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Permian Radiolarian Biostratigraphy of the Semanggol Formation, south Kedah, Peninsular Malaysia

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Abstract: Thirty-seven taxa of Permian radiolarians were retrieved from chert samples collected from an outcrop at a construction site approximately 4.5 km east of Kuala Ketil Town. The chert samples were collected from interbedded siliceous shale, chert and tuff facies and thinly bedded chert facies. Five radiolarian assemblage-zones were recognized i.e. *Pseudoalbaillella scalprata* m. *rhombothoracata* Zone, *Follicucullus monacantha* Zone, *Follucucullus porrectus* Zone, *Neoalbaillella ornithoformis* Zone and *Neoalbaillella opima* Zone. The radiolarian zones represent an age range from late Early Permian to Late Permian.

Abstrak: Tiga puluh tujuh taksa radiolaria Perm telah diperolehi daripada sampel rijang yang dikutip dari satu singkapan tapak binaan yang terletak 4.5 km di timur pekan Kuala Ketil. Sampel rijang dikutip daripada fasies selanglapis syal bersilika, rijang dan tuff dan fasies rijang berpelapisan nipis. Lima zon himpunan radiolaria telah dikenali iaitu; Zon *Pseudoalbaillella scalprata* m. *rhombothoracata*, Zon *Follicucullus monacanthus*, Zon *Follicucullus porrectus*, Zon *Neoalbaillella ornithoformis* dan *Neoalbaillella optima*. Zon radiolaria ini mewakili julat usia dari akhir Perm Awal hingga Perm Akhir.

INTRODUCTION

In the past two decades, Permian radiolarian studies have rapidly developed to allow for the establishment of a taxonomic base for biozonation in various parts of the world. A Permian radiolarian biostratigraphy of the bedded chert sequences of southwest Japan has been proposed by Ishiga and his colleagues (Ishiga *et al.*, 1982; Ishiga,1990) using albaillellids, which have short stratigraphic range. The latest Permian radiolarian biostratigraphy has been revised and refined by Kuwahara *et al.* (1998) and Kuwahara (1999). This scheme is considered as a standard for the Asian region.

The Semanggol Formation is widely distributed in north Perak, south and north Kedah. The rocks comprise chert unit, interbedded sandstone and mudstone (rhythmite) unit and conglomerate unit. The units were previously considered as members of the Semanggol Formation by Burton (1973). The chert unit was considered as the oldest unit (Burton, 1973). The discovery of Middle Triassic radiolarians suggests that the three units are partly of the same age (Basir Jasin, 1997).

Permian radiolarian bearing siliceous rocks have been reported from the Semanggol Formation (Sashida *et al.*,1993, 1995; Spiller and Metcalfe, 1995; Basir Jasin, 1996, 1997; Spiller, 2002). Sashida *et al.* (1993, 1995) reported the occurrence of *Follicucullus monacanthus*, *Neoalbaillella optima* and *Neoalbaillella ornithoformis* Assemblage-Zones, Middle and Late Permian radiolarians from Bukit Barak and Bukit Nyan, north Kedah. Spiller and Metcalfe (1995) and Spiller (2002) subsequently indicated the oldest chert belongs to the *Pseudoalbaillella longtanensis* Zone. Basir Jasin (1996, 1997) discovered the *Pseudoalbaillella scalprata* m. *rhombothoracata* Zone from the chert sequence exposed at Bukit Larek and Bukit Yoi, north Kedah. This is the oldest radiolarian zone in the Semanggol Formation to date. Most of the studies were conducted in the north Kedah area.

In south Kedah, Basir Jasin (1994,1997) reported some Permian and Middle Triassic radiolarians discovered from chert exposed near the Merbau Pulas area. Spiller (2002) recorded the occurrence of poorly preserved Middle Triassic *Triassocampe* sp. from Kampung Keledang west of Baling.

Recently, we discovered a new extensive outcrop about 4.5 km. east of the Kuala Ketil town in south Kedah (Fig. 1). We collected 40 samples of siliceous shale and chert for micropaleontological studies.

GEOLOGICAL SETTING

The rocks in south Kedah consist of the Ordovician-Early Devonian Mahang Formation and the Permo-Triassic Semanggol Foramation. It is strange that the Carboniferous rocks are not exposed. There should be a continuous deposition of Paleozoic rocks in the area as in the north Kedah area. These Paleozoic formations were deposited in a relatively deep marine environment and there was no trace of any unconformity related to a major tectonic event during this time. Courtier (1974) proposed the Tawar Formation as a probable new Carboniferous lithostratigraphic unit but no fossils were recovered. Burton (1988) considered the Tawar chert as part of the Semanggol Formation. The stratigraphy of the area is not fully understood. There are widespread faults in the Semanggol Formation. The boundary between the Mahang and the Semanggol Formations is a fault contact. The Semanggol Formation in south Kedah is represented by only two units i.e. the chert and the interbedded sandstone and mudstone (rhythmite) units. The conglomerate unit is absent. The chert forms prominent ridges which strike NNE-SSW.

Extensive quarrying activities in north and south Kedah exposed volcanogenic sediments such as tuffaceous shale and tuff. The volcanic sediments were not recorded

