Bulletin of the Geological Survey of Japan, vol. 51 (4), p. 143-165, 2000

Triassic and Jurassic radiolarians from the Tokuyama area, Mino terrane, central Japan

Satoru KOJIMA* and Makoto SAITO**

Satoru KOJIMA and Makoto SAITO (2000) Triassic and Jurassic radiolarians from the Tokuyama area, Mino terrane, central Japan. *Bull. Geol. Surv. Japan.* vol. 51 (4), p. 143-165. 6 figs, 12 plates.

Abstract: Occurrence of Late Triassic and Middle Jurassic radiolarians are described from chert, siliceous shale and manganese carbonate nodule (MCN) in the Tokuyama area, Mino terrane, central Japan. The Mino terrane composed of Jurassic accretionary complexes is subdivided into several tectonostratigraphic units, among which the Samondake and Funafuseyama units are recognized in this area. The Middle Jurassic Samondake unit consists mainly of massive sandstone, turbidite, siliceous shale and chert, with minor amounts of melange and mixed rock which means a rock unit with block-in-matrix texture unmappable at a scale of 1:24,000. The Middle Jurassic Funafuseyama unit includes melanges and greenstone sheets between them. The MCNs included as blocks in the mixed rock of the Samondake unit yield well-preserved late Aalenian to Bajocian radiolarians, while Aalenian to Bajocian radiolarians occur from the siliceous shales of the unit. One chert sample of the Funafuseyama unit includes late Carnian to middle Norian radiolarians. Although origin of the mixed rock of the Samondake unit is unclear, the forming age of the mixed rock is younger than the radiolarian age of MCNs in case that the MCNs are allochthonous blocks in the mixed rock. If the MCNs authigenically formed after the formation of the mixed rocks, age of the mixed rocks is as old as, or younger than, that of the MCNs. This estimation is suggested by the geochemical constraints on the modern and ancient MCN-forming environments. Ages of MCN and siliceous shale revealed by the radiolarian fossils are concordant to ages of rocks of the Samondake unit reported by previous researches.

1. Introduction

The Tokuyama area in northwestern part of the Mino terrane (Fig.1) is in a deep mountainous region of central Japan, and little geologic information is available after the pioneer work of Kajita (1963). He made a geologic mapping in the upper reach area of the Ibi River, including the Tokuyama area, and revealed the outline of lithologic assemblage and geologic structure in this area. He, however, erroneously assigned most of the rocks in this area to the Upper Paleozoic on the basis of the fusulinacean fossils in limestone blocks. Miyamura (1965) and Hattori (1976) published geological maps of the Fujihashi area, south of the Tokuyama area, and Hattori and Yoshimura (1982) surveyed the Nanjo Mountains northwest of this area. The ages of rocks in the Tokuyama area, however, are still uncertain, because of little geological knowledge of this area.

We have studied the geology and paleontology of the Tokuyama area since late 1980s. During the course of this study, one of us (S.K.) found Triassic and Jurassic radiolarians in chert, siliceous shale and manganese carbonate nodule (MCN) in this area. Part of the results were preliminarily reported by Kojima and Okamoto (1990). In this paper, we describe the outline of geology and the occurrence of the radiolarian fossils in detail.

2. Geologic setting

The Mino terrane in central Japan is mainly composed of the upper Paleozoic greenstone-limestone complexes, Permian to early Jurassic radiolarian bedded cherts, and middle to upper Jurassic clastic rocks, together with the Jurassic melanges with blocks of the above mentioned rocks in a shale matrix (*e.g.*, Mizutani, 1990). The terrane is considered to be formed as Jurassic accretionary complexes along the eastern continental margin of Asia (*e.g.*, Mizutani and Kojima, 1992). Rocks in the Mino terrane are sub-

*Department of Civil Engineering, Gifu University, Gifu 501-1193, Japan
**Geology Department, GSJ

Keywords : Triassic, Jurassic, radiolarians, manganese carbonate nodule, accretionary complex, Tokuyama, Mino terrane, micropaleontology

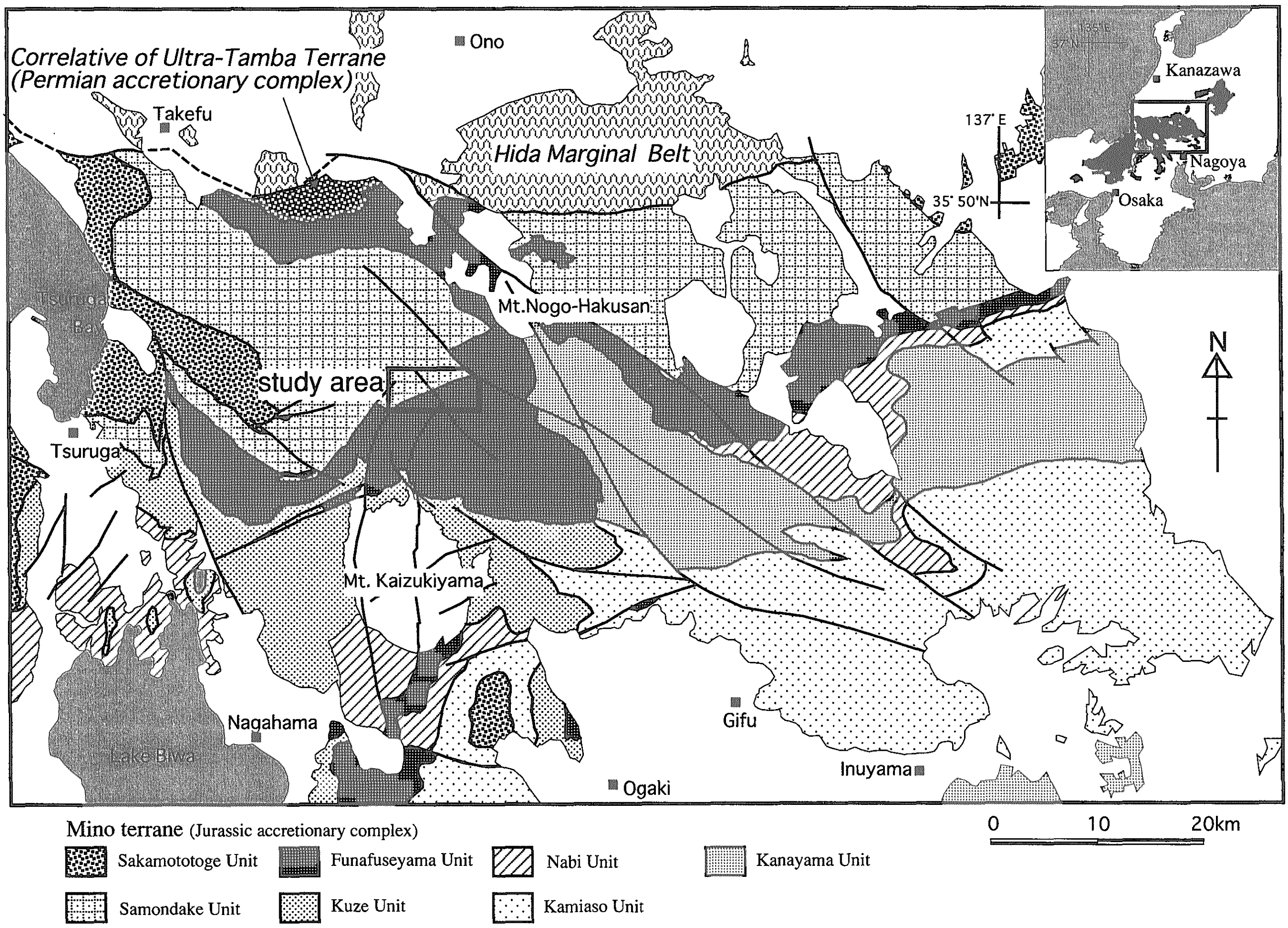


Fig. 1 Index map showing locality of the study area and unit subdivision of the Mino terrane. Modified from Saito and Sawada (2000).

divided into several tectonostratigraphic units on the basis of their lithology, age and geologic structure (Fig.1; Wakita, 1988; Otsuka, 1988). According to the subdivision by Wakita *et al.* (1992), rocks of the Middle Jurassic Samondake and Funafuseyama units are widely distributed around the Tokuyama area. The Samondake unit consists mainly of the Middle Jurassic clastic rocks with minor amounts of siliceous shale and chert. The Funafuseyama unit is composed of the Lower to Middle Jurassic melanges with large blocks and sheets of the Permian limestone, greenstone, Permian to Lower Jurassic chert, Middle Jurassic siliceous shale, and sandstone (Wakita, 1988).

In the map area shown in Fig.2, rocks of the Samondake unit are distributed in the northwestern part and rocks of the Funafuseyama unit is in the southeastern part, between which a steeply dipping fault runs from ENE to WSW. These rocks are cut by the Ibigawa fault, one of the left-lateral active faults striking NW-SE in central Japan (Matsuda, 1974).

The Samondake unit in this area is characterized by the massive coarse-grained sandstone with irregular-shaped black shale fragments several centimeters in diameter. Rocks designated as sandstone in Fig.2, however, include fairly large amounts of proximal and distal turbidites; they show various kinds of sedimentary structures, like graded bedding, convolute lamination and sole markings. Flute casts at the locality (A) in Fig.2 indicate that the clastic materials were transported from SSE. Shale is gray to black in color, faintly bedded and includes sandy laminae in places. Siliceous shale and chert formations several hundred meters in thickness are embedded within the clastic formations. Siliceous shales are gray, greenish gray and reddish brown in color, and are thinly bedded or massive. They gradually change to the bedded cherts. A small amount of melange (Sx in Fig.2) is distributed in a narrow zone between the two parallel faults. The melange is composed of black shale sometimes including blocks of sandstone, chert and siliceous shale, and larger slabs of sandstone and chert. This melange is often sheared by minor faults. The lithologic units shown as Ss, Sm, Si and Sc in Fig. 2 also include minor amounts of chaotic rocks composed of blocks of sandstone, chert, siliceous shale and MCN in a shale matrix (Fig.3). This chaotic rock has a block-in-matrix texture, but has not a mappable distribution in a small scale geologic map like Fig.2. In this paper, we name this chaotic rock as the mixed rock. Between the clastic and siliceous formations, in

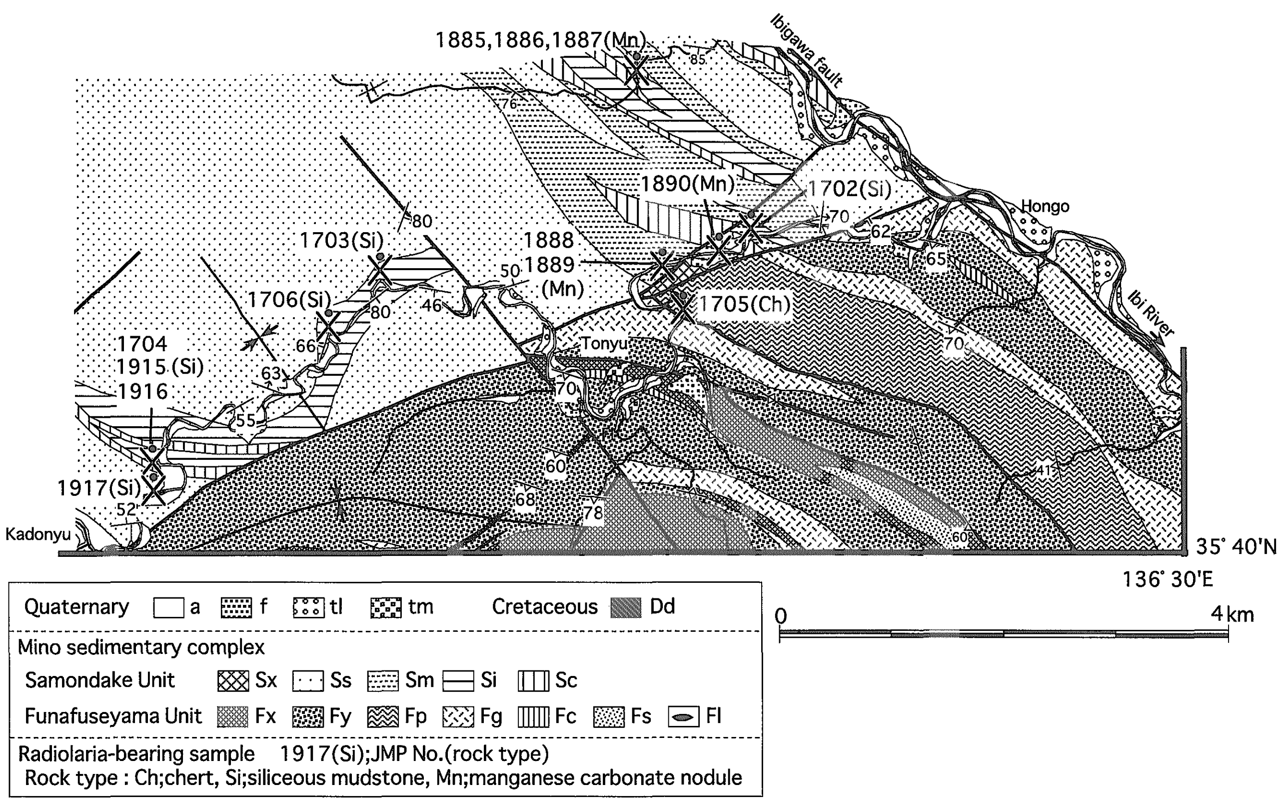


Fig. 2 Geologic map of the Tokuyama area. a: alluvial lowland deposits, f: small fan deposits, tl: lower terrace deposits, tm: middle terrace deposits, Dd: hornblende diorite porphyry dike, Ss, Sm, Si, Sc, Sx: rocks of the Samondake unit, Sx: melange composed of shale, sandstone, chert, siliceous shale and siliceous claystone, Ss: sandstone, Sm: shale, Si: siliceous shale and tuffaceous shale, Sc: chert, Fx, Fy, Fp, Fg, Fc, Fs, Fl: rocks of the Funafuseyama unit, Fx: melange composed of shale, sandstone, chert and siliceous shale, Fy: melange composed of shale, sandstone, chert, siliceous shale, limestone and greenstone, Fp: foliated melange composed of shale, sandstone, chert, siliceous shale, limestone and greenstone, Fg: greenstone, Fc: chert, Fs: sandstone, Fl: limestone.

