

Reexamination of radiolarian biochronology of the Shimizu Formation (Northern Chichibu Belt) in the Shimizu-Misato area, western Kii Peninsula, Southwest Japan

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1. Introduction

Jurassic to Early Cretaceous accretionary complexes of Southwest Japan are widely distributed in the Mino, Northern Chichibu, and Southern Chichibu Belts. Tectonic history of each belt has been revealed for the last few decades especially by the progressions of radiolarian biostratigraphic studies. However, the detailed stratigraphy of the Northern Chichibu Belt was not established due to the small amount of radiolarian age data compared to those in the Mino and Southern Chichibu Belts. A highly resolved biostratigraphical dating of radiolarians in the Northern Chichibu Belt is necessary to determine its detailed stratigraphy.

In order to get more precise information on the radiolarian age of the Northern Chichibu Belt, we reexamined the radiolarian ages of the Shimizu Formation, which is a part of the Northern Chichibu Belt. Kurimoto (1986) already reported the Late Carboniferous to Early Jurassic radiolarians from cherts and the Early to Middle Jurassic radiolarians from mudstones in the formation. However the amount of radiolarians found by Kurimoto (1986) in the formation is not enough to establish the detailed stratigraphy of the formation.

As a result of our reexamination of the same rock samples used by Kurimoto (1986) and a newly obtained sample, more precise radiolarian ages were determined on the basis of newly identified radiolarian species.

2. Geology of the Shimizu Formation

The Shimizu-Misato area is located on the western Kii Peninsula, Southwest Japan (Fig. 1). The area is underlain by non- to highly-metamorphosed Jurassic and Cretaceous accretionary complexes belonging to the Sambagawa, Mikabu, Northern Chichibu, Southern Chichibu, and Shimanto Belts. The Cretaceous fluvial to shallow marine sequences cover parts of the Northern Chichibu, Kurosegawa, and Southern

Chichibu Belts.

The Shimizu Formation of the Northern Chichibu Belt was formerly defined as a stratigraphic unit that is composed of Jurassic coarse-grained sediments and olistostromes distributed in the Shimizu-Misato area, western Kii Peninsula (Kurimoto, 1986). This formation is characterized by chaotic mixtures of blocks of greenstone, limestone, chert, mudstone, and sandstone within a scaly-mudstone matrix (Kurimoto, 1986). The limestone blocks contain Carboniferous to Permian fusulinaceans (Hirayama and Tanaka, 1956; Kurimoto, 1986). Cherts bear Carboniferous, Permian, Triassic, and Late Triassic to probably Early Jurassic radiolarians (Kurimoto, 1986). Radiolarians from mudstones range in age from middle Early to middle Middle Jurassic (Kurimoto, 1986). The Shimizu Formation strikes ENE-WSW and dips steeply northward. This formation is bounded by faults with other Paleozoic and Mesozoic geological bodies.

3. Radiolarian assemblage and age

Radiolarians from seven rock samples were extracted for examination. Samples S17 and S18 consist of red cherts, while samples S1, S9, S13, S14, and S28 are composed of mudstones. All of the samples used in this study are the same samples used by Kurimoto (1986) except for the newly collected sample S28 (Table 1). Radiolarians extracted from samples S14 and S28 are well and moderately preserved, respectively. The other samples yield poorly preserved radiolarians. The radiolarians identified from the Shimizu Formation are listed in Table 2 and shown in Plates 1 to 6.

In this paper, radiolarian zones and their age assignments are based on Carter *et al.* (1998) and Hori (2002) for the lower Lower Jurassic and Matsuoka (1995a) for the middle Lower Jurassic and later age (Fig. 3). The first occurrence biohorizon of *Parahsuum simplicum*, defining the base of the *Parahsuum simplicum*

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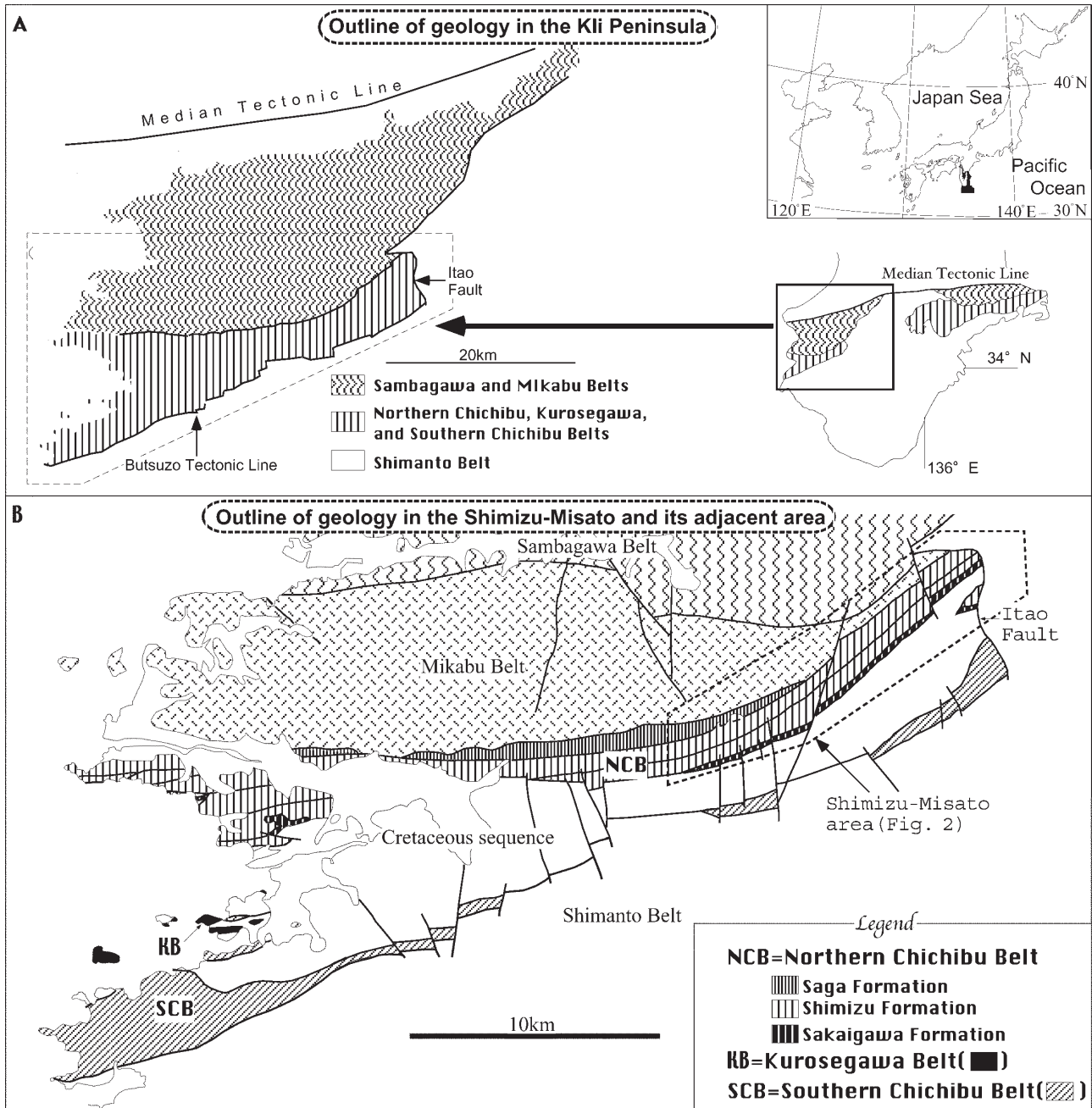


Fig. 1 A: outline of geology of the Kii Peninsula, Southwest Japan. B: Simplified geological map of the Shimizu-Misato and its adjacent area. Modified from Kurimoto *et al.* (1998).

