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Late Palaeozoic radiolarians from the Bentong–Raub suture zone, and the Semanggol Formation of Peninsular Malaysia—initial results

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Abstract—Cherts and tuffaceous siltstones from the Bentong–Raub suture zone, Peninsular Malaysia, have yielded radiolarians indicating Late Devonian (Famennian) and Early Carboniferous (Tournaisian, late? Tournaisian and Viséan) ages. Cerium anomalies from these Devonian and Carboniferous cherts indicate deposition in an open ocean. This ocean is interpreted to be the Palaeo-Tethys ocean which existed between Sibumasu and East Malaya during at least the Devonian and Early Carboniferous. Radiolarians extracted from siliceous sediments of the Semanggol Formation of NW Peninsular Malaysia have indicated both Early Permian and Late Permian (Guadalupian) ages. This extends the age of the Semanggol Formation down to the Early Permian and confirms the presence of a deep-marine basin in what is now NW Peninsular Malaysia during the Permian.

Introduction

Cherts comprise a significant proportion of the varied rock types found in oceanic accreted terranes. These cherts, with their radiolarian microfossil faunas and distinctive geochemical signatures can provide information about the age, depositional environment and tectonic history of oceanic terranes. They can therefore assist in unravelling the tectonic history of the Southeast Asian region, including the history of the Palaeo-Tethys Ocean.

This paper presents the initial results of palaeontological and geochemical studies of cherts from the Bentong–Raub suture zone and the Semanggol Formation of Peninsular Malaysia.

Regional Setting

The Southeast Asian region is a complex tectonic collage of allochthonous continental fragments with a variety of tectonic histories (Audley-Charles, 1983, 1988; Hutchison, 1989; Klimetz, 1987; Mitchell, 1981; Stauffer, 1983; Audley-Charles *et al.*, 1988; Metcalfe, 1983, 1984, 1986, 1988, 1990, 1993). They have been rifted and moved from their original location by various plate tectonic mechanisms and have subsequently been amalgamated and/or accreted to form Southeast Asia as we see it today (Audley-Charles, 1983, 1988; Hutchison, 1989; Metcalfe, 1983, 1984, 1986, 1988, 1990, 1993). There is general concensus the most of these fragments or terranes had their origins in eastern Gondwanaland (Audley-Charles, 1983, 1988; Burrett and Long, 1988; Burrett and Stait, 1985; Burrett *et al.*, 1990; Hutchison, 1989; Metcalfe, 1983, 1984, 1986, 1988, 1990, 1993), but the time of rifting from the parent craton and the times of amalgamation and/or accretion remains contentious. The various terranes are now separated by major faults or suture zones. Some of these suture zones, contain mélange, oceanic sediments (mainly cherts) and serpentinites.

The Bentong–Raub Suture Zone

The Bentong–Raub suture zone of Peninsular Malaysia (Fig. 1) is a narrow north–south trending zone extending from Thailand through Bentong and Raub and east of Malacca. It is approximately 13 km wide and comprises mélange, oceanic sediments (mainly cherts), schist, and discontinuous, narrow, elongate bodies of

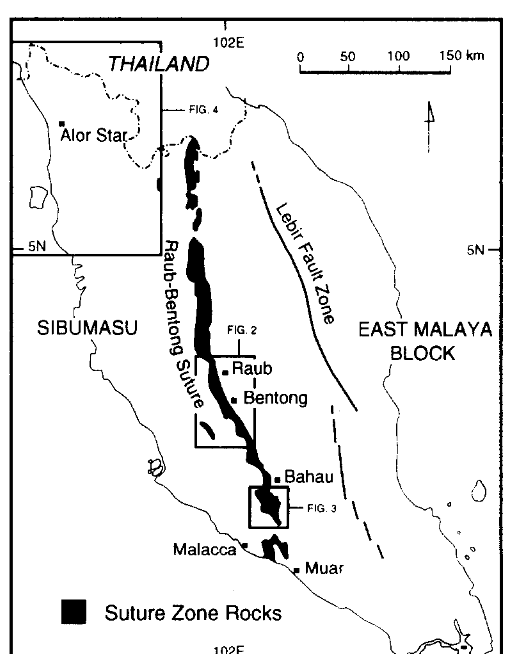

Fig. 1. Map of Peninsular Malaysia showing the Bentong–Raub suture zone. Inset maps show the location of Figs 2–4.

