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Jurassic, Triassic and Permian radiolarians from the Hirayu complex of the Mino Belt in the Nyukawa-Hirayu area, Gifu Prefecture, central Japan

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ABSTRACT

This study is focused on radiolarians from the Hirayu complex in the Nyukawa-Hirayu area, central Japan. The Hirayu Complex, which is a part of the Jurassic accretionary complex of the Mino Belt, is characterized by a melange including clasts of sandstone, felsic tuff, siliceous mudstone, red mudstone, chert, limestone and mafic volcanic rocks in a matrix of black mudstone and gray siltstone. Newly obtained radiolarians from this area constrain the age of black mudstone, gray siltstone, felsic tuff, siliceous mudstone and red mudstone as follows: black mudstone is Bajocian to Callovian, gray siltstone is Bajocian, felsic tuff is late Pliensbachian to Bajocian, siliceous mudstone is late Pliensbachian to early Aalenian and red mudstone is Toarcian in age. Radiolarians from chert in this study indicate Permian to Early Triassic, early Anisian of Middle Triassic and middle Sinemurian to early Aalenian of Jurassic in age. The radiolarians clearly show that the clasts of siliceous mudstone, red mudstone and chert are older in age than the melange matrix.

INTRODUCTION

The Mino Belt in central Japan is underlain mainly by accretionary complexes of Jurassic to Early Cretaceous age (e.g. Otsuka, 1988; Wakita, 1988). Detailed mapping and radiolarian biostratigraphic study have advanced our understanding of the structure and age of the accretionary complexes. In particular, radiolarian age of trench-fill terrigenous sedimentary rocks is important to make the regional correlation of the accretionary complexes, because it is available to determine the age of accretion (e.g. Nakae, 2000a). However, there is little agreement on the regional correlation of the complexes in the Mino Belt because detailed structure and age in some areas have not been revealed precisely (e.g. Nakae, 2000b; Yamakita and Otoh, 2000).

The Nyukawa-Hirayu area is situated in about 130 km north of Nagoya, central Japan (Fig. 1a). The rocks of the Hirayu Complex (Otsuka, 1988) which is a part of the Mino Belt crop out in this area. Although some radiolarians have been reported from the Hirayu Complex since 1980's (Kojima, 1982, 1984; Sashida et al., 1982; Adachi

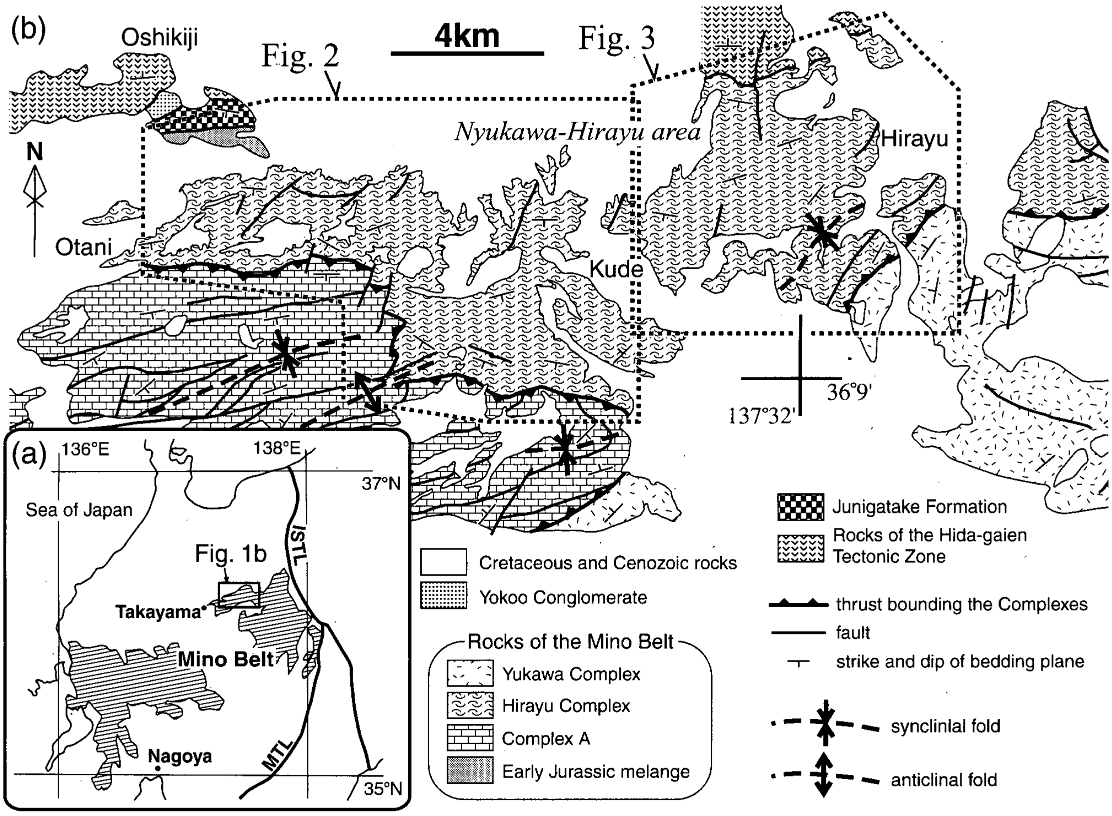

Fig. 1 (a) Index map showing the Mino Belt and (b) simplified geological map in the study area. The longitude and latitude correspond to the World Geodesic Datum. MTL: Median Tectonic Line, ISTL: Itoigawa-Shizuoka Tectonic Line.

and Kojima, 1983; Otsuka, 1988; Harayama, 1990; Imazato and Otoh, 1993), the age data are still not enough to clarify the correlation of the Hirayu Complex.

In order to improve the accuracy of the age data of the Hirayu Complex, radiolarian study is made for the Nyukawa-Hirayu area. This paper reports newly obtained radiolarians from the Hirayu Complex, and discusses the age of the radiolarian-bearing rocks.

GEOLOGICAL SETTING OF THE NYUKAWA-HIRAYU AREA

Paleozoic-Mesozoic rocks in the Nyukawa-Hirayu area are largely distributed in the Hida-gaien Tectonic Zone and the Mino Belt (Fig. 1b). The rocks of the Hida-gaien Tectonic Zone in this area are comprised mainly of Paleozoic shelf facies rocks (e.g. Wakita et al., 2001), and lies in fault contact with the rocks of the Mino Belt. The rocks of the Mino Belt in this area are comprised of the Early and Middle Jurassic accretionary complexes. The Middle Jurassic accretionary complexes are divided into the Complex A, Yukawa Complex and Hirayu Complex.

The Complex A consists of an imbricate stack of thrust slabs composed of Middle Jurassic clastic rocks, Permian-Triassic chert, Permian limestone and mafic volcanic rocks. The Complex A includes the Kohachigagawa Formation, Gombo Formation and