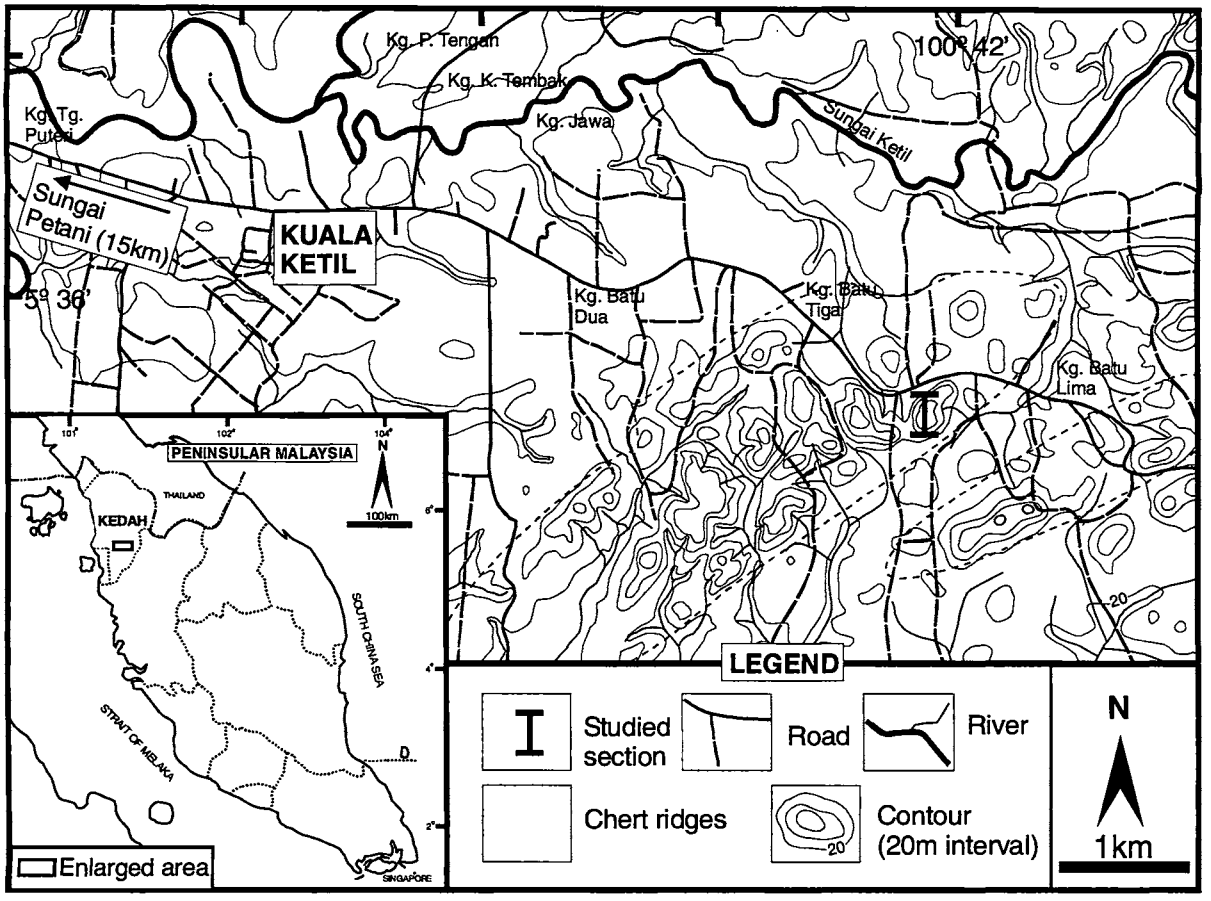

Fig. 1. Map showing the chert unit and studied section in the Kuala Ketil area, south Kedah.

by Burton (1973,1988) because of lack of exposures. There was no record of volcanic activities in the area. This indicates that the Semanggol basin was very close to the Semantan basin where the volcanic activities were active. The presence of radiolarian chert indicates that the Semanggol Formation was deposited in a deep-water environment.

DESCRIPTION OF THE OUTCROP

A very extensive outcrop was exposed at a construction site, approximately 4.5 km. east of the Kuala Ketil town. The section is oriented north–south direction (Fig.2). The outcrop was cut by several strike-slip and thrust faults. The rocks strike generally east-west and dip southwards. The rock sequence at this locality may represent the chert unit (equivalent to Burton's chert member, 1973). A detailed study of the outcrop revealed seven lithofacies (in ascending order) as follows:-

Laminated black mudstone
Interbedded mudstone and sandstone
Thinly bedded to massive tuff
Interbedded siliceous shale, chert and tuffaceous sandstone
Thinly bedded chert
Gray mudstone
Thinly bedded chert.

Twenty meters thick mylonite was observed between thinly bedded chert and gray mudstone. The mylonite represents a shear zone, which is related to a major fault movement. A similar sequence was also recognized at Bukit Larek, north Kedah. The laminated black mudstone was considered as the lowermost part of the Semanggol Formation (Basir Jasin, 1997). At this locality, the contact with the Carboniferous rocks was not observed.

PERMIAN RADIOLARIAN BIOSTRATIGRAPHY

Sashida *et al.* (1995) recognized three radiolarian biozones in north Kedah i.e. *Follucucullus monacanthus, Neoalbaillella ornithoformis* and *Neoalbaillella optima* Zones. Spiller (1995, 2002) identified three zones: *Pseudoalbaillella longtanensis, Follicucullus porrectus*