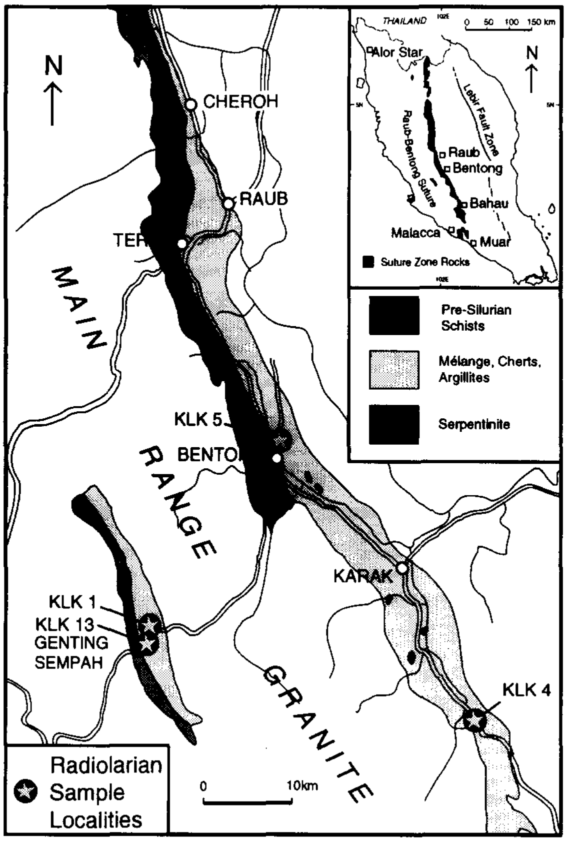

Fig. 2. Map of the Bentong–Raub area showing location of radiolarian sample localities KLK1, KLK4, KLK5 and KLK13.

sepentinised mafic–ultramafic rocks representing ophiolite (Hutchison, 1989; Tjia, 1987, 1989). The suture separates two continental tectonostratigraphic terranes, Sibumasu to the west and the East Malaya Block to the east. The Sibumasu block is characterised by a Palaeozoic passive margin sequence which includes a belt of Late Carboniferous–Early Permian glacial marine diamictites (Metcalfe, 1988; Stauffer and Lee, 1989; Stauffer and Mantajit, 1981). Early Permian faunas have an affinity with Gondwanaland (Archbold *et al.*, 1982; Shi and Waterhouse, 1991). There is also a general absence of Carboniferous–Permian volcanism on Sibumasu. In contrast, the East Malaya block is distinguished by abundant Carboniferous–Permian volcanism and *Gigantopteris* floras of Cathasian affinity in the early Late Permian (Asama, 1984). The S-type Main Range Granite (granitoid belt) (Fig. 2) is located along the western margin of the Bentong–Raub suture zone, although in places it intrudes the suture zone itself (Hutchison, 1989). A belt of pre-Silurian quartz mica schist (Hutchison, 1989; Tjia, 1987, 1989), separates the Main Range Granite from the suture zone rocks. The Bentong–Raub suture zone has been interpreted to represent the former ocean (Palaeo–Tethys), which once separated Sibumasu and the East Malaya Block (Hutchison, 1987; Sengör, 1984; Sengör *et al.*, 1988; Metcalfe 1988, 1990, 1991, 1992, 1993). The time of suturing (amalgamation) of these two allochthonous terranes remains problematic. Helmke (1983, 1985) proposed that Sibumasu accreted to Indochina and East Malaya in the Permian, or possibly as early as the Carboniferous, while Mitchell (1989) favoured an early Triassic collision. Sengör (Sengör 1984; Sengör *et al.*, 1988) suggested the late Triassic, and Audley-Charles (1988) the Middle–Late Cretaceous. Metcalfe (1991, 1993) favours a latest Permian to early Triassic age for the event.

