorded in the Semanggol Formation of north and south Kedah. The zone was first reported from Bukit Larek and Bukit Yoi, north Kedah (Basir, 1996, 1997) and subsequently also was 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 assemblage zone is assignable to late Sakmian, late Early Permian.

***Pseudoalbaillella longtanensis* Zone**

The radiolarian assemblage represented in this zone exhibits very low specific diversity and consists of *Pseudoalbaillella longtanensis* Sheng and Wang, *Pseudoalbaillella aidensis* Nishimura and Ishiga, *Pseudoalbaillella fusiformis* (Holdsworth and Jones) (Plate 5, Figs. 1-6). Other taxa recorded are *Pseudoalbaillella* cf. *longicornis* and *Pseudoalbaillella* sp. Nishimura & Ishiga (1987) reported the occurrence short ranging species of *Pseudoalbaillella aidensis* corresponds to *Pseudoalbaillella longtanensis* Zone. The assemblage was discovered from the Semanggol Formation exposed at Bukit Yoi, Pokok Sena, Kedah (Basir, 2008). The zone represents Kungurian, Middle Permian.

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***Pseudoalbaillella globosa* assemblage Zone**

The zone is characterized by the abundance of the zonal marker, *Pseudoalbaillella globosa* Ishiga, Kito and Imoto together with *Pseudoalbaillella yanaharensis* Nishimura and Ishiga, *Pseudoalbaillella fusiformis* (Holdsworth and Jones), *Latentifistula texana* Nazarov and Ormiston, and *Racidor inflata* (Sashida and Tonishi) (Plate 5, figs. 7-12). *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 Yugan *et al.*, 1994). The assemblage is found in chert samples of the Semanggol Formation exposed at Bukit Yoi, Pokok Sena, Kedah (Basir, 2008). The zone represents Roadian, Middle Permian.

***Follicucullus monacanthus* Zone**

The zone is dominated by an abundance of *Follicucullus monacanthus* Ishiga and Imoto with *Follicucullus scholasticus* Ormiston and Babcock, *Entactinia itsukaitchiensis* Sashida and Nishimura, and *Hagleria mammilla* Sheng and Wang (Plate 6, figs. 1-4). This zone exhibits very low specific diversity. Six taxa were recovered from Genting Serampang (Basir *et al.*, 1995a) and four taxa is recorded from Kuala Ketil area (Basir *et al.*, 2005a). In Thailand, Sashida & Solyapongse (2002) also noted that this zone is very poor in specific diversity. 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