Zone, was initially placed at the Triassic / Jurassic boundary in Japan (Yao, 1982; Yao *et al.*, 1980; Matsuoka and Yao, 1986; Matsuoka, 1995a), but later it was shifted to lower Sinemurian (Early Jurassic) based on the ammonite biostratigraphic framework in the Queen Charlotte Islands, British Columbia, Canada (Carter *et al.*, 1998). Recently, Hori (2002) set the *Pantanellium tanuense* Zone as the lowest radiolarian zone of the Jurassic below the *Parahsuum simplum* Zone. Correlation of the Lower to Middle Jurassic biostratigraphy among Matsuoka (1995a), Hori (1990), Sashida (1988) and Aita (1987) can be done by using the first and last occurrence biohorizons presented by

Matsuoka (1995a) (Fig. 3).

3.1 Radiolarians from mudstones

(1) Sample S1

Previous work: Kurimoto (1986) identified the following radiolarians in sample S1: *Archaeodictyomitra* cf. *rigida* Pessagno, *Protunuma* sp., *Tricolocapsa* (?) *fusiformis* Yao, and *Unuma* sp. The presence of *Tricolocapsa* (?) *fusiformis* Yao and *Unuma* sp. in this sample indicates the *Tricolocapsa plicarum* Zone (Tp Zone) of middle Middle Jurassic age (Kurimoto, 1986).

Radiolarian assemblage: The following radiolarians are identified: *Eucyrtidiellum* spp., *Hsuum* spp.,

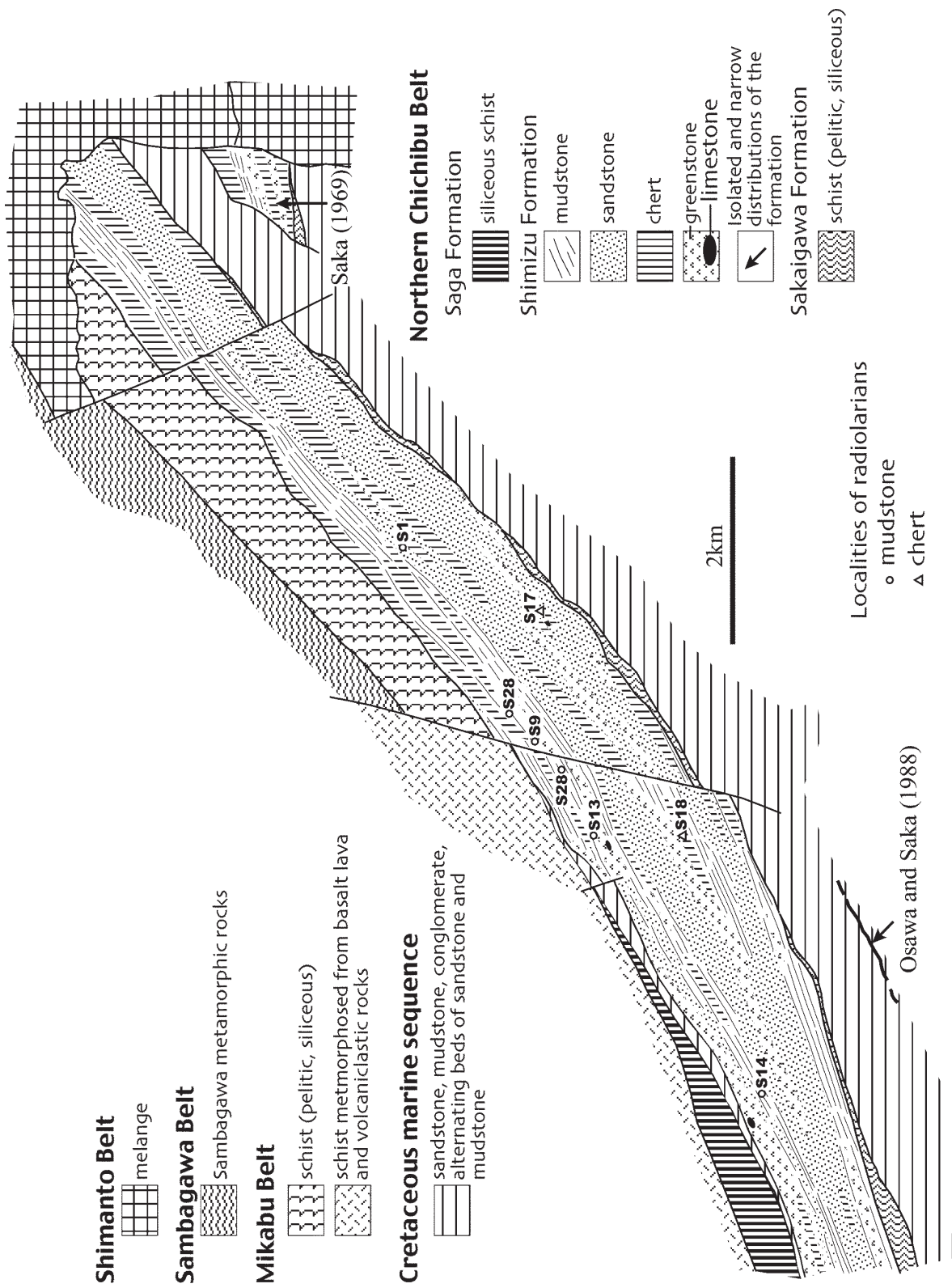


Fig. 2 Geological sketch map of the Shimizu Formation in the Shimizu-Misato area with localities of examined samples. Modified from Kurimoto (1986). Isolated distributions of the Shimizu Formation are from Saka (1969) and Osawa and Saka (1988). © The Geological Society of Japan.

this study	Kurimoto 1986	rock types	radiolarian ages
S1	Loc. 1	mudstone	early to middle Bajocian
S9	Loc. 9	mudstone	late Bathonian
S13	Loc. 13	mudstone	late Bajocian to middle Bathonian
S14	Loc. 14	mudstone	middle Toarcian
S17	Loc. 17	red chert	late Norian to Hettangian or Pliensbachian
S18	Loc. 18	red chert	late Norian to Hettangian or Pliensbachian
S28		mudstone	Aalenian

Table 1 Rock types and ages of examined samples in this study and correlation of samples between this study and Kurimoto (1986).

Paronaella spp., *Parvicingula* spp., *Protunuma* sp., *Sethocapsa* (?) sp., *Stichocapsa* cf. *japonica* Yao, *Stichocapsa* spp., *Syringocapsa* (?) sp., and *Tricolocapsa* spp. (Plate 1, figs. 7-14).

Age: The range of *Stichocapsa japonica* is from the Tp Zone to the middle part of the *Tricolocapsa conexa* Zone (Tc Zone) (Aita, 1987). *Tricolocapsa* (?) *fusiformis* occurs from the middle part of the *Laxtorum* (?) *jurassicum* Zone (Lj Zone) to the middle part of the Tp Zone (Matsuoka, 1995a). Thus, the age of sample S1 can be assigned to early to middle Bajocian corresponding to the lower to middle part of the Tp Zone.

(2) Sample S9

Previous work: Kurimoto (1986) identified the following radiolarians in sample S9: *Guexella nudata* (Kocher), *Stichocapsa* sp., *Tricolocapsa conexa* Matsuoka, *Tricolocapsa* cf. *parvipora* Tan, and *Tricolocapsa plicarum* Yao. This sample indicates the late Middle Jurassic in age (Tc Zone) because of the presence of *Guexella nudata* and *Tricolocapsa conexa* (Kurimoto, 1986).

Radiolarian assemblage: In this study, the following radiolarians are identified: *Archaeodictyomitra* spp., *Emiluvia* sp., *Hsuum* spp., *Parvicingula* cf. *dhimenaensis* Baumgartner, *Parvicingula* spp., *Sethocapsa* sp., *Stichocapsa* spp., *Tricolocapsa* cf. *plicarum*, *Tricolocapsa* sp. M sensu Baumgartner et al. 1995, and *Tricolocapsa* spp. (Plate 1, figs. 15-21)

Age: Matsuoka (1995b) described the range of *Tricolocapsa* sp. M corresponds to the upper half of the range of *Tricolocapsa tetragona* Matsuoka. The range of *Tricolocapsa tetragona* is restricted from the uppermost part of the Tp Zone to the middle part of the Tc Zone (Matsuoka, 1995a). Thus, the age of sample S9 can be determined to be late Bathonian (lower to middle part of the Tc Zone).