Radiolarian Biostratigraphy

Samples of siliceous radiolarian-bearing sediments from the Bentong–Raub suture zone (Fig. 2) were collected with the aim of determining the age and geochemistry of the rocks which formed in the palaeo-ocean which once separated Sibumasu and the East Malaya block, as well as helping to constrain the time of suturing of the two blocks.

The preservation of the microfossils is generally very poor and the specimens have a microcrystalline silica coating on the tests due to recrystallization. However, moderately well preserved, datable radiolarians have been extracted from five localities (Figs 2 and 3).

Late Devonian (Famennian) fauna (Fig. 5a–e) has been extracted from bedded cherts adjacent to mélange near Bentong (KLK5). The age is indicated by fragmentary specimens of *Holoeciscus foremanae* Cheng, *Popofskyellum* sp. and *Archocyrtium* sp. Several specimens of an elongate form of *Holoeciscus* described as "*Holoeciscus longus*" by Schwartzapfel (unpublished Ph.D. thesis, University of Texas, Dallas, 1990) have also been found. This fauna is associated with numerous poorly preserved spheroidal radiolarians with bladed spines.

Thinly bedded black cherts exposed south of Karak, Pahang (KLK4) have yielded numerous fragmentary specimens of *Albaillella undulata* Deflandre and *Albaillella deflandrei* Gourmelon, with associated poorly preserved spheroidal radiolarians, which indicate an Early Carboniferous (Tournaisian) age (Fig. 5f–h).

Early Carboniferous (late? Tournaisian) radiolarians (Fig. 5i–m), including *Archocyrtium eupectum* Braun and

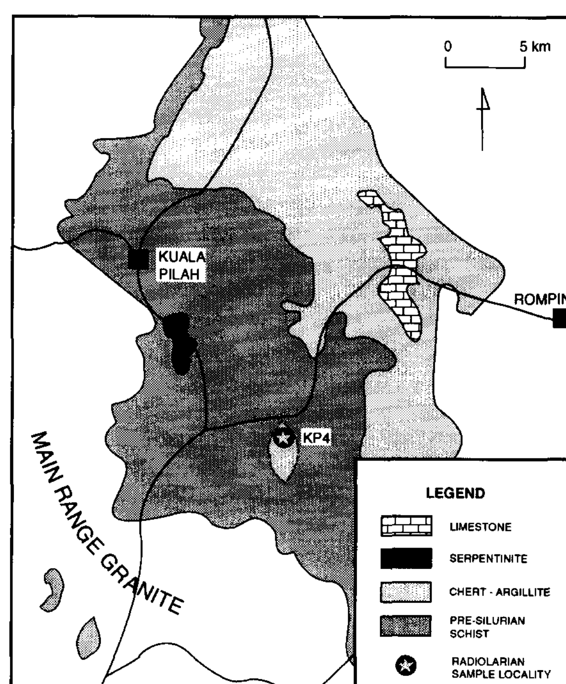

Fig. 3. Map of the Kuala Pilah area showing location of radiolarian sample locality KP4.