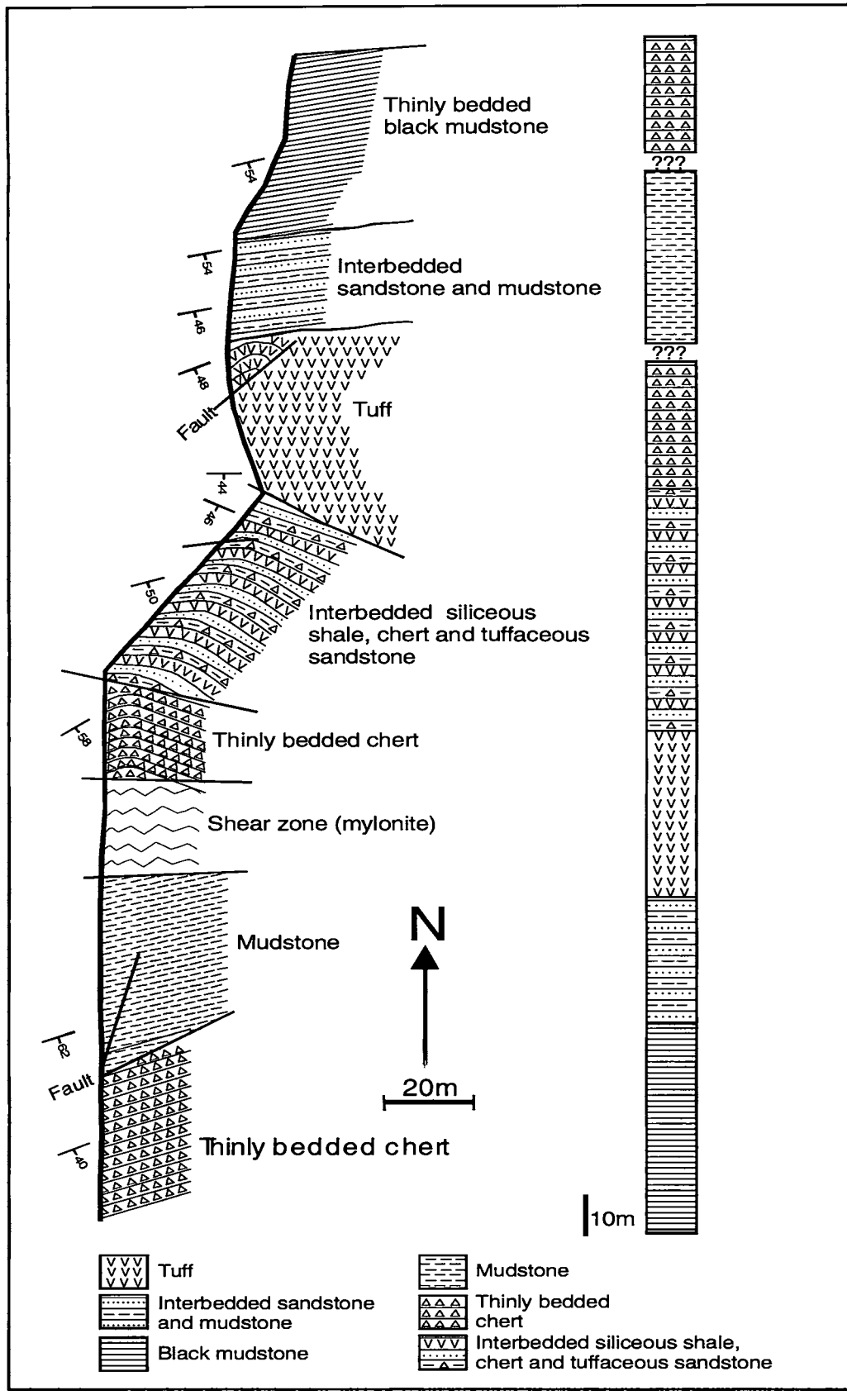

Fig. 2. Lithofacies and lithologic log of the rock sequence exposed at the studied section.

and *Neoalbaillella ornithoformis* Zones. Two zones, *Pseudoalbaillella scalprata* m. *rhombothoracata* and *Albaillella levis* Zones were identified by Basir Jasin (1997). Forty siliceous shale and chert samples were collected from the outcrop near Kuala Ketil, south Kedah. Twenty samples yielded fairly well-preserved radiolarian specimens. A total of thirty-seven taxa were recognized. The stratigraphic distribution of the taxa is presented in Figure 3. Five biozones are recognized based on the modified scheme of Ishiga (1990) by Kuwahara *et al.* (1998).

Pseudoalbaillella scalprata m. *rhombothoracata* Assemblage Zone.

This assemblage was discovered from a sample (KK4), which was collected from thinly bedded chert in the siliceous shale, chert and tuffaceous sandstone facies. The radiolarian species comprise *Pseudoalbaillella scalprata* m. *rhombothoracata* Ishiga, *Pseudoalbaillella scalprata* m. *scalprata* Ishiga, *Pseudoalbaillella scalprata* m. *postscalprata* Ishiga, *Pseudoalbaillella* cf. *lomentaria* Ishiga and Imoto, *Latentifistula* sp., *Latentifistula* cf. *patagilaterala, Ruzhencevispongus* sp., *Quinqueremis* sp., and *Entactinia* sp. (Plate 1). This assemblage is assignable to Sakmarian, late Early Permian, based on the scheme by Ishiga (1986). This is the oldest radiolarian zone discovered in the Semanggol Formation.

Follicucullus monacanthus Assemblage Zone

This assemblage was discovered from one sample (KK7) collected from the thinly bedded chert in the siliceous shale, chert and tuffaceous sandstone facies. The sample is dominated by an abundance of *Follicucullus monacanthus* Ishiga and Imoto with some *Entactinia* sp. and *Quadriremis* sp (Plate 2). In Thailand, Sashida and Solyapongse (2002) found that this zone is very poor in specific diversity and characterized by abundance of *Follicucullus monacanthus*. This zone is assigned to Wordian, Middle Permian (Sashida and Salyapongse, 2002).

Follicucullus porrectus Assemblage Zone

The assemblage is found in 5 samples (KK10, KK12, KK13, KK14, and KK15) from the siliceous shale, chert and tuffaceous sandstone facies. The zone is characterized by the occurrence of the zonal marker *Follicucullus porrectus* Rudenko. The most common species in the zone are *Follicucullus scholasticus* Ormiston and Babcock and *Follicucullus elongatus. Quinqueremis* sp. and *Entactinia* sp. are very rare (Plate 2). *Follicucullus elongatus* Spiller is an endemic species, recorded in Permian of Peninsular Malaysia (Spiller, 2002). This assemblage indicates Capitanian to Wuchapingian, late Middle Permian to early Late Permian age.

Neoalbaillella ornithoformis Assemblage Zone

The radiolarian assemblage occurs in thinly bedded chert facies (Samples KK16, KK21, KK22, KK24, KK26, KK29, KK30, KK31, KK32, KK33, KK34). The zone is characterized by the occurrence of *Neoalbaillella ornithoformis* Takemura and Nakaseko, *Albaillella protolevis* Kuwahara, *Albaillella levis* Ishiga, Kito Imoto, *Albaillella lauta* Kuwahara, *Albaillella excelsa* Ishiga, Kito and Imoto, *Neoalbaillella grypus* Ishiga, Kito and Imoto, *Copicyntra akikawaensis* Sashida and Tonishi, *Triplanospongos musashiensis* Sashida and Tonishi, *Triplanospongos dekkaensis* (Noble and Renne), *Nazarovella gracilis* De Wever and Caridroit, *Nazarovella inflata* Sashida and Tonishi, *Entactinosphaera pseudocimelia* Sashida and Tonishi, *Latentifistula texana* Nazarov and Ormiston, *Latentibifistula asperspongiosa* Sashida and Tonishi, *Octatormentum floriferum* Sashida and Tonishi, *Copicyntra* sp., *Copiellintra* sp., *Deflandrella* sp. and *Ishigaum* sp. (Plate 3). *Albaillella lauta* Kuwahara and *Albaillella excelsa* Ishiga, Kito and Imoto appeared at the top of *Neoalbaillella ornithoformis* Assemblage Zone (Kuwahara, 1999). This zone indicates Wuchiapingian, Late Permian age (Sashida and Salyapongse 2002).

