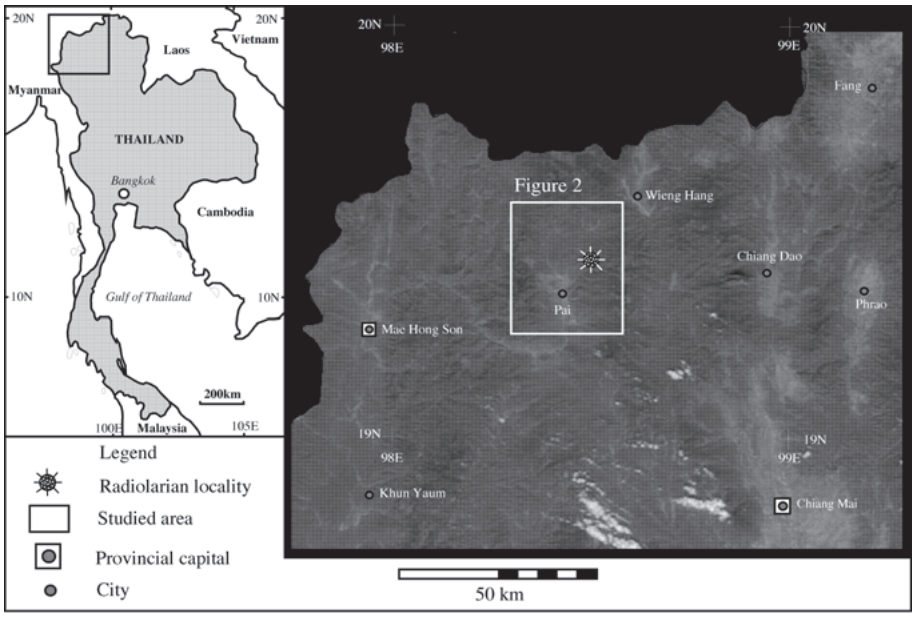

Fig. 1. Index map of northwestern Thailand showing the studied area and the radiolarian locality.

bedded sandstone, shale, chert and slate (Fig. 2). Limestones, forming isolated karstic hills are widespread and contain abundant Carboniferous and Permian foraminifers and other fossils. In general most Thai geologists correlate these limestones with the Ratburi Group. Limestones in this area are lithologically variable, but mainly consist of massive limestones, with local occurrences of dolomitic limestone with lenticular or nodular cherts. The relationship between limestone units and Palaeozoic siliceous sedimentary units is not clear. Field observations indicate the limestones unconformably overlie siliceous sediments, and where faulted the basal contact is locally marked by breccias.

The studied section is located approximately 7– 8 km north of Pai (Fig. 2), or at position 438455 on Thai topographic map sheet 4647 I Amphoe Pai, in the area of Ban Tan Jed Ton village. The section is exposed for approximately 850 m along a gravel road connecting Pai and Wieng Haeng that has been cut through a high mountainous area. The section consists of gray to greenish gray, partly dark gray, well-bedded chert with 4 to 10 cm thick beds intercalated with thin shale and clay (mm – few cm) layers. The main and lowermost exposed section is about 150 m long, before being obscured by strongly weathered yellow volcanic rocks for about 200 m. The second section, which is believed to be a separate block, is composed of greenish gray well-bedded chert and about 10 m long. Ten chert samples were collected from the main section (PAI-391 to PAI-400) and three more were taken from the second (PAI-401 to PAI-403). The next three samples (PAI-404 to PAI-406) were taken from a small chert outcrop exposed on the other side of 200 m of weathered tuffaceous material. Four chert samples were collected (PAI-407 to PAI-412) from the last section which ends at a summit approximately 150 m from the previous section. This chert has long been regarded as chert beds intercalated within the Upper Silurian to Carboniferous Mae Hong Son Formation (Bunopas 1981), or newly established Carboniferous-Permian of Chauviroj et al. (1985). According to field observations, no outcrops were found which expose the strata underlying the chert.

Under the microscope, the chert from lower part consists of mainly cryptocrystalline to microcrystalline quartz associated with very fine clay minerals. Radiolarians are rather well preserved and abundant and filled by chalcedony. Further up the lithologic column the cherts consist of cryptocrystalline quartz with more abundant fine clay mineral and fine volcanic grains, without any traces of fossils. This probably indicates that there was volcanic activity within or nearby the site of deposition area conditions did not favour the preservation of radiolarian skeletons.