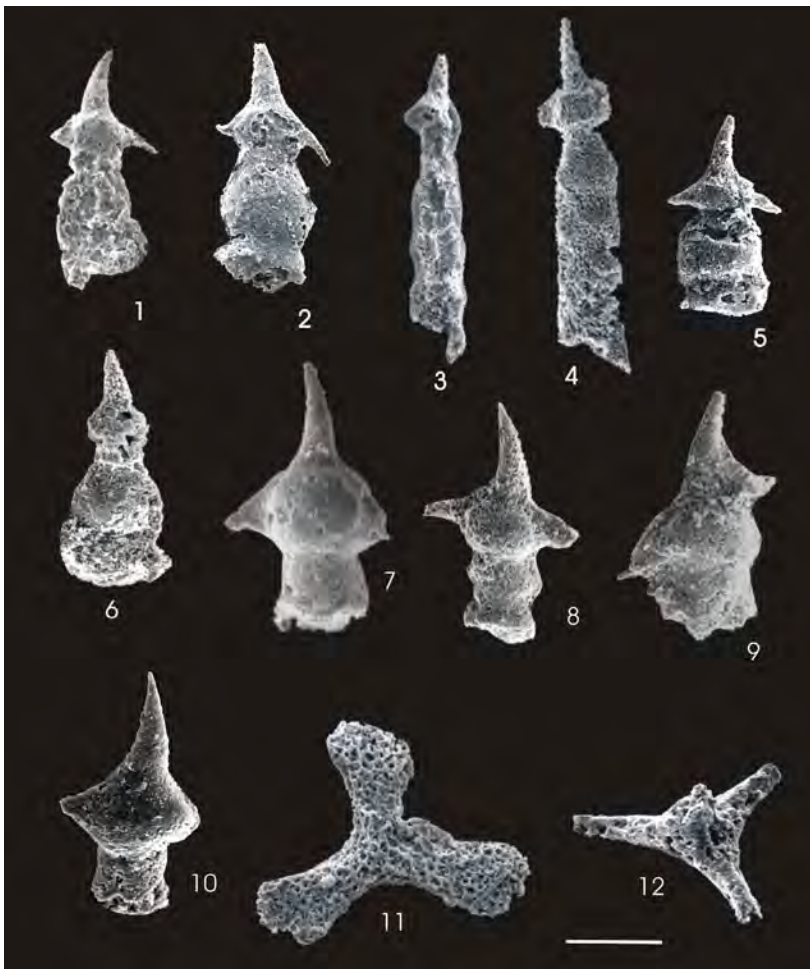


Plate 5: *Pseudoalbaillella longtanensis* and *Pseudoalbaillella globosa* zones late Early Permian and early Middle Permian respectively. (Scale bar = 100µm)

- 1., 2. *Pseudoalbaillella longtanensis* Sheng and Wang
 3., 4. *Pseudoalbaillella aidensis* Nishimura and Ishiga
 5., 6. *Pseudoalbaillella fusiformis* (Holdsworth and Jones)
 7., 8. *Pseudoalbaillella globosa* Ishiga, Kito and Imoto.
 9., 10. *Pseudoalbaillella yanaharensis* Nishimura and Ishiga
 11. *Latentifistula texana* Nazarov and Ormiston
 12. *Raciditor inflata* (Sashida and Tonishi).

specific diversity and contains zonal marker *Follicucullus porrectus* Rudenko, *Follicucullus scholasticus* Ormiston and Babcock, *Follicucullus elongates* Spiller (Plate 6, figs. 5-10). Other species are *Quinqueremis* sp. dan *Entactinia* sp. The zone indicates Capitanian, late Middle Permian to early Late Permian.

***Neoalbaillella ornithoformis* Zone**

The zone is recognized based on the occurrence of *Neoalbaillella ornithoformis* Takemura and Nakaseko, *Albaillella protolevis* Kuwahara, *Albaillella levis* Ishiga, Kito and Imoto, *Albaillella lauta* Kuwahara, *Albaillella excelsa* Ishiga, Kito and Imoto, *Neoalbaillella grypus* Ishiga, Kito and Imoto, *Entactinosphaera pseudocimelia* Sashida and Tonishi and *Octatormentum floriferum* Sashida and Tonishi (Plate 7, figs. 1-9). *Albaillella lauta* Kuwahara and *Albaillella excelsa* Ishiga, Kito and 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 the chert sequence at Kuala Ketil, Kampung Lanjut Malau and Merbau Pulas, Kedah. Twenty taxa were recorded from the 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 markers *Neoalbaillella optima* Ishiga, Kito and Imoto, *Albaillella triangularis* Ishiga, Kito and Imoto, *Albaillella flexa* Kuwahara, *Albaillella excelsa* Ishiga, Kito and Imoto, *Albaillella levis* Ishiga, Kito and Imoto *Copiellintra fontainei* (Sashida), *Copicyntra akikawaensis* Sashida and Tonishi, and *Foremanhelena triangula* De Wever and Caridroit (Plate 7, figs. 10-17). This assemblage was recovered from chert samples of the Kuala Ketil area, Kedah (Basir *et al.*, 2005a). The assemblage indicates Changxingian, Late Permian (Kuwahara, 1999).

***Entactinia chiakensis* Zone**

The zone is characterized by the occurrence of *Entactinosphaera chiakensis* Sashida and Igo, *Cenosphaera andoi* Sugiyama dan *Archaeosemantis cristianensis* Dumitrica, *Entactinia nikorni* Sashida and Igo and *Thaisphaera minuta* Sashida and Igo (Plate 8, figs. 1-5). Sashida & Igo (1992) reported *Entactinosphaera chiakensis*, *Entactinia nikorni* and *Thaisphaera minuta* from the latest Spathian. 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 Semanggol Formation (Basir *et al.*, 2005b).