(3) Sample S13

Previous work: Kurimoto (1986) identified the following radiolarians in sample S13: *Archicapsa* sp. A, *Archaeodictyomitra* cf. *rigida*, *Stichocapsa* sp., *Tricolocapsa* (?) *fusiformis*, and *Unuma* sp. Kurimoto

rock type	red chert				
radiolarian species : fossil localities	S17	S18			
LATE TRIASSIC - EARLY EARLY JURASSIC RADIOLARIANS					
<i>Canoptum rhaeticum</i> Kozur and Mostler		○			
<i>Canoptum</i> sp. A	○	○			
<i>Canoptum</i> sp. B		○			
<i>Canoptum</i> spp.	○□	○□			
<i>Dictyomitrella</i> sp. C sensu Yao 1982	○				
<i>Gorgansium</i> spp.	○	○			
<i>Proparvicingula</i> sp. A	○	○			
<i>Proparvicingula</i> sp. B		○			
<i>Pseudocanoptum gracile</i> Suzuki		○			
<i>Pseudocanoptum</i> sp. A		○			
rock type	mudstone				
radiolarian species : fossil localities	S1	S9	S13	S14	S28
EARLY AND MIDDLE JURASSIC RADIOLARIANS					
<i>Archaeodictyomitra</i> cf. <i>rigida</i> Pessagno	□		□		
<i>Archaeodictyomitra</i> (?) sp. A sensu Kojima et al. 1991				○	
<i>Archaeodictyomitra</i> sp. B				○	
<i>Archaeodictyomitra</i> sp. C				○	
<i>Archaeodictyomitra</i> spp.		○	○	○	○
<i>Archaeospongoprimum</i> sp.				○	
<i>Archicapsa pachyderma</i> Tan					○
<i>Archicapsa</i> sp. A			□		
<i>Canoptum</i> cf. <i>anulatum</i> Pessagno and poisson					○
<i>Canoptum</i> cf. <i>poissoni</i> Pessagno					○□
<i>Canoptum</i> cf. <i>rugosum</i> Pessagno and poisson					○□
<i>Canoptum</i> spp.					○□
<i>Droilus</i> (?) sp.					□
<i>Emiluvia</i> spp.		○			○
<i>Eucyrtidiellum</i> sp. C2 sensu Nagai 1986					○
<i>Eucyrtidiellum</i> spp.	○				
<i>Eucyrtidiellum</i> (?) sp.			○		
<i>Guexella nudata</i>			□		
<i>Hagiastrium</i> spp.					○
<i>Hsuum hisuikyoenense</i> Isozaki and Matsuda					○
<i>Hsuum</i> sp. A					○
<i>Hsuum</i> spp.		○	○	○	○
<i>Laxtorum</i> (?) <i>jurassicum</i> Isozaki and Matsuda					○
<i>Lupherium</i> (?) sp. B sensu Carter et al. 1988					○
<i>Napora</i> sp. A					○
<i>Napora</i> spp.					○
<i>Orbiculiforma</i> sp. A					○
<i>Orbiculiforma</i> sp. B					○
<i>Parahsuum</i> cf. <i>kanyoenense</i> Sashida					○
<i>Parahsuum</i> cf. <i>longiconicum</i> Sashida					○
<i>Parahsuum simplicium</i> Yao					○
<i>Parahsuum takarazawaense</i> Sashida					○
<i>Parahsuum</i> spp.					○□
<i>Paronaella</i> cf. <i>mulleri</i> Pessagno sensu Carter et al. 1988					○
<i>Paronaella</i> spp.		○			○
<i>Parvicingula gigantocomis</i> Kishida and Hisada					○
<i>Parvicingula</i> cf. <i>dhimenaensis</i> Baumgartner			○		
<i>Parvicingula</i> (?) sp. A					○
<i>Parvicingula</i> spp.		○	○	□	
<i>Parvicingula</i> (?) spp.				○	
<i>Praeconocaryomma</i> sp.					○
<i>Protunuma</i> sp.	○□				
<i>Pseudoristola</i> sp.					○
<i>Sethocapsa</i> spp.		○			
<i>Sethocapsa</i> (?) spp.		○			
<i>Spongosatumnalis</i> (?) <i>diplocyclis</i> Yao					○
<i>Staurolonche</i> spp.					○
<i>Stichocapsa convexa</i> Yao					○
<i>Stichocapsa</i> cf. <i>convexa</i> Yao					□
<i>Stichocapsa japonica</i> Yao					○
<i>Stichocapsa</i> cf. <i>japonica</i> Yao		○			
<i>Stichocapsa</i> sp. A					○
<i>Stichocapsa</i> sp. B		○	○□	○	
<i>Stichocapsa</i> spp.				□	○
<i>Syringocapsa</i> sp. A		○			
<i>Syringocapsa</i> (?) sp.					○
<i>Triactoma</i> spp.			□		
<i>Tricolocapsa conexa</i> Matsuoka			□		
<i>Tricolocapsa</i> (?) <i>fusiformis</i> Yao				□	
<i>Tricolocapsa</i> cf. <i>parvipora</i> Tan				□	
<i>Tricolocapsa plicarum</i> s.l. Yao				○	
<i>Tricolocapsa</i> cf. <i>plicarum</i> s.l. Yao				○	
<i>Tricolocapsa</i> sp. M sensu Baumgartner et al. 1995					○
<i>Tricolocapsa</i> spp.		○	○	○	○
<i>Trillius elkhornensis</i> Pessagno and Blome					○
<i>Trillius</i> spp.					○
<i>Unuma</i> spp.	□		□		○
<i>Wrangellium</i> cf. <i>oregonense</i> Yeh					○

○: radiolarians identified in this study
 □: radiolarians identified by Kurimoto (1986)

Table 2 List of radiolarans from the Shimizu Formation of the Northern Chichibu Belt, western Kii Peninsula, Southwest Japan.