Samples from the main chert section (PAI-391 through PAI-400) yielded the following Upper Permian radiolarian faunas: *Follicucullus ventricosus* Ormiston & Babcock, *F. scholasticus* Ormiston & Babcock, *F. orthogonus* Caridroit & De Wever, *F. porrectus* Rudenko, *F. charveti* Caridroit & De Wever, *F.* sp. cf. *F. bipartitus* Caridroit & De Wever, *Hegleria mammilla* (Sheng & Wang) and others. The association of *F. charveti* and *F. porrectus* Rudenko is diagnostic for assignment to the lower Wuchiapingian. Sample PAI-403 contains fewer radiolarians, however the occurrence of *F. monacanthus* Ishiga & Imoto is the diagnostic of the Middle Permian *F. monacanthus* Assemblage (Capitanian), therefore these chert beds are assigned to the Capitanian.

3. Radiolarian biostratigraphy

Twenty-two chert samples were collected, and nine samples yielded Permian radiolarians (Plate 1). The studied chert sec-

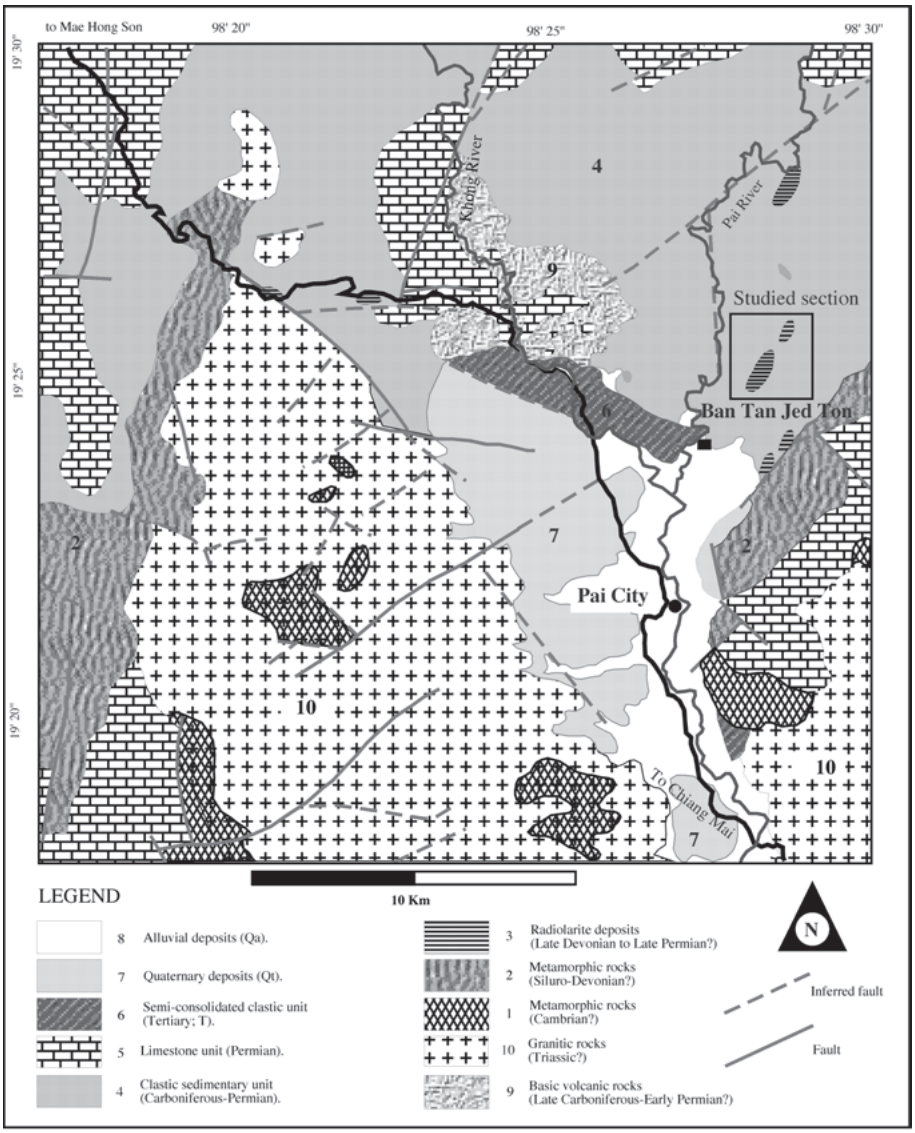

Fig. 2. Simplified geologic map of Pai area, Mae Hong Son province, northwestern Thailand (see Fig. 1 for location); shows the studied sections. (after Geologic map 1:50,000 Sheet Amphoe Pai Quadrangle, Geological Survey Division, Department of Mineral Resources, Bangkok, Thailand 1985; Intawong et al. 1997, modified)