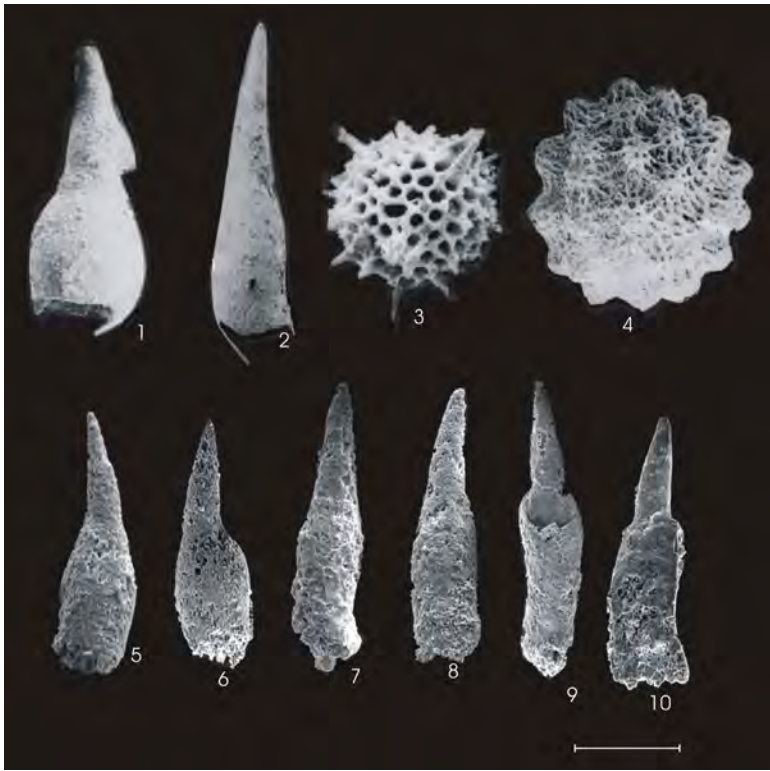


Plate 6: *Follicucullus monacanthus* and *Follicucullus porrectus* Zone, Middle Permian. (Scale bar is indicated in parentheses).

1. *Follicucullus monacanthus* Ishiga and Imoto (100µm)
2. *Follicucullus scholasticus* Ormiston and Babcock (100µm)
3. *Entactinia itsukaichiensis* Sashida and Tonishi (58µm)
4. *Hagleria mammilla* Sheng and Wang (100µm)
- 5., 6. *Follicucullus porrectus* Rudenko (120µm)
- 7., 8. *Follicucullus scholasticus* Ormiston and Babcock (120µm)
- 9., 10. *Follicucullus elongatus* Spiller (115µm).