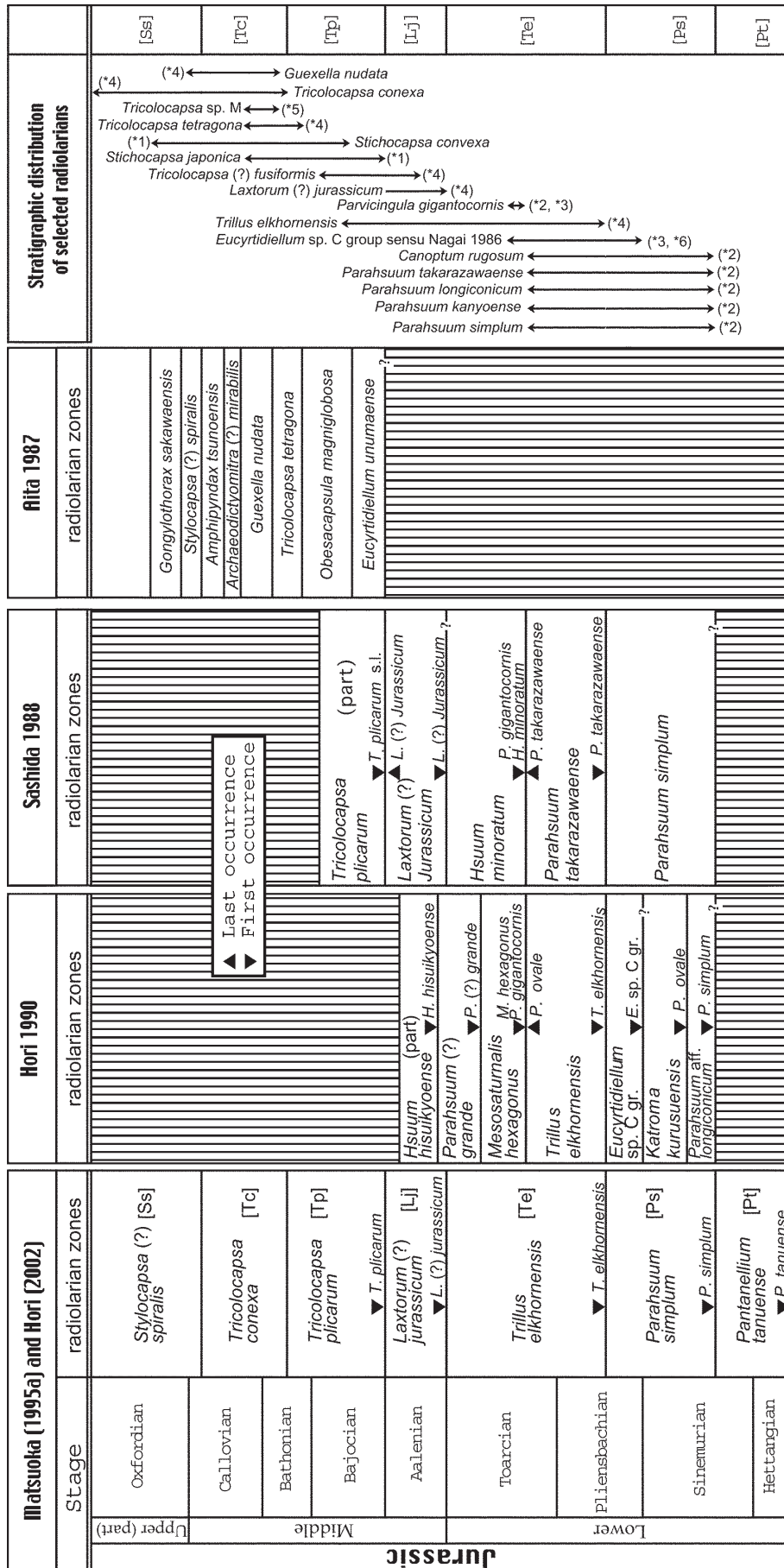


Fig. 3 Early to Middle Jurassic radiolarian zonation in Japan with stratigraphic distribution of selected radiolarians. Radiolarian zones are based on Matsuoka (1995a), Hori (1990, 2002) and Sashida (1988), and selected radiolarian stratigraphic distribution is based on Aita (1987) (*1), Sashida (1988) (*2), Hori (1990) (*3), Matsuoka (1995a) (*4), Matsuoka (1995b) (*5), and Nagai (1995) (*6).

(1986) indicated that the age of this sample is middle Middle Jurassic (Tp Zone) due to the presence of *Unuma* sp.

Radiolarian assemblage: In this study, the following radiolarians are identified: *Archaeodictyomitra* spp., *Eucyrtidiellum* (?) sp., *Hsuum* spp., *Parvicingula* (?) sp., *Stichocapsa convexa* Yao, *Stichocapsa japonica*, *Stichocapsa* spp., and *Tricolocapsa* spp. (Plate 1, figs. 1-6)

Age: *Stichocapsa convexa* and *Stichocapsa japonica* co-occur from the middle part of the Tp Zone to the middle part of the Tc Zone (Aita, 1987). The co-existence of both species has been reported from rocks of the upper part of the Tp Zone in some areas (e.g., Sashida *et al.*, 1999; Kashiwagi, 2001). Calcareous shale in the Rotti Island, Indonesia, yields *Stichocapsa convexa* and *Stichocapsa japonica* with *Cyrtocapsa mastoidea* Yao and *Tricolocapsa plicarum* (Sashida *et al.*, 1999). The latter two species co-occur in the upper part of the Tp Zone, which ranges in age from late Bajocian to middle Bathonian (Matsuoka, 1995a). *Stichocapsa convexa* and *Stichocapsa japonica* co-occur with *Eucyrtidiellum semifactum* Nagai and Mizutani, *Protunuma turbo* Matsuoka, and *Tricolocapsa tetragona* in the accretionary complex of Southwest Japan (Kashiwagi, 2001). This assemblage indicates the upper part of the Tp Zone to the lower part of the Tc Zone (Matsuoka, 1995a). Considering the aforementioned biostratigraphic evidence, radiolarians from sample S13 indicates late Bajocian to middle Bathonian age (upper part of the Tp Zone).

(4) Sample S14

Previous work: Kurimoto (1986) identified the following radiolarians in sample S14: *Canoptum* cf. *poissoni* Pessagno, *Canoptum* cf. *rugosum* Pessagno and Poisson, *Canoptum* sp., *Droltus* (?) sp., *Parahsuum* sp., *Parvicingula* sp., and *Stichocapsa* cf. *convexa*. This assemblage has the common content of the *Parahsuum simplum* Assemblage and the *Parahsuum* (?) *grande* Assemblage (middle Early Jurassic age) (Kurimoto, 1986).

Radiolarian assemblage: The following well-preserved radiolarians are identified: *Archaeodictyomitra* sp. A sensu Kojima *et al.* 1991, *Archaeodictyomitra* sp. B, *Archaeodictyomitra* spp., *Archaeospongoprimum* sp., *Canoptum* cf. *anulatum* Pessagno and Poisson, *Canoptum* cf. *poissoni*, *Canoptum* cf. *rugosum*, *Canoptum* spp., *Emiluvia* spp., *Eucyrtidiellum* sp. C₂ sensu Nagai 1986, *Hagiastrium* spp., *Lupherium* (?) sp. B sensu Carter *et al.*, 1988, *Napora* sp. A, *Napora* sp., *Orbiculiforma* sp. A, *Orbiculiforma* sp. B, *Parahsuum* cf. *kanyoense* Sashida, *Parahsuum* cf. *longiconicum* Sashida, *Parahsuum simplum* Yao, *Parahsuum takarazawaense* Sashida, *Parahsuum* spp., *Paronaella* cf. *mulleri* Pessagno sensu Carter *et al.*, 1988, *Paronaella* spp., *Parvicingula gigantocornis* Kishida

and Hisada, *Parvicingula* (?) sp. A, *Praeconocaryomma* sp., *Pseudoristola* sp., *Spongosaturnalis* (?) *diplocyclis* Yao, *Staurolonche* spp., *Stichocapsa convexa*, *Stichocapsa* sp. A, *Stichocapsa* sp. B, *Syringocapsa* sp. A, *Tricolocapsa* sp., *Trillus elkhornensis* Pessagno and Blome, *Trillus* spp., and *Wrangellium* cf. *oregonense* Yeh. (Plates 3-5).

Age: The occurrence of *Parvicingula gigantocornis* is restricted to the lower part of the *Mesosaturnalis hexagonus* Zone (Mh Zone) (Hori, 1990) and lower part of the *Hsuum minoratum* Zone (Sashida, 1988). *Canoptum rugosum*, *Parahsuum kanyoense*, *Parahsuum longiconicum* and *Parahsuum takarazawaense* co-occur in the *Parahsuum takarazawaense* Zone (Sashida, 1988). *Eucyrtidiellum* sp. C Nagai group, including *Eucyrtidiellum* sp. C₂, occurs from the *Eucyrtidiellum* (?) sp. C Zone to the middle part of the Mh Zone (Hori, 1990; Nagai, 1995). *Trillus elkhornensis* ranges in age from middle Pliensbachian to middle Bathonian (*Trillus elkhornensis* Zone to Tp Zone) (Matsuoka, 1995a). Thus, the age of sample S14 is assignable to middle Toarcian.

(5) Sample S28

Sample S28 was newly collected from the Shimizu Formation.

Radiolarian assemblage: The following radiolarians are identified from sample S28: *Archaeodictyomitra* spp., *Archicapsa pachyderma* Tan, *Hsuum hisuikyoense* Iozaki and Matsuda, *Hsuum* sp. A, *Laxtorum* (?) *jurassicum* Iozaki and Matsuda, *Parahsuum* spp., and *Unuma* spp. (Plate 2).

Age: *Hsuum hisuikyoense* and *Laxtorum* (?) *jurassicum* are indicative of the Lj Zone, which corresponds to Aalenian age (Matsuoka, 1995a). Thus, the age of sample S28 is Aalenian.