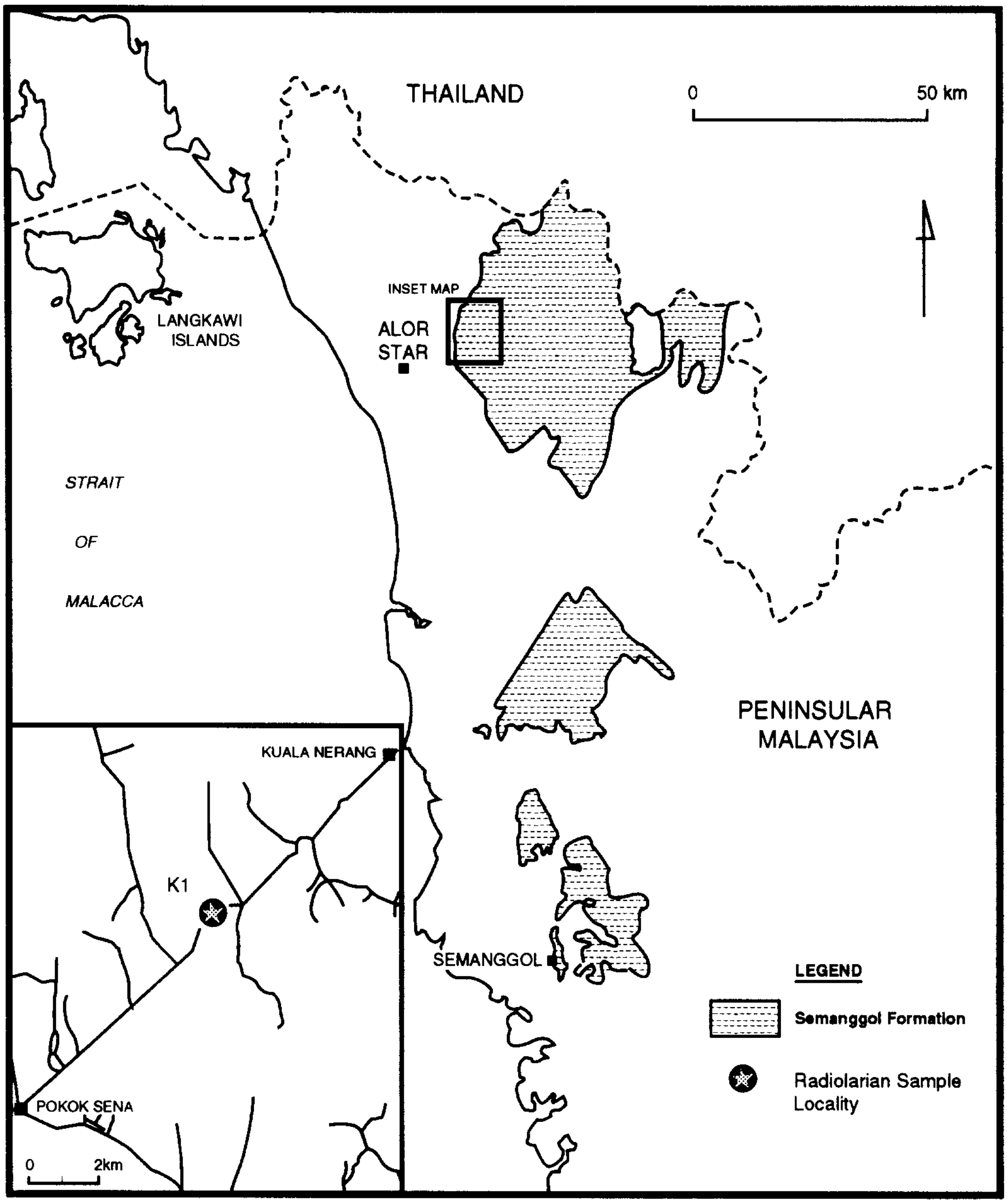

Fig. 4. Map showing the distribution of the Semanggol Formation in northwest Peninsular Malaysia. Inset map shows the location of the radiolarian sample locality K1.

Ceratoikiscum sp., have been extracted from steeply dipping, isoclinally folded black chert beds near Kuala Pilah, Negeri Sembilan (KP4) (Fig. 3). The fauna also includes moderately preserved entactinids.

An olistrostromal block of interbedded chert, mudstone and siltstone within mélange exposed near Genting Sempah, Selangor (Metcalfe, 1987) (KLK13) has yielded fragmentary specimens of *Albaillella cartalla* Ormiston and Lane, and specimens of *Entactinia variospina* Won, which indicate an Early Carboniferous (Viséan) age (Fig. 6a–d).

A second locality near Genting Sempah (KLK1) has yielded poorly preserved radiolarians including *Archocyrtium* sp., which indicate a Late Devonian or Early Carboniferous age (Fig. 5h–p). Further material is required to precisely constrain the age of the cherts at this locality.

The Semanggol Formation

The Semanggol formation crops out in NW Peninsular Malaysia (Fig. 4). Burton (1973) divided the formation into three members; the lower Chert Member, the Rhythmite Member and the upper Conglomerate Member. Until recently, the Semanggol Formation was reported as being entirely of Triassic age. This was based on bivalves and conodonts which indicated a Middle Triassic age for the Chert Member (Kobayashi and Tamura, 1984) and an early Late Triassic age for the Rhythmite Member (Kobayashi and Tamura, 1984). However, Sashida *et al.* (1992, 1993) recovered Late Permian radiolarians representing the *Follicucullus monacanthus* and *Neoalbaillella ornithoformis* Zones of Ishiga (1990) from the lower Chert Member, thus extending the age of the Semanggol Formation down to the Late Permian.