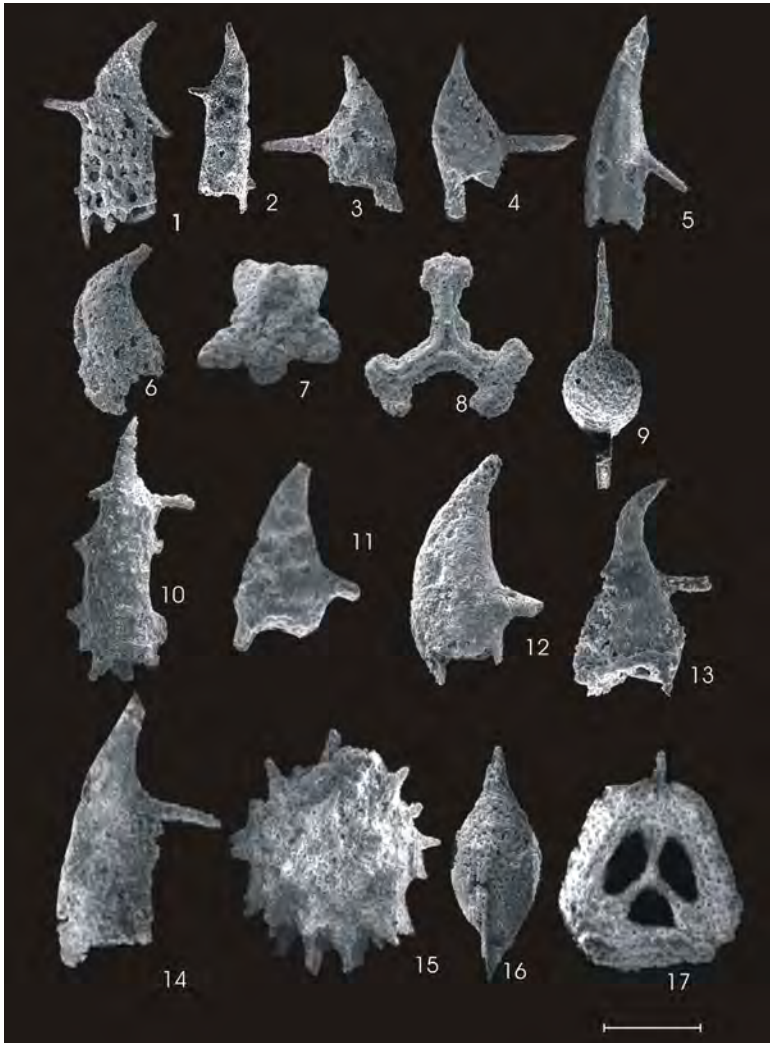


Plate 7: *Neobaillella ornithoformis* and *Neobaillella optima* zones, Late Permian. (Scale bar is indicated in parentheses).

1. *Pseudoalbaillella ornithoformis* Takemura and Nakaseko (100µm)
2. *Pseudoalbaillella excelsa* Ishiga, Kito and Imoto (110µm)
3. *Albaillella protolevis* Kuwahara (110µm)
4. *Albaillella levis* Ishiga, Kito and Imoto (110µm)
5. *Albaillella lauta* Kuwahara (100µm)
6. *Neobaillella grypus* Ishiga, Kito and Imoto (100µm)
7. *Octatormentum floriferum* Sashida and Tonishi (180µm)
8. *Triplanospongos dekkensis* (Noble and Renne) (138µm)
9. *Entactinosphaera pseudocimelia* Sashida and Tonishi. (140µm)
10. *Neobaillella optima* Ishiga, Kito and Imoto (100µm)
11. *Albaillella triangularis* Ishiga, Kito and Imoto (90µm)
12. *Albaillella levis* Ishiga, Kito and Imoto (90µm)
13. *Albaillella flexa* Kuwahara (100µm)
14. *Albaillella excelsa* Ishiga, Kito and Imoto (100µm)
15. *Copicyntra akikawaensis* Sashida and Tonishi (100µm)
16. *Copiellintra fontainei* (Sashida) (100µm)
17. *Foremanhelenatriangula* De Wever and Caridroit. (120µm).

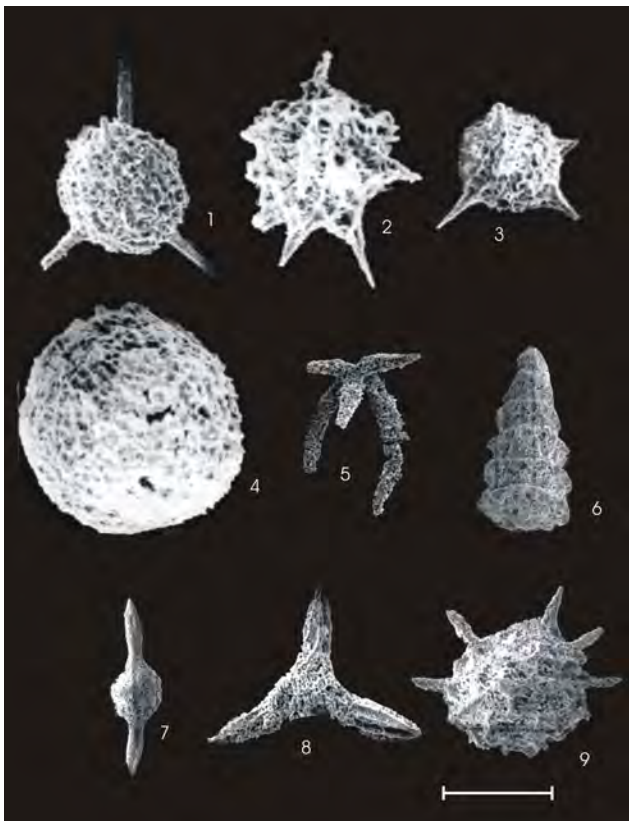


Plate 8: *Entactinosphaera chiakensis* and *Triassocampe coronata* Zones, late Early Triassic and early Middle Triassic respectively. (Scale bar is indicated in parentheses).

1. *Entactinosphaera chiakensis* Sashida and Igo (100µm)
2. *Entactinia nikorni* Sashida and Igo (50µm)
3. *Thaisphaera minuta* Sashida and Igo (100µm)
4. *Cenosphaera andoi* Sugiyama (90µm)
5. *Archaeosemantis cristianensis* Dumitrica (100µm)
6. *Triassocampe coronata* Bragin (100µm)
7. *Pseudostylosphaera japonica* (Nakaseko and Nishimura) (200µm)
8. *Eptingium manfredi* Dumitrica (100µm)
9. *Acanthosphaera awaensis* Nakaseko and Nishimura (115µm).