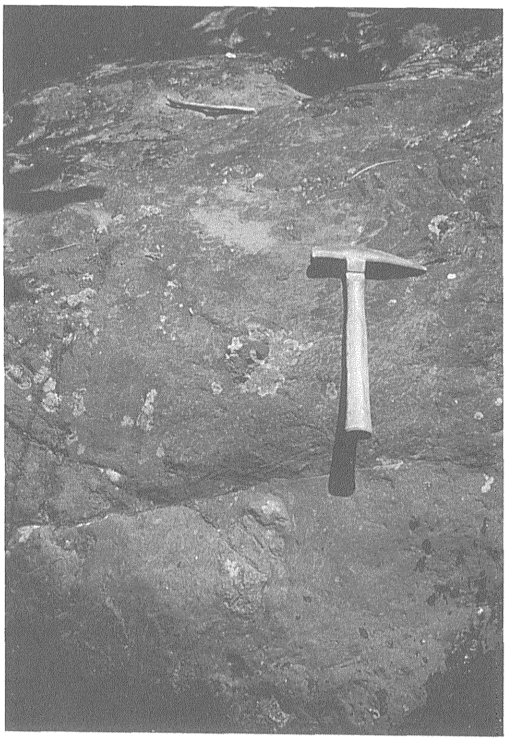
most cases, occurs black shale with blocks of sandstone, siliceous shale and chert.

The Funafuseyama unit in the area of Fig.2 consists mainly of melanges, which are subdivided into three types; One of them includes blocks of shale, sandstone, chert and siliceous shale in a black shale matrix. The second type is characterized by the blocks of greenstone and limestone together with those of the first type melange. The third type melange is similar to the second type in composition, but differs from the latter in having a foliated texture. Greenstone sheets about 100 m × 10 km in size occur between these melanges. Hornblende diorite porphyry dikes 10 m to 20 m in width are often intruded into these melanges and greenstone sheets. A K-Ar whole-rock age of 81 Ma was reported on one of the dykes by Saito and Sawada (2000).

3. Sample description

Rock samples treated in this paper are stored and registered in the Rad File, Nagoya University Furukawa Museum, and have registration numbers with the prefix JMP. The radiolarian data base, the Rad File, is established, organized and maintained by the researchers of the Furukawa Museum, Department of Earth and Planetary Sciences of Nagoya University, and Nihon Fukushi University (Kojima and Mizutani, 1982; Kojima *et al.*, 1989; Mizutani *et al.*, 1998). Localities of the samples are shown in Fig.2. Only the chert sample, JMP1705, is collected from the Funafuseyama unit, while others are from the Samondake unit.

The samples JMP1885 to 1890 (Figs.4 and 5) are all MCNs included in the mixed rocks of the Samondake unit (Fig.3). The samples JMP1885 to 1887 are collected from a series of exposure: the distance between the JMP1885 and 1886 localities is about 1 m, and the locality of the sample JMP1887 is about 10 m south of the others. Stratigraphic relations between them are impossible to determine, because they occur in the mixed rock. The samples JMP1888 and 1889 occur side by side in a small exposure of mixed rock. The mixed rock consists of the blocks of sandstone, siliceous shale and MCN enclosed in a gray to greenish gray, partly siliceous, shale matrix, which is not apparently sheared. The blocks are about 2 to 30 cm in diameter, and are sparsely scattered in the matrix



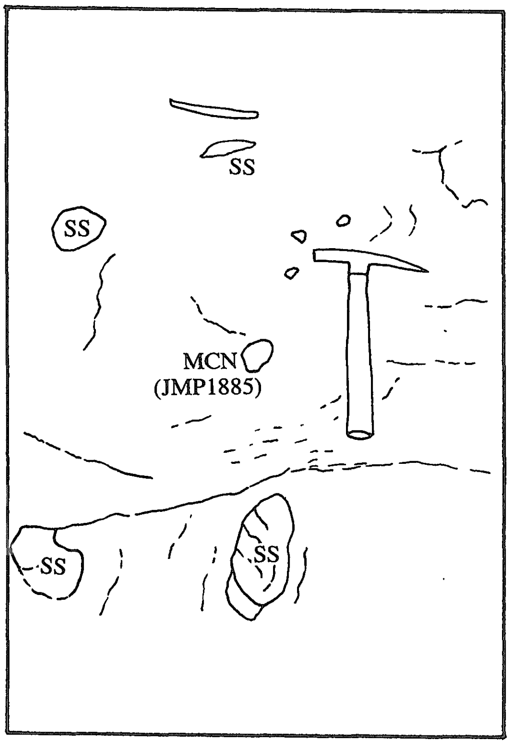


Fig. 3 Photograph showing the occurrence of Radiolaria-bearing manganese carbonate nodule. SS: sandstone, MCN (JMP1885): manganese carbonate nodule with the sample number.

(Fig.3). The nodules are 5 to 30 cm in diameter, black in color on the weathered surface, and are filled with rhodochrosite micro-nodules about 1 mm in diameter. They show petrographic characteristics mostly common to those described by Hattori (1985) and Adachi (1986).

The samples listed in Fig.6 are siliceous shales: most of them are gray to greenish gray in color, whereas the samples JMP1915 and 1916 are reddish brown. The siliceous shales are massive or bedded. The sample JMP1702 is gray to black, partly slumped, siliceous shale. The sample JMP1703 is taken from the siliceous shales occurring as a sheet-like block in the mixed rock, which also includes blocks of chert and sandstone. The samples JMP1704, 1915 and 1916 are collected from a series of exposure; The sample JMP1704 occurs along a road cut, while others are exposed on a river bed below the road. This siliceous shale is closely associated with the bedded chert, although direct relationship between them cannot be observed in the field. The sample JMP1706 is siliceous shale exposed along a road cut. About 10 m east of this exposure occur broken formations originated from the turbidite, although their relationship is unclear because of the concrete earth-retaining wall. The sample JMP1917 is a siliceous shale block enclosed in the mixed rock.

One chert sample, designated as JMP1705 in Fig.2, yields radiolarians preserved well enough to determine the geologic age. The chert is bedded and reddish brown in color, and gradually changes to siliceous shale.

4. Radiolarian assemblages

All the fossil individuals reported in this paper are deposited in the Nagoya University Furukawa Museum. All figures in Plates 1-12 are numbered, for example, as 12345/6789, whose numerator represents a sequential number of SEM (scanning electron microscope) photomicrograph and the denominator indicates that of the rock specimen (JMP number in Figs.4-5) from which the fossil was extracted; Both of the numbers are registered in the Rad File.

Radiolarians listed in Figs.4-6 and shown in Plates 1-12 are named mainly after the catalog of Baumgartner *et al.* (1995). Some genus and species, like *Tricolocapsa, Stichocapsa* and hagiastrid radiolarians, are classified on the basis of their internal skeletal structures. We, however, observed the fossil individuals only by using SEM, and our identifications are based entirely on their external morphological characteristics. Followings are some remarks on the radiolarians reported in this paper.

4.1 Spumellaria

Although all forms of *Gorgansium* are collectively treated as *G.* spp. by Baumgartner *et al.* (1995), we distinguished three morphotypes: *G. morganense, G.* sp. A and *G.* sp. B. *G. morganense* is reported from the

Sample Number (JMP-)	1885	1886	1887	1888	1889	1890
Acanthocircus bispinus				■	■	
Acanthocircus suboblongus						cf.
Acanthocircus sp.				■		
Archaeohagiastrum longipes				■		
Archaeohagiastrum munitum				■	■	
Archaeospongoprunum spp.	■	■		■	■	■
Gorgansium morganense		■				■
Gorgansium sp. A	■					
Gorgansium sp. B			■	■	■	
Gorgansium spp.	■	■	■	■	■	■
Hagiastrid spp.	■	■	■	■	■	■
Hexasaturnalis hexagonus			■	■	■	
Hexasaturnalis tetraspinus				■		
Higumastra wintereri				■		
Higumastra sp.				■		
Homoeoparonaella aff. *elegans*			■	■	■	
Japonisaturnalis japonicus				cf.		
Orbiculiforma sp.				■		
Pantanellium (?) sp. A	■	■				
Pantanellium spp.	■	■	■	■	■	■
Paronaella porosa				■	■	
Paronaella sp.				■		
Tetraditryma sp.				■		
Triactoma jakobsae				■	■	
Triactoma spp.	■	■	■	■	■	■
Trillus elkhornensis				■		
Trillus spp.	■	■	■	■	■	■
Xiphostylus vallieri				cf.		
Xiphostylus spp.				■	■	
Zartus dickinsoni group		■				
Zartus spp.	■	■	■			■

Fig. 4 List of Jurassic radiolarians (Spumellaria) from manganese carbonate nodule in the Tokuyama area.

upper Pliensbachian formation in eastern Oregon by Pessagno and Blome (1980). Some forms with less circular cortical shell (*e.g.*, Plate 6, fig.10) than the holotype are also designated as *G. morganense* in this report. *G.* sp. A is characterized by shorter spines than other species of *Gorgansium*, whereas *G.* sp. B has longer and slender spines. *Homoeoparonaella* sp. aff. *H. elegans* is a species described by Baumgartner *et al.* (1995), and differs from *H. elegans* in having "less expanded ray tips, subaligned and tetragonal pore frames on almost all test surface, and less prominent nodes at pore frame vertices". *Pantanellium* (?) sp. A is characterized by several secondary spines developed from the nodal points of pore frames; The secondary spines are shorter than the primary spines, triradiate in axial section, and arranged not only in the median plane perpendicular to the polar spines.

Sample Number (JMP-)	1885	1886	1887	1888	1889	1890
Andromeda sp.		■		■		■
Arcanicapsa sp.			■	■	■	■
Archaeodictyomitra spp.	■	■				■
Archicapsa pachyderma	■					
Archicapsa spp.	■	■			■	
Bernoullius spp.				■	■	■
Dictyomitrella (?) *kamoensis*	■	■				
Elodium aff. *cameroni*				■		
Eucyrtidiellum disparile			■	■		
Eucyrtidiellum (?) *quinatum*	■		■	■	■	
Eucyrtidiellum unumaense	■	■				■
Eucyrtidiellum spp.	■	■	■	■	■	■
Hilarisirex sp.				■		
Hsuum matsuokai			■	■	■	
Hsuum spp.	■	■	■	■	■	■
Laxtorum (?) *jurassicum*				■		
Napora latissima				■		
Napora pyramidalis	cf.	cf.				
Napora spp.	■	■	■	■	■	
Parahsuum aff. *cruciferum*				■		
Parahsuum spp.	■	■		■	■	
Parares spp.		■		■	■	
Parvicingula spp.	■	■		■	■	■
Perispyridium gujohachimanense	cf.					cf.
Perispyridium tamarackense				cf.		
Perispyridium spp.	■	■		■	■	■
Podobursa sp.						■
Saitoum spp.	■			■	■	■
Stichocapsa biconica			■	■	■	
Transhsuum hisuikyoense				■		
Tricolocapsa plicarum						cf.
Tricolocapsa aff. *plicarum*		■				
Tricolocapsa ruesti	cf.	cf.				cf.
Turanta sp. A				■		
Turanta spp.				■		■
Unuma echinatus	■	■	■	■	■	■
Unuma sp. A	■	■				
Unuma spp.	■	■	■	■	■	■
Yamatoum connicinum	cf.					
Yamatoum komamiensis				■	■	
Yamatoum spinosum	■					
Yamatoum spp.	■	■	■	■	■	■

Fig. 5 List of Jurassic radiolarians (Nassellaria) from manganese carbonate nodule in the Tokuyama area.

4.2 Nassellaria

Dictyomitrella (?) sp. aff. *D.* (?) *kamoensis* can be distinguished from *D.* (?) *kamoensis* reported by Mizutani and Kido (1983) by having one row of small

Sample Number (JMP-).	1702	1703	1704	1706	1915	1916	1917
Acanthocircus suboblongus		cf.					
Archaeospongoprunum spp.	■	■					
Gorgansium morganense	■						
Gorgansium sp. A			■				
Gorgansium spp.			■				
Hagiastrid spp.	■	■	■	■			
Hexasaturnalis tetraspinus		cf.		cf.			
Higumastra sp.	■						
Pantanellium sp.			■	■			
Paronaella sp.		■					
Trillus elkhornensis			cf.				
Trillus spp.	■	■	■	■	■	■	■
Zartus dickinsoni group	■	■		■			
Zartus spp.	■	■	■	■			■
Archaeodictyomitra spp.	■	■					■
Archicapsa pachyderma		■	■				■
Archicapsa spp.	■	■	■	■		■	■
Dictyomitrella (?) *kamoensis*	cf.	■		■			
Dictyomitrella (?) aff. *kamoensis*		■		■			
Eucyrtidiellum disparile			■		cf.	■	
Eucyrtidiellum pustulatum				cf.			
Eucyrtidiellum (?) *quinatum*			cf.		cf.		
Eucyrtidiellum spp.	■		■	■	■	■	
Hsuum matsuokai			■	cf.	cf.	■	
Hsuum spp.		■	■	■	■	■	
Laxtorum (?) *hichisoense*			cf.				
Laxtorum (?) *jurassicum*			■	cf.		cf.	
Laxtorum (?) aff. *jurassicum*		■					
Napora spp.	■	■	■	■			
Parahsuum spp.		■	■	■	■	■	
Paronaella sp.		■		■			
Saitoum spp.	■		■	■			
Transhsuum hisuikyoense			■	■	cf.	cf.	
Tricolocapsa plicarum	cf.						
Tricolocapsa aff. *plicarum*	■	■		■			■
Tricolocapsa ruesti	cf.		cf.	cf.			
Tricolocapsa (?) *fusiformis*	cf.						
Unuma echinatus		cf.		■			
Unuma sp. A		■		■			
Unuma spp.	■	■	■	■			

Fig. 6 List of Jurassic radiolarians from siliceous shale in the Tokuyama area.