tion extends over two radiolarian assemblage zones: the *Follicucullus monacanthus*, and *Follicuculllus charveti – F. porrectus* assemblage zones. These zones have been reported by Ishiga (1986, 1990) from Japan, Wang et al. (1994) from China and Caridroit in De Wever et al. (2001) and are known to occur in the middle Maokouan (Capitanian) to lower Wuchiapingian.

Follicucullus monacanthus assemblage zone.

This assemblage zone is found within sample PAI-403. It is characterized by the occurrence of *Follicucullus monacanthus* ISHIGA & IMOTO, which is the characteristic taxon. Other radiolarians species that occur in this assemblage include *F. scholasticus* ORMISTON & BABCOCK, *Pseudotormentus* sp. cf. *P. kamigoriensis* CARIDROIT & DE WEVER, *F. orthogonus* CARIDROIT & DE WEVER, *F. ventricosus* ORMISTON & BABCOCK, and *Ormistonella robusta* CARIDROIT & DE WEVER. The *Follicucullus monacanthus* assemblage is known from Japan (e.g. Ishiga 1986), Far East Russia (Rudenko & Panasenko 1990), Oregon in North America (Blome & Reed 1992), South China (Wang et al. 1994), and is also reported in studies by Caridroit (in De Wever et al. 2001, fig. 202, p. 313).

Follicucullus charveti – F. porrectus assemblage zone

This assemblage zone is found within green chert samples PAI-393, 396, 398 & 399. It is defined by the co-occurrence of *Follicucullus charveti* CARIDROIT & DE WEVER and *F. porrectus* RUDENKO. The range of this assemblage is considered as a total range of *F. charveti* CARIDROIT & DE WEVER. The other characteristic species are *Follicucullus venticosus* ORMISTON & BABCOCK, *Follicucullus scholasticus* ORMISTON & BABCOCK, *Follicucullus* sp. cf. *F. bipatitus* CARIDROIT & DE WEVER, *Ishigaum similicutis* CARIDROIT & DE WEVER, *Triplanospongus musashiensis* SASHIDA & TONISHI, *Latentifistula texana* NAZAROV & ORMISTON, *Hegleria mammilla* (SHENG & WANG), and others. The assemblage contains the same radiolarian species reported from Japan (e.g. Ishiga 1990), North