Neoalbaillella optima Assemblage Zone.

The assemblage is discovered from thinly bedded chert facies (KK36, KK37, KK39) at the top of the section. This zone is defined based on the occurrence of *Albaillella triangularis* which first appeared at the base of the *Neoalbaillella optima* Zone (Kuwahara, 1999). The assemblage is composed of *Neoalbaillella optima* Ishiga, Kito and Imoto, *Albaillella triangularis* Ishiga, Kito and Imoto, *Albaillella flexa* Kuwahara, *Albaillella excelsa* Ishiga, Kito and Imoto, *Albailella levis* Ishiga, Kito and Imoto, *Copicyntra akikawaensis* Sashida and Tonishi, *Copiellintra fontainei* (Sashida), *Triplanospongos musashiensis* Sashida and Tonishi and *Foremanhelena triangula* De Wever and Caridroit (Plate 4). *Neoalbaillela ornithoformis* also occurs in the zone. The zone is assigned to Changxingian, Late Permian.

The Permian radiolarian biozonation of Ishiga (1982, 1990), especially the Late Permian has been revised and refined by Kuwahara *et al.*, (1998), Kuwahara (1999) and Wenchen et al. (2004). Kuwahara *et al.* (1998) redefined the *Neolabaillella ornithoformis* and *Neolabaillella optima* Zones and placed *Neoalbaillella optima* Zone on top of *Neoalbaillella ornithoformis* Zone. Kuwahara (1999) conducted a detailed study on the Late Permian albaillellids and described seven new species. She constructed a phylogenetic lineage of the Late Permian *Albaillella.* The phylogenetic lineage has been used by Wenchen *et al.* (2004) to propose new radiolaria zones for the Late Permian near the Permo-Triassic boundary in Meishan, China. Wenchen *et al.* (2004) noted that *Neoalbaillella ornithoformis* and *Neoalbaillella optima* have the same stratigraphic range. In the present study, we discovered only three of those newly described species of Kuwahara (1999) i.e. *Albaillella protolevis, Albaillella lauta* and *Albaillella flexa.* Other zonal markers are not present and therefore a complete biozones of Wenchen *et al.* (2004) cannot be established.

Five radiolarian biozones were recognized (Fig. 4). The age of the chert from south Kedah is very much similar to that of north Kedah except that the radiolarian biozones of the north Kedah were established based on