Triassocampe coronata Zone

The zone is based on the presence of zonal markers *Triassocampe coronata* Bragin together with *Pseudostylosphaera japonica* (Nakaseko dan Nishimura), *Eptingium manfredi* Dumitrica and *Acanthosphaera awaensis* Nakaseko and Nishimura (Plate 8, figs. 6-9). *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 and Nishimura), *Triassocampe scalaris* Dumitrica, Kozur and Mostler, *Pseudostylosphaera tenue* (Nakaseko and Nishimura), *Pseudostylosphaera japonica* (Nakaseko and Nishimura), *Pseudostylosphaera coccostyla* (Rüst), and *Eptingium manfredi* Dumitrica (Plate 9, figs. 1-7).



Plate 9: *Triassocampe deweveri* and *Oertlispongus inaequispinosus* Zones, Middle Triassic. (Scale bar is indicated in parentheses).

- 1., 2. *Triassocampe deweveri* (Nakaseko and Nishimura) (100µm)
3. *Triassocampe scalaris* Dumitrica, Kozur and Mostler (100µm)
4. *Pseudostylosphaera tenui* (Nakaseko and Nishimura) (100µm)
5. *Pseudostylosphaera japonica* (Nakaseko and Nishimura) (100µm)
6. *Pseudostylosphaera coccostyla* (Rüst) (100µm)
7. *Eptingium manfredi* Dumitrica (130µm)
- 8., 9. *Oertlispongus inaequispinosus* Dumitrica, Kozur and Mostler (100µm)
10. *Muelleritortis cochleata* (Nakaseko and Nishimura) (120µm)
11. *Triassocampe annulata* (Nakaseko and Nishimura) (100µm)
12. *Baumgartneria retrospina* Dumitrica (90µm)
13. *Baumgartneria lata* Kozur and Mostler (90µm)
14. *Acanthosphaera awaensis* Nakaseko and Nishimura (100µm)

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, 1995a; Spiller, 2002), Pokok Pauh (Basir, 1994a, 1997) and Merbau Pulas, Kedah (Basir, 1994a).

Oertlispongus inaequispinosus Zone

The assemblage is composed of *Oertlispongus inaequispinosus* Dumitrica, Kozur and Mostler, *Muelleritortis*

cochleata (Nakaseko and Nishimura), *Triassocampe annulata* (Nakaseko and Nishimura), *Baumgartneria retrospina* Dumitrica, *Baumgartneria lata* Kozur and Mostler and *Acanthosphaera awaensis* (Nakaseko and Nishimura) (Plate 9, 8-14). The zone is characterized by the occurrence of zonal markers *Oertlispongia inaequispinosa* Dumitrica, Kozur and Mostler, *Muelleritortia cochleata* (Nakaseko and Nishimura), *Triassocampe annulata* (Nakaseko and Nishimura), *Baumgartneria retrospina* Dumitrica, and *Baumgartneria lata* Kozur and Mostler (Kozur & Mostler, 1994; Feng & Liang, 2003). Kozur & Mostler (1994) reported the assemblage as *Oertlispongia inaequispinosa* 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 & Zaiton, 2001a). The zone is characterized by the occurrence of *Palaeosaturnalis triassica* Kozur and Mostler, *Palaeosaturnalis karnicus* Kozur and Mostler, *Capnuhosphaera triassica* De Wever, *Capnuhosphaera deweveri* Kozur and Mostler, *Sarla viscainoensis* Pessagno, *Tetraporobrachia asymmetrica* Kozur and Mostler, *Pseudostylosphaera cf. spinulosa* Nakaseko and Nishimura, *Xenorum flexum* Blome, *Paronaella reiflingensis* (Kozur and Mostler), *Annulotriassocampe sulovensis* (Kozur and Mock), and *Castrum perornatum* Blome (Plate 10, figs 1-11). 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* is absent in the present material.