Radiolarian Biostratigraphy

In the course of the present study, samples collected from a sequence of interbedded tuffaceous mudstone and chert from a locality near Pokok Sena (K1) (Fig. 4 inset map) have indicated both Early and Late Permian ages for part of the lower Chert Member. The sample lowest in the stratigraphic sequence contained numerous poorly preserved specimens of *Pseudoalbaillella* sp. indicating a probable latest Early Permian age (Fig. 6e–f). This information further extends the age of the Semanggol Formation down to the Early Permian.

Two samples higher in the stratigraphic sequence contained numerous specimens of *Follicucullus scholasticus* Ormiston and Babcock morphotype I and *Follicucullus scholasticus* Ormiston and Babcock morphotype II from the *F. scholasticus* Zone of Ishiga (1990), indicating a Late Permian (Guadalupian) age (Fig. 6g–l).

Discussion

The lower Chert Member of the Semanggol Formation appears to range in age from the Early Permian (this study) to early Late Triassic (Metcalfe, 1990). The cherts yielding Permian radiolarians exhibit a similar strike and dip to cherts and limestones that have yielded Upper Triassic (lower Carnian) conodonts and appear on field evidence to form a conformable sequence with these. The Lower Triassic has not, however, been recorded so far in the Semanggol Formation, but if present, it would provide important information on a poorly known part of the geological column (from a radiolarian biostratigraphy point of view). The possibility of locating the Permian–Triassic boundary in a deep-marine sequence, where radiolarian and conodont biostratigraphy may be studied, is also an exciting prospect. The tectonic history of the Semanggol Formation and its relationship to adjacent lithologies has recently been re-examined. Hussin (1993) has reinterpreted the stratigraphy of the Semanggol Formation in the Semanggol area (Fig. 4). The presence of an orthoconglomerate facies containing chert clasts which unconformably overlies cherts previously regarded as the lower Chert Member is said to indicate a major tectonic event that disrupted the deposition of the older chert (Hussin, 1993). The Rhythmite Member has been dated as Late Triassic (Kobayashi and Tamura, 1984), therefore the interpreted timing of this event would be early Late Triassic.

The Early Permian–Late Triassic, deep marine pelagic/turbidite sequence of the Semanggol Formation is equivalent in age to the shallow marine Chuping and Kodiang Limestones which also crop out in NW Peninsular Malaysia.

Metcalfe (1990) has proposed that the pelagic/turbidite sequence of the Semanggol Formation accumulated in either a foredeep basin or an intracratonic pull-apart basin related to strike–slip faulting. The Chuping and Kodiang Limestone sequences were deposited as part of an elongate carbonate platform on the Sibumasu block, adjacent to, and contemporaneous with the Semanggol Formation. Ophiolite rocks and other evidence of a suture zone in this area is not seen (Hutchison, 1989).

Chert Geochemistry

The cerium anomaly (Ce/Ce*) preserved in marine sequences reflects the depositional environment of the sediment (Shimizu and Masuda, 1977; Matsumoto *et al.*, 1988; Murray *et al.*, 1990). Ce/Ce* values of < 0.3 are indicative of spreading ridge proximity, Ce/Ce* values of 0.3–0.9 indicate ocean basin floor deposition and Ce/Ce* values of 0.90–1.3 indicate continental margin proximity (Murray *et al.*, 1990).

Initial geochemical analyses of cherts from the Bentong–Raub suture zone has been reported by Metcalfe (1992). The cerium anomaly (Ce/Ce*) values mostly indicate deposition on the ocean basin floor, but values consistent with deposition near mid-ocean ridge and continental margin are also recorded. This preliminary data indicates that the marine depositional environment was within a major open ocean, and not a restricted back arc basin as initially proposed by Hutchison (1978), an aborted rift (Khoo and Tan, 1983), or a transcurrent fault setting that developed into an extensional regime, as proposed by Chakraborty (1988), where continental margin sedimentation would predominate. Further geochemical analyses of chert samples are in progress.