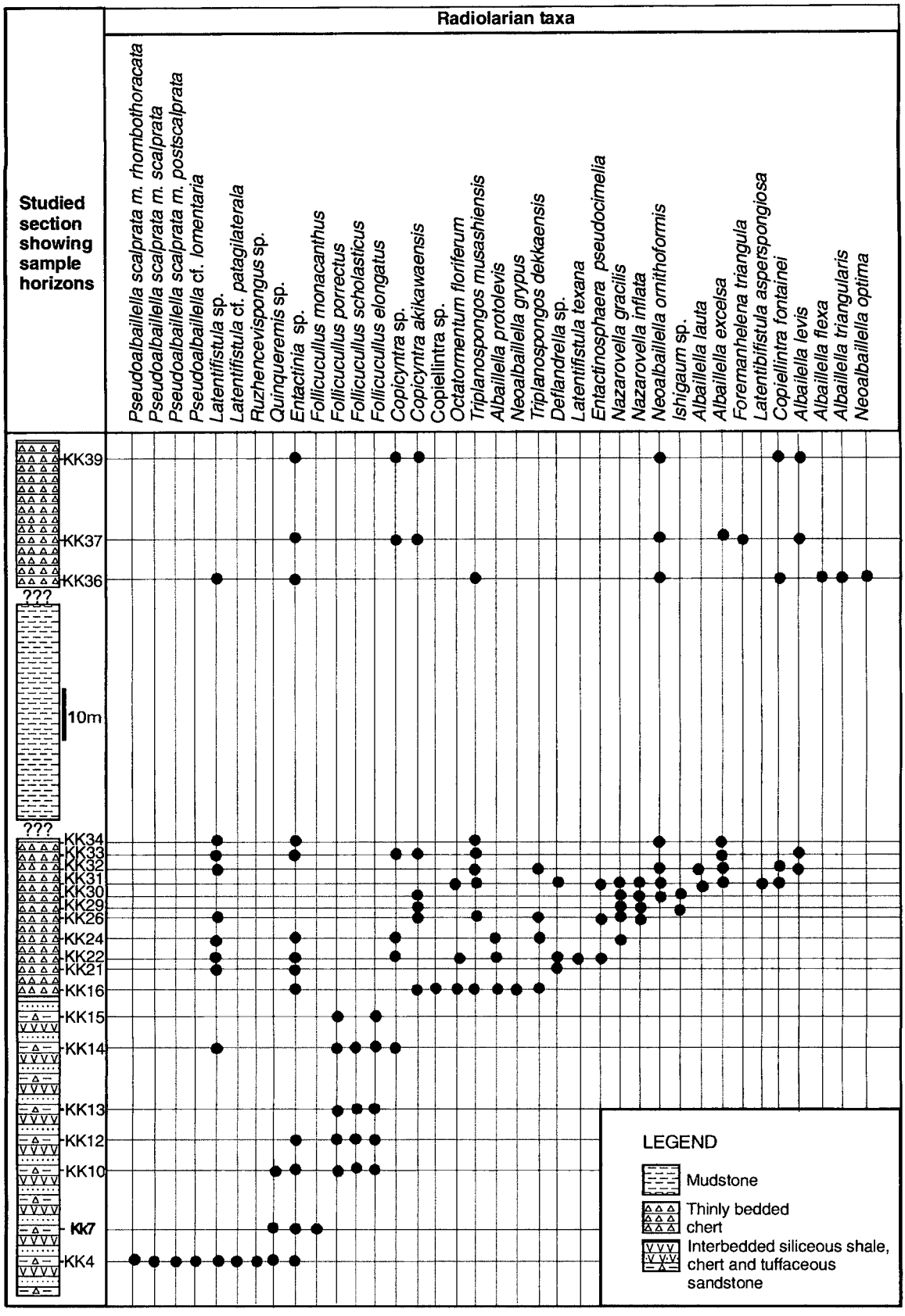

Fig. 3. Stratigraphic distribution of radiolarians in the section.

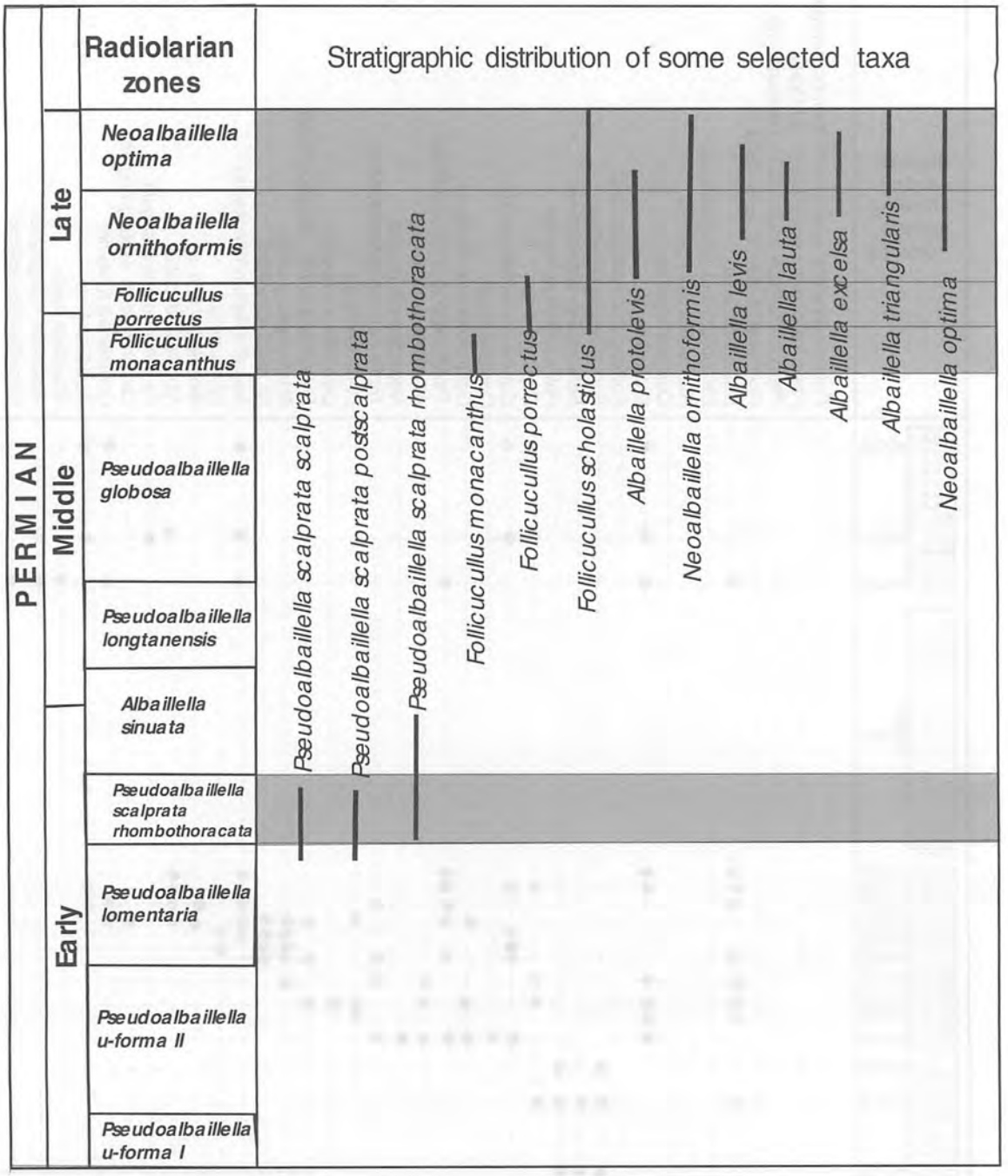

Fig. 4. Stratigraphic distribution of some important species of radiolarians.