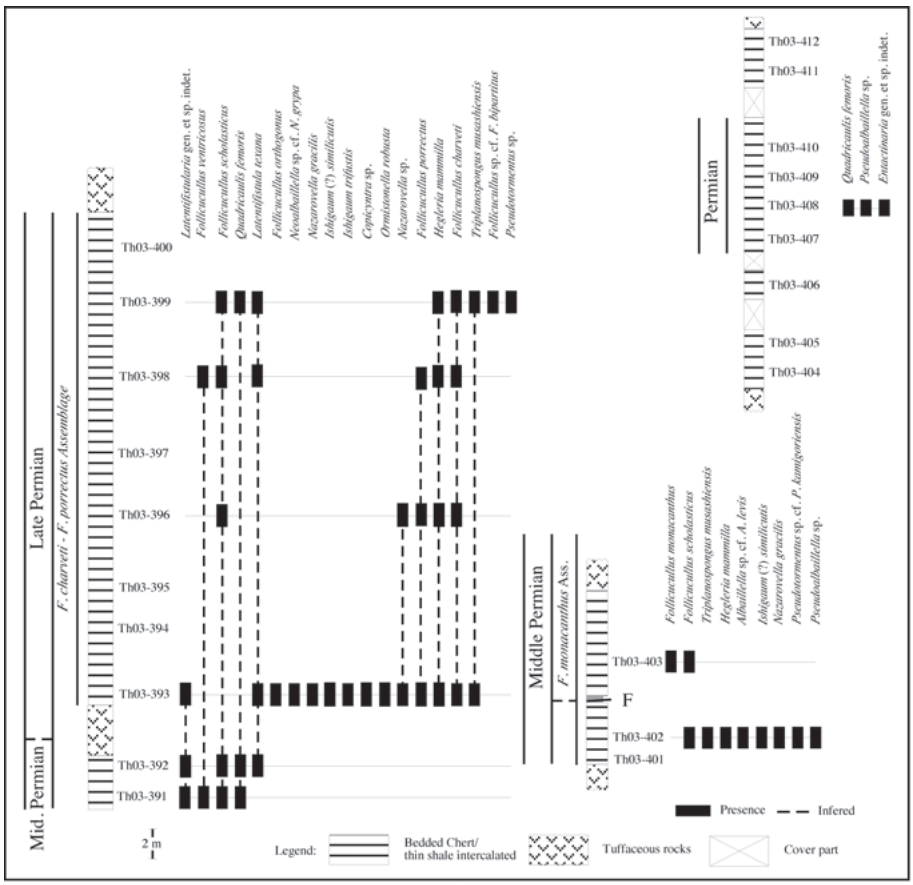

Fig. 3. Columnar sections of the studied bedded chert section exposed on road between Pai and Wieng Hang cities in Ban Tan Jed Ton area (Pai city, Mae Hong Son province), showing distribution of characteristic taxa of radiolarians obtained.

America (e.g. Murchey 1990), South China (e.g. Wang et al. 1994) and New Zealand (e.g. Caridroit & Ferriere 1988). It is comparable to the *F. scholasticus – F. venticosus* zone from China (Wang et at. 1994) and the *F. ventricosus – Ps. fusiformis* assemblage of North America (Murchey 1990).

4. Discussion: Follicucullus faunas and palaeobiogeography

Follicucullus charveti CARIDROIT & DE WEVER is characterized by a long apical cone, which is slightly curved to the ventral side (Pl. 1; Fig. 8). Specimens from the area we studied have a strongly inflated pseudothorax and a short pseudoabdomen with small, disk-like, rather short ventral flap compared to those reported from Japan and S. China (e.g. Caridroit & De Wever 1986; Wang & Li 1994). *F. scholasticus* ORMISTON & BABCOCK m. I (e.g. Ishiga 1985; Blome & Reed 1992; Wang et al. 1994), and *F. scholasticus* ORMISTON & BABCOCK m. II (e.g. Ishiga 1985) are considered as two different species. The first is the most abundant form and found in all levels of the section. This form has a smooth, undulating shell, however, somewhat obscure separated portions can be observed in some specimens. Small very short flaps, extending at apertural margin of the dorsal and ventral sides, are well preserved on most specimens. The second morphotype, on the other hand, has a bulbous shell characteristic similar to those reported from Japan by Caridroit & De Wever (1986) and from the Prymorye region, Far East Russia by Rudenko & Panasenko (1990) and is here regarded as *F. porrectus* RUDENKO. Specimens of *Follicucullus ventricosus* ORMISTON & BABCOCK (Pl. 1; Fig. 9) from the study area are closely similar to those reported from N. America (Ormiston & Babcock 1979; Blome & Reed 1992) and from S. China (Wang et al. 1994) having a slightly curved apical cone and big pseudothorax, with short pseudoabdomen; both ventral and dorsal flap are very short.

Materials presented in this study also contains some broken pieces that have been assigned to species such as *Gustefana obliqueannulata* KOZUR (Pl. 1; Fig. 30) and *Nazarovella phlogidea* WANG (Pl. 1; Fig. 31). These forms in fact have little taxonomic value and in our collections all of these broken pieces appear to be the ending part of an arm of already defined radiolarian species.

It is not yet proven that siliceous skeleton zooplanktonic faunas are useful indicators for palaeo-ecology and/or palaeogeographic position. Nevertheless, the possible palaeogeographic implications of the occurrence of a particular taxon with distinctive form at a few localities merit some discussion. The Upper Permian *Follicucullus charveti – F. porectus* radiolarian assemblage recognized in this study is believed to be equivalent to the *F. bipartitus- F. charveti* assemblage known from southwest Japan (e.g. Caridroit & De Wever 1984, 1986),