pores between the two rows of pits. According to Wakita (1988), this type of Radiolaria is considered to occur from slightly older horizons than *D.* (?) *kamoensis*. *Elodium* sp. aff. *E. cameroni* is similar to *E. cameroni* reported by Carter *et al.* (1988) from the middle Toarcian to Aalenian formations of the Queen Charlotte Islands, but differs slightly from the latter in having a well-developed apical horn with ridges and grooves. *Laxtorum* (?) sp. aff. *L.* (?) *jurassicum* is different from *L.* (?) *jurassicum* in having spongy meshwork comprised of polygonal pore frames on the abdomen and proximal part of post-abdominal chambers. *Parahsuum* sp. aff. *P. cruciferum* is similar to *P. cruciferum* reported by Takemura (1986) from a MCN in the Gujo-hachiman area, northern Mino terrane, but differs from the latter in having poorly developed longitudinal costae. *Tricolocapsa* sp. aff. *T. plicarum* is distinguished from *T. plicarum* by having well-developed basal appendage. This form is reported by Matsuoka and Yao (1986) and Matsuoka (1995) as *Stichocapsa tegiminis* group ranging in age from the upper part of the *Laxtorum* (?) *jurassicum* Zone to the *Tricolocapsa plicarum* Zone. *S. tegiminis* originally reported by Yao (1979), however, has no longitudinal plicae, and the pores of *S. tegiminis* are not arranged longitudinally. In this paper we name this form of Radiolaria as *T.* sp. aff. *T. plicarum* on the basis of the external similarity observed by SEM. *Turanta* sp. A is similar to *T. morinae* reported by Pessagno and Blome (1982) from the lower Bajocian in Oregon, but differs from the latter in having more sturdy spines. Siliceous shale and MCN in the Tokuyama area yield a variety of Radiolaria similar to *Unuma echinatus*. Since the original definition of *U. echinatus* (Ichikawa and Yao, 1976) clearly restricts the species to the forms with a "inversely subconical basal appendage" and "a distinct basal spine", some forms (*e.g.*, Plate 4, fig.1) having a terminal segment with aperture should not be included in *U. echinatus*. Most of the individuals from this area, however, have broken basal appendages, and we tentatively include all the forms of *Unuma* with longitudinal plicae and radial spines in *U. echinatus*. *Unuma* sp. A has characteristics similar to some species of *Unuma* (*e.g.*, longitudinal plicae and two or three rows of pores between them), but differs from other species of *Unuma* in having a spherical last chamber and having no basal appendage.

5. Age of MCN

Recently Jurassic radiolarian biostratigraphy has been extensively studied by many workers in Japan, Europe and North America (*e.g.*, Matsuoka and Yao, 1986; Matsuoka, 1995; Baumgartner *et al.*, 1995; Pessagno *et al.*, 1993; Carter *et al.*, 1988). By referring to these reports we could precisely determine the ages of rocks in the Tokuyama area.

The MCN sample JMP1888 yields following radiolarians:

Acanthocircus bispinus
Archaeohagiastrum longipes
(B: early Aalenian - early Callovian)
Archaeohagiastrum munitum
(B: late Aalenian - early Oxfordian)
Hexasaturnalis hexagonus
(B: early Aalenian - late Bajocian)

Hexasaturnalis tetraspinus
(B: early Aalenian - middle Bathonian)
Higumastra wintereri
(B: early Aalenian - early Oxfordian)
Paronaella porosa (CCS: Toarcian)
Triactoma jakobsae
(B: early Aalenian - late Bajocian)
Trillus elkhornensis
(PB: late Pliensbachian - middle Bajocian)
Eucyrtidiellum disparile
Eucyrtidiellum (?) *quinatum*
(B: early Aalenian - late Bajocian)
Hsuum matsuokai
(B: early Aalenian - early Bathonian)
Laxtorum (?) *jurassicum*
(B: late Aalenian - middle Bajocian)
Napora latissima
(B: late Bajocian - early Callovian)
Stichocapsa biconica
Transhsuum hisuikyoense
(B: late Aalenian - early Callovian)
Unuma echinatus
(B: early Aalenian - middle Bathonian)
Yamatoum komamiensis (B: late Aalenian)

The age ranges of radiolarian species in parentheses are based on B: Baumgartner *et al.* (1995), CCS: Carter *et al.* (1988) and PB: Pessagno and Blome (1980); They indicate that the age of this sample is most probably late Aalenian to late Bajocian. Coexistence of *Laxtorum* (?) *jurassicum*, *Transhsuum hisuikyoense*, *Trillus elkhornensis*, etc. characterizes the *Laxtorum* (?) *jurassicum* Zone of Matsuoka (1995), which is assigned to the Aalenian to early Bajocian. *Acanthocircus bispinus* is described from MCN in the Inuyama area (Yao, 1972), the age of which is correlated to the *Tricolocapsa plicarum* Zone just above the *L.* (?) *jurassicum* Zone. *Eucyrtidiellum disparile* is reported to occur from the *L.* (?) *jurassicum* Zone and probably lower part of the *Tricolocapsa plicarum* Zone (Nagai and Mizutani, 1990). *Stichocapsa biconica* was described by Matsuoka (1991) from the *Archicapsa pachyderma* Zone below the *L.* (?) *jurassicum* Zone. These lines of evidence indicate that the MCN sample JMP1888 is late Aalenian to late Bajocian in age and is correlated to the *L.* (?) *jurassicum* Zone of the Japanese Jurassic radiolarian zones defined by Matsuoka (1995).

The MCN samples JMP1887 and 1889 yield such radiolarians common to JMP1888 as *Acanthocircus bispinus* (JMP1889), *Archaeohagiastrum munitum* (JMP1889), *Gorgansium* sp. B, *Hexasaturnalis hexagonus*, *Homoeoparonaella* sp. aff. *H. elegans*, *Paronaella porosa* (JMP1889), *Triactoma jakobsae* (JMP1889), *Eucyrtidiellum disparile* (JMP1887), *Eucyrtidiellum* (?) *quinatum*, *Hsuum matsuokai*, *Stichocapsa biconica*, *Unuma echinatus* and *Yamatoum komamiensis* (JMP1889), and are considered to be of the same age with JMP1888. Although *Gorgansium morganense* (JMP1889) is reported from the Pliensbachian in North America as mentioned above, the morphotypes herein designated as *G. morganense* seem to occur from the younger formations in Japan. The age assignment of the sample JMP1889 is supported by their occurrence that the samples JMP1888 and 1889 are collected from the small exposure.

The radiolarian assemblages obtained from the MCN samples JMP1885 and 1886 lack most of the species listed above, and are characterized by such radiolarians as *Pantanellium* (?) sp. A, *Dictyomitrella* (?) *kamoensis*, *Eucyrtidiellum unumaense*, *Unuma echinatus* and *Unuma* sp. A. Of these Radiolaria, *D.* (?) *kamoensis* is believed to occur from the lower Bajocian to lower Callovian (Baumgartner *et al.*, 1995). Range of *E. unumaense* is early Bajocian to early Oxfordian (Baumgartner *et al.*, 1995), or is estimated to cover both of the *Tricolocapsa plicarum* and *Tricolocapsa conexa* Zones (Matsuoka, 1995). The last appearance biohorizon of *Archicapsa pachyderma* obtained from JMP1885 is in the upper part of the *T. plicarum* Zone, and that of *Tricolocapsa* sp. aff. *T. plicarum* (= *Stichocapsa tegiminis* group of Matsuoka and Yao, 1986; Matsuoka, 1995) from JMP1886 coincides with the top of the *T. plicarum* Zone. Age ranges of *Yamatoum spinosum* from JMP1885 and *Zartus dickinsoni* group from JMP1886 are indicated as early Aalenian to late Bajocian and Bajocian, respectively, by Baumgartner *et al.* (1995). All these lines of evidence strongly suggest that the samples JMP1885 and 1886 are Bajocian in age, or are correlated to (the most probably lower part of) the *T. plicarum* Zone (Bajocian to early Bathonian: Matsuoka, 1995).

Although the radiolarian assemblage from the MCN sample JMP1890 is lacking in the species useful for age determination, it includes *Eucyrtidiellum unumaense*, *Unuma echinatus* and *Tricolocapsa* sp. cf. *T. plicarum*; These fossils make it possible to assign the age of MNC to the *T. plicarum* Zone.

6. Age of siliceous shale and chert

Although diversity of radiolarian assemblages in the siliceous shale is lower than that in the MCN, they have well-preserved marker taxa in order to correlate them with the Japanese radiolarian zones defined by Matsuoka and Yao (1986) and Matsuoka (1995). The sample JMP1704 yields *Trillus* sp. cf. *T. elkhornensis*, *Archicapsa pachyderma*, *Eucyrtidiellum disparile*, *Eucyrtidiellum* (?) sp. cf. *E. quinatum*, *Hsuum matsuokai*, *Laxtorum* (?) sp. cf. *L.* (?) *hichisoense*, *Laxtorum* (?) *jurassicum* and *Transhsuum hisuikyoense*, and is assigned to the *Laxtorum* (?) *jurassicum* Zone of Matsuoka (1995). The samples JMP1915 and 1916 have similar radiolarian assemblages, and occur closely associated with the sample JMP1704; These three siliceous shale samples are concluded to be correlated to the *L.*(?) *jurassicum* Zone, which is Aalenian in age (Matsuoka, 1995).

The samples JMP1703 and 1706 yield not only the radiolarians common to the sample JMP1704 but also *Zartus dickinsoni* group, *Dictyomitrella*(?) *kamoensis*, *Dictyomitrella*(?) sp. aff. *D.*(?) *kamoensis*, *Tricolocapsa* sp. aff. *T. plicarum*, *Unuma* (sp. cf. *U.*) *echinatus*: younger elements than those of the *Laxtorum*(?) *jurassicum* Zone. The fossil data might indicate that the sample JMP1703 and 1706 are younger in age than JMP1704, and are assigned to the upper part of the *Laxtorum*(?) *jurassicum* Zone or the lower part of the *Tricolocapsa plicarum* Zone, which is late Aalenian or Bajocian (Matsuoka, 1995).

Radiolarian assemblage from the sample JMP1702 is characterized by *Gorgansium morganense*, *Zartus dickinsoni* group, *Dictyomitrella*(?) sp. cf. *D.*(?) *kamoensis*, *Tricolocapsa* sp. cf. *T. plicarum*, *T.* sp. aff. *T. plicarum*, *Tricolocapsa*(?) sp. cf. *T.*(?) *fusiformis*, and lacks the species characteristic of the *Laxtorum* (?) *jurassicum* Zone. Although preservation of the radiolarians is not well enough to determine the age precisely, coexistence of these fossils suggests that the sample is correlated to, most probably lower part of, the *Tricolocapsa plicarum* Zone (Bajocian to early Bathonian; Matsuoka, 1995).

Radiolarian assemblage from the sample JMP1917 is lacking in the key taxa to determine the age. But the occurrence of *Archicapsa pachyderma* and *Tricolocapsa* sp. aff. *T. plicarum* indicates that the sample is most probably assigned to the upper part of the *Laxtorum*(?) *jurassicum* Zone or the lower part of the *Tricolocapsa plicarum* Zone.

The chert sample JMP1705 yields *Capnodoce* sp. cf. *C. sarisa*, *Tritortis* sp., *Corum regium*, *Triassocampe* sp. Of these radiolarians, *C. regium* is known to occur from the upper Carnian (?) to middle Norian in North America (Blome, 1984), and also from the TR6A to 6B Zones (late Carnian to early Norian) defined by Sugiyama (1997) in the southern Mino terrane. Since the ranges of other taxa are consistent with the age, the chert is determined to be late Carnian to early or middle Norian in age.

7. Discussion

7.1 Origin and radiolarian age of MCN (manganese carbonate nodule)

Since the MCNs treated in this paper occur as blocks in the mixed rocks, there are two possibilities for the origin of the MCNs: allochthonous or autochthonous (in this paper, the autochthonous origin means that the MCNs authigenically formed after the formation of the mixed rocks). Origin of the mixed rocks and melanges of the Samondake unit has not been revealed until now, and it is beyond the scope of this paper. If the MCNs are allochthonous, only we can say is that the age of the mixed-rock formation is younger than that of the MCNs.

If the MCNs are autochthonous in origin, what can we say ? Geochemical studies of MCNs in the Mino terrane together with those from modern oceans indicate that they formed during the diagenetic process in a sediment column below the oxidized layer near the sediment/water interface (e.g., Sugitani, 1989; Sugisaki *et al.*, 1991). Possible environments for the formation of MCN include, for example in the Sea of Japan, the layer at the depth of 260 cm with both Mn and CO_2 (Sugisaki *et al.*, 1991). If the mixed rocks and melanges of the Tokuyama area tectonically formed in deeper places of the accretionary prism, as discussed by Kimura (1997) and Wakita (2000), it would be difficult to explain the autochthonous origin of the MCNs. As the result, if the MCNs are autochthonous, the mixed rocks are most probably of sedimentary origin, formed near the ocean floor. In this case, authigenic mineralization of the manganese carbonates took place within the Radiolaria-bearing siliceous shale in the mixed rocks, which might be either a block or a matrix, and then the MCN trapped the radiolarian remains within it. The process implies that the mixed rocks are as old as, or younger than, the age of radiolarians in the MCNs.