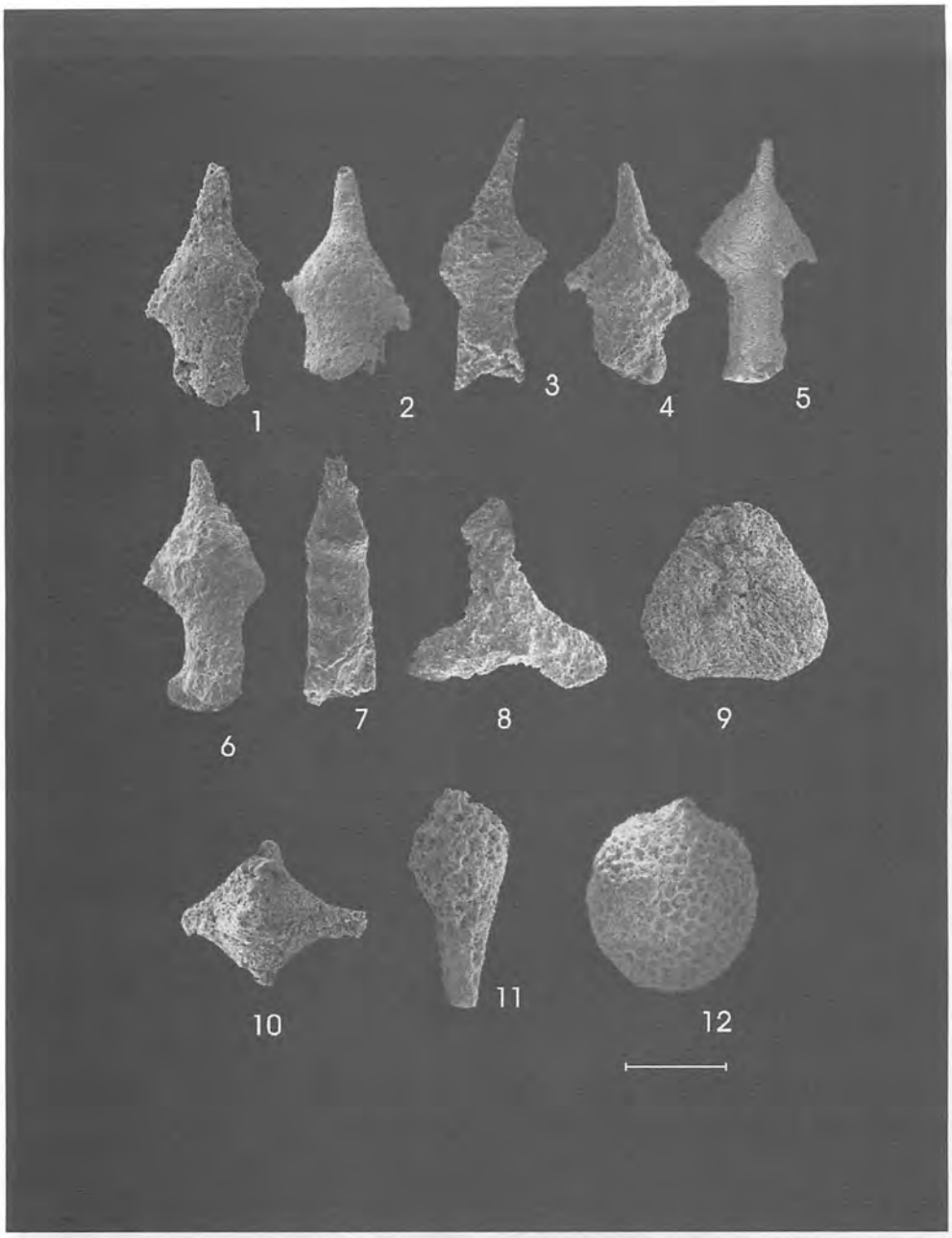

Plate 1. Radiolarian assemblage of the *Pseodoalbaillella scalprata* m. *rhombothoracata* Zone. (Scale bar in μm is indicated in parenthesis)

1, 2. *Pseudoalbaillella scalprata* m. *scalprata* Ishiga (100μm)
3, 4. *Pseudoalbaillella scalprata* m. *postscalprata* Ishiga (100μm)
5, 6. *Pseudoalbaillella scalprata* m. *rhombothoracata* Ishiga. (140μm)
7. *Pseudoalbaillella* cf. *lomentaria* Ishiga and Imoto (130μm)
8. *Latentifistula* cf. *patagilaterala* Nazarov and Ormiston (126μm)
9. *Ruzhencevispongus* sp.(115μm)
10. *Quinqueremis* sp. (120μm)
11. *Latentifistula* sp. (100μm)
12. *Entactinia* sp. (120μm)