Fig. 5. Scanning electron micrographs of radiolarians from Peninsular Malaysia. Scale bar represents 100 μm except for k and m, where scale bar represents 10 μm. (a) *Holoeciscus foremanae* Cheng (Locality KLK5 of Late Devonian age, Bentong–Raub suture zone). (b) Elongate form of *Holoeciscus* described as "*Holoeciscus longus*" by Schwartzapfel (unpublished Ph.D. thesis, University of Texas, Dallas, 1990) (locality KLK5 of Late Devonian age, Bentong–Raub suture zone). (c) Elongate form of *Holoeciscus* described as "*Holoeciscus longus*" by Schwartzapfel (unpublished Ph.D. thesis, University of Texas, Dallas, 1990) (locality KLK5 of Late Devonian age, Bentong–Raub suture zone). (d) *Popofskyellum* sp. (locality KLK5 of Late Devonian age, Bentong–Raub suture zone). (e) *Archocyritium* sp. (locality KLK5 of Late Devonian age, Bentong–Raub suture zone). (f) *Albaillella undulata* Deflandre (locality KLK4 of Early Carboniferous age, Bentong–Raub suture zone). (g) *Albaillella deflandrei* Gourmelon (locality KLK4 of Early Carboniferous age, Bentong–Raub suture zone). (h) *Albaillella deflandrei* Gourmelon (locality KLK4 of Early Carboniferous age, Bentong–Raub suture zone). (i) *Archocyrtium eupectum* Braun (locality KP4 of Early Carboniferous age, Bentong–Raub suture zone). (j) *Archocyrtium eupectum* Braun (locality KP4 of Early Carboniferous age, Bentong–Raub suture zone). (k) *Ceratoikiscum* sp. (locality KP4 of Early Carboniferous age, Bentong–Raub suture zone). (l) Entactiniidae gen. et sp. indet. (locality KP4 of Early Carboniferous age, Bentong–Raub suture zone). (m) Entactiniidae gen. et sp. indet. (locality KP4 of Early Carboniferous age, Bentong–Raub suture zone). (n) *Archocyrtium* sp. (locality KLK1 of Late Devonian or Early Carboniferous age, Bentong–Raub suture zone). (o) *Archocyrtium* sp. (locality KLK1 of Late Devonian or Early Carboniferous age, Bentong–Raub suture zone). (p) Entactiniidae gen. et sp. indet. (locality KLK1 of Late Devonian or Early Carboniferous age, Bentong–Raub suture zone).