7.2 Age of the Samondake unit

Age of the Samondake unit is difficult to determine, because the unit consists mainly of coarse clastic rocks barren of age-diagnostic fossils. Only one exception is the late Bathonian to early Callovian ammonite, *Kepplerites* (*Seymourites*) sp., found from the fine-grained sandstone in the Gujo-hachiman area about 50 km east of this area (Sato *et al.*, 1985). Wakita (1988) summarized radiolarian ages of rocks of the Samondake unit mostly in the Gujo-hachiman area as follows; shale: *Unuma echinatus* (= *Tricolocapsa plicarum* Zone in this paper) and *Guexella nudata* Assemblage Zones; siliceous shale: *Hsuum hisuikyoense* (=*Laxtorum*(?) *jurassicum* Zone in this paper) and *U. echinatus* Assemblage Zones; MCNs in siliceous shale: *H. hisuikyoense* and *U. echinatus* Assemblage Zones. Hattori (1988, 1989) and Hattori and Sakamoto (1988) reported radiolarians from MCNs of the Samondake unit in the Nanjo Mountains to the northeast of the study area; The age varies from Pliensbachian to Aalenian. Of these, the MCN from the Kanmuriyama-Kanakusadake area is very similar to those from the present study area in occurrence, age and radiolarian assemblages. Recently Kobayashi (1998) preliminary reported radiolarian fossils ranging in age from the *Laxtorum*(?) *jurassicum* to *Tricolocapsa plicarum* Zones from shale, siliceous shale and MCNs in the Samondake area that is the type locality of the Samondake unit. Saito and

Sawada (2000) published a geologic map (1:50,000) of the Yokoyama district and reported radiolarians of *Trillus elkhornensis* to *Tricolocapsa plicarum* Zones from siliceous mudstone and those of *Tricolocapsa plicarum* to *Tricolocapsa conexa* Zones from mudstone of the Samondake unit. In this paper, we described radiolarians ranging from the *Laxtorum* (?) *jurassicum* to *Tricolocapsa plicarum* Zones in siliceous shales. It is confirmed that the age of siliceous shale in the Samondake unit of the Tokuyama area is Aalenian to early Bathonian, which indicates the age of arrival of the oceanic plate with pelagic sediments of the Samondake unit on the subduction zone.

Ages of MCNs in the Mino terrane are reviewed by Okumura and Otsuka (1996). They noticed that the ages have a younging polarity to the east; the nodules in the Nanjo Mountains yield radiolarians of *Parahsuum simplum* Assemblage (early Early Jurassic), whereas those in the Misogawa area have radiolarians of *Gongylothorax sakawaensis* - *Stichocapsa naradaniensis* Assemblage (early Late Jurassic). According to Okumura and Otsuka (1996) most of the MCNs have been found in siliceous shale, shale and chert. The radiolarian ages of MCNs reported in this paper, although they may not directly indicate the age of the mixed rocks, perfectly fit the polarity trend. This fact implies the ages are equivalent to those of the host siliceous shale or shale.

8. Conclusion

We described well-preserved late Aalenian to Bajocian radiolarians from the MCNs included as blocks in the mixed rocks of the Samondake unit in the Tokuyama area, Mino terrane. Since the MCNs occur as blocks, the age does not directly indicate the depositional age of the mixed rocks. By considering the depositional environment of modern MCNs and development of accretionary complex, we discussed relationship between radiolarian ages of the MCNs and forming ages of the mixed rocks.

Siliceous shales of the Samondake unit also yield well-preserved Aalenian to Bajocian radiolarians. The ages are concordant to the ages of siliceous shale in the Samondake unit reported by previous researchers. The siliceous shale is considered to form part of the oceanic plate stratigraphy composed of the basal greenstone, pelagic sediments (radiolarian chert), siliceous shale, shale and coarse clastic rocks derived from continent. The age of siliceous shale indicates the age of arrival of the oceanic plate with pelagic sediments of the Samondake unit on the subduction zone.

Acknowledgements: We thank Mr. S. Okamoto of Idemitsu Oil Development Co., Ltd. for his help in the field. Thorough review by Dr. S. Nakae of GSJ greatly improved the manuscript.

References

Adachi, M. (1986) Rock-forming minerals of Mn-carbonate nodules and layers in Jurassic shales of the Mino terrane: a preliminary report. *News of Osaka Micropaleontol., Spec. Vol.*, no.7, 275-286. (JE)

Baumgartner, P.O., O'Dogherty, L., Gorican, S., Dumitrica-Jud, R., Dumitrica, P., Pillevuit, A., Urquhart, E., Matsuoka, A., Danelian, T., Bartolini, A., Carter, E., De Wever, P., Kito, N., Marcucci, M. and Steiger, T. (1995) Radiolarian catalogue and systematics of Middle Jurassic to Early Cretaceous Tethyan genera and species. *In* Baumgartner, P.O., O'Dogherty, L., Gorican, S., Urquhart, E., Pillevuit, A. and De Wever, P., eds., *Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology*. Mēmoires de Gēologie (Lausanne), no.23, 37-685.

Blome, C.D. (1984) Upper Triassic Radiolaria and radiolarian zonation from western North America. *Bull. Amer. Paleont.*, **85**, no.318, 88p.

Carter, E.S., Cameron, B.E.B. and Smith, P.L. (1988) Lower and Middle Jurassic radiolarian biostratigraphy and systematic paleontology, Queen Charlotte Islands, British Columbia. *Geol. Surv. Canada Bull.*, no.386, 109p.

Hattori, I. (1976) Lithology and Markov analysis of the Paleozoic strata in the Fujibashi area, Gifu Prefecture, central Japan. *Jour. Geol. Soc. Japan*, **82**, 19-33.

Hattori, I. (1985) Length-slow chalcedony in the Paleozoic-Mesozoic strata of the Mino Terrane, Fukui Prefecture, central Japan, and its geologic significance. *Jour. Geol. Soc.*, **91**, 453-461. (JE)

Hattori, I. (1988) Radiolarian fossils from manganese nodules at the upper reach of the Tarumigawa in the Nanjo Massif, Fukui Prefecture, Central Japan, and the tectonic significance of the northwestern Mino Terrane. *Bull. Fukui Municipal Museum Natural History*, no.35, 55-101. (JE)

Hattori, I. (1989) Jurassic radiolarians from manganese nodules at three sites in the western Nanjo Massif, Fukui Prefecture, central Japan (data). *Mem. Fac. Educ. Fukui Univ., II*, **39**, 47-134. (JE)

Hattori, I. and Sakamoto, N. (1988) Geology and Jurassic radiolarians from manganese nodules of the Kanmuriyama-Kanakusadake area in the Nanjo Massif, Fukui Prefecture, Central Japan. *Bull. Fukui Municipal Museum Natural History*, no.36, 25-79. (JE)

Hattori, I. and Yoshimura, M. (1982) Lithofacies distribution and radiolarian fossils in the Nanjo area in Fukui Prefecture, central Japan. *News of Osaka Micropaleontol., Spec. Vol.*, no.5, 103-116. (JE)

Ichikawa, K. and Yao, A. (1976) Two new genera of Mesozoic cyrtoid radiolarians from Japan. *In* Takayanagi, Y. and Saito, T., eds., *Progress in Micropaleontology*, Micropaleontology Press, 110-117.

Kajita, S. (1963) Geology of the upper reaches area of the Ibi River, central Japan. *Sci. Rep. Fac. Liberal Arts and Educ., Gifu Univ.*, **3**, 192-201. (JE)

Kimura, K. (1997) Offscraping underplating and out-of-sequence thrusting process of an accretionary prism: On-land example from the Mino-Tamba Belt, central Japan. *Bull. Geol. Surv. Japan*, **48**, 313-337.

Kobayashi, Y. (1998) Triassic and Jurassic radiolarian assemblages from the Samondake Unit of the Mino Terrane in the Neo-Izumi area, central Japan. *Jour. Fac. Sci., Shinshu Univ.*, **33**, 27-63. (JE)

Kojima, S. and Mizutani, S. (1982) A data base management system of the radiolarian photomicrographs. *News of Osaka Micropaleontol., Spec. Vol.*, no.5, 457-467. (JE)

Kojima, S., Mizutani, S., Nagai, H., Saito, M., Tsukamoto, H. and Yogo, M. (1989) Design and utilization of the data base system for radiolarian fossils in the Nagoya University Museum. *Bull. Nagoya Univ. Museum, Spec. Rep.*, no.1, 1-192. (JE)

Kojima, S. and Okamoto, S. (1990) Jurassic radiolarian assemblages in Mn-carbonate nodules from northern Fujihashi Village, Gifu Prefecture. *Abst., 97th Ann. Meet. Geol. Soc. Japan*, 150. (J)

Matsuda, T. (1974) Surface faults associated with Nobi (Mino-Owari) Earthquake of 1891, Japan. *Bull. Earthquake Inst.*, **14**, 85-126. (JE)

Matsuoka, A. (1991) Early Jurassic radiolarians from the Nanjo Massif in the Mino terrane, central Japan, Part 1. *Tricolocapsa, Stichocapsa*, and *Minocapsa*, n. gen. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no.161, 720-738.

Matsuoka, A. (1995) Jurassic and Lower Cretaceous radiolarian zonation in Japan and in the western Pacific. *The Island Arc*, **4**, 140-153.

Matsuoka, A. and Yao, A. (1986) A newly proposed radiolarian zonation for the Jurassic of Japan. *Marine Micropaleontology*, **11**, 91-106.

Miyamura, M. (1965) The Paleozoic formation in the Yokoyama district, Gifu Prefecture, Central Japan. *Jour. Geol. Soc. Japan*, **71**, 5-17 (JE)

Mizutani, S. (1990) Mino Terrane. *In* Ichikawa, K., Mizutani, S., Hara, I., Hada, S. and Yao, A., eds., *Pre-Cretaceous Terranes of Japan*. Publication of IGCP Project No.224: Pre-Jurassic Evolution of Eastern Asia, 121-135.

Mizutani, S., Isogai, Y., Nagai, H. and Kojima, S. (1998) On Rad-File (IDB) -Image database of radiolarian fossils-. *Bull. Nagoya Univ. Furukawa Museum, Spec. Rep.*, no.8, 1-114. (JE)

Mizutani, S. and Kido, S. (1983) Radiolarians in Middle Jurassic siliceous shale from Kamiaso, Gifu Prefecture, central Japan. *Trans. Palaeont. Soc. Japan, N.S.*, no.132, 253-262.

Mizutani, S. and Kojima, S. (1992) Mesozoic radiolarian biostratigraphy of Japan and collage tectonics along the eastern continental margin of Asia. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **96**, 3-22.

Nagai, H. and Mizutani, S. (1990) Jurassic *Eucyrtidiellum* (Radiolaria) in the Mino terrane. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 159, 587-602.

Okumura, A. and Otsuka, T. (1996) Late Middle Jurassic and early Late Jurassic radiolarian assemblages from the Misogawa complex of the Mino terrane, central Japan. *Jour. Fac. Sci., Shinshu Univ.*, **31**, 21-42. (JE)

Otsuka, T. (1988) Paleozoic-Mesozoic sedimentary complex in the eastern Mino Terrane, central Japan and its Jurassic tectonism. *Jour. Geosci., Osaka City Univ.*, **31**, 63-122.

Pessagno, E.A., Jr. and Blome, C.D. (1980) Upper Triassic and Jurassic Pantanelliinae from California, Oregon and British Columbia. *Micropaleontology*, **26**, 225-273.

Pessagno, E.A., Jr. and Blome, C.D. (1982) Bizarre Nassellariina (Radiolaria) from the Middle and Upper Jurassic of North America. *Micropaleontology*, **28**, 289-318.

Pessagno, E.A., Jr., Blome, C.D., Hull, D.M. and Six, W.M. (1993) Jurassic Radiolaria from the Josephine ophiolite and overlying strata, Smith River subterrane (Klamath Mountains), northwestern California and southwestern Oregon. *Micropaleontology*, **39**, 93-116.

Saito, M. and Sawada, Y. (2000) *Geology of the Yokoyama district. With Geological Sheet Map at 1:50,000*. Geol. Surv. Japan 126p. (JE)

Sato, T., Kasahara, Y. and Wakita, K. (1985)

Discovery of a Middle Jurassic ammonite *Kepplerites* from the Mino Belt, central Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no.139, 218-221.

Sugisaki, R., Sugitani, K. and Adachi, M. (1991) Manganese carbonate bands as an indicator of hemipelagic sedimentary environments. *Jour. Geol.*, **99**, 23-40.

Sugitani, K. (1989) Geochemistry of manganese bands hosted by sedimentary rocks in the Mino Terrane, central Japan: Its comparison with marine sediments and the geological significance. *Jour. Geol. Soc. Japan*, **95**, 255-275. (JE)

Sugiyama, K. (1997) Triassic and Lower Jurassic radiolarian biostratigraphy in the siliceous claystone and bedded chert units of the southern Mino terrane, Central Japan. *Bull. Mizunami Fossil Museum*, no.24, 79-193.

Takemura, A. (1986) Classification of Jurassic nassellarians (Radiolaria). *Palaeontographica, Abt. A*, **195**, 29-74.

Wakita, K. (1988) Origin of chaotically mixed rock bodies in the Early Jurassic to Early Cretaceous sedimentary complex of the Mino terrane, central Japan. *Bull. Geol. Surv. Japan*, **39**, 675-757.

Wakita, K. (2000) Mêlagnes of the Mino terrane. *Mem. Geol. Soc. Japan*, no.55, 145-163. (JE)

Wakita, K., Harayama, S., Kano, K., Mimura, K. and Sakamoto, T. (1992) *1:200,000 Geological Map, Gifu*. Geol. Surv. Japan. (J)

Yao, A. (1972) Radiolarian fauna from the Mino belt in the northern part of the Inuyama area, central Japan. Part I. Spongosaturnalids. *Jour. Geosci., Osaka City Univ.*, **15**, 21-64.

Yao, A. (1979) Radiolarian fauna from the Mino belt in the northern part of the Inuyama area, central Japan. Part II: Nassellaria 1. *Jour. Geosci., Osaka City Univ.*, **22**, 21-72.