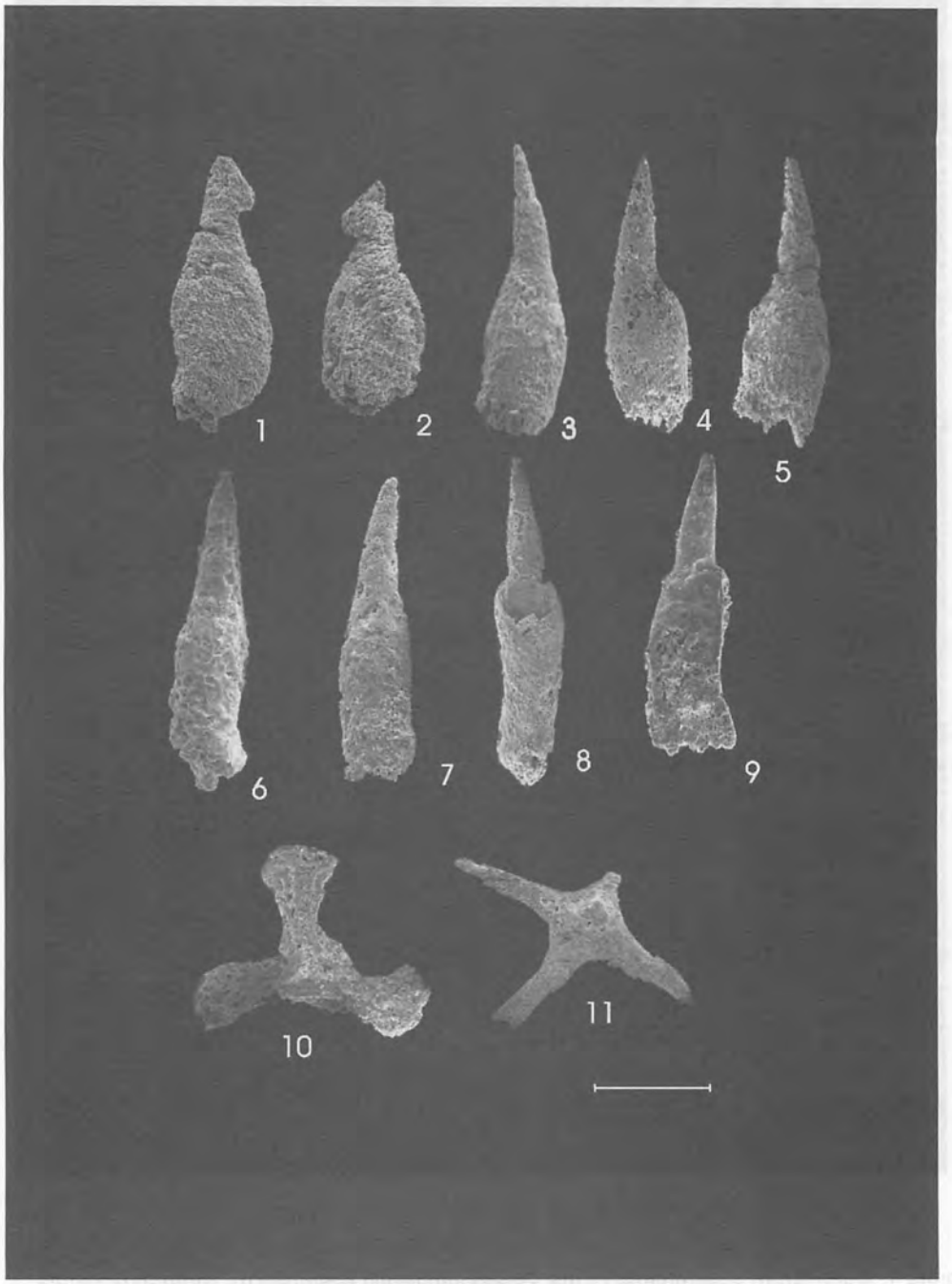

Plate 2. Radiolarian assemblage from the *Follicucullus monacanthus* and *Follicucullus porrectus* Zones. (Scale bar in μm is indicated in parenthesis)

1, 2. *Follicucullus monacanthus* Ishiga and Imoto. (100μm)
3, 4, 5. *Follicucullus porrectus* Rudenko (120μm)
6, 7. *Follicucullus scholasticus* Ormiston and Babcock (120μm)
8, 9. *Follicucullus elongatus* Spiller (115μm)
10. *Triplanospongos* cf. *musachiensis* Sashida and Tonishi (135μm)
11. *Quinquiremis* sp. (135μm)

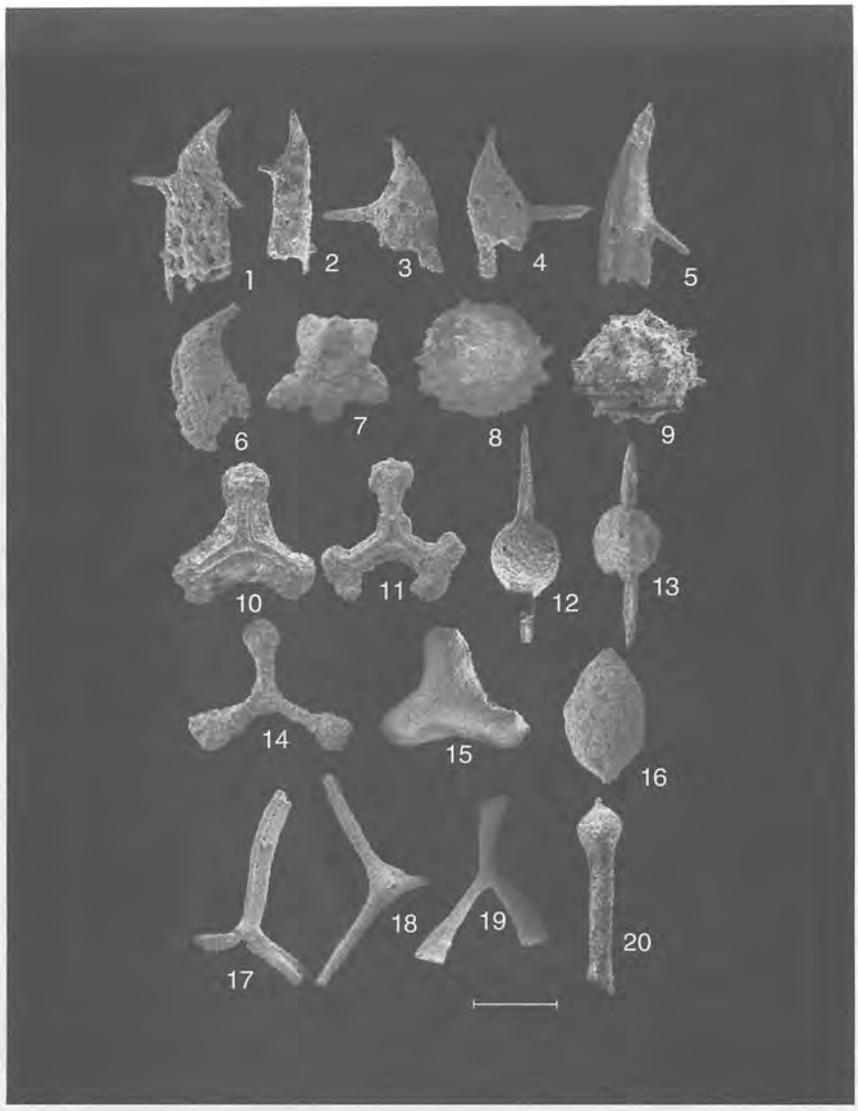

Plate 3. Radiolarian assemblage of the *Neoalbaillella ornithoformis* Zone
(Scale bar in μm is indicated in parenthesis)

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. *Neoalbaillella grypus* Ishiga, Kito and Imoto (100μm)
7. *Octatormentum floriferum* Sashida and Tonishi (180μm)
8. *Copicyntra* sp. (100μm)
9. *Copicyntra akikawaensis* Sashida and Tonishi (135μm)
10. *Triplanospongos musashiensis* Sashida and Tonishi (135μm)
11. *Triplanospongos dekkaensis* (Noble and Renne)(138μm)
12, 13. *Entactinosphaera pseudocimelia* Sashida and Tonishi. (140μm)
14. *Latentifistula texana* Nazarov and Ormiston (140μm)
15. *Latentibifistula asperspongiosa* Sashida and Tonishi (230μm)
16. *Copiellintra* sp.(100μm)
17. *Nazarovella gracilis* De Wever and Caridroit (200μm)
18. *Nazarovella inflata* Sashida and Tonishi (130μm)
19. *Deflandrella* sp.(130μm)
20. *Ishigaum* sp.(230μm)