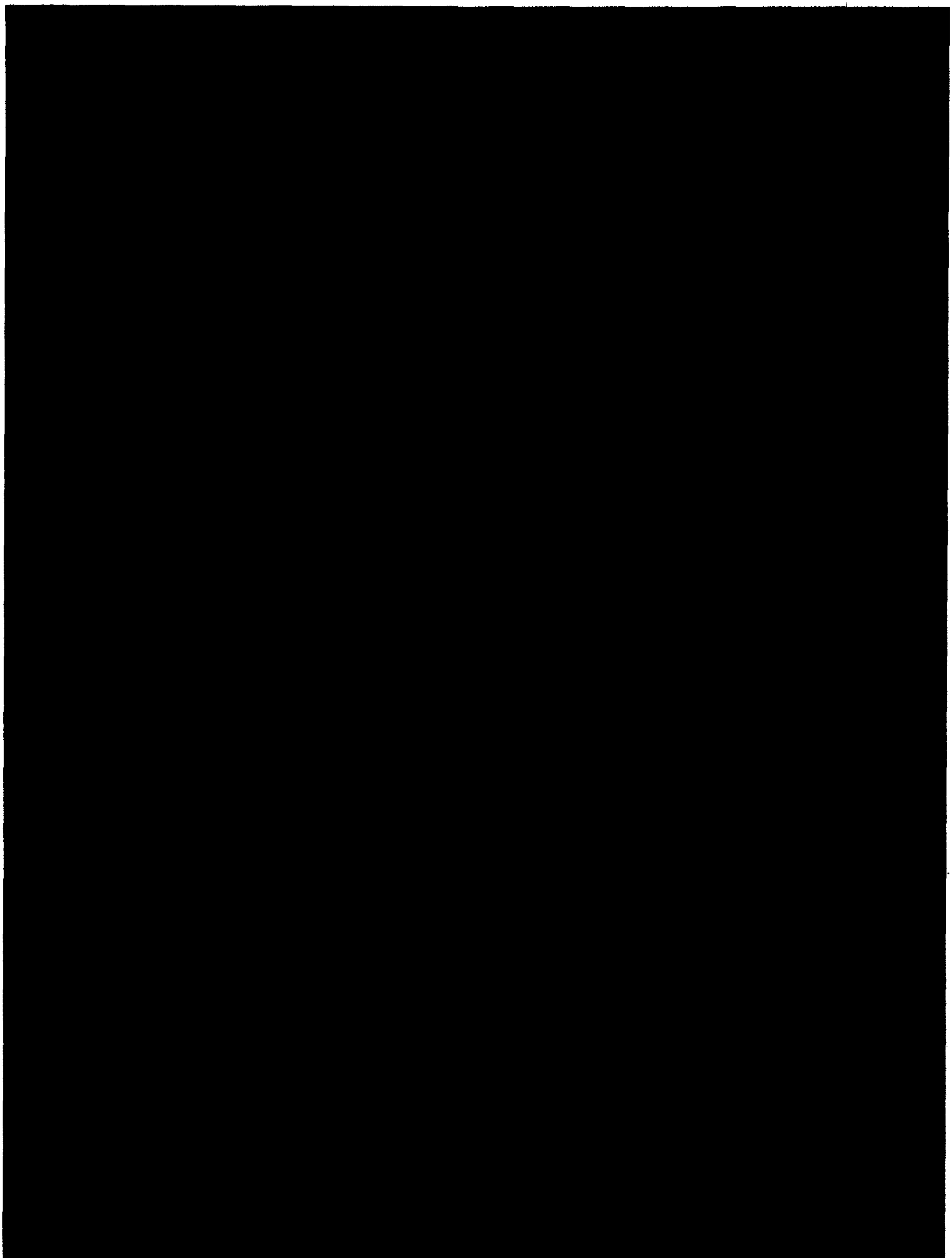

Fig. 5.