3.2 radiolarians from red cherts

(1) Samples S18 and S17

Previous work: Kurimoto (1986) identified *Canoptum* spp. in sample S18. The presence of *Canoptum* spp. indicates the age from Late Triassic (Carnian? to Norian) to Early Jurassic (Pliensbachian to Toarcian?) (Pessagno *et al.*, 1979). Thus, the age of sample S18 is from Late Triassic to Early Jurassic (Kurimoto, 1986).

Radiolarian assemblage: The following radiolarians are obtained from sample S18: *Canoptum rhaeticum* Kozur and Mostler, *Canoptum* sp. A, *Canoptum* sp. B, *Canoptum* spp., *Gorgansium* spp., *Proparvicingula* sp. A, *Proparvicingula* sp. B, *Pseudocanoptum gracile* Suzuki, and *Pseudocanoptum* sp. A. (Plate 6)

Age: *Canoptum* is the most dominant genus in this assemblage. We distinguish three species such as *Canoptum rhaeticum*, *Canoptum* sp. A, and *Canoptum*

sp. B in this genus. Kozur and Mostler (1990) pointed out that *Canoptum triassicum* Yao described by Yao (1982) is a younger synonym of *Canoptum rhaeticum* Kozur and Mostler. *Canoptum triassicum* was originally reported from the late Norian to Rhaetian chert of central Japan (Yao *et al.*, 1980; Yao, 1982). Many researchers have mentioned that *Canoptum rhaeticum* (= *Canoptum triassicum*) is a characteristic species indicating latest Norian to Rhaetian (late Triassic) in age (e.g., Yao *et al.*, 1980; Yao, 1982; Kishida and Hisada, 1985; Yoshida, 1986; Carter, 1993; Yeh and Cheng, 1996; Hori, 2002), whereas some researchers pointed out that *Canoptum rhaeticum* occurs in the Hettangian to Sinemurian formations (Igo and Nishimura, 1984; Kozur and Mostler, 1990; Sugiyama, 1997).

Dictyomitrella sp. C was first reported from the *Canoptum triassicum* Zone to the lower part of the *Parahsuum simplum* Zone (Yao, 1982). Carter *et al.* (1998) noted that *Dictyomitrella* sp. C moderately resembles *Proparvicingula moniliformis* Carter, which indicates the Rhaetian age (Carter, 1993).

Proparvicingula sp. A has a multicystid test with four to five closely spaced post-abdominal chambers separated by nodose circumferential ridges. At least two rows of pores per chamber are recognized (Plate 6, fig. 14). Cephalis and thorax are imperforate. *Proparvicingula moniliformis*, which is monospecific in this genus, indicates Rhaetian in age (Carter, 1993).

The occurrence of *Pseudocanoptum gracile* indicates at least early Pliensbachian in age as far as it is known (Suzuki, 1995ab, 1997).

Based on the above-mentioned biostratigraphic facts, the age of sample S18 ranges from late Norian (Late Triassic) to Hettangian or Pliensbachian (Early Jurassic).

Sample S17, which is also red chert, contains the following radiolarians; *Canoptum* spp., *Dictyomitrella* sp. C sensu Yao 1982, *Gorgansium* spp., and *Proparvicingula* sp. A. Considering the similar faunal constituents with those of sample S18, radiolarians in sample S17 indicate the same age as sample S18.

4. Results and conclusions

The radiolarians obtained from the seven samples in the Shimizu Formation are reexamined in this study. The results are as follows.

(1) This study clarified more precise radiolarian ages than those examined by Kurimoto (1986). Samples S1 and S13, which are assigned to the *Tricolocapsa plicarum* (Tp) Zone (middle Middle Jurassic) by Kurimoto (1986), are settled on the lower and upper parts of the Tp Zone, respectively (early to middle Bajocian, late Bajocian to middle Bathonian). Sample S9, which is assigned to the *Tricolocapsa conexa* (Tc)

Zone (late Middle Jurassic) by Kurimoto (1986), ranges in age from the lower to middle part of the Tc Zone (late Bathonian). Sample S14, which is assigned to the middle Early Jurassic between the *Parahsuum simplum* Assemblage Zone and the *Parahsuum* (?) *grande* Assemblage Zone by Kurimoto (1986), is restricted to the lower part of the *Mesosaturnalis hexagonus* Zone (middle Toarcian).

(2) Radiolarians of the *Laxtorum* (?) *jurassicum* Zone (Aalenian), detected from the newly collected mudstone (sample S28), are first reported in this area.

(3) Samples S17 and S18, of which ages range from Late Triassic to probably Early Jurassic by Kurimoto (1986), are not precisely determined in age. Some radiolarians newly collected in this study also indicate Late Triassic and Early Jurassic.

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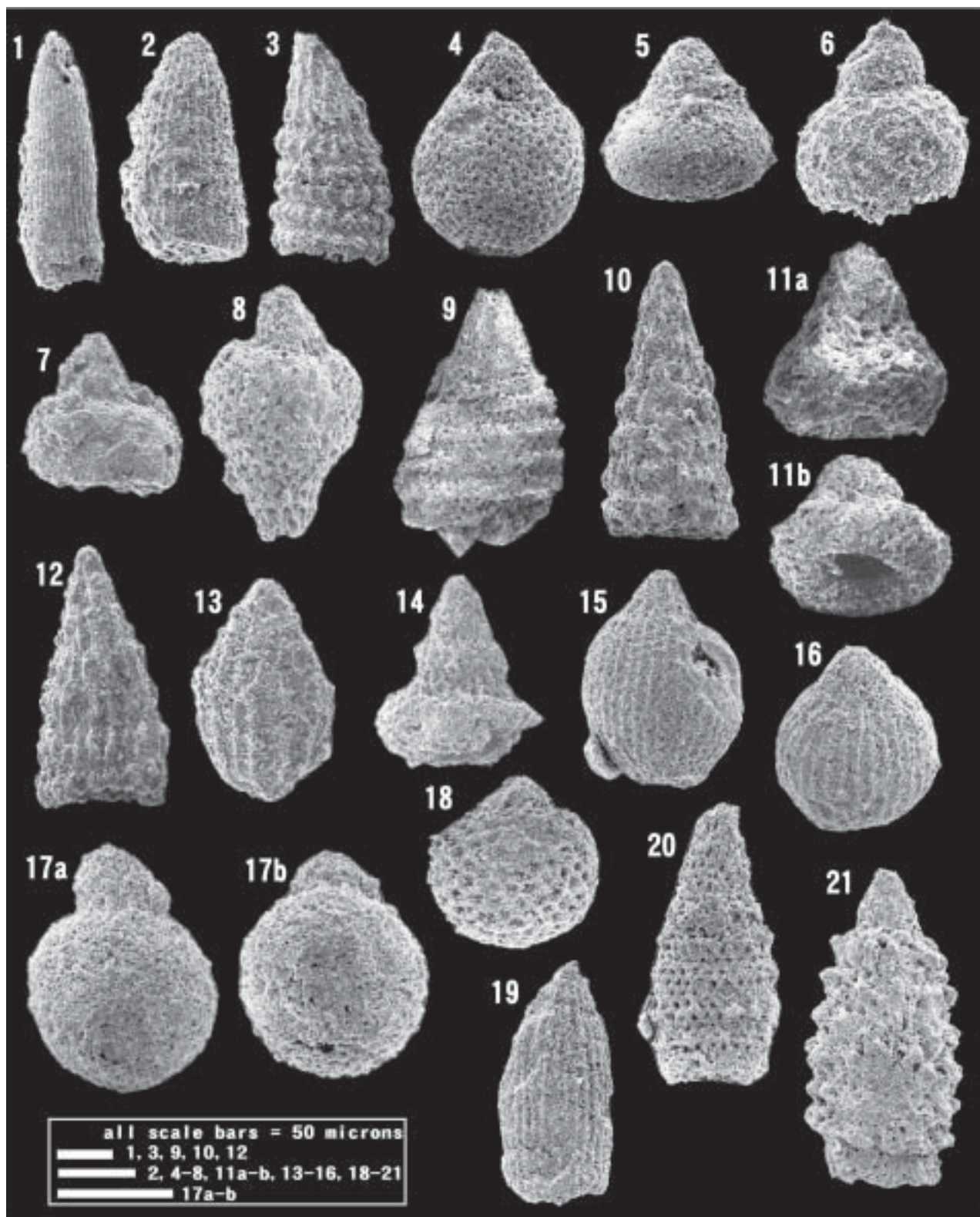