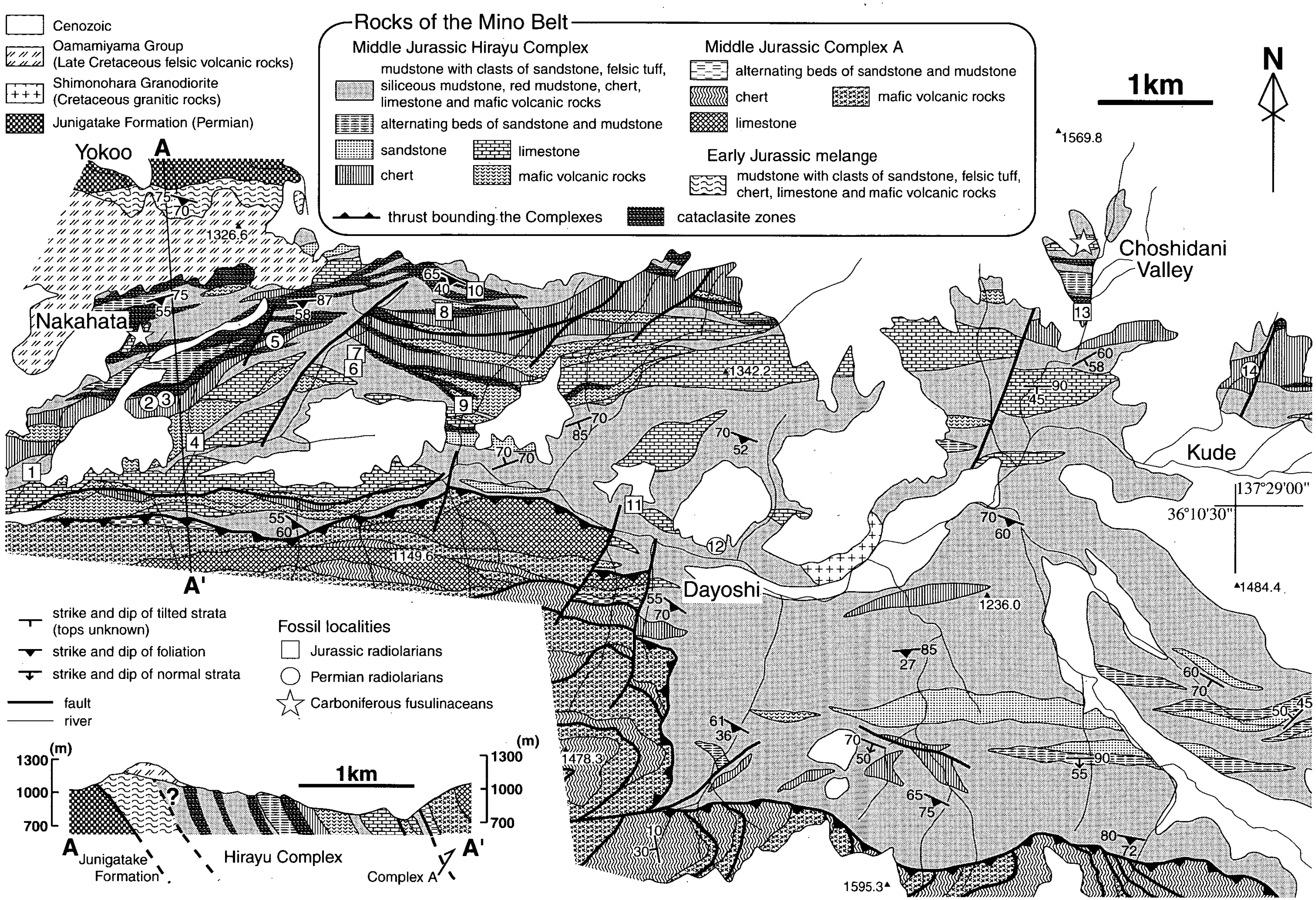

Fig. 2 Geological map and profile in the western part of the Nyukawa-Hirayu area with fossil localities. The mapped area is shown in Fig. 1.

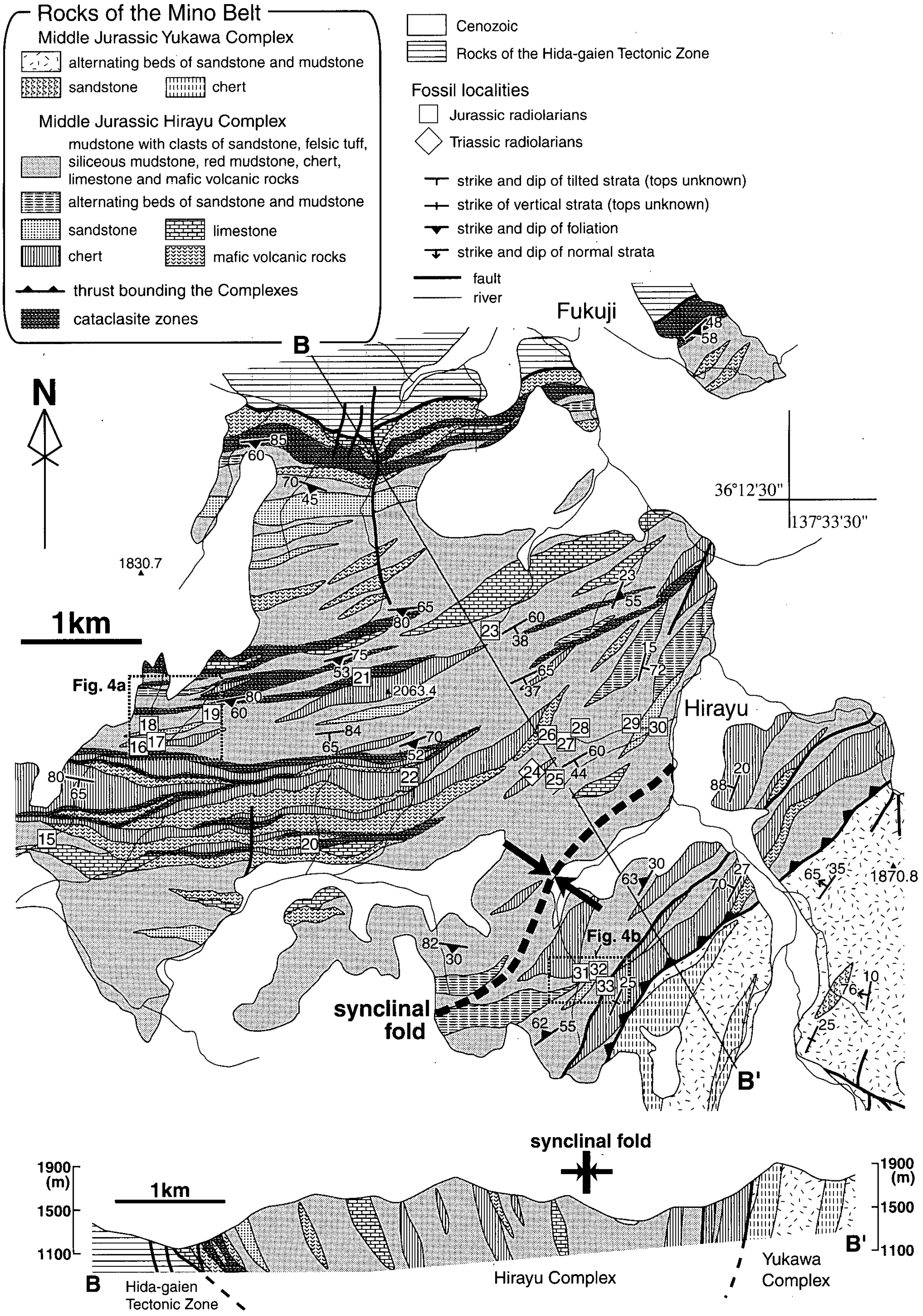

Fig. 3 Geological map and profile in the eastern part of the Nyukawa-Hirayu area with fossil localities. The mapped area is shown in Fig. 1.

undivided Paleozoic-Mesozoic strata defined by Yamada et al. (1985). The Yukawa Complex consists of an imbricate stack of coherent beds composed of Middle Jurassic mudstone, sandstone, felsic tuff and Lower Jurassic chert (Otsuka, 1988). The Complex A is thrust over the Hirayu and Yukawa Complexes, and the Hirayu Complex is thrust over the Yukawa Complex.