JE: in Japanese with English abstract
J: in Japanese

難読・重要地名
Tokuyama 徳山　Samondake 左門岳
Funafuseyama 舟伏山

Received December 27, 1999
Accepted February 18, 2000

中部日本，美濃帯，徳山地域からの三畳紀・ジュラ紀放散虫

小嶋　智・斎藤　眞

要　旨

美濃帯，徳山地域のチャート，珪質頁岩，マンガン炭酸塩ノジュール（以下MNCと略す）から後期三畳紀および中期ジュラ紀の放散虫化石の産出を記載した．ジュラ紀付加体からなる美濃帯はいくつかの構造層序単元に区分できるが，徳山地域にはそのうちの左門岳ユニットと舟伏山ユニット（いずれも中期ジュラ紀）が分布する．前者は，主として塊状砂岩，タービダイト，珪質頁岩，チャートと少量のメランジュと混在岩からなる．一方，後者は3種のメランジュとそれらの間に分布する緑色岩シートからなる．左門岳ユニットの混在岩中にブロックとして含まれるMCNは，保存良好なAalenian後期からBajocianの放散虫を産し，同ユニットの珪質頁岩はAalenianからBajocianの放散虫を産する．舟伏山ユニットのチャートからは，わずか1試料であるが，Carnian後期からNorian中期の放散虫が得られた．

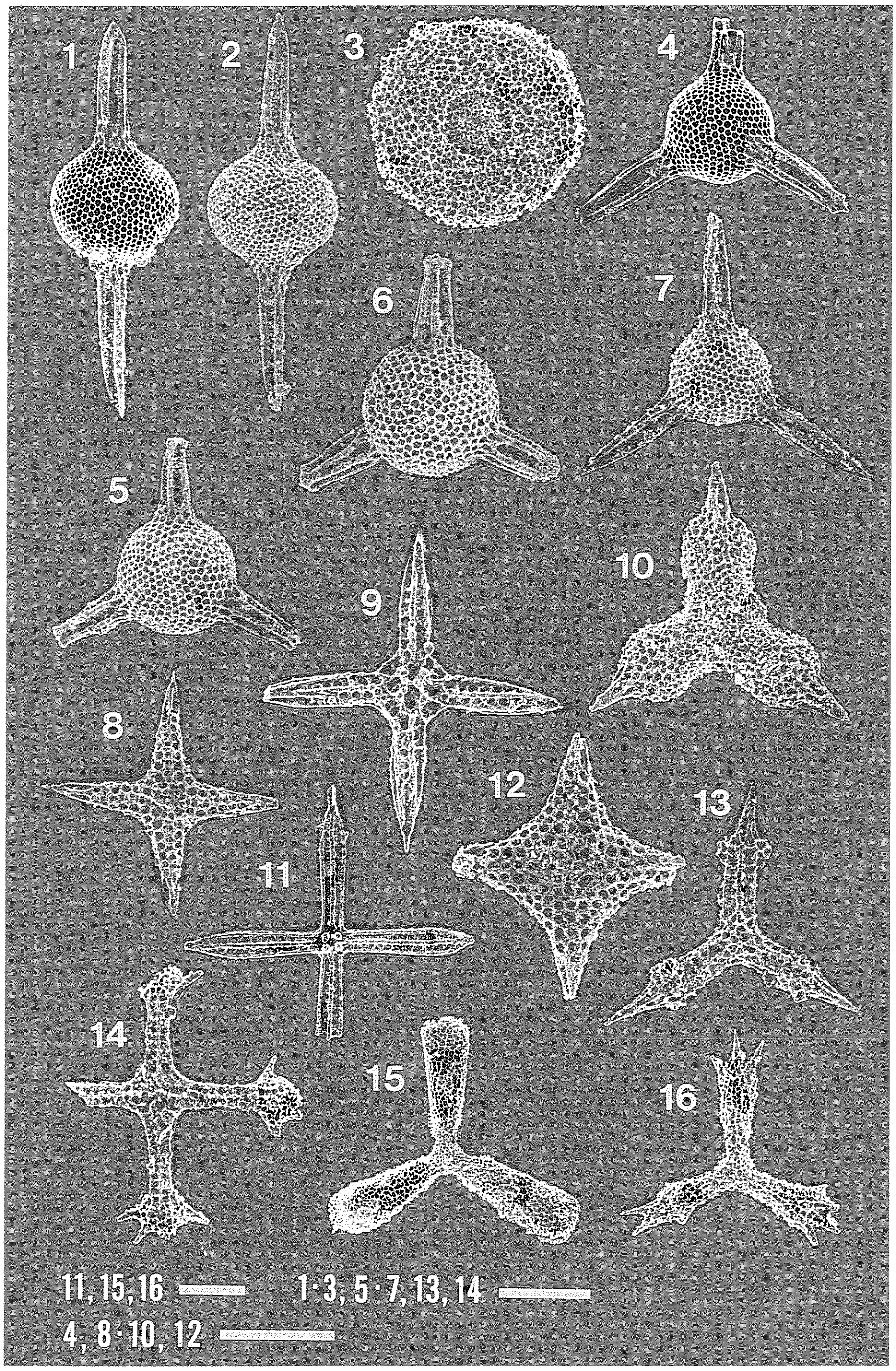


Plate 1 Jurassic radiolarians from manganese carbonate nodule in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Xiphostylus* sp. cf. *X. vallieri* (55685/1888)
2. *Xiphostylus* sp. cf. *X. vallieri* (55734/1888)
3. *Orbiculiforma* sp. (55683/1888)
4. *Triactoma jakobsae* (55126/1888)
5. *Triactoma jakobsae* (55156/1888)
6. *Triactoma jakobsae* (55182/1888)
7. *Triactoma* sp. (55745/1888)
8. *Higumastra wintereri* (55750/1888)
9. *Archaeohagiastrum munitum* (55164/1888)
10. *Paronaella porosa* (55726/1888)
11. *Archaeohagiastrum longipes* (55198/1888)
12. *Higumastra* sp. (55729/1888)
13. *Homoeoparonaella* sp. aff. *H. elegans* (55733/1888)
14. *Tetraditryma* sp. (55015/1888)
15. *Hagiastrid* gen. et sp. indet. (55677/1888)
16. *Paronaella* sp. (55065/1888)

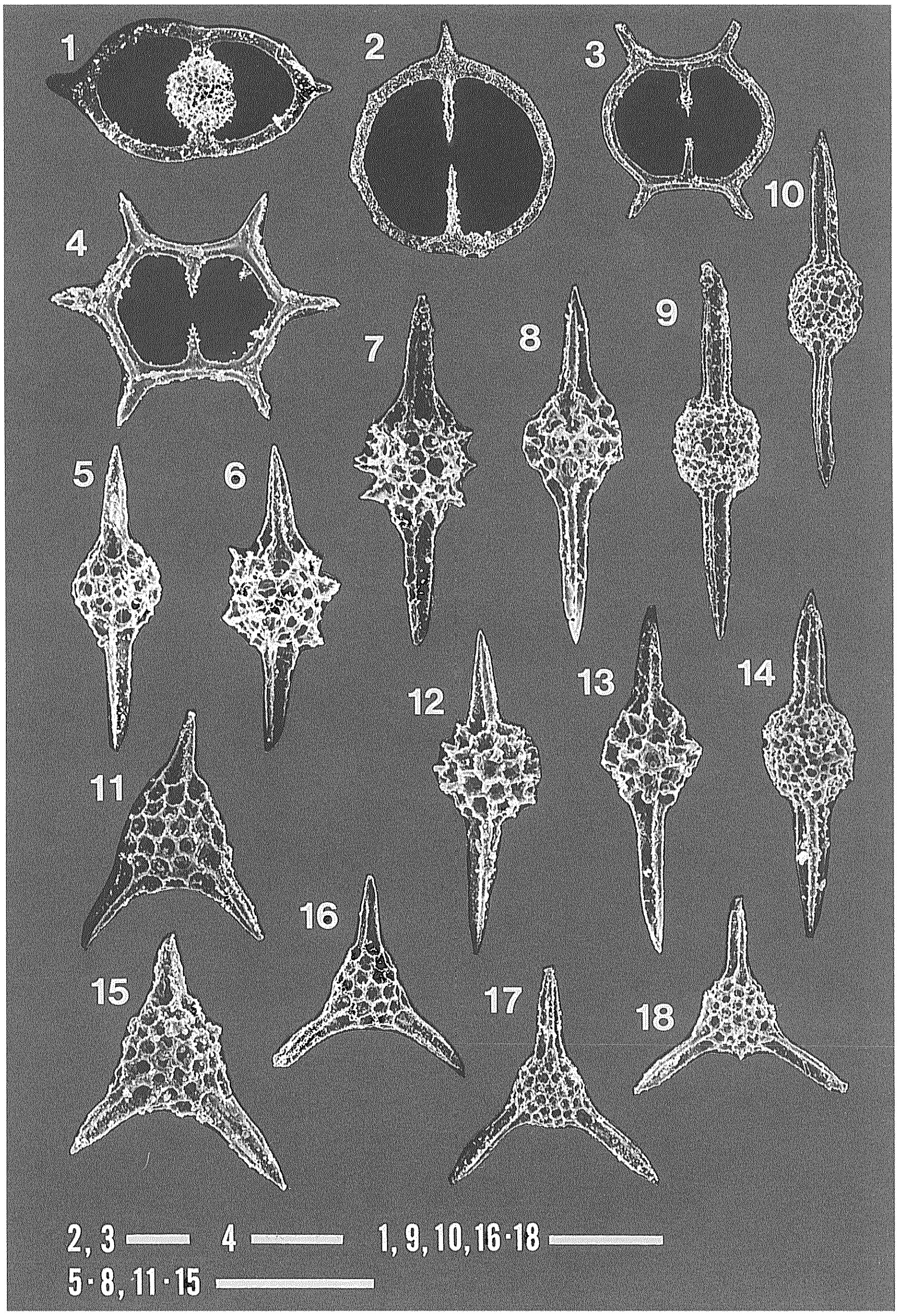


Plate 2 Jurassic radiolarians from manganese carbonate nodule in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1mm.

1. *Acanthocircus bispinus* (55693/1888)
2. *Acanthocircus* sp. (55747/1888)
3. *Hexasaturnalis tetraspinus* (55720/1888)
4. *Hexasaturnalis hexagonus* (55037/1888)
5. *Pantanellium* sp. (55150/1888)
6. *Pantanellium* sp. (55125/1888)
7. *Pantanellium* sp. (55195/1888)
8. *Trillus elkhornensis* (55684/1888)
9. *Archaeospongoprunum* sp. (55751/1888)
10. *Archaeospongoprunum* sp. (55038/1888)
11. *Gorgansium* sp. (55030/1888)
12. *Pantanellium* sp. (55690/1888)
13. *Trillus elkhornensis* (55067/1888)
14. *Archaeospongoprunum* sp. (55755/1888)
15. *Gorgansium* sp. (55759/1888)
16. *Gorgansium* sp. B (55160/1888)
17. *Gorgansium* sp. B (55760/1888)
18. *Gorgansium* sp. B (55758/1888)

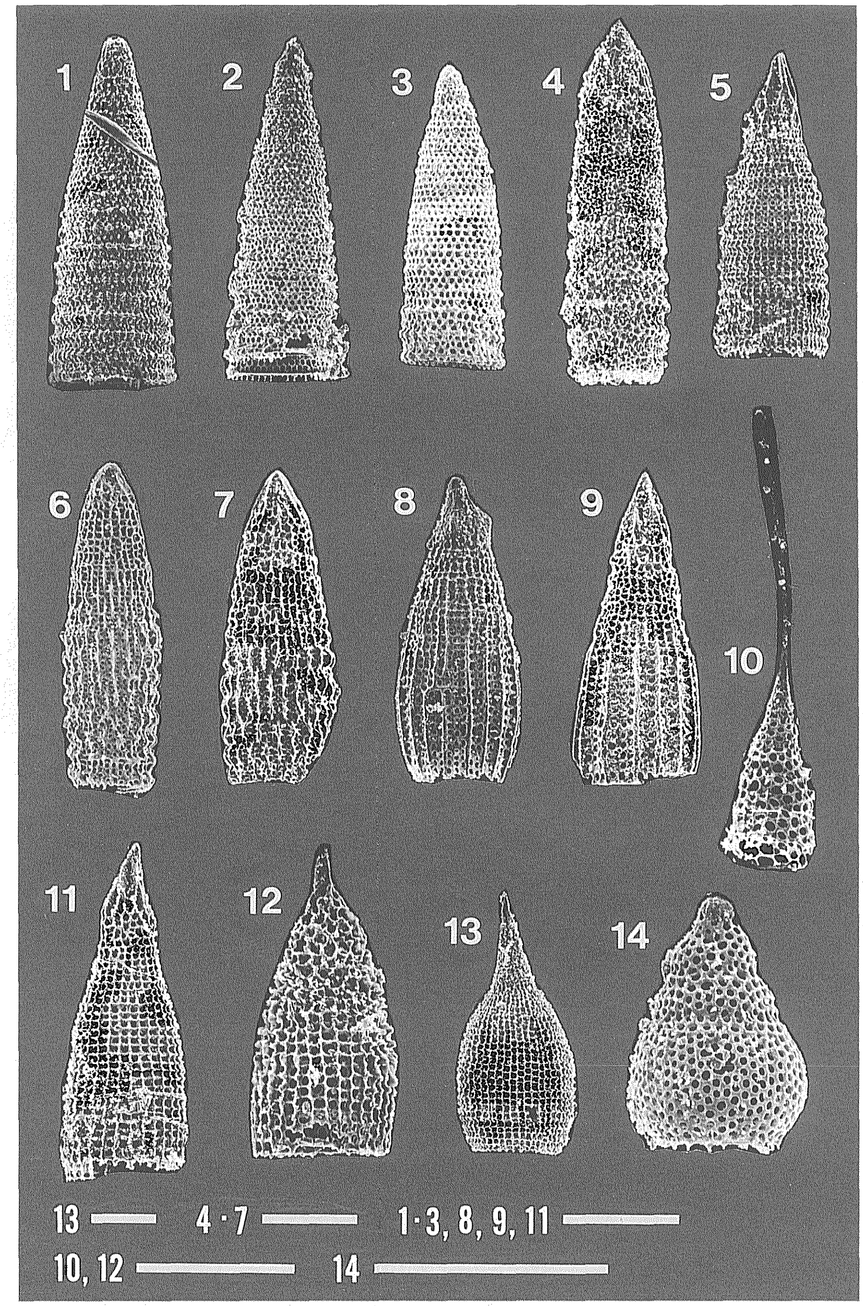


Plate 3 Jurassic radiolarians from manganese carbonate nodule in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar=0.1mm.