Sixteen radiolarian assemblage zones were identified from the chert-bearing rock formations in Peninsular Malaysia (Figure 3). The oldest zone is *Trilonche menax* Zone of early Frasnian age, Late Devonian. Spiller (2002) reported the occurrence of poorly preserved and fragmentary specimens of Permian radiolarians belonging to *Holoeciscus* 2 and *Holoeciscus* 3 assemblage zones from chert blocks of the Bentong-Raub Suture Zone.

Two assemblage zones were recovered from Early Carboniferous namely *Albaillella deflandrei* and *Albaillella indensis* Zones. The *Albaillella indensis* Zone is based on the occurrence of *Cubaxonium? octaedrospongiosum* Won which was recorded in the zone (Braun & Schmidt-Effing, 1993). Spiller (2002) recorded *Albaillella cartalla* Zone of Viséan age from the Bentong-Raub Suture Zone based on fragmentary specimens of *Albaillella cartalla* (Ormiston and Lane), *Stigmatosphaerostylus varioospina* (Won) and *Latiifistula impella* (Ormiston and Lane). There were no radiolarian siliceous deposits during the Late Carboniferous.

Eight radiolarian zones were identified from the Permian siliceous deposits. Most of them were recovered from the

Semanggol Formation in Kedah. The oldest zone in Permian is *Pseudoalbaillella lomentaria* zone, latest Asselian-early Sakmarian which was recovered from the chert sequence exposed at Pos Blau, Kelantan. The *Pseudoalbaillella scalprata m. rhombothoracata* Zone, *Pseudoalbaillella longtanensis* Zone, *Pseudoalbaillella golobosa* Zone, *Follicucullus monacanthus* Zone, *Follicucullus porrectus* Zone, *Neoalbaillella ornithoformis* Zone and *Neoalbaillella optima* Zone were found in the Semanggol Formation in Kedah. However, Spiller (2002) managed to find *Albaillella sinuata* zone based on the occurrence of fragmentary specimens of *Albaillella sinuata* Ishiga and Watase, *Pseudoalbaillella scalprata m. rhombothoracata* Ishiga and *Pseudoalbaillella elongata* Ishiga and Imoto.

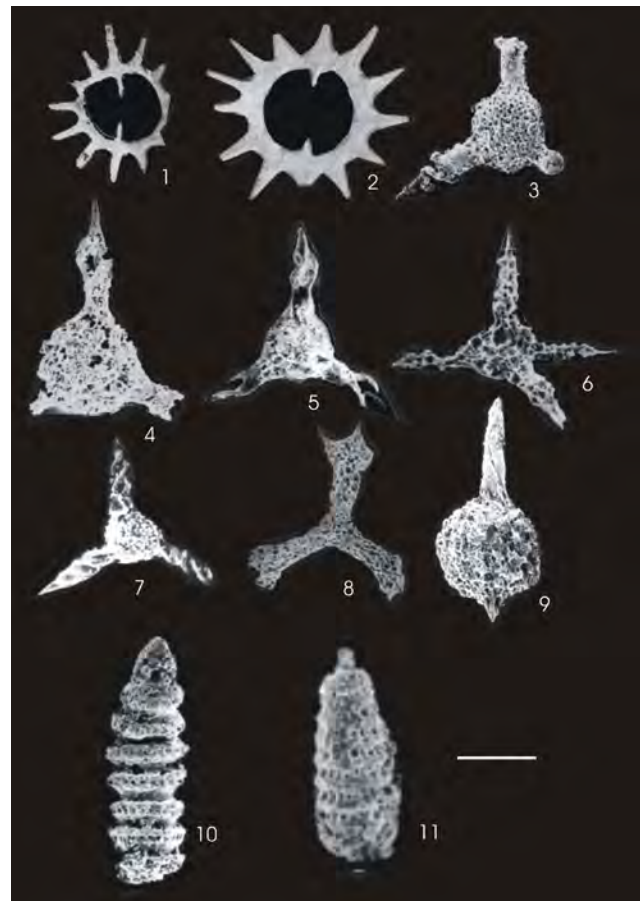


Plate 10: *Capnodoce* zone, Late Triassic. (Scale bar is indicated in parentheses).