The Early Jurassic accretionary complex which is located at the northwestern marginal part of the Nyukawa-Hirayu area (Figs. 1b and 2) is a melange including clasts of sandstone, felsic tuff, siliceous mudstone, chert and mafic volcanic rocks in a scaly foliated mudstone matrix (Niwa et al., 2002a, b). Relationship between the Early Jurassic melange and the Middle Jurassic Hirayu Complex is unknown because the Late Cretaceous to Cenozoic rocks cover the boundary. The Early Jurassic melange lies in fault contact with the Permian Junigatake Formation, which is made up largely of alternating beds of sandstone and mudstone with felsic tuff intercalations.

The Hirayu Complex which is focused in this paper was defined as the Middle Jurassic melange including clasts of sandstone, radiolarian-bearing siliceous mudstone, chert, limestone and mafic volcanic rocks in a pelitic matrix (Otsuka, 1988). The Dayoshi Formation, which consists of pelitic rocks including clasts of sandstone, chert, limestone and mafic volcanic rocks (Yamada et al., 1985), is interpreted as a part of the Hirayu Complex (Otsuka, 1988).

On the basis of our field survey, the Hirayu Complex is characterized by a melange including clasts of sandstone, alternating beds of sandstone and mudstone, green felsic tuff, brownish siliceous mudstone, red mudstone, chert, Toishi-type siliceous claystone (Imoto, 1984), limestone and mafic volcanic rocks (Figs. 2 and 3) in a matrix of black mudstone and gray siltstone. The clasts are lenticular or oval in shape, and their major axes range from mm to km. The foliation defined by an alignment of scaly cleavage is developed in the matrix of black mudstone. It generally strikes east to northeast and dips south, whereas it dips steeply north in the southeastern part of the Nyukawa-Hirayu area. Clasts are aligned subparallel to the foliation. The bedding planes of alternating beds of sandstone and mudstone, felsic tuff, siliceous mudstone, red mudstone, chert, siliceous claystone and limestone are subparallel to the foliation. The rocks of the Hirayu Complex are folded with a northeast-trending axis plane in the southeastern part of the Nyukawa-Hirayu area (Figs. 1b and 3).

Shear zones run in the northern part of the Hirayu Complex (Figs. 2 and 3). The shear zones are characterized by the elongation of clasts and the development of closely spaced cleavage in the muddy matrix. The sheared rocks consist of protocataclasite to ultracataclasite. Sasaki et al. (2001) named the shear zones "cataclasite zones." The cataclasite zones trend east to northeast. Width of the cataclasite zones ranges from several tens to hundreds meters.

Kojima (1982, 1984), Sashida et al. (1982), Adachi and Kojima (1983), Otsuka (1988), Harayama (1990) and Imazato and Otoh (1993) reported Permian to Jurassic radiolarians from the component rocks of the Hirayu Complex. According to the previous works, age of the melange matrix is middle to late Middle Jurassic (Adachi and Kojima, 1983; Kojima, 1984; Imazato and Otoh, 1993). Ages of the chert clasts range from Permian to Triassic (Kojima, 1982, 1984; Adachi and Kojima, 1983). In addition, Imazato and Otoh (1993) reported the clasts of chert breccia including early Middle Jurassic radiolarians. Limestone clasts yield Late Carboniferous to Middle Permian fusulinoideans (e.g. Isomi and Nozawa, 1957; Igo, 1964, 1965; Kojima, 1984) and Middle Permian brachiopods (Tazawa, 1997). Late Carboniferous fusulinoideans were obtained from two lenticular limestone clasts at the Nakahata (Loc. 3 of Isomi and Nozawa, 1957) and the Choshidani Valley (this study; Fig. 2). Fusulinoideans from the Choshidani Valley include *Obsoletus obsoletus* (Schellwien), *Protriticites subschwagerinoides* Rozovskaya and *Triticites* sp. The Carboniferous limestone clasts are bounded by fault with the intensely foliated mudstone of the melange matrix.

DESCRIPTION OF RADIOLARIAN-BEARING ROCKS

Radiolarians are extracted from a melange matrix of black mudstone and gray siltstone, and clasts of green felsic tuff, brownish siliceous mudstone, red mudstone and chert in the Hirayu Complex of the Nyukawa-Hirayu area.

Black mudstone and gray siltstone in this area consist mainly of fine-grained clay minerals, biotite, muscovite, chlorite, quartz and opaque minerals. Scaly fabric defined by partings along aligned phyllosilicates is partly developed within the mudstone and siltstone. Black mudstone exhibits an intertonguing, transitional relationship with gray siltstone.

Green felsic tuff in this area occurs mostly as lenticular or irregular-shaped clasts in the melange matrix. In some places, green felsic tuff is bedded. The lenticular felsic tuff clasts are arranged subparallel to the foliation of the melange matrix. The bedded felsic tuff is in fault contact with bedded chert (Fig. 4). Green felsic tuff includes glassy fragments and plagioclase crystals. Major components of the felsic tuff are quartz crystals, opaque minerals, and secondary minerals of sericite, illite and chlorite. Most of the components are less than 0.05 mm in size except spherical aggregates of chlorite.

Brownish siliceous mudstone in this area lies in fault contact with bedded chert, and their bedding planes are subparallel to each other (Figs. 4a and 5). The siliceous mudstone includes radiolarian shells and grains of quartz, muscovite and opaque minerals in a fine-grained matrix of illite and quartz. Most of the grains are less than 0.04 mm in size.

Red mudstone in this area occurs mostly as lenticular clasts in the melange matrix. In some places, red mudstone is bedded. The bedded red mudstone occurs in close proximity to bedded chert and lies subparallel to the trend of the chert (Fig. 4a). Red mudstone includes rock fragments of chert and felsic tuff, and grains of quartz and opaque minerals in a fine-grained matrix of quartz, illite, biotite and chlorite. All the fragments and grains are less than 0.05 mm in size.

Chert in this area occurs as bedded chert, massive chert, or chert breccia. The bedded chert and chert breccia commonly yield radiolarians, whereas the massive chert contains scarce. Color of chert is gray, white, black, green or red. The bedded chert is composed of 2 to 15 cm thick siliceous layers and several mm to 2 cm thick muddy layers. The siliceous layers consist of quartz-filled moulds of radiolarians and a matrix of microquartz. The muddy layers consist of microquartz and clay minerals.