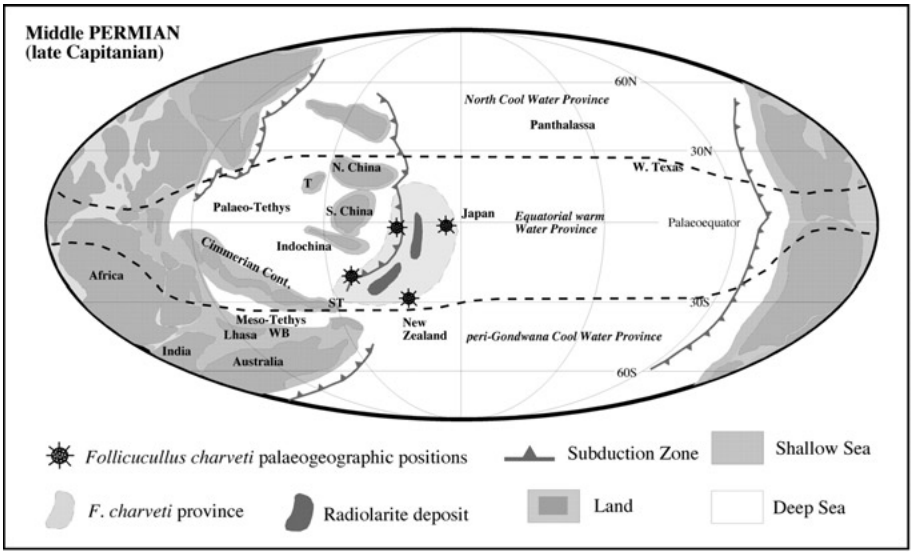

Fig. 4. Palaeogeographic reconstruction during Middle Permian (late Capitanian) showing relative palaeogeographic positions and possible *Follicucullus charveti* province discussed in the text. (Palaeogeographic map and terrane positions are based on Scotese 1997; Metcalfe 1996, and water province areas are after Henderson & Mei 2003, where ST: Shan-Thai; T: Tarim; WB: West Burma).

northern New Zealand (e.g. Caridroit & Ferrière 1988; Takemura et al. 1999), and south & southwest China (e.g. Wang & Li 1994). According to the known literature reported so far, this assemblage has only been discovered from the four different geographic areas mentioned above. Regarding *Follicucullus charveti* CARIDROIT & DE WEVER, a diagnostic taxon of this assemblage, it is not clear whether it occurs in a restricted area with short period (early Wuchiapigian). The occurrence of this fauna in a restricted area as plotted on a palaeogeographic map may suggest that its geographic range was probably confined to a special part in the tropical palaeoequator (low-latitude) realm within the equatorial warm water province. As this species can likely be defined as a warm-water taxon the palaeogeographic positions of terranes containing radiolarites with this fauna were probably at low latitudes not far from one another (Fig. 4).