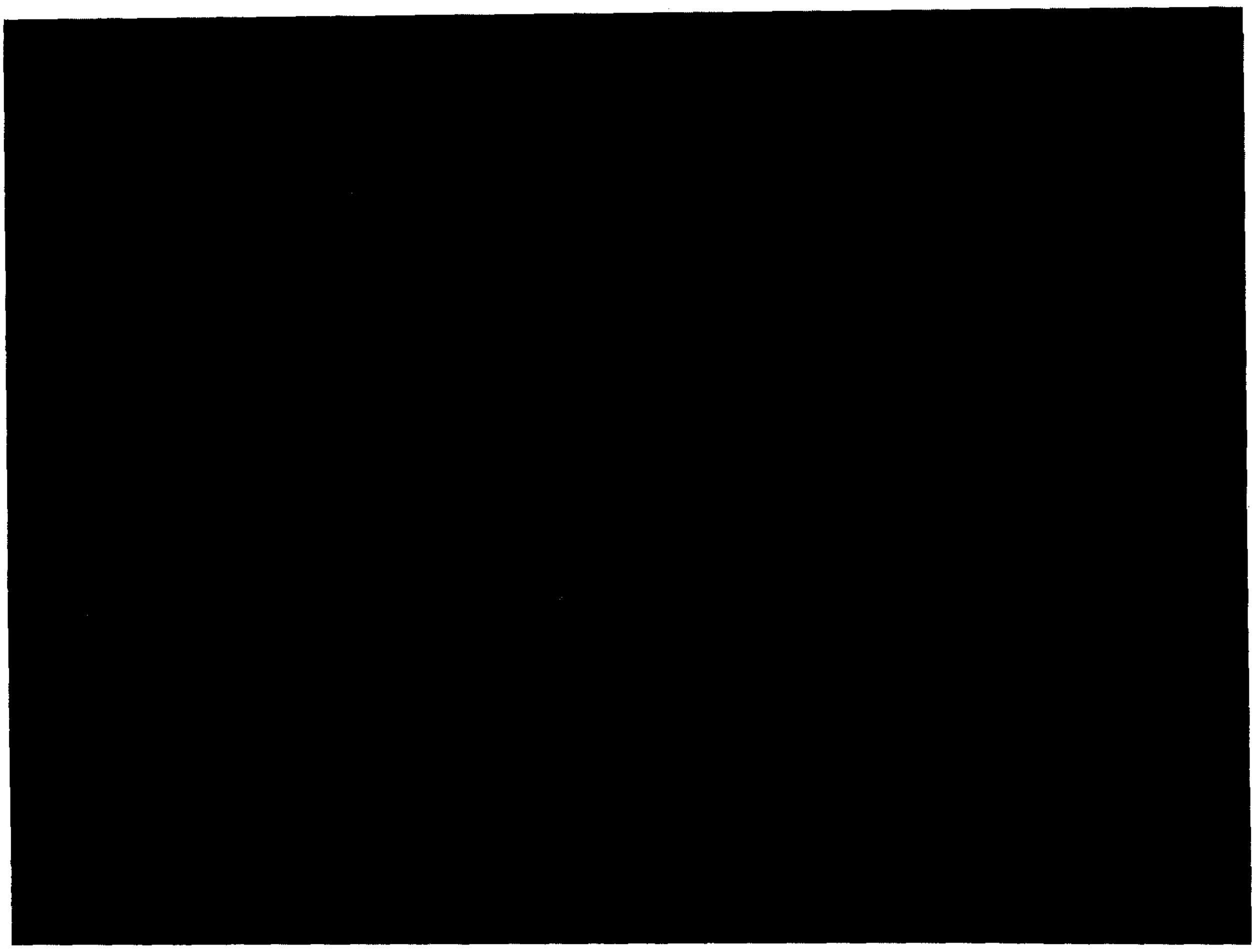

Fig. 6. Scanning electron micrographs of radiolarians from Peninsular Malaysia. Scale bar represents 100 μm. (a) *Albaillella cartalla* Ormiston and Lane (locality KLK13 of Early Carboniferous age, Bentong–Raub suture zone). (b) *Albaillella cartalla* Ormiston and Lane (locality KLK13 of Early Carboniferous age, Bentong–Raub suture zone). (c) *Entactinia variospina* Won (locality KLK13 of Early Carboniferous age, Bentong–Raub suture zone). (d) *Entactinia variospina* Won (locality KLK13 of Early Carboniferous age, Bentong–Raub suture zone). (e) *Pseudoalbaillella* sp. (locality K1 of Permian age, Semanggol Formation). (f) *Pseudoalbaillella* sp. (locality K1 of Permian age, Semanggol Formation). (g) *Follicucullus scholasticus* Ormiston and Babcock morphotype I Ishiga (locality K1 of Permian age, Semanggol Formation). (h) *Follicucullus scholasticus* Ormiston and Babcock morphotype II Ishiga (locality K1 of Permian age, Semanggol Formation). (i) *Follicucullus scholasticus* Ormiston and Babcock morphotype II Ishiga (locality K1 of Permian age, Semanggol Formation).

Conclusions

Initial results of this study indicate that the radiolarian assemblages extracted from siliceous sediments in the Bentong–Raub suture zone have Late Devonian–Early Carboniferous ages. The ages indicated are:

KLK1 —Late Devonian or Early Carboniferous age;
KLK5 —Late Devonian (Famennian);
KLK4 —Early Carboniferous (Tournaisian);
KP4 —Early Carboniferous (late? Tournaisian);
KLK13 —Early Carboniferous (Visean).

These data, together with initial geochemical analysis indicate that an ocean (Palaeo–Tethys) existed between the Sibumasu and East Malaya block at least during Late Devonian to Early Carboniferous time.

The Early and Late Permian ages obtained from the lower Chert Member of the Semanggol Formation suggests deep marine sedimentation during the Permian. The provenance, depositional setting and tectonic history of this region remains an enigma.

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