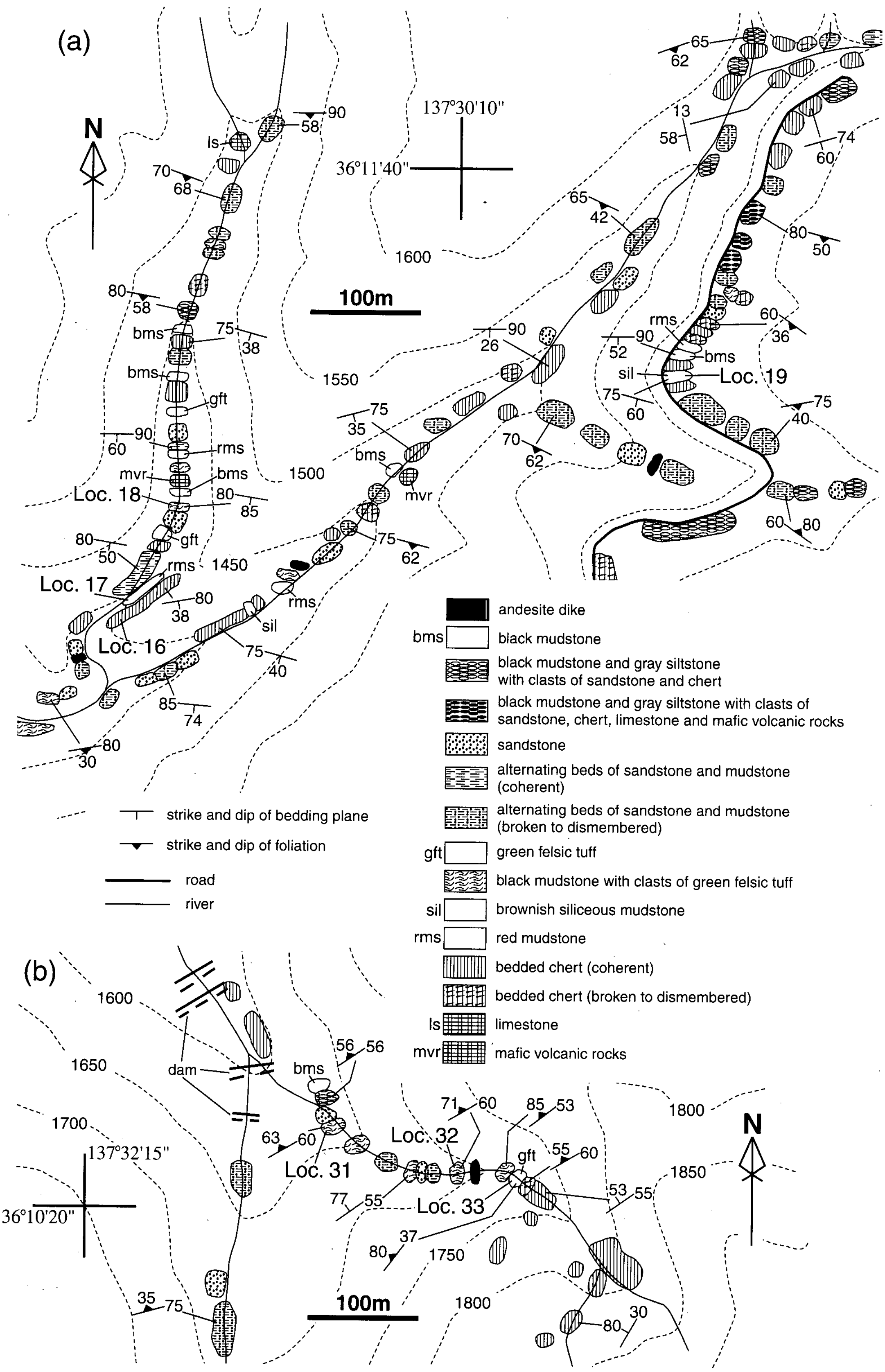

Fig. 4 Route maps in and around the fossil localities 16–19 (a) and 31–33 (b). The mapped areas are shown in Fig. 3.

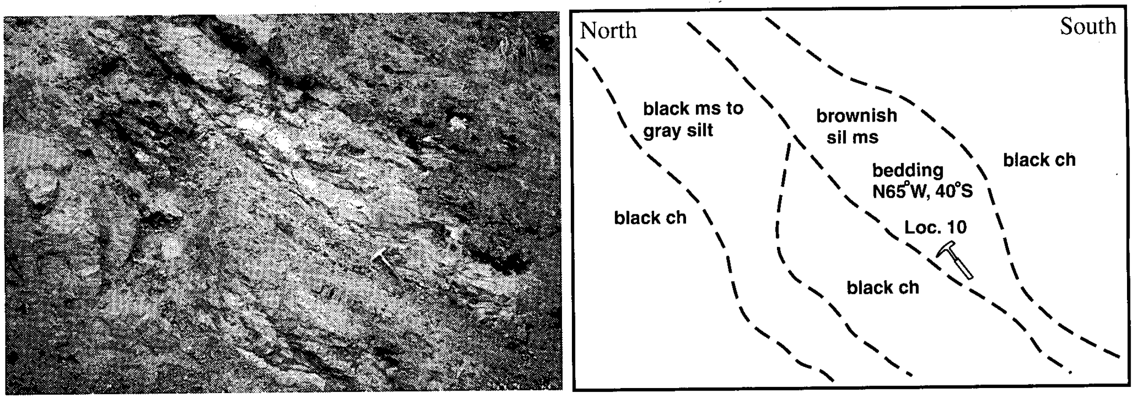

Fig. 5 Photograph and sketch showing the mode of occurrence of the rocks in and around the brownish siliceous mudstone of fossil locality 10. The brownish siliceous mudstone occurs in fault contact with black chert, black mudstone and gray siltstone. The locality is shown in Fig. 2. sil ms: siliceous mudstone, ms: mudstone, silt: siltstone, ch: chert.

Table 1. List of radiolarians from chert of the Hirayu Complex.

	JMP number	2808	2809	2815	2820	2801	2792	2799	2791
	radiolarian locality	2	3	5	12	14	16	22	24
Jurassic	*Bipedis* sp.							+	
	Canoptum (?) sp.						+		
	Eucyrtidiellum sp.						+	+	
	Hexasaturnalis hexagonus (Yao)							cf.	
	Pantanellium sp.						+	+	
	Parahsuum simplum Yao						+		
	Parahsuum transiens Hori and Yao							cf.	
	Parahsuum spp.						+	+	
	Parahsuum (?) sp. A						+		
	Parahsuum (?) sp.							+	
	Parvicingula gigantocornis Kishida and Hisada							cf.	
	Parvicingula sp.							+	
	Stichocapsa japonica Yao							+	
	Stichocapsa sp. aff. *S. whalenae* of Goričan, Šmuc and Baumgartner (2003)						+		
	Stichocapsa sp. A of Yeh and Cheng (1998)						+		
	Xiphostylus sp.						+		
Triassic	*Eptingium japonicum* (Nakaseko and Nishimura)								cf.
	Pseudostylosphaera tenuis (Nakaseko and Nishimura)								cf.
	Pseudostylosphaera sp. A of Sugiyama (1992)								+
	Pseudostylosphaera spp.								+
	Triassocampe coronata Bragin								+
	Triassocampe sp. aff. *T. diordinis* of Sugiyama (1992)								+
	Triassocampe myterocorys Sugiyama								cf.
	Triassocampe spp.								+
	Zevius sp.								+
Permian	*Entactinia* spp.	+	+	+	+				
	Follicucullus porrectus Rudenko		+						
	Follicucullus sp.		+			+			
	Ishigaum sp.		+						
	Pseudoalbaillella (?) sp.	+							
	Raciditor sp.	+							

Table 2. List of radiolarians from red mudstone (Loc. 17), siliceous mudstone (Locs. 10 and 19) and felsic tuff (Locs. 23 and 33) of the Hirayu Complex.

rock type	red mudstone	siliceous mudstone		felsic tuff	
JMP number	2797	2821	2796	2802	2837
radiolarian locality	17	10	19	23	33
Archaeodictyomitra sp.			+		+
Archaeospongoprunum sp.			+		
Archicapsa (?) *pachyderma* (Tan)		+		+	
Canoptum rugosum Pessagno and Poisson			+		
Dictyomitrella (?) sp. aff. *D. kamoensis* of Kobayashi (1998)			+		
Eucyrtidiellum disparile Nagai and Mizutani			+		+
Eucyrtidiellum sp.		+	+	+	+
Hexasaturnalis hexagonus (Yao)					+
Hexasaturnalis tetraspinus (Yao)					cf.
Hexasaturnalis sp.					+
Homoeoparonaella sp.			+		
Hsuum sp. X of Hori and Otsuka (1989)	cf.	+			
Hsuum sp.	+	+			
Pantanellium sp.			+		+
Parahsuum parvum Takemura			+	cf.	
Parahsuum spp.	+	+	+		+
Parahsuum (?) sp. B of Hori and Otsuka (1989)	cf.				
Parahsuum (?) sp. aff. *P.* (?) B of Hori and Otsuka (1989)		+			
Parvicingula nanoconica Hori and Otsuka		cf.			
Parvicingula sp.	+	+			
Saitoum sp.					+
Stichocapsa sp.		+	+		
Stypolarcus laboriosus Tan					cf.
Transhsuum sp.		+	+		
Tricolocapsa sp.	+	+		+	+
Trillus elkhornensis Pessagno and Blome					cf.
Trillus sp.	+		+		+
Unuma sp.				+	
Zartus sp.			+		
Nassellaria gen. et sp. indet A	+				
Nassellaria gen. et sp. indet B			+		

Table 3. List of radiolarians from gray siltstone (Loc. 13) and black mudstone of the Hirayu Complex. All samples except for gray siltstone of Loc. 13 are black mudstone.