Plate 1 Scanning electron microphotographs of Middle Jurassic radiolarians from the mudstone (samples S1, S9 and S13) in the Shimizu Formation of the Northern Chichibu Belt. 1-6: S13, 7-14: S1, 15-21: S9

1: *Archaeodictyomitra* sp. C, 2: *Archaeodictyomitra* sp., 3: *Hsuum* sp., 4: *Stichocapsa convexa*, 5: *Stichocapsa japonica*, 6: *Eucyrtidiellum* (?) sp., 7: *Eucyrtidiellum* sp., 8: *Syringocapsa* (?) sp., 9: *Parvicingula* sp., 10: *Hsuum* sp., 11ab: *Stichocapsa* cf. *japonica*, 12: *Hsuum* sp., 13: *Protunuma* sp., 14: *Sethocapsa* (?) sp., 15: *Tricolocapsa* cf. *plicarum* s.l., 16: *Tricolocapsa* cf. *plicarum* s.l., 17ab: *Tricolocapsa* sp. M sensu Baumgartner et al., 1995, 18: *Tricolocapsa* sp. 19: *Archaeodictyomitra* sp., 20: *Parvicingula* sp., 21: *Parvicingula* cf. *dhimenaensis*.

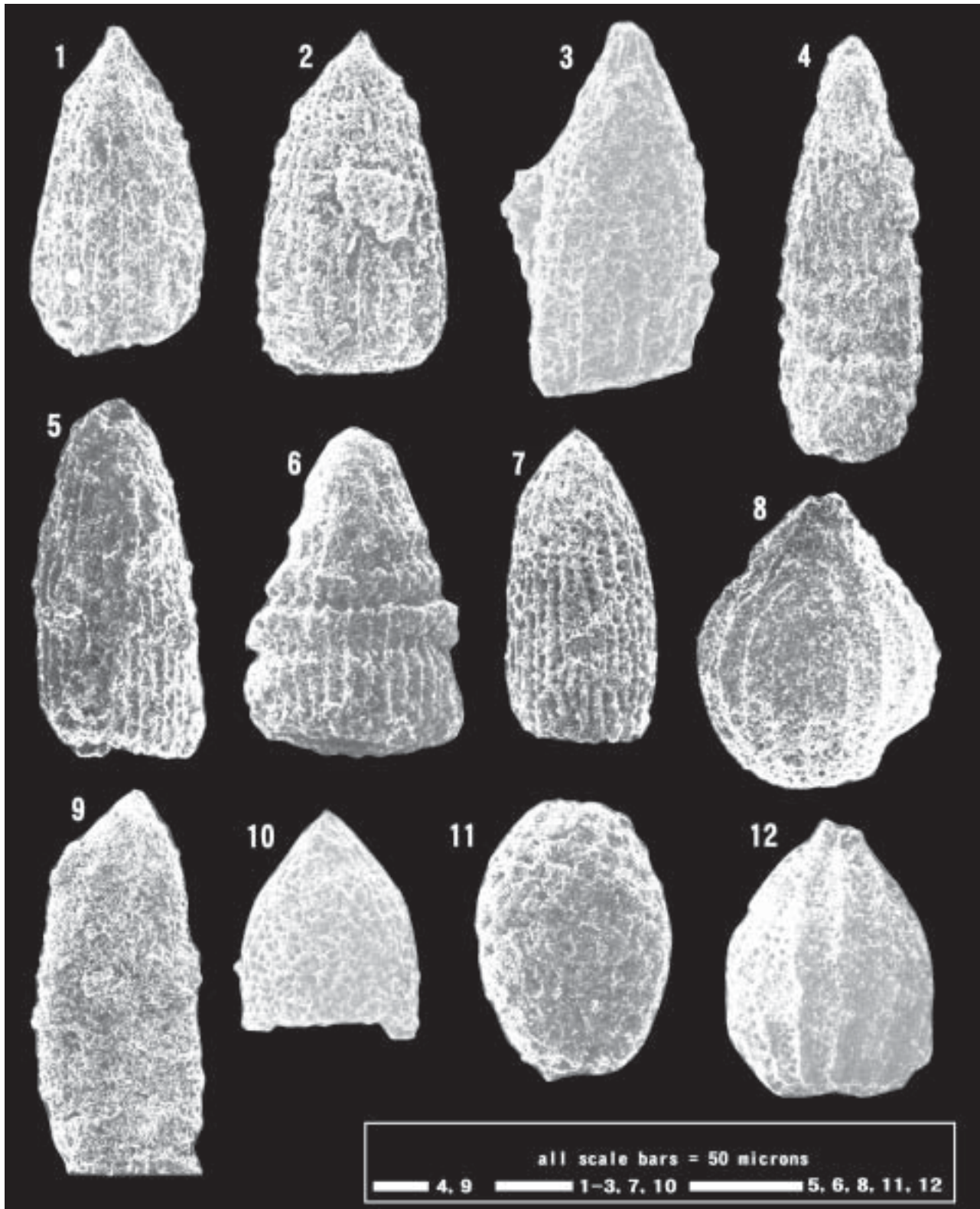


Plate 2 Scanning electron microphotographs of Aalenian (Middle Jurassic) radiolarians from the mudstone of sample S28 in the Shimizu Formation of the Northern Chichibu Belt.

1- 3: *Hsuum* sp. A, 4: *Hsuum hisuikyense*, 5-7: *Archaeodictyomitra* spp., 8: *Unuma* sp., 9-10: *Laxtorum* (?) *jurassicum*, 11: *Archicapsa pachyderma*, 12: *Unuma* sp.