1. *Palaeosaturnalis karnicus* Kozur and Mostler (130µm)
2. *Palaeosaturnalis triassicus* (Kozur and Mostler)(100µm)
3. *Capnuhosphaera triassica* De Wever (67µm)
4. *Capnuhosphaera deweveri* Kozur and Mostler (100µm)
5. *Sarla vizcainoensis* Pessagno (60µm)
6. *Tetraporobrachia asymmetrica* Kozur and Mostler (94µm)
7. *Xenorum flexum* Blome (100µm)
8. *Paronaella reiflingensis* (Kozur and Mostler)(117µm)
9. *Pseudostylosphaera cf. spinulosa* Nakaseko and Nishimura (106µm)
10. *Annulotriassocampe sulovensis* (Kozur and Mock)(61µm)
11. *Castrum perornatum* Blome (100µm).

Ma	PERIOD	EPOCH	AGE	ASSEMBLAGE ZONES		
210 220 230 240 250	TRIASSIC	Late	Rhaetian			
			Norian	<i>Capnodoce</i>		
			Carnian			
			Middle	Ladinian	<i>Oertlispongus inaequispinosus</i>	
				Anisian	<i>Triassocampe deweveri</i> <i>Triassocampe coronata</i>	
		Early	Olenekian	<i>Entactinosphaera chiakensis</i>		
			Induan			
		260 270 280 290 300	PERMIAN	Lopingian	Changhsingian	<i>Neobaillella optima</i>
					Wuchiapingian	<i>Neobaillella ornithoformis</i>
				Gadaplupian	Capitanian	<i>Follicucullus porrectus</i>
Wordian	<i>Follicucullus monacanthus</i>					
Roadian	<i>Pseudoalaillella globosa</i>					
Cisuralian	Kungurian			<i>Pseudoalaillella longtanensis</i>		
	Artinskian					
	Sakmarian				<i>Pseudoalaillella scalprata m. rhombothoracata</i> <i>Pseudoalaillella lomentaria</i>	
				Asselian		
	310 320 330 340 350 360			CARBONIFEROUS	Late	Gzhelian
Kasimovian						
Moscovian						
Bashkirian						
Early		Serpukhovian				
		Visean				
					<i>Albaillella indensis</i>	
		Tournaisian	<i>Albaillella deflandrei</i>			
		DEVONIAN	Late		Famennian	
					Frasnian	<i>Trilonche minax</i>

Figure 3: Radiolarian biostratigraphy of Peninsular Malaysia.

Pseudoalaillella elongata Ishiga and Imoto has very short stratigraphic range and originally was reported to be restricted to the middle part of the *Pseudoalaillella scalprata m. rhombothoracata* zone (Ishiga, 1990). Spiller (2002) extended the range of *Pseudoalaillella elongata* to the *Albaillella sinuata* zone. Spiller (2002) maintains that the *Neobaillella optima* zone is older than *Neobaillella ornithoformis* zone. Kuwahara *et al.* (1998) reexamined the Late Permian radiolarian stratigraphy and concluded that the *Neobaillella ornithoformis* zone is older than the the *Neobaillella optima* zone.

Five biozones were recognized in the Triassic. The oldest zone is *Entactinosphaera chiakensis* zone. *Entactinosphaera chiakensis* has a very short range and is restricted to Spathian, Early Triassic (Kamata, 1999). The zone is comparable to the *Parentactinia nakatsugawaensis* assemblage of Sugiyama (1992). Other zones are *Triassocampe coronata* Zone, *Triassocampe deweveri* Zone, *Oertlispongus inaequispinosus* zone and *Capnodoce* zone. At the end of Triassic there was a tectonic episode related to uplifting and termination of deep sea deposits of the Peninsular Malaysia.

CONCLUSION

Radiolarian chert deposits are quite widespread especially in the Late Paleozoic and Early Mesozoic of the western belt of Peninsular Malaysia. No radiolarians were retrieved from the oldest chert from the Setul and the Mahang Formations. The oldest radiolarian zone is the *Trilonche minax* zone recovered from the chert block in the Bentong-Raub Suture Zone. Deposition of chert was quite abundant in the Early Carboniferous and diminished in the Late Carboniferous. Two zones were recognized in Early Carboniferous. Radiolarian cherts were more extensive in Permian and eight radiolarian assemblage zones were recognized. Five biozones were identified from the Triassic rocks.

To date, the radiolarian biostratigraphy is the most reliable tool for the stratigraphy of the deep marine sediments of Peninsular Malaysia. The biostratigraphic zones reflect the productivity of the radiolarians, which was very high during late Devonian-Early Carboniferous, through Permian and Triassic. The research on radiolarians is still going on to fill the biostratigraphic gaps in the Late Devonian, Early Carboniferous and Permian.

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