JMP number	2816	2810	2811	2807	2794	2795	2813	2793	2800	2798	2786	2785	2784	2790	2788	2789	2787	2783	2824	2838
radiolarian locality	1	4	6	7	8	9	11	13	15	18	20	21	25	26	27	28	29	30	31	32
Archaeodictyomitra (?) *amabilis* Aita		+										+		+						
Archaeodictyomitra spelae Chiari, Cortese and Marcucci														cf.						
Archaeodictyomitra spp.		+	+			+	+	+		+	+	+	+	+		+	+		+	+
Archaeospongoprunum spp.	+												+			+				
Bistarkum sp.													+				+			
Cryptamphorella (?) *geodora* Cortese															cf.					
Cyrtocapsa mastoidea Yao	+											+								
Dictyomitrella (?) *kamoensis* Mizutani and Kido		+					cf.			cf.				+		+	+			cf.
Droltus (?) sp. of Kobayashi (1998; Plate 5-8)																				+
Eucyrtidiellum gujoensis (Takemura and Nakaseko)													+							
Eucyrtidiellum semifactum Nagai and Mizutani		+				+														+
Eucyrtidiellum unumaense (Yao)		+					+							+		+			+	+
Eucyrtidiellum sp. aff. *E. unumaense* of Nagai (1986)																			+	
Eucyrtidiellum sp.	+	+	+				+	+					+	+		+	+		+	+
Napora sp.																+				
Pachyoncus kamiasoensis Mizutani and Kido																cf.				
Pachyoncus sp.										+										
Pantanellium foveatum Mizutani and Kido			cf.																	
Pantanellium spp.	+		+							+			+			+			+	
Parahsuum sp.		+																		
Paronaella mulleri Pessagno													cf.							
Paronaella pygmaea Baumgartner													cf.							
Paronaella sp.										+	+		+							
Parvicingula cappa Cortese										+			+							
Parvicingula dhimenaensis Baumgartner	+	cf.						cf.					+	cf.	+		+			+
Parvicingula spp.	+	+	+				+	+		+		+	+	+	+	+	+	+		+
Protunuma fusiformis Ichikawa and Yao		cf.										cf.								
Protunuma (?) *ochiensis* Matsuoka														+						
Protunuma turbo Matsuoka														+						
Protunuma sp. B of Hull (1997)	+	+					+												+	
Protunuma sp.		+						+											+	+
Pterotrabs sp.										+										
Ristola decora Pessagno and Whalen																		cf.		
Saitoum sp.													+			+				
Sethocapsa kodrai Chiari, Marcucci and Prela																+				

Table 3 (continued)

JMP number	2816	2810	2811	2807	2794	2795	2813	2793	2800	2798	2786	2785	2784	2790	2788	2789	2787	2783	2824	2838
radiolarian locality	1	4	6	7	8	9	11	13	15	18	20	21	25	26	27	28	29	30	31	32
Sethocapsa funatoensis Aita		cf.							+											
Sethocapsa sp.	+							+												
Spongocapsula sp.							+													
Stichocapsa convexa Yao										+										
Stichocapsa himedaruma Aita						+														
Stichocapsa japonica Yao	+							+		+										+
Stichocapsa robusta Matsuoka		+															cf.			+
Stichocapsa sp. b of Kido et al. (1982)																				+
Stichocapsa sp. A		+																		+
Stichocapsa spp.		+	+				+	+						+		+				
Stichomitra (?) *takanoensis* Aita												+		+						
Transhsuum brevicostatum (Ozvoldova)														cf.		cf.				
Transhsuum maxwelli Pessagno	cf.	+														cf.	cf.			+
Transhsuum parasolense (Pessagno and Whalen)																cf.				
Transhsuum spp.		+	+				+	+		+		+	+	+	+	+	+		+	+
Tricolocapsa conexa Matsuoka														+						
Tricolocapsa formosa Chiari, Marcucci and Prela		+												+						
Tricolocapsa (?) *fusiformis* Yao								+		+			+			+	+			
Tricolocapsa (?) sp. aff. *T.* (?) *fusiformis* of Matsuoka (1983)		+					+					+		+		+			+	+
Tricolocapsa plicarum plicarum Yao	+									+			+							
Tricolocapsa plicarum ssp. A of Baumgartner et al. (1995)		+	+											+		+	+			
Tricolocapsa plicarum s.l. Yao			+					+		+			cf.			+				
Tricolocapsa tetragona Matsuoka	+		+											+	+					
Tricolocapsa spp.		+	+	+	+	+	+	+	+	+	+	+		+					+	+
Tritrabs sp.														+						
Unuma gorda Hull		cf.																		
Unuma latusicostatum (Aita)								cf.									cf.			
Unuma sp.							+						+			+				
Unuma (?) sp.																				+
Williriedellum carpathicum Dumitrica		+																		
Williriedellum (?) *marcuccii* Cortese	cf.			cf.								+								
Williriedellum sp.		+	+				+	+											+	
Nassellaria gen. et sp. indet C group			+					+					+			+	+			+
Nassellaria gen. et sp. indet D												+		+						

RADIOLARIAN ASSEMBLAGES AND THEIR AGES

Radiolarians were obtained from a melange matrix of black mudstone and gray siltstone, and clasts of green felsic tuff, brownish siliceous mudstone, red mudstone and bedded chert in the Hirayu Complex (Figs. 6–13, Tables 1–3). Radiolarian zones and their age assignments are based on Matsuoka (1983, 1995a) and Matsuoka and Yao (1986) for Jurassic (Fig. 14), Sugiyama (1992, 1997) for Triassic, Kuwahara et al. (1998) for Late Permian and Ishiga (1986) for Late Carboniferous to Middle Permian.

1. Radiolarians from chert

Radiolarians were obtained from bedded chert in 8 localities (Table 1). Six samples from Locs. 2, 3, 14, 16, 22 and 24 include radiolarians showing the detailed age, whereas two samples from Locs. 5 and 12 include *Entactinia* spp. ranging from Ordovician to Early Jurassic in age (De Wever et al., 2001).

Loc. 2: Gray bedded chert in this locality yields *Entactinia* sp. (Fig. 6.6), *Pseudoalbaillella* (?) sp. (Fig. 6.5) and *Raciditor* sp. (Fig. 6.10). *Pseudoalbaillella* indicates Late Carboniferous to Middle Permian age (Ishiga, 1986). *Raciditor* indicates Carboniferous? to Permian age (De Wever et al., 2001). Thus, the age of the chert in Loc. 2 is restricted during Late Carboniferous? to Middle Permian.

Loc. 3: Green bedded chert in this locality yields *Entactinia* sp., *Follicucullus porrectus* (Figs. 6.1–6.3), *Follicucullus* sp. and *Ishigaum* sp. (Fig. 6.9). *Follicucullus japonicus* Ishiga, which is a synonym of *Follicucullus porrectus* Rudenko, indicates late Middle to Late Permian age (Ishiga, 1991). Judging from the presence of *Follicucullus porrectus*, the age of the chert in Loc. 3 is restricted during late Middle to Late Permian.

Loc. 14: Green bedded chert in this locality yields *Follicucullus* sp. (Fig. 6.4). *Follicucullus* sp. indicates that the age of this sample is restricted during late Middle Permian to Early Triassic (Ishiga, 1986; Sugiyama, 1997).