Acknowledgements

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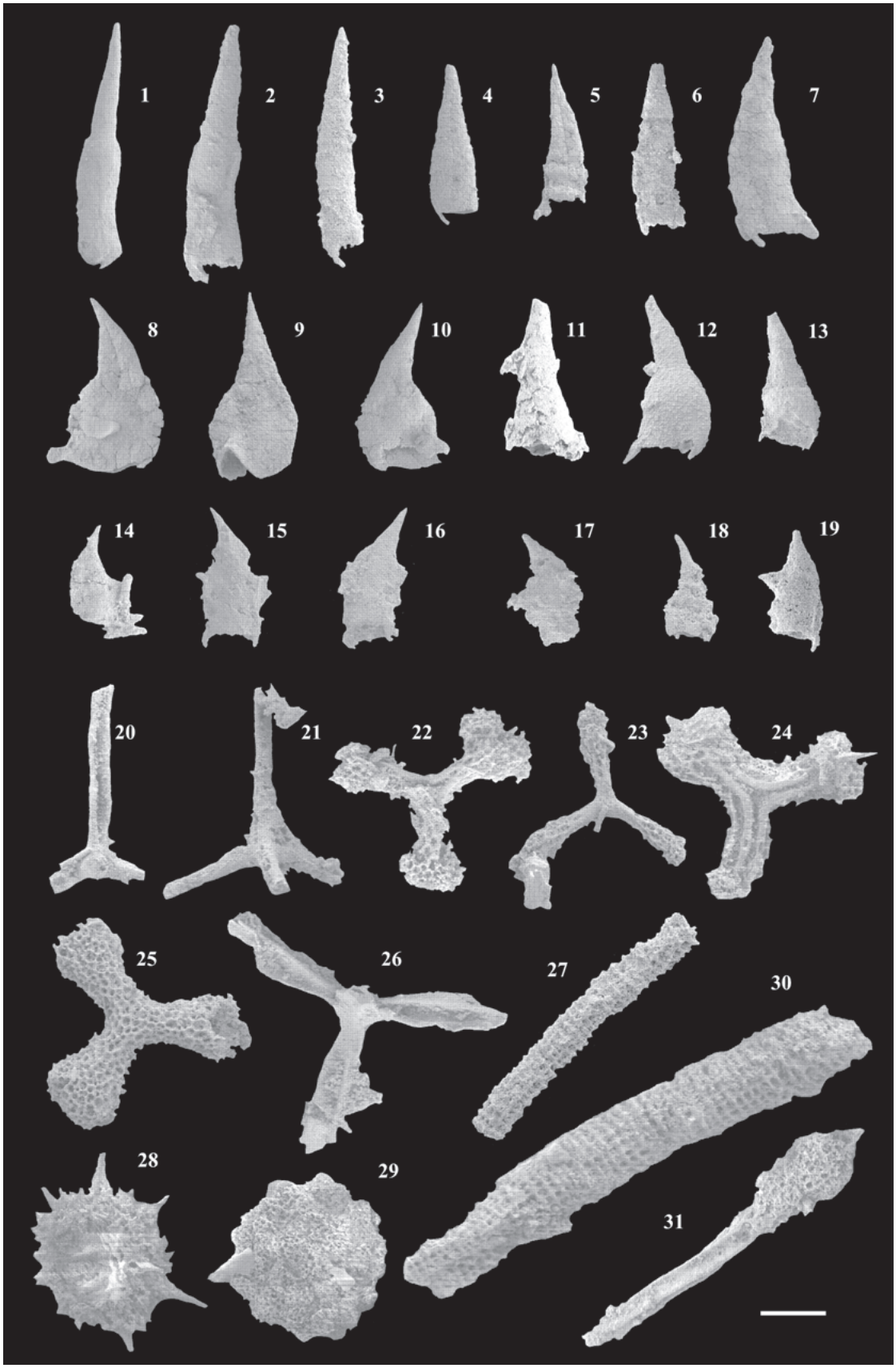
Plate 1

Permian radiolarians from Pai area, northwestern Thailand. All figures are scanning electronic micrographs. Scale bar 100 µm applies to all specimens. 1–6. *Follicucullus scholasticus* ORMISTON & BABCOCK, PAI-421; 7. *Follicucullus porrectus* RUDENKO, PAI-421; 8–10. *Follicucullus charveti* CARIDROIT & DE WEVER, PAI-421; 11. *Follicucullus monacanthus* ISHIGA & IMOTO, PAI-421; 12–13. *Follicucullus ventricosus* ORMISTON & BABCOCK, PAI-419; 14. *Follicucullus orthogonus* CARIDROIT & DE WEVER, PAI-421; 15–17. *Pseudoalbaillella* sp. A, PAI-421; 18. *Neoalbaillella* sp. cf. *N. grypa* ISHIGA ET AL., PAI-421; 19. *Albaillella* sp. aff. *A. levis* ISHIGA ET AL., PAI-421; 20. *Nazarovella gracilis* DE WEVER & CARIDROIT, PAI-402; 21. *Quadricaulis femoris* CARIDROIT & DE WEVER, PAI-393; 22. *Ishigaum* (?) *similicutis* CARIDROIT & DE WEVer, PAI-393; 23. *Ishigaum trifustis* DE WEVER & CARIDROIT, PAI-393; 24. *Trianospongos musashiensis* SASHIDA & TONISHI, PAI-393; 25. *Latentifistula texana* NAZAROV & ORMISTON, PAI-398; 26. *Ormistonella robusta* DE WEVER & CARIDROIT, PAI-393; 27. *Pseudotormentus* sp. cf. *P. kamigoriensis* DE WEVER & CARIDROIT, PAI-402; 28. *Copicyntra* sp., PAI-393; 29. *Hegleria mammila* (SHENG & WANG), PAI-393; 30–31. broken part of latentifistulinid (30: cf. *Gustefana obliqueannulata* KOZUR; 31: cf. *Nazarovella phlogidea* WANG), PAI-393.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