1. *Parvicingula* sp. (55238/1888)
2. *Parvicingula* sp. (55761/1888)
3. *Parvicingula* sp. (55123/1888)
4. *Laxtorum* (?) *jurassicum* (55700/1888)
5. *Elodium* sp. aff. *E. cameroni* (55732/1888)
6. *Transhsuum hisuikyoense* (55665/1888)
7. *Transhsuum hisuikyoense* (55180/1888)
8. *Hsuum matsuokai* (55719/1888)
9. *Hsuum matsuokai* (55165/1888)
10. Nassellaria gen. et sp. indet. (55087/1888)
11. *Parahsuum* sp. aff. *P. cruciferum* (55680/1888)
12. *Parahsuum* sp. (55033/1888)
13. *Parahsuum* sp. (55762/1888)
14. Nassellaria gen. et sp. indet. (55034/1888)

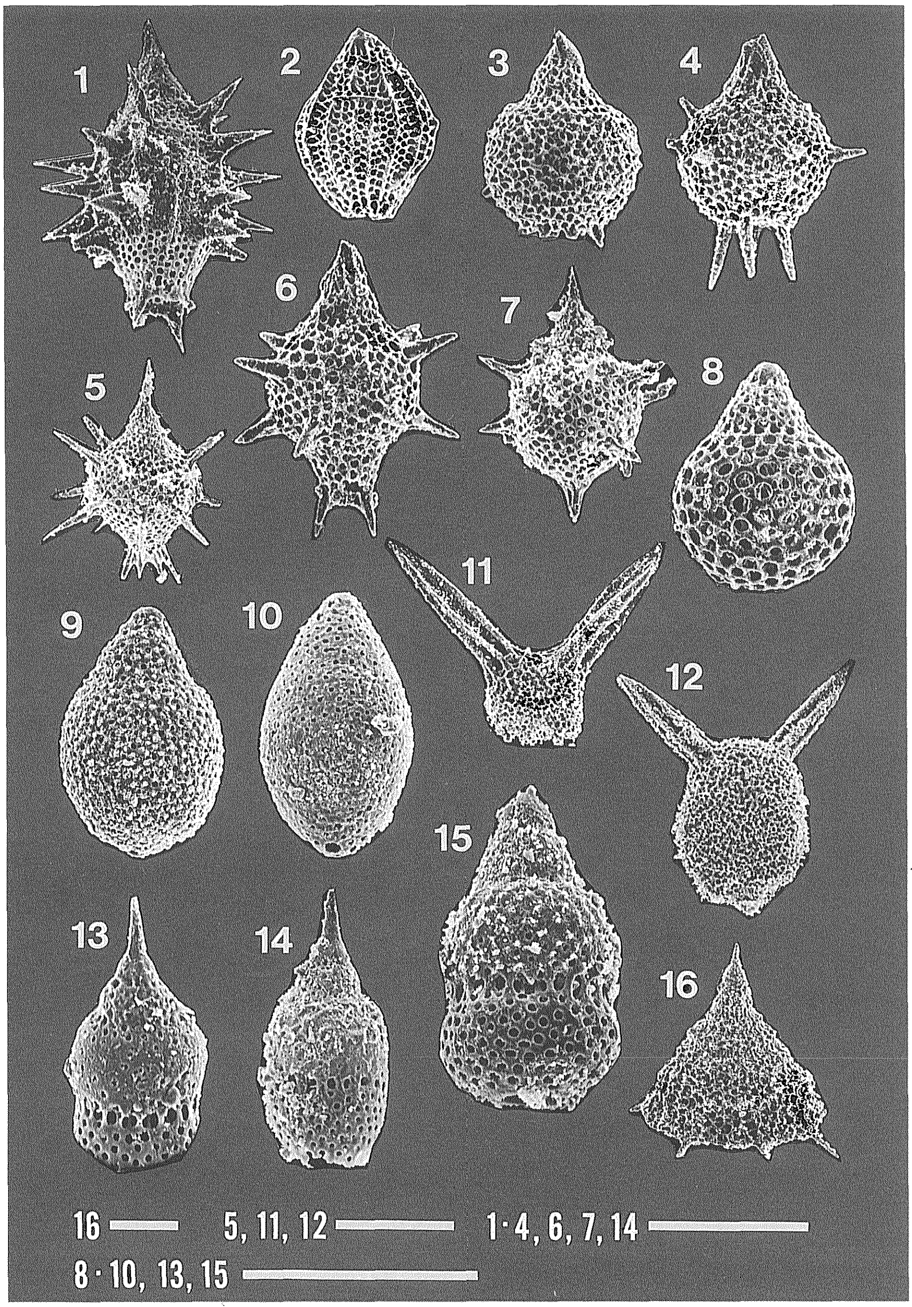


Plate 4 Jurassic radiolarians from manganese carbonate nodule in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Unuma echinatus* (55749/1888)
2. *Unuma* sp. (55117/1888)
3. Nassellaria gen. et sp. indet. (55234/1888)
4. *Arcanicapsa* sp. (55207/1888)
5. *Yamatoum komamiensis* (55675/1888)
6. *Yamatoum komamiensis* (55217/1888)
7. *Yamatoum* sp. (55107/1888)
8. *Tricolocapsa* (?) sp. (55145/1888)
9. *Stichocapsa* (?) sp. (55184/1888)
10. *Stichocapsa biconica* (55708/1888)
11. *Bernoullius* sp. (55691/1888)
12. *Bernoullius* sp. (55737/1888)
13. *Eucyrtidiellum disparile* (54996/1888)
14. *Eucyrtidiellum disparile* (55728/1888)
15. *Eucyrtidiellum* (?) *quinatum* (55004/1888)
16. *Andromeda* sp. (55738/1888)

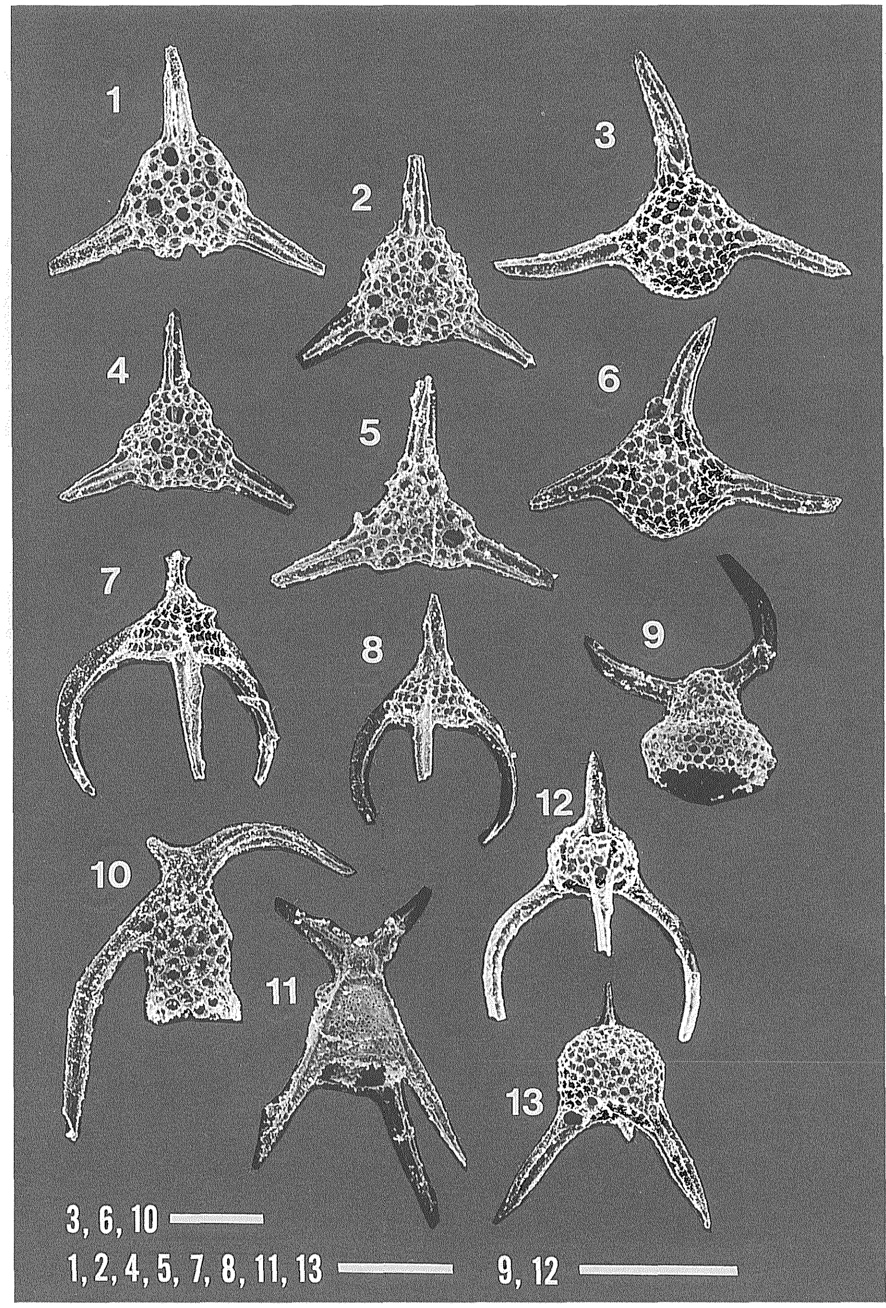


Plate 5 Jurassic radiolarians from manganese carbonate nodule in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Perispyridium* sp. cf. *P. tamarackense* (55223/1888)
2. *Perispyridium* sp. cf. *P. tamarackense* (55742/1888)
3. *Turanta* sp. A (55096/1888)
4. *Perispyridium* sp. (55736/1888)
5. *Perispyridium* sp. (55735/1888)
6. *Turanta* sp. A (55103/1888)
7. *Napora latissima* (55167/1888)
8. *Napora* sp. (55671/1888)
9. Nassellaria gen. et sp. indet. (55757/1888)
10. *Parares* sp. (55741/1888)
11. *Hilarisirex* sp. (55725/1888)
12. *Saitoum* sp. (55216/1888)
13. *Saitoum* sp. (55651/1889)

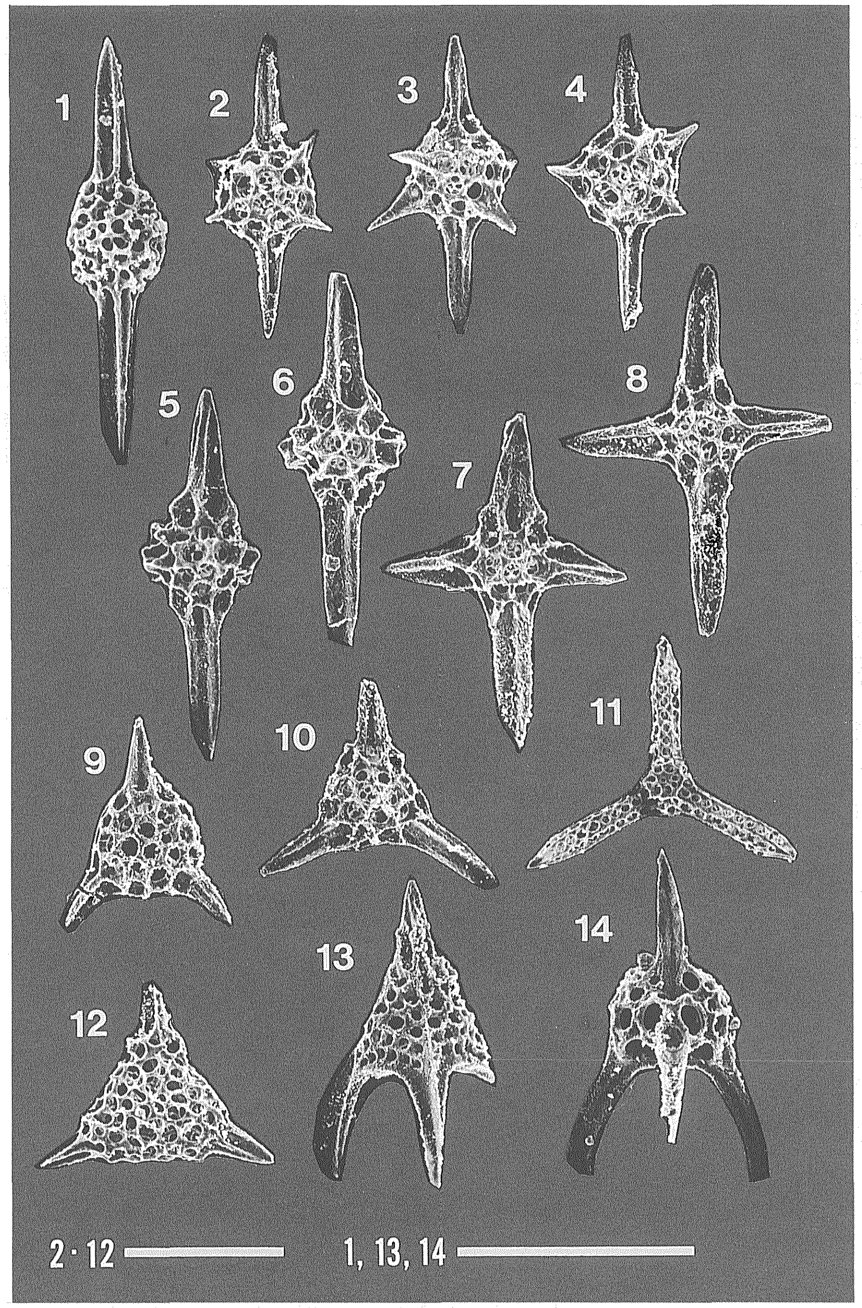


Plate 6 Jurassic radiolarians from manganese carbonate nodule in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Archaeospongoprunum* sp. (54761/1885)
2. *Pantanellium* (?) sp. A (54699/1885)
3. *Pantanellium* (?) sp. A (54830/1886)
4. *Pantanellium* (?) sp. A (54745/1885)
5. *Trillus* sp. (54783/1886)
6. *Trillus* sp. (54836/1886)
7. *Zartus dickinsoni* group (54833/1886)
8. *Zartus dickinsoni* group (54776/1886)
9. *Gorgansium* sp. A (54756/1885)
10. *Gorgansium morganense* (54827/1886)
11. Hagiastrid gen. et sp. indet. (54668/1885)
12. *Perispyridium* sp. (54632/1885)
13. *Napora* sp. cf. *N. pyramidalis* (54576/1885)
14. Nassellaria gen. et sp. indet. (54716/1885)