Loc. 24: Gray bedded chert in this locality yields *Eptingium* sp. cf. *E. japonicum*, *Pseudostylosphaera* sp. cf. *P. tenuis*, *Pseudostylosphaera* sp. A of Sugiyama (1992), *Triassocampe coronata*, *Triassocampe* sp. aff. *T. diordinis* of Sugiyama (1992) and *Triassocampe* sp. cf. *T. myterocorys* (Figs. 6.11–6.22). Their co-occurrence suggests restriction of this sample to the *Triassocampe coronata* group Lowest-occurrence Zone assigned to early Anisian of Middle Triassic (Sugiyama, 1997).

Loc. 16: Green bedded chert in this locality yields *Canoptum* (?) sp. (Figs. 7.7 and 7.8), *Eucyrtidiellum* sp. (Fig. 7.4), *Parahsuum simplum* (Fig. 7.9), *Parahsuum* spp. (Figs. 7.11 and 7.12), *Parahsuum* (?) sp. A (Fig. 7.15), *Stichocapsa* sp. A of Yeh and Cheng (1998) (Figs. 7.18 and 7.19), *Stichocapsa* sp. aff. *S. whalenae* of Goričan, Šmuc and Baumgartner (2003) (Fig. 7.20) and *Xiphostylus* sp. (Fig. 7.3). *Parahsuum simplum* indicates middle Sinemurian to Toarcian age (Carter et al., 1998). *Stichocapsa* sp. A of Yeh and Cheng (1998) is characteristic species of the *Parahsuum simplum* Assemblage (Yao, 1982) corresponding to the Ps Zone (Matsuoka, 1995a). *Stichocapsa* sp. aff. *S. whalenae* of Goričan, Šmuc and Baumgartner (2003) indicates at least early Toarcian age as far as it is known (Goričan et al., 2003). Judging from the co-occurrence of *Parahsuum simplum*, *Stichocapsa* sp. A of Yeh and Cheng (1998) and *Stichocapsa* sp. aff. *S. whalenae* of Goričan, Šmuc and Baumgartner (2003), the age of

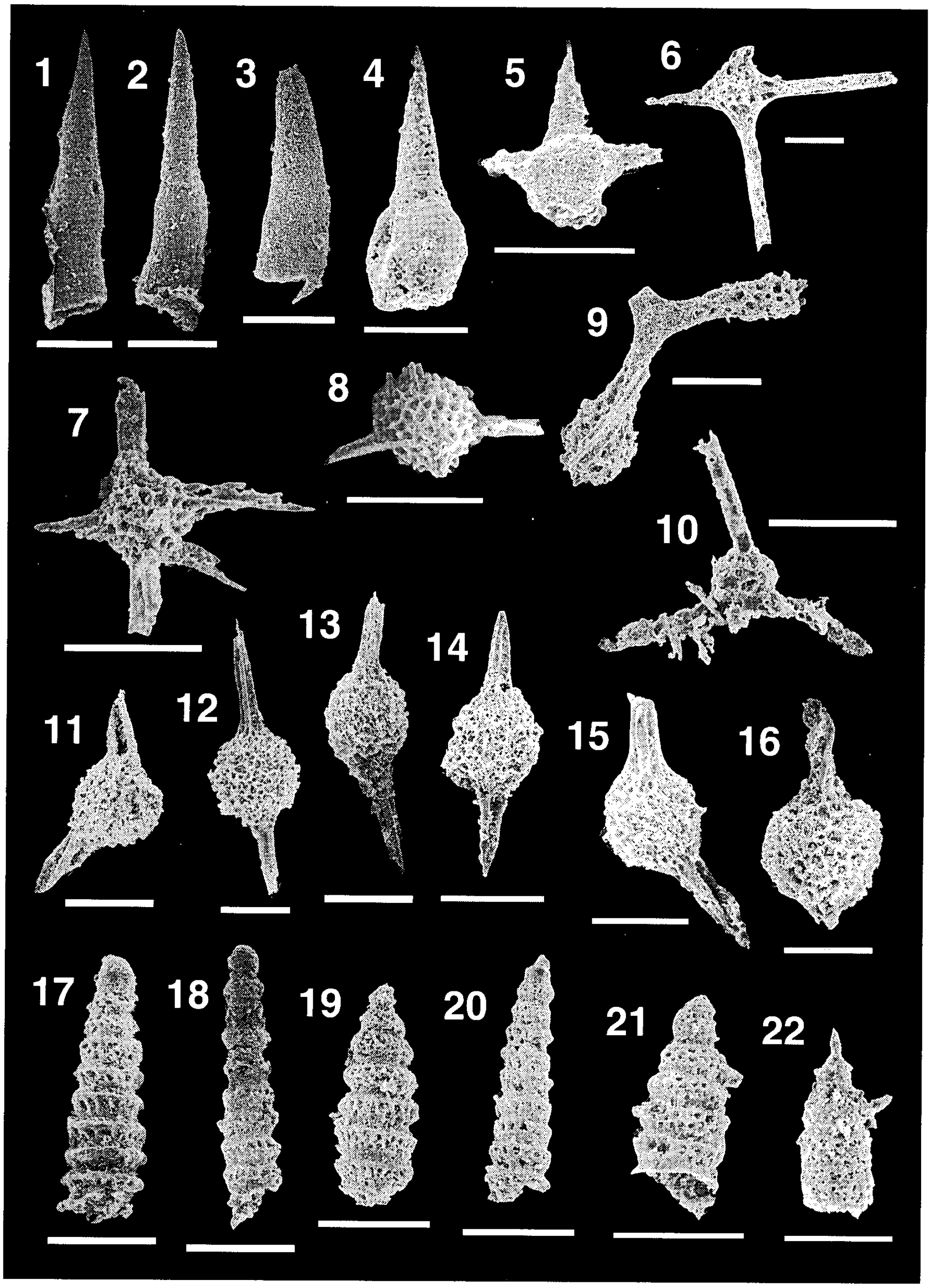

Fig. 6 Photomicrographs of radiolarians from chert. Fossil localities are shown in Figs. 2 and 3. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. All scale bars indicate 0.1 mm. 1–3: *Follicucullus porrectus* (Loc. 3, 69071, 69073, 69069), 4: *Follicucullus* sp. (Loc. 14, 69272), 5: *Pseudoalbaillella* (?) sp. (Loc. 2, 69111), 6–8: *Entactinia* spp. (6: Loc. 2, 69066; 7: Loc. 5, 69110; 8: Loc. 12, 69101), 9: *Ishigaum* sp. (Loc. 3, 68978), 10: *Raciditor* sp. (Loc. 2, 68975), 11: *Eptingium* sp. cf. *E. japonicum* (Loc. 24, 69788), 12: *Pseudostylosphaera* sp. cf. *P. tenuis* (loc. 24, 69760), 13: *Pseudostylosphaera* sp. A of Sugiyama (1992) (Loc. 24, 69766), 14–16: *Pseudostylosphaera* spp. (Loc. 24, 69769, 69754, 69778), 17: *Triassocampe coronata* (Loc. 24, 69758), 18: *Triassocampe* sp. aff. *T. diordinis* of Sugiyama (1992) (Loc. 24, 69762), 19: *Triassocampe* sp. cf. *T. myterocorys* (Loc. 24, 69777), 20–21: *Triassocampe* spp. (Loc. 24, 69787, 69783), 22: *Zevius* sp. (Loc. 24, 69786).