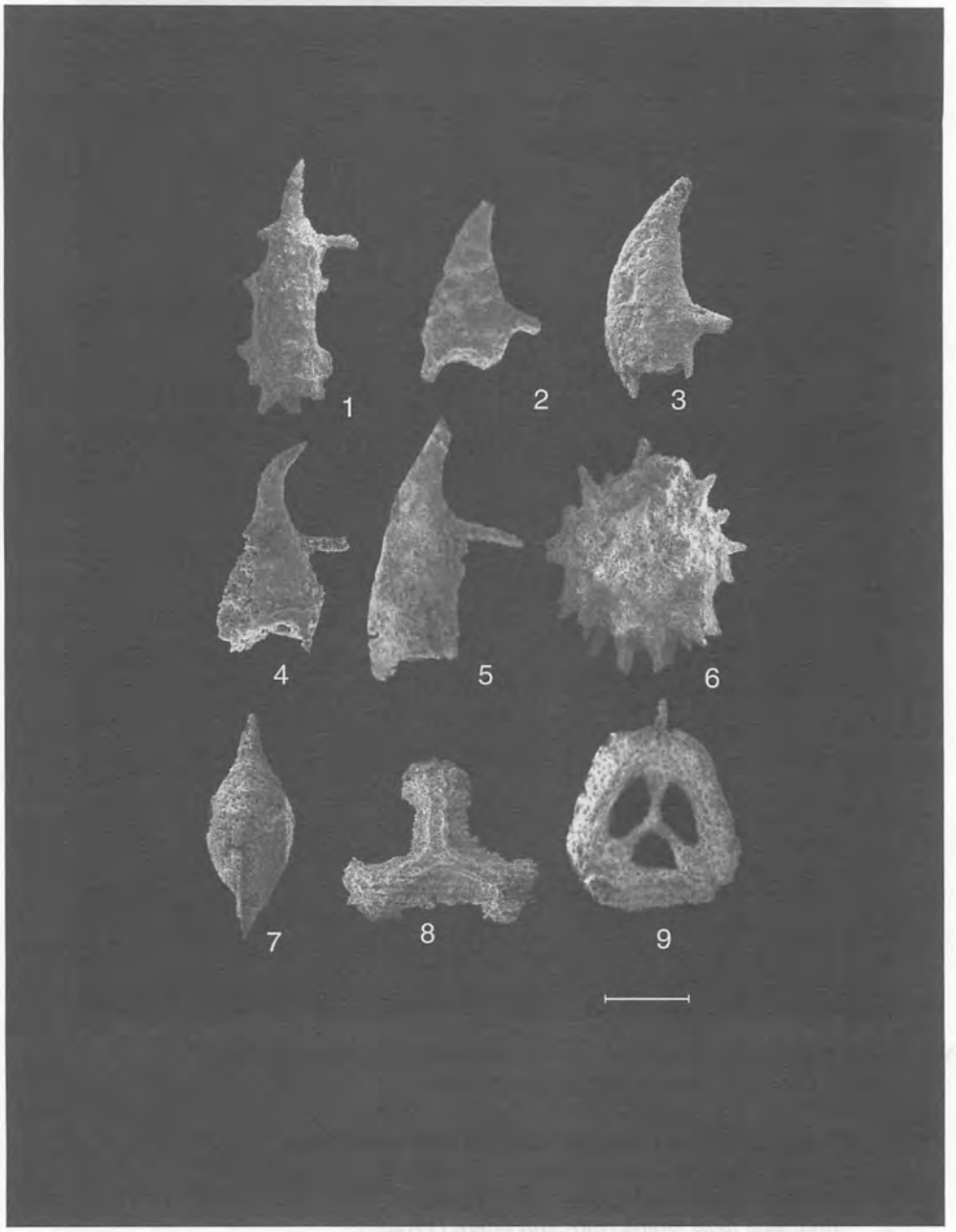

Plate 4. Radiolarian assemblage of *Neoalbaillella optima* Zone
(Scale bar in μm is indicated in parenthesis)

1. *Neoalbaillella optima* Ishiga, Kito and Imoto (100μm)
2. *Albaillella triangularis* Ishiga, Kito and Imoto (90μm)
3. *Albaillella levis* Ishiga, Kito and Imoto(90μm)
4. *Albaillella flexa* Kuwahara (100μm)
5. *Albaillella excelsa* Ishiga, Kito and Imoto (100μm)
6. *Copicyntra akikawaensis* Sashida and Tonishi (100μm)
7. *Copiellintra fontainei* (Sashida)(100μm)
8. *Triplanospongos musashiensis* Sashida and Tonishi (120μm)
9. *Foremanhelena triangula* De Wever and Caridroit.(120μm)

many outcrops from different localities whereas in south Kedah the biozones were constructed based on one extensive outcrop.

CONCLUSIONS

The rock sequence in the area is represented by seven lithofacies i.e. laminated black mudstone, interbedded sandstone and mudstone, tuff, interbedded siliceous shale, chert and tuffaceous sandstone, thinly bedded chert, gray mudstone and thinly bedded chert. A total of 40 siliceous shale and chert samples were collected. Twenty-one samples yielded 39 taxa of fairly well-preserved radiolarian faunas.

Five biozones were recognized, based on the stratigraphic distribution of *Follicucullus* and *Albaillella* i.e. *Pseudoalbaillella scalprata* m. *scalprata*, *Follicucullus monacanthus*, *Follicucullus porrectus*, *Neoalbaillella ornithoformis* and *Neoalbaillella optima* Zones. *Pseudoalbaillella scalprata* m. *rhombothoracata* Zone represents the oldest chert in the Semanggol Formation, which indicates an age of Sakmarian, late Early Permian. *Follicucullus monacanthus* Zone is restricted to Wordian, Middle Permian. *Follicucullus porrectus* Zone is estimated to be Capitanian-Wuchiapingian, late Middle Permian to early Late Permian. *Neoalbaillella ornithoformis* Zone is assigned to Wuchiapingian, Late Permian and finally *Neoalbaillella optima* Zone indicates Changxingian, Late Permian.

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