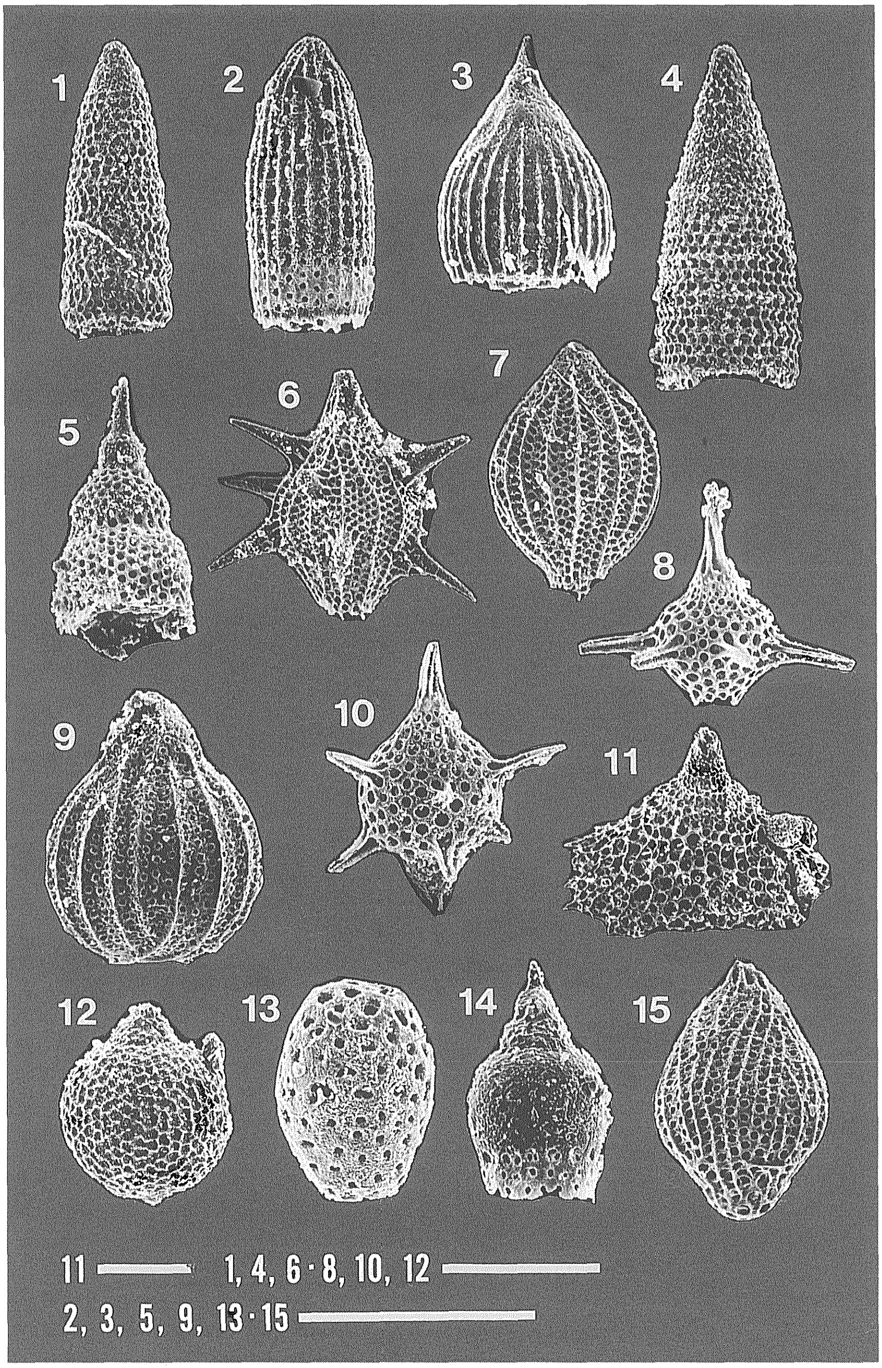


Plate 7 Jurassic radiolarians from manganese carbonate nodule in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Dictyomitrella* (?) *kamoensis* (54784/1886)
2. *Archaeodictyomitra* sp. (54570/1885)
3. Nassellaria gen. et sp. indet. (54725/1885)
4. *Parvicingula* sp. (54703/1885)
5. Nassellaria gen. et sp. indet. (54645/1885)
6. *Unuma echinatus* (54813/1886)
7. *Unuma* sp. (54793/1886)
8. *Yamatoum* sp. cf. *Y. connicinum* (54749/1885)
9. *Unuma* sp. A (54680/1885)
10. *Yamatoum spinosum* (54718/1885)
11. *Andromeda* sp. (54799/1886)
12. *Tricolocapsa* sp. cf. *T. ruesti* (54788/1886)
13. *Archicapsa pachyderma* (54642/1885)
14. *Eucyrtidiellum unumaense* (54835/1886)
15. *Tricolocapsa* sp. aff. *T. plicarum* (54822/1886)

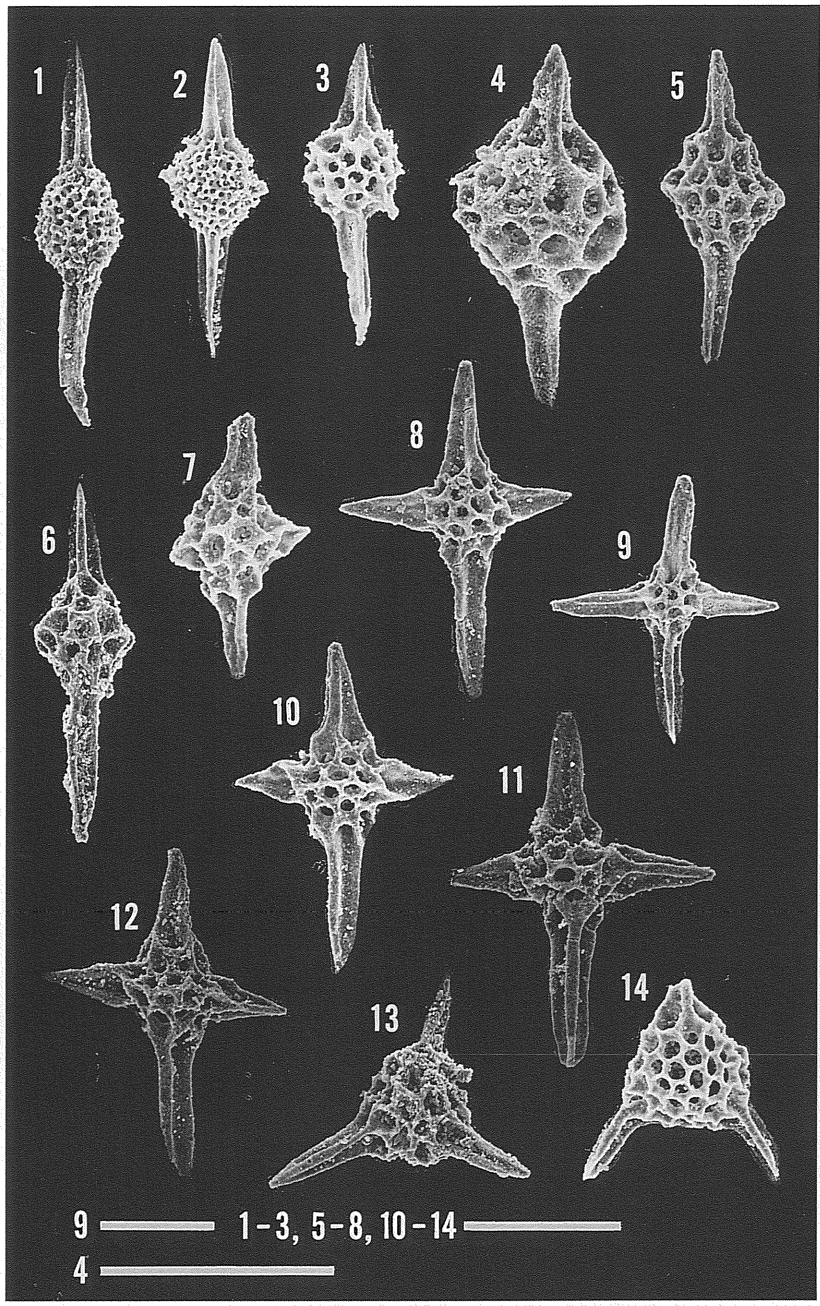


Plate 8 Jurassic radiolarians from siliceous shale in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Archaeospongoprunum* sp. (49086/1702)
2. *Archaeospongoprunum* sp. (49199/1703)
3. *Pantanellium* sp. (49705/1706)
4. *Pantanellium* sp. (49296/1704)
5. *Trillus* sp. cf. *T. elkhornensis* (49573/1704)
6. *Trillus* sp. (49166/1703)
7. *Zartus* sp. (49347/1704)
8. *Zartus dickinsoni* group (49157/1703)
9. *Zartus* sp. (49658/1706)
10. *Zartus dickinsoni* group (49708/1706)
11. *Zartus dickinsoni* group (49626/1706)
12. *Zartus dickinsoni* group (49745/1706)
13. *Gorgansium morganense* (49009/1702)
14. *Gorgansium* sp. A (49334/1704)

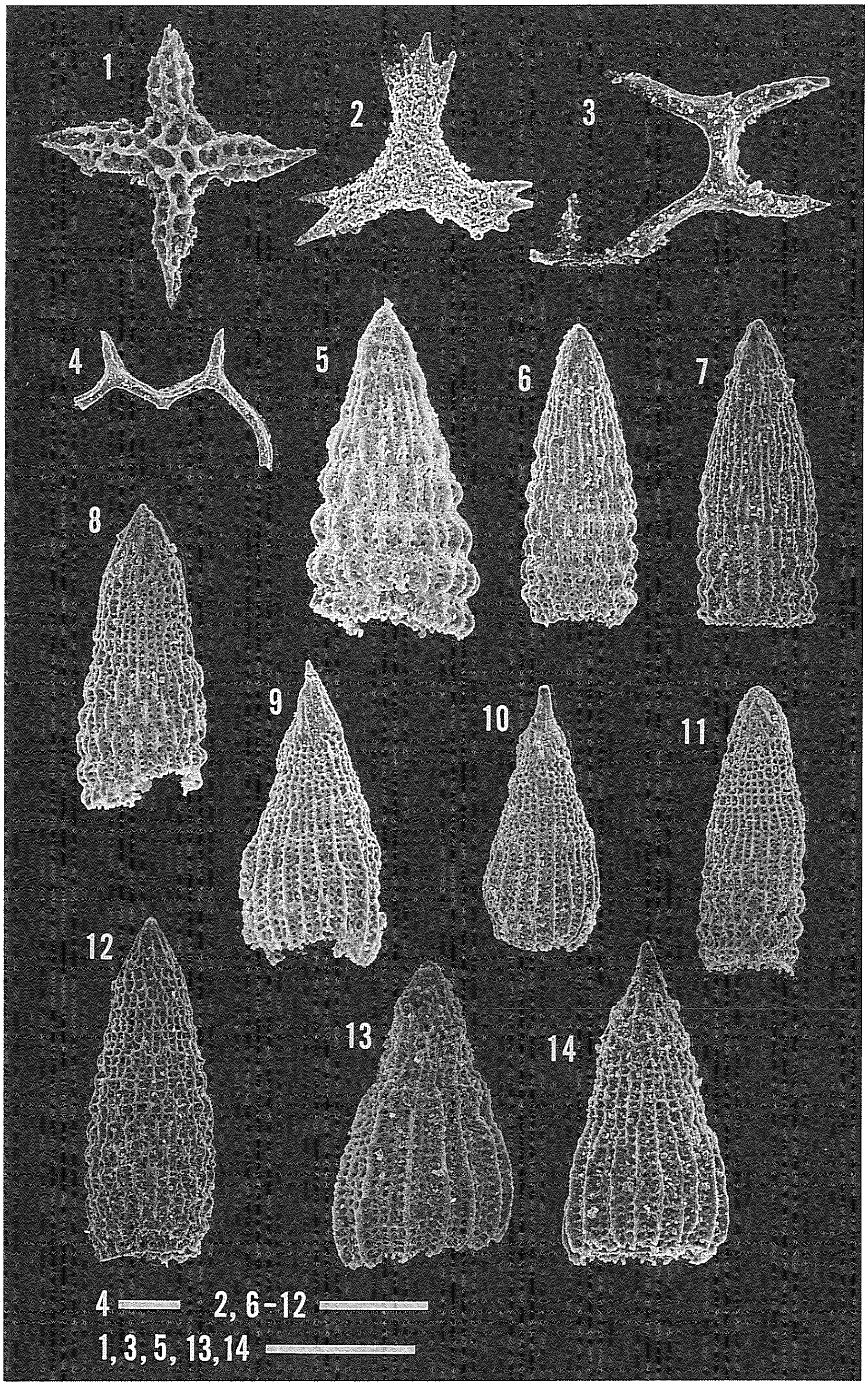


Plate 9 Jurassic radiolarians from siliceous shale in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Higumastra* sp. (49076/1702)
2. *Paronaella* sp. (49120/1703)
3. *Acanthocircus* sp. cf. *A. suboblongus* (49231/1703)
4. *Hexasaturnalis* sp. cf. *H. tetraspinus* (49100/1703)
5. *Hsuum* sp. (49729/1706)
6. *Hsuum* sp. (49200/1703)
7. *Hsuum* sp. (49101/1703)
8. *Transhsuum hisuikyoense* (49561/1704)
9. *Hsuum matsuokai* (49321/1704)
10. *Hsuum matsuokai* (49264/1704)
11. *Transhsuum hisuikyoense* (49265/1704)
12. *Transhsuum* sp. cf. *T. hisuikyoense* (56311/1916)
13. *Hsuum* sp. cf. *H. matsuokai* (56302/1916)
14. *Hsuum matsuokai* (56360/1916)