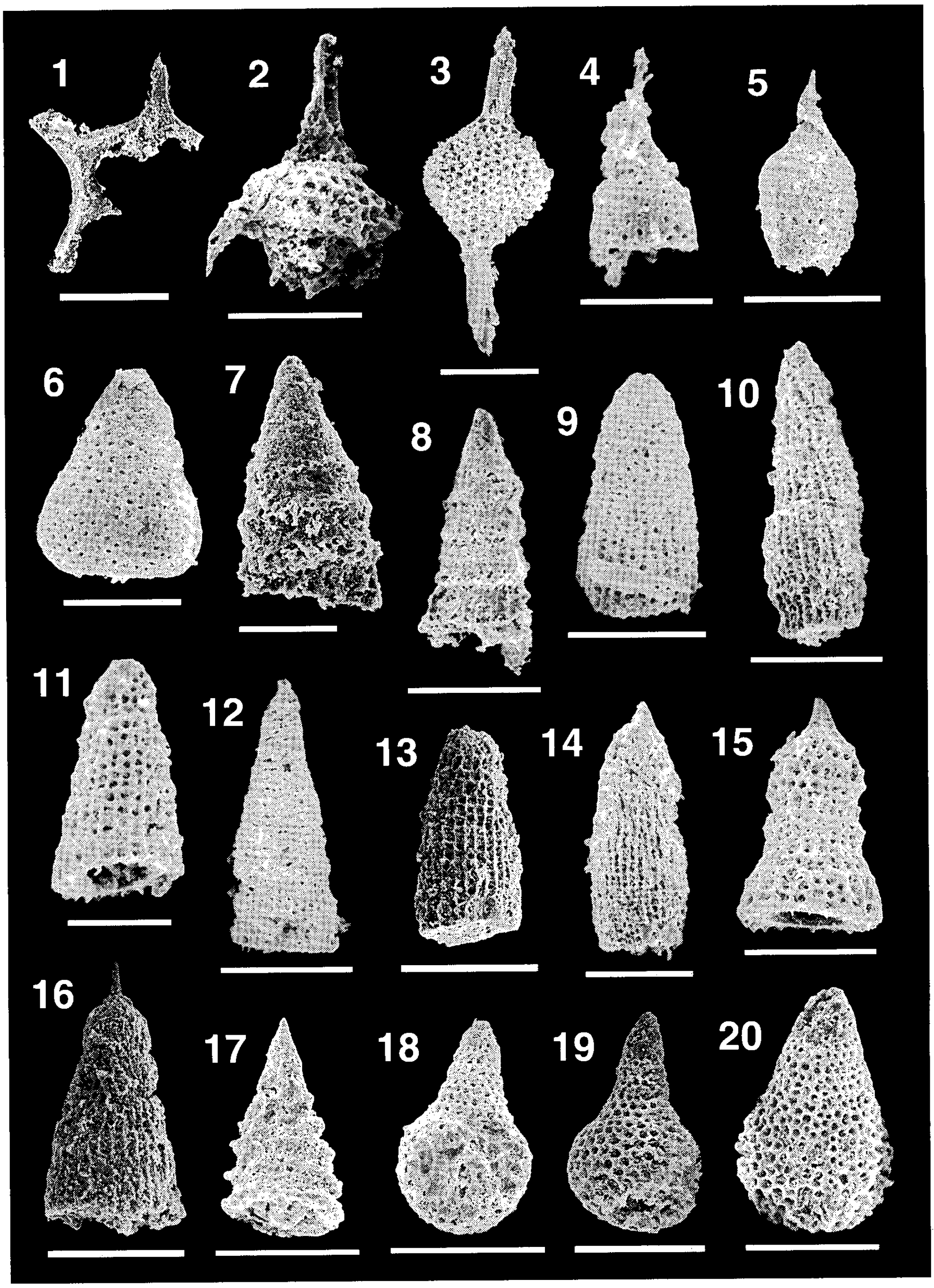

Fig. 7 Photomicrographs of radiolarians from chert. Fossil localities are shown in Figs. 3 and 4. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. Scale bars: 1–5, 8, 9 and 11–20 indicate 0.1 mm. 6, 7 and 10 indicate 0.05 mm. 1: *Hexasaturnalis* sp. cf. *H. hexagonus* (Loc. 22, 69227), 2: *Bipedis* sp. (Loc. 22, 69268), 3: *Xiphostylus* sp. (Loc. 16, 71107), 4–5: *Eucyrtidiellum* sp. (4: Loc. 16, 71120; 5: Loc. 22, 71101), 6: *Stichocapsa japonica* (Loc. 22, 71102), 7–8: *Canoptum* (?) sp. (Loc. 16, 69198, 71106), 9: *Parahsuum simplum* (Loc. 16, 71117), 10: *Parahsuum* sp. cf. *P. transiens* (Loc. 22, 71093), 11–14: *Parahsuum* spp. (11–12: Loc. 16, 71105, 71118; 13–14: Loc. 22, 69224, 71096), 15: *Parahsuum* (?) sp. A (Loc. 16, 71108), 16: *Parahsuum* (?) sp. (Loc. 22, 69230), 17: *Parvicingula* sp. cf. *P. gigantocornis* (Loc. 22, 71103), 18–19: *Stichocapsa* sp. A of Yeh and Cheng (1998) (Loc. 16, 71110, 69197), 20: *Stichocapsa* sp. aff. *S. whalenae* of Goričan, Šmuc and Baumgartner (2003) (Loc. 16, 69196).