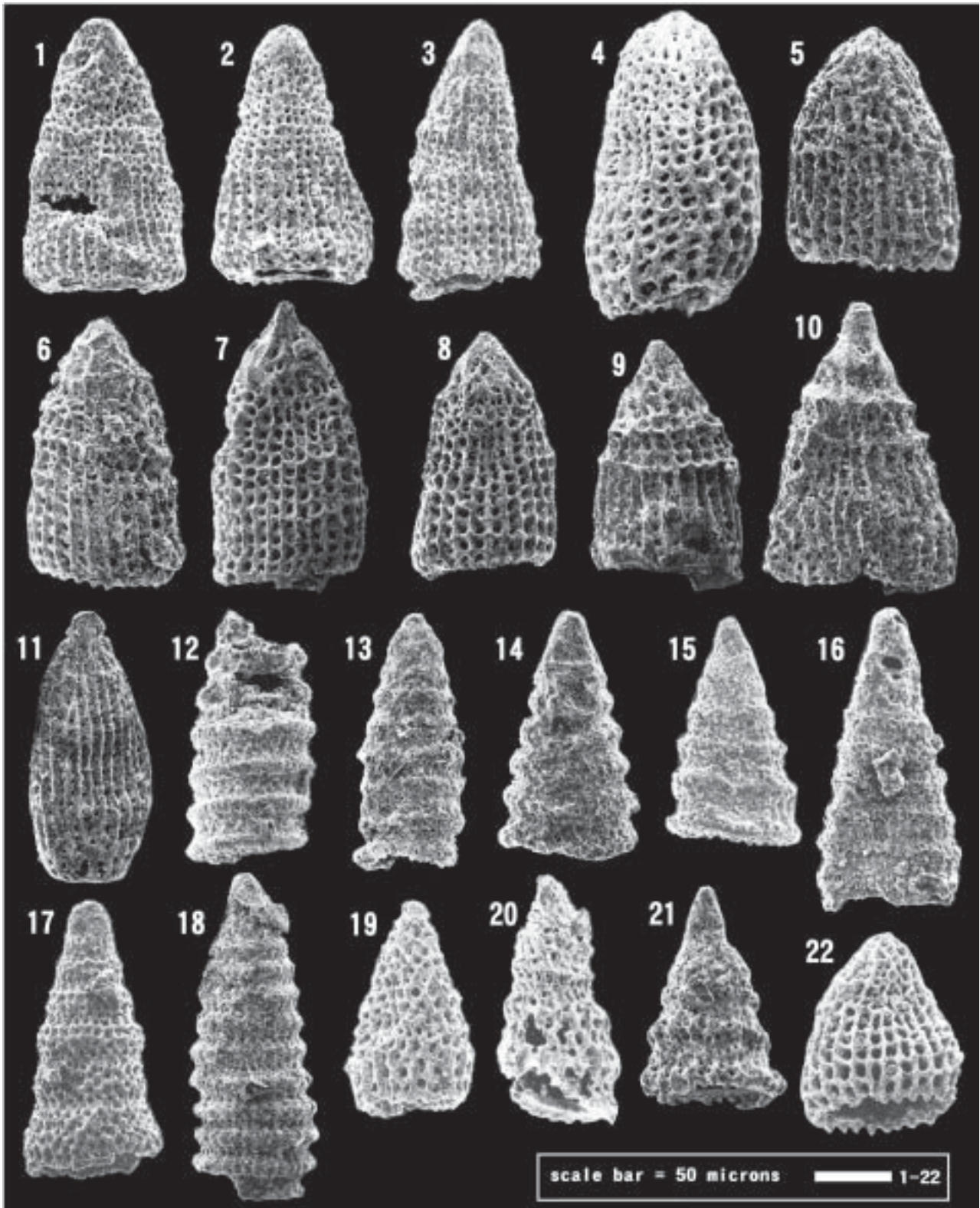


Plate 3 Scanning electron photomicrographs of early Toarcian (Early Jurassic) radiolarians from the mudstone of sample S14 in the Shimizu Formation of the northern Chichibu Belt.

1- 3: *Parahsuum simplum*, 4: *Parahsuum takarazawaense*, 5: *Parahsuum* sp. 6: *Parahsuum* cf. *kanyoense*, 7: *Parahsuum* cf. *longiconicum*, 8-9: *Parahsuum* cf. *kanyoense*, 10: *Parahsuum* cf. *longiconicum*, 11: *Archaeodictyomitra* sp. sensu Kojima *et al.*, 1991, 12: *Canoptum* cf. *anulatum*, 13: *Canoptum* cf. *poissoni*, 14: *Canoptum* cf. *rugosum*, 15: *Canoptum* sp., 16: *Canoptum* cf. *poissoni*, 17: *Parvicingula* (?) sp. A, 18: *Lupherium* (?) sp. B sensu Carter *et al.* 1988, 19: *Pseudoristola* sp. 20: *Wrangellium* cf. *oregonense*, 21: *Parvicingula gigantocornis*, 22: *Archaeodictyomitra* (?) sp. A sensu Kojima *et al.* 1991,

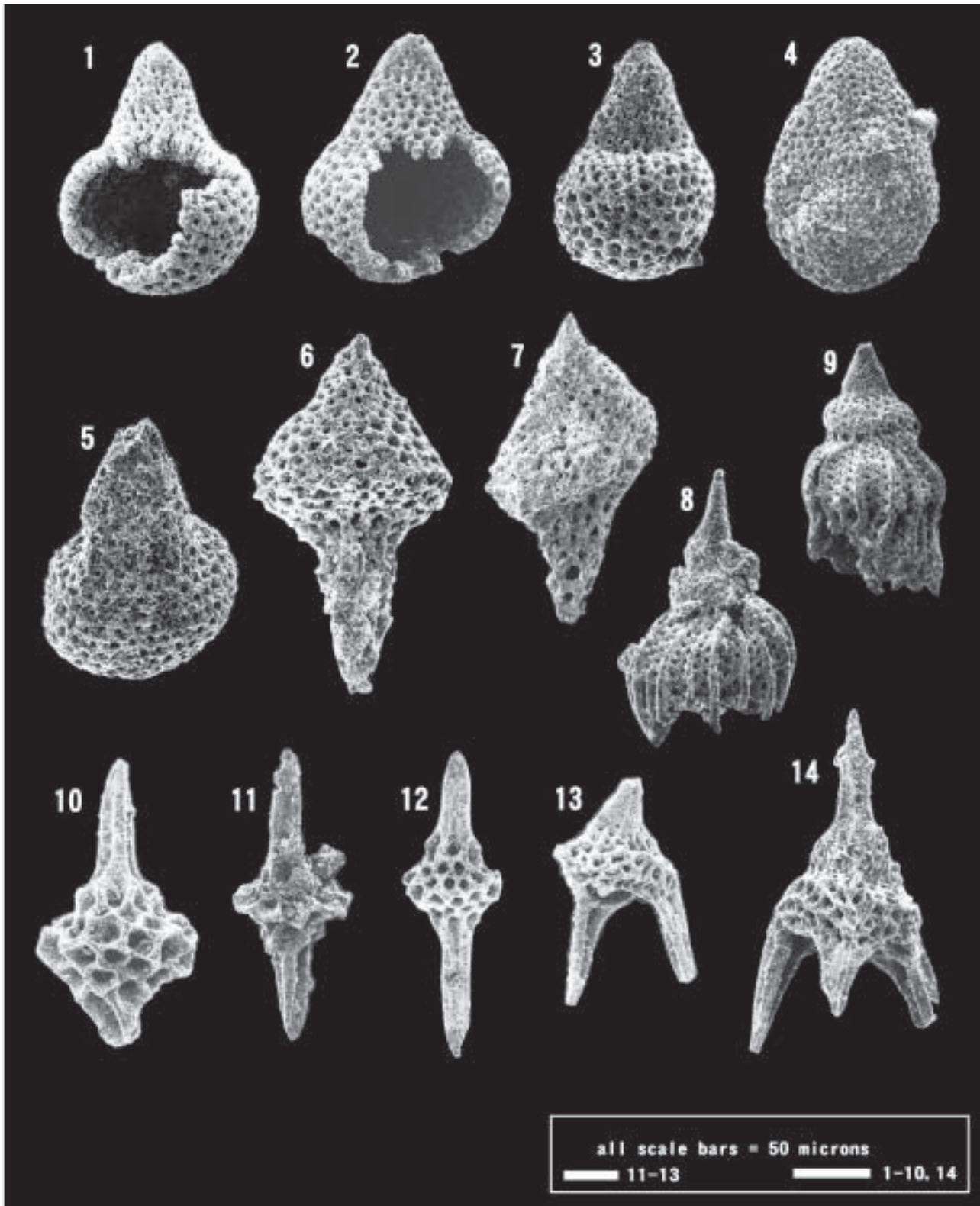


Plate 4 Scanning electron microphotographs of early Toarcian (Early Jurassic) radiolarians from the mudstone of sample S14 in the Shimizu Formation of the Northern Chichibu Belt.

1- 2: *Stichocapsa convexa*, 3: *Stichocapsa* sp. A, 4: *Stichocapsa* sp. B, 5: *Stichocapsa* sp. A, 6-7: *Syringocapsa* sp. A, 8-9: *Eucyrtidiellum* sp. C₂ sensu Nagai 1986, 10-12: *Trillus elkhornensis*, 13: *Napora* sp., 14: *Napora* sp. A