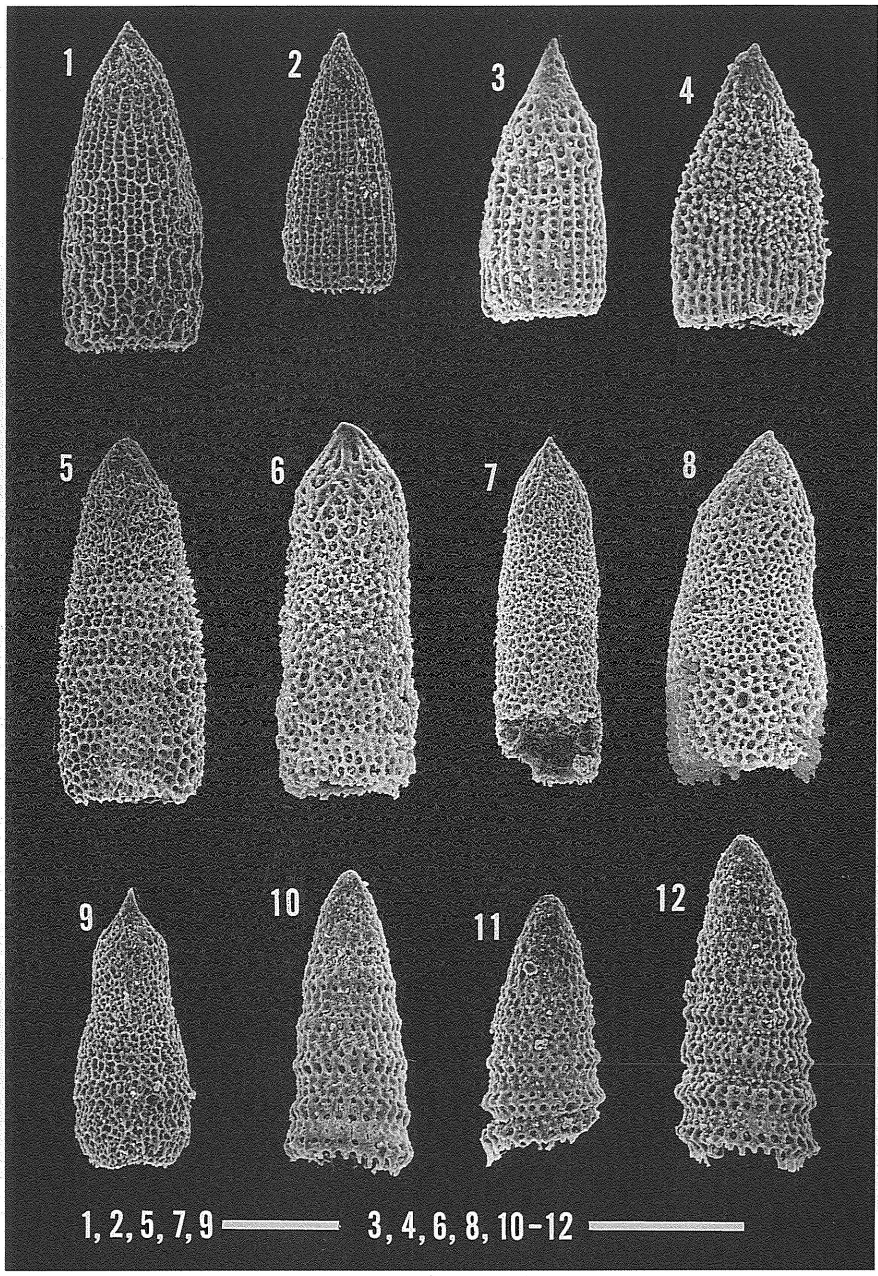


Plate 10 Jurassic radiolarians from siliceous shale in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Parahsuum* sp. (56305/1916)
2. *Parahsuum* sp. (56298/1916)
3. *Parahsuum* sp. (49360/1704)
4. *Parahsuum* (?) sp. (49230/1703)
5. *Laxtorum* (?) sp. aff. *L.* (?) *jurassicum* (49246/1703)
6. *Laxtorum* (?) *jurassicum* (49350/1704)
7. *Laxtorum* (?) *jurassicum* (49315/1704)
8. *Laxtorum* (?) sp. cf. *L.* (?) *hichisoense* (49330/1704)
9. *Laxtorum* (?) sp. cf. *L.* (?) *jurassicum* (56346/1916)
10. *Dictyomitrella* (?) *kamoensis* (49624/1706)
11. *Dictyomitrella* (?) *kamoensis* (49229/1703)
12. *Dictyomitrella* (?) sp. aff. *D.* (?) *kamoensis* (49126/1703)

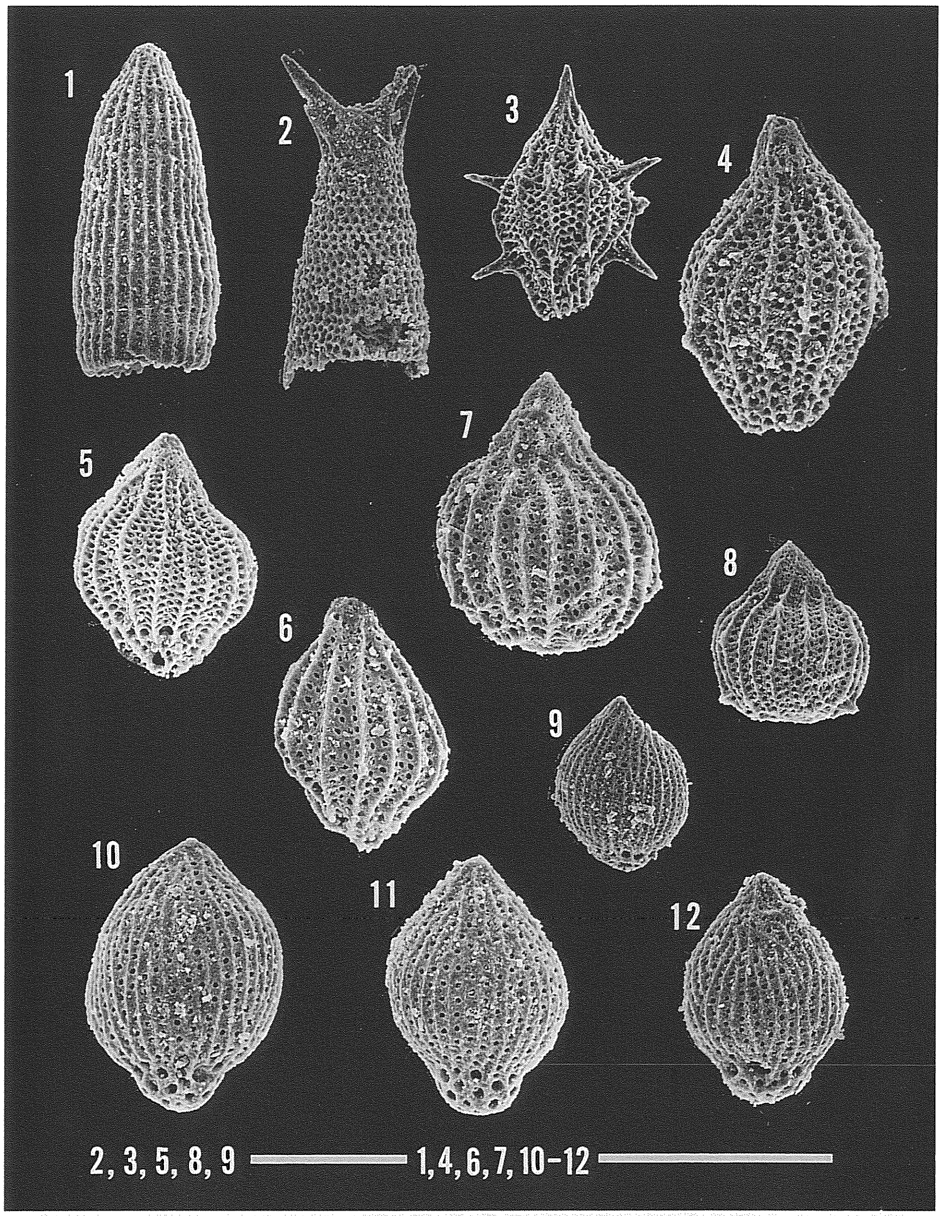


Plate 11 Jurassic radiolarians from siliceous shale in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Archaeodictyomitra* sp. (49198/1703)
2. *Hsuum* (?) sp. (56300/1916)
3. *Unuma echinatus* (49689/1706)
4. *Unuma* sp. (49327/1704)
5. *Unuma* sp. (49665/1706)
6. *Unuma* sp. (49648/1706)
7. *Unuma* sp. A (49734/1706)
8. *Unuma* sp. A (49108/1703)
9. *Tricolocapsa* sp. cf. *T. plicarum* (49061/1702)
10. *Tricolocapsa* sp. aff. *T. plicarum* (49728/1706)
11. *Tricolocapsa* sp. aff. *T. plicarum* (49722/1706)
12. *Tricolocapsa* sp. aff. *T. plicarum* (49069/1702)

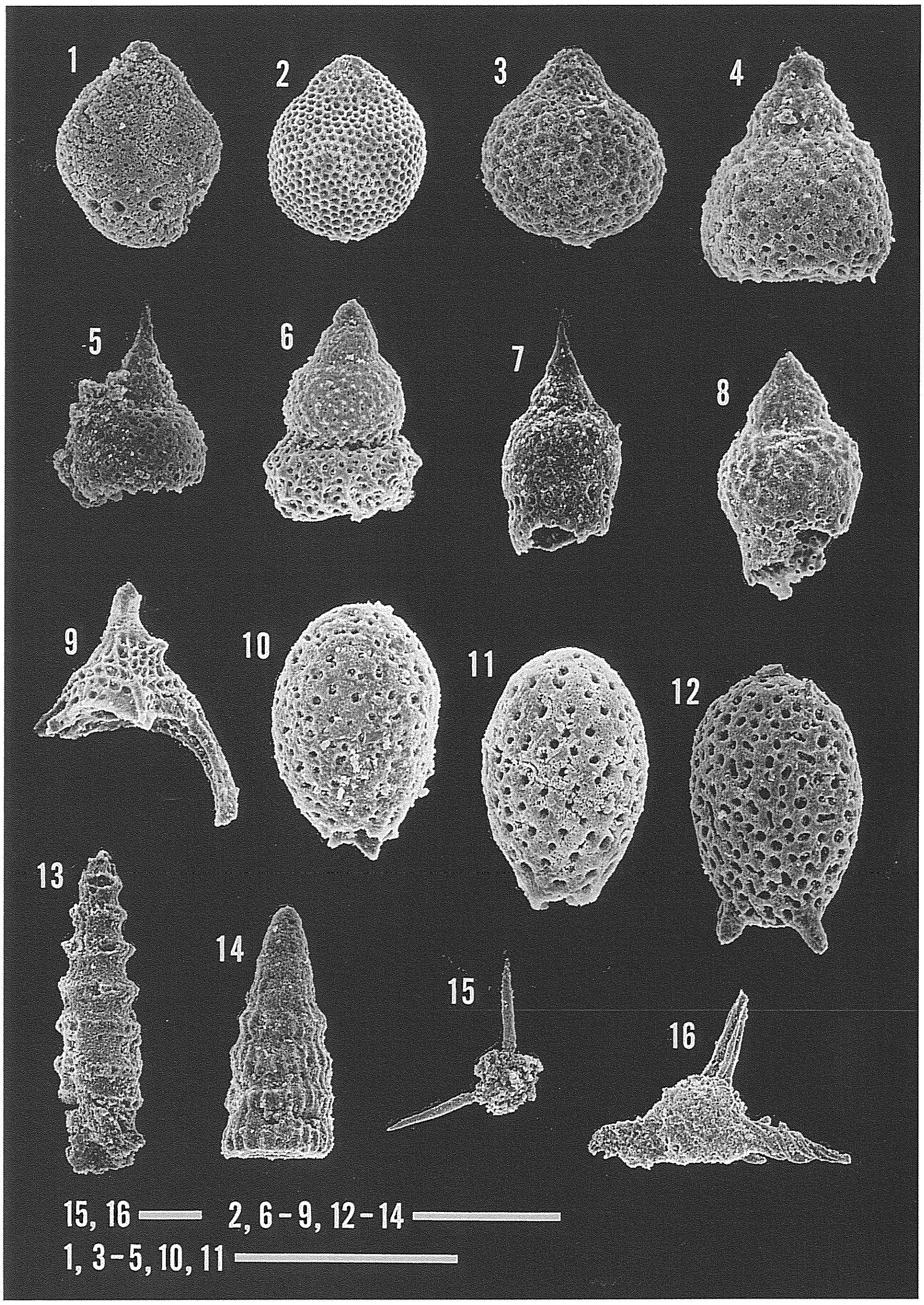


Plate 12 Jurassic radiolarians from siliceous shale and Triassic radiolarians from chert in the Tokuyama area. For the numbers in the parentheses, see explanations in the text. Scale bar = 0.1 mm.

1. *Tricolocapsa* (?) sp. cf. *T.* (?) *fusiformis* (49048/1702)
2. *Tricolocapsa* (?) sp. (49114/1703)
3. *Tricolocapsa* sp. cf. *T. ruesti* (49362/1704)
4. *Eucyrtidiellum disparile* (49588/1704)
5. *Eucyrtidiellum disparile* (49267/1704)
6. *Eucyrtidiellum* sp. cf. *E. quinatum* (49317/1704)
7. *Eucyrtidiellum* sp. (49307/1704)
8. *Eucyrtidiellum* (?) sp. cf. *E.* (?) *pustulatum* (49644/1706)
9. *Napora* sp. (49590/1704)
10. *Archicapsa pachyderma* (49339/1704)
11. *Archicapsa pachyderma* (49184/1703)
12. *Archicapsa* sp. (49253/1704)
13. *Triassocampe* sp. (50439/1705)
14. *Corum regium* (50428/1705)
15. *Capnodoce* sp. cf. *C. sarisa* (50438/1705)
16. *Tritortis* sp. (50431/1705)