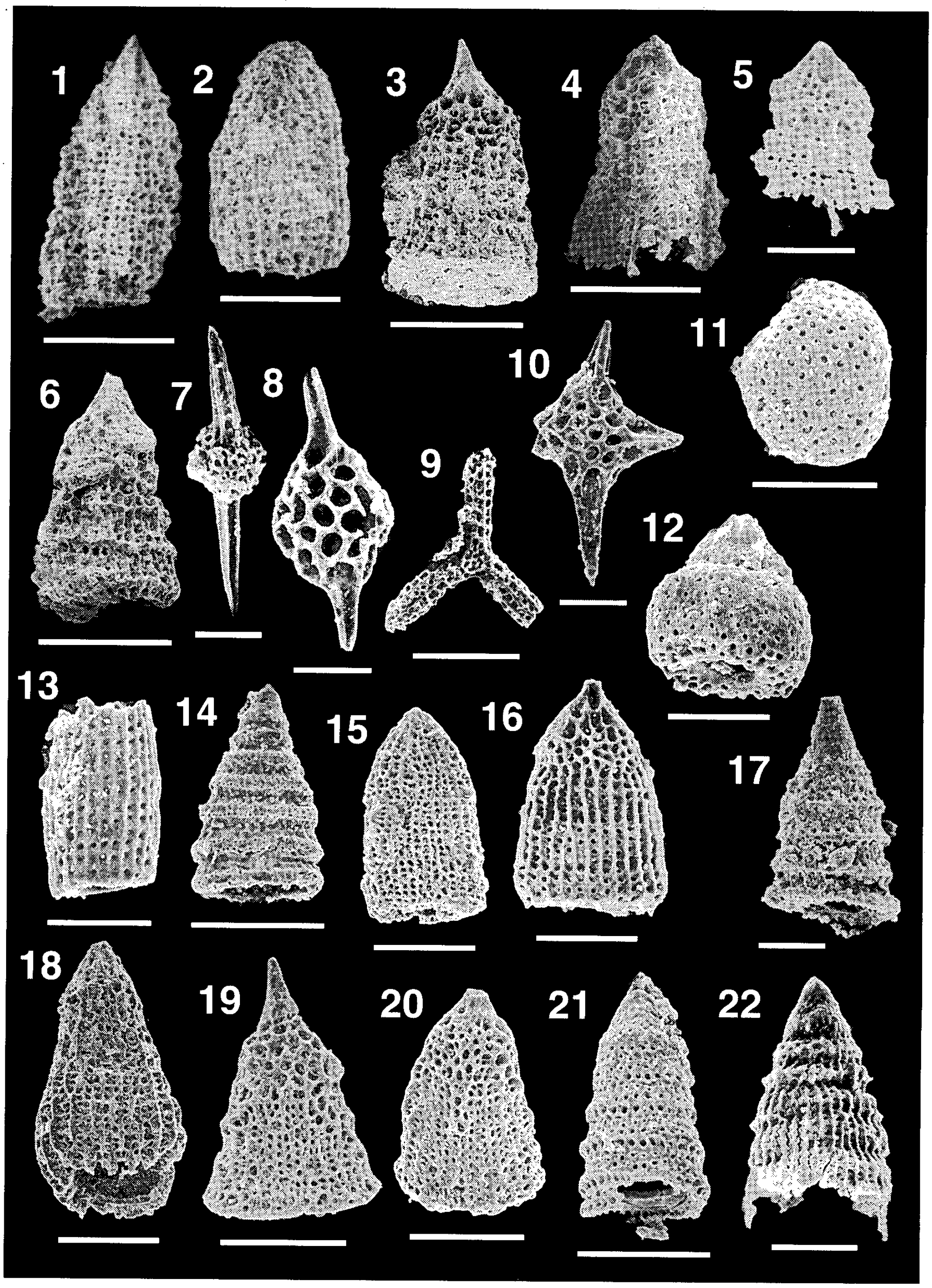

Fig. 8 Photomicrographs of radiolarians from red mudstone (1–6) and siliceous mudstone (7–22). Fossil localities are shown in Figs. 2 to 5. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. Scale bars: 1–4, 6, 9, 14–15, 18–20 and 22 indicate 0.1 mm. 5, 7, 8, 10–13, 16, 17 and 21 indicate 0.05 mm. 1: *Hsuum* sp. (Loc. 17, 71121), 2: *Parahsuum* sp. (Loc. 17, 71123), 3: *Parahsuum* (?) sp. cf. *P.* (?) sp. B of Hori and Otsuka (1989) (Loc. 17, 69194), 4-5: *Hsuum* sp. cf. *H.* sp. X of Hori and Otsuka (1989) (Loc. 17, 71125, 71127), 6: Nassellaria gen. et sp. indet A (Loc. 17, 69206), 7: *Archaeospongoprunum* sp. (Loc. 19, 69161), 8: *Pantanellium* sp. (Loc. 19, 69164), 9: *Homoeoparonaella* sp. (Loc. 19, 69166), 10: *Zartus* sp. (Loc. 19, 69153), 11: *Archicapsa* (?) *pachyderma* (Loc. 10, 69036), 12: *Eucyrtidiellum disparile* (Loc. 19, 69152), 13: *Archaeodictyomitra* sp. (Loc. 19, 69146), 14: *Canoptum rugosum* (Loc. 19, 69156), 15: *Hsuum* sp. (Loc. 10, 69104), 16: *Parahsuum parvum* (Loc. 19, 69171), 17: *Parvicingula* sp. cf. *P. nanoconica* (Loc. 10, 69032), 18: *Hsuum* sp. X of Hori and Otsuka (1989) (Loc. 10, 69102), 19–20: *Parahsuum* (?) sp. aff. *P.* (?) sp. B of Hori and Otsuka (1989) (Loc. 10, 69103, 69106), 21: *Dictyomitrella* (?) sp. aff. *D.* (?) *kamoensis* of Kobayashi (1998) (Loc. 19, 69147), 22: Nassellaria gen. et sp. indet B (Loc. 19, 69168).

the chert in Loc. 16 is restricted during middle Sinemurian to Toarcian (Fig. 14).

Loc. 22: Gray bedded chert in this locality yields *Eucyrtidiellum* sp. (Fig. 7.5), *Hexasaturnalis* sp. cf. *H. hexagonus* (Fig. 7.1), *Parahsuum* sp. cf. *P. transiens* (Fig. 7.10), *Parahsuum* spp. (Figs. 7.13 and 7.14), *Parahsuum* (?) sp. (Fig. 7.16), *Parvicingula* sp. cf. *P. gigantocornis* (Fig. 7.17) and *Stichocapsa japonica* (Fig. 7.6). *Parahsuum transiens* ranges from the middle part of the Te Zone to the lower part of the Lj Zone (Hori, 1990). *Parvicingula gigantocornis* is representative species of the *Parvicingula gigantocornis* Assemblage (Kishida and Hisada, 1985) corresponding to the middle part of the Te Zone to the lower part of the Lj Zone (Matsuoka and Yao, 1986). *Hexasaturnalis hexagonus* ranges from the middle part of the Te Zone to the Tp Zone (Matsuoka, 1995a). Judging from the co-occurrence of *Hexasaturnalis* sp. cf. *H. hexagonus*, *Parahsuum* sp. cf. *P. transiens* and *Parvicingula* sp. cf. *P. gigantocornis*, the age of the chert in Loc. 22 is restricted during Toarcian to early Aalenian (Fig. 14).

2. Radiolarians from red mudstone

One sample of red mudstone in Loc. 17 yields identifiable radiolarians (Table 2). The red mudstone is bedded and occurs in close proximity to the green bedded chert of Loc. 16 (Fig. 4a). Bedding plane of the red mudstone is subparallel to that of the chert. Radiolarians from Loc. 17 include *Hsuum* sp. cf. *H.* sp. X of Hori and Otsuka (1989) (Figs. 8.4 and 8.5), *Parahsuum* (?) sp. cf. *P.* (?) sp. B of Hori and Otsuka (1989) (Fig. 8.3) and Nassellaria gen. et sp. indet A (Fig. 8.6). The co-occurrence of *Hsuum* sp. X of Hori and Otsuka (1989) and *Parahsuum* (?) sp. B of Hori and Otsuka (1989) suggests assignment to the middle to upper part of the Te Zone (Hori, 1990). Thus, the age of the red mudstone in Loc. 17 is restricted to Toarcian (Fig. 14).

3. Radiolarians from brownish siliceous mudstone

Radiolarians were obtained from brownish siliceous mudstone in Locs. 10 and 19 (Table 2). The siliceous mudstone lies in fault contact with gray bedded chert in both localities (Figs. 4a and 5).

Loc. 10: Radiolarian assemblage includes *Archicapsa* (?) *pachyderma* (Fig. 8.11), *Hsuum* sp. X of Hori and Otsuka (1989) (Fig. 8.18), *Parahsuum* (?) sp. aff. *P.* (?) sp. B of Hori and Otsuka (1989) (Figs. 8.19 and 8.20) and *Parvicingula* sp. cf. *P. nanoconica* (Fig. 8.17). The co-occurrence of *Hsuum* sp. X of Hori and Otsuka (1989) and *Parvicingula nanoconica* suggests assignment to the middle to upper part of the Te Zone (Hori, 1990). Thus, the age of the siliceous mudstone in Loc. 10 is restricted to Toarcian (Fig. 14).

Loc. 19: Radiolarian assemblage includes *Canoptum rugosum* (Fig. 8.14), *Eucyrtidiellum disparile* (Fig. 8.12), *Dictyomitrella* (?) sp. aff. *D. kamoensis* of Kobayashi (1998) (Fig. 8.21) and Nassellaria gen. et sp. indet. B (Fig. 8.22). *Dictyomitrella* (?) sp. aff. *D. kamoensis* of Kobayashi (1998) indicates at least early Aalenian age as far as it is known (Kobayashi, 1998). *Eucyrtidiellum disparile* ranges from the Te to Lj Zone (Nagai, 1995). *Canoptum rugosum* is assigned to the *Parahsuum takarazawaense* Zone (Sashida, 1988) corresponding to the upper part of the Ps Zone to the lower part of the Te Zone. Judging from the co-occurrence of *Canoptum rugosum*, *Dictyomitrella* (?) sp. aff. *D. kamoensis* of Kobayashi (1998) and *Eucyrtidiellum disparile*, the age of the siliceous mudstone in Loc. 19 is restricted during late Pliensbachian to early Aalenian (Fig. 14).