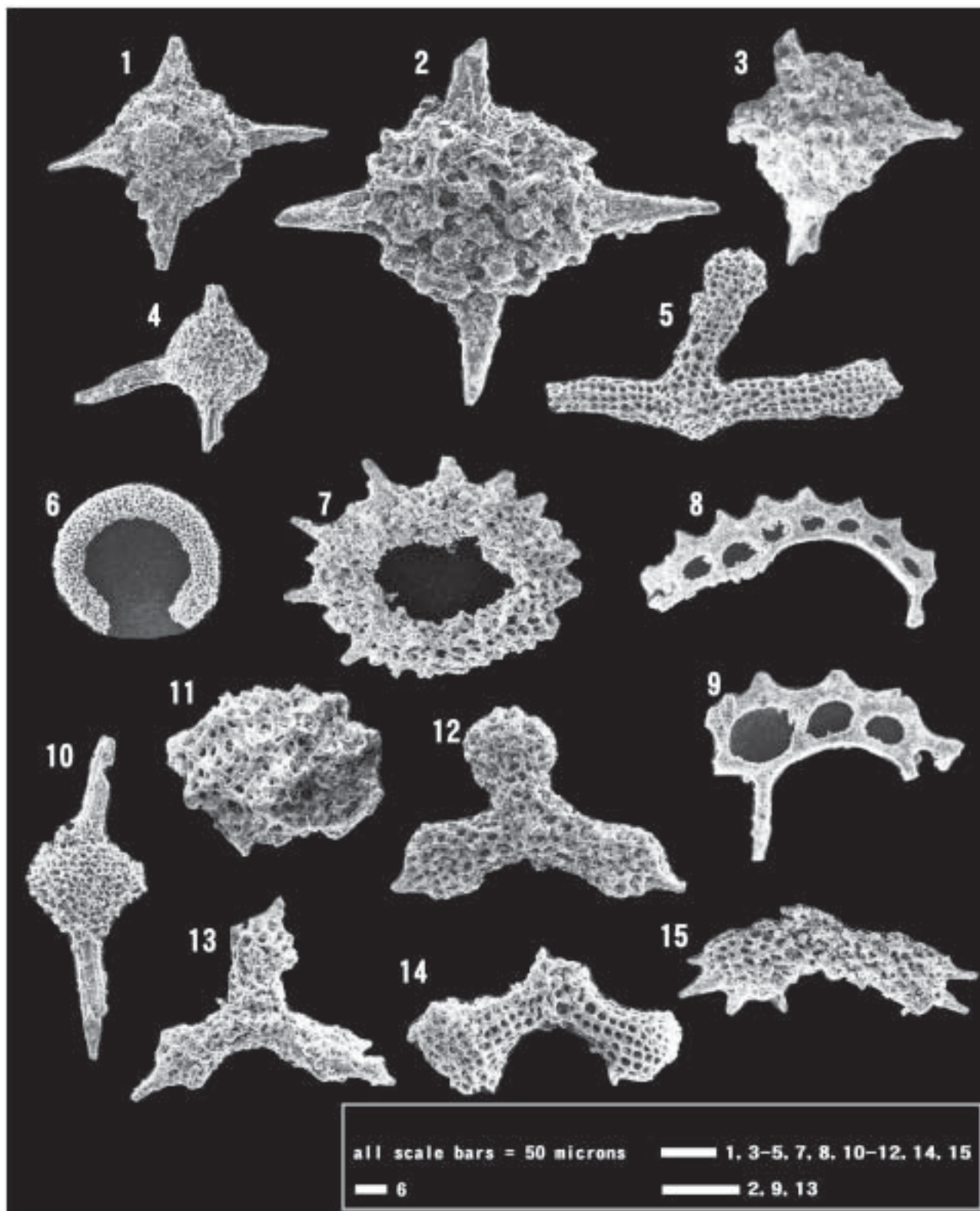


Plate 5 Scanning electron microphotographs of early Toarcian (Early Jurassic) radiolarians from the mudstone of sample S14 in the Shimizu Formation of the Northern Chichibu Belt.

1- 3: *Staurolonche* spp., 4: *Spongostaurus* sp., 5: *Hagiastrum* sp., 6: *Orbiculiforma* sp. A, 7: *Orbiculiforma* sp. B, 8-9: *Spongosaturnalis* (?) *diplocyclis*, 10: *Archaeospongoprunum* sp., 11: *Praeconocaryomma* sp., 12: *Paronaella* cf. *mulleri* Pessagno sensu Carter *et al.*, 1988., 13-15: *Paronaella* spp.,

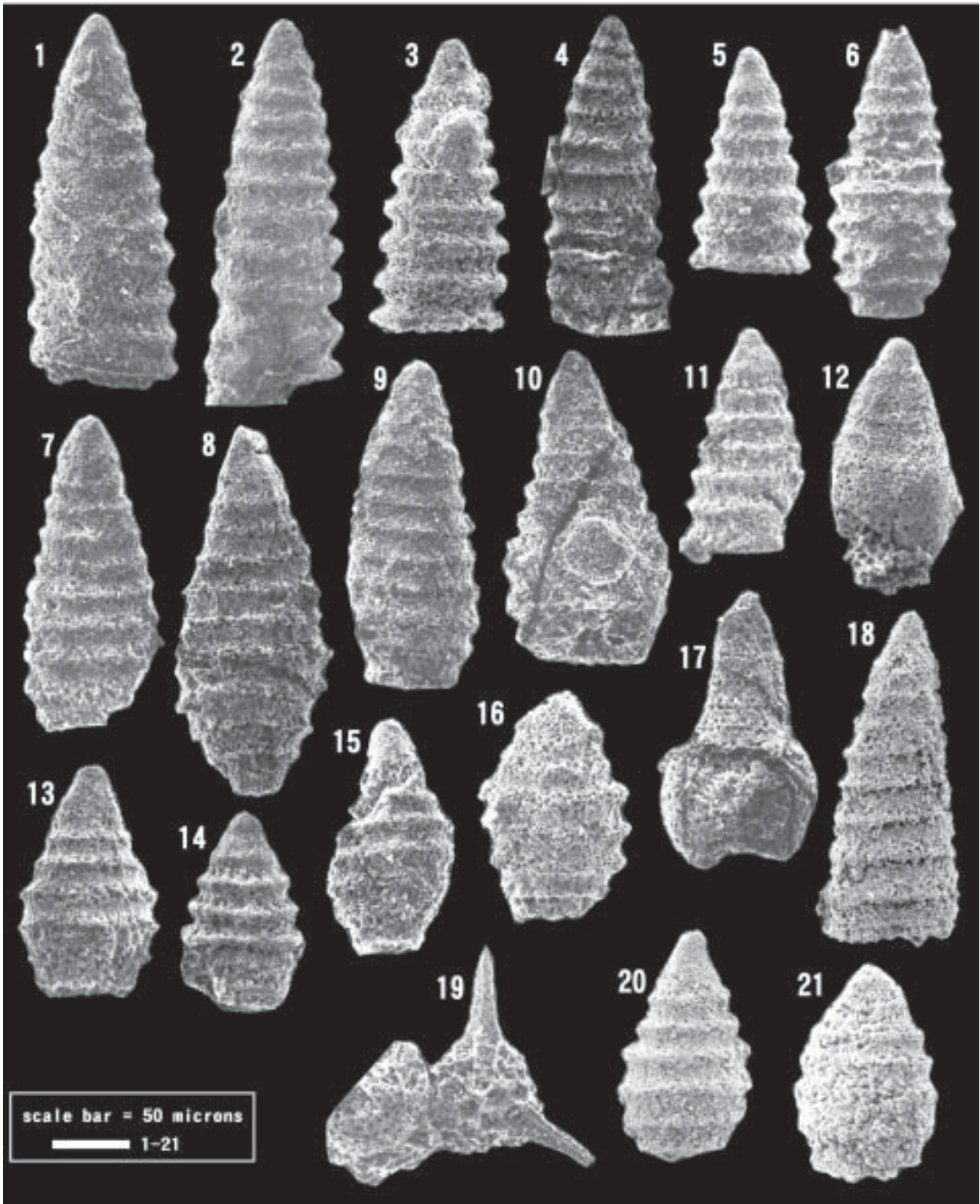


Plate 6 Scanning electron microphotographs of Late Triassic to early Early Jurassic radiolarians from the red cherts of samples S17 and S18 in the Shimizu Formation of the Northern Chichibu Belt. Figures 1-17 and 19 are from sample S18. Figures 18, 20 and 21 are from sample S17.

1-2: *Canoptum rhaeticum*, 3: *Canoptum* sp. A, 4-5: *Canoptum rhaeticum*, 6-10: *Canoptum* sp. B, 11: *Proparvicingula* sp. B, 12: *Pseudocanoptum gracile*, 13-16: *Proparvicingula* sp. A, 17: *Pseudocanoptum* sp., 18: *Dictyomitrella* sp. C sensu Yao 1982, 19: *Gorgansium* sp., 20-21: *Proparvicingula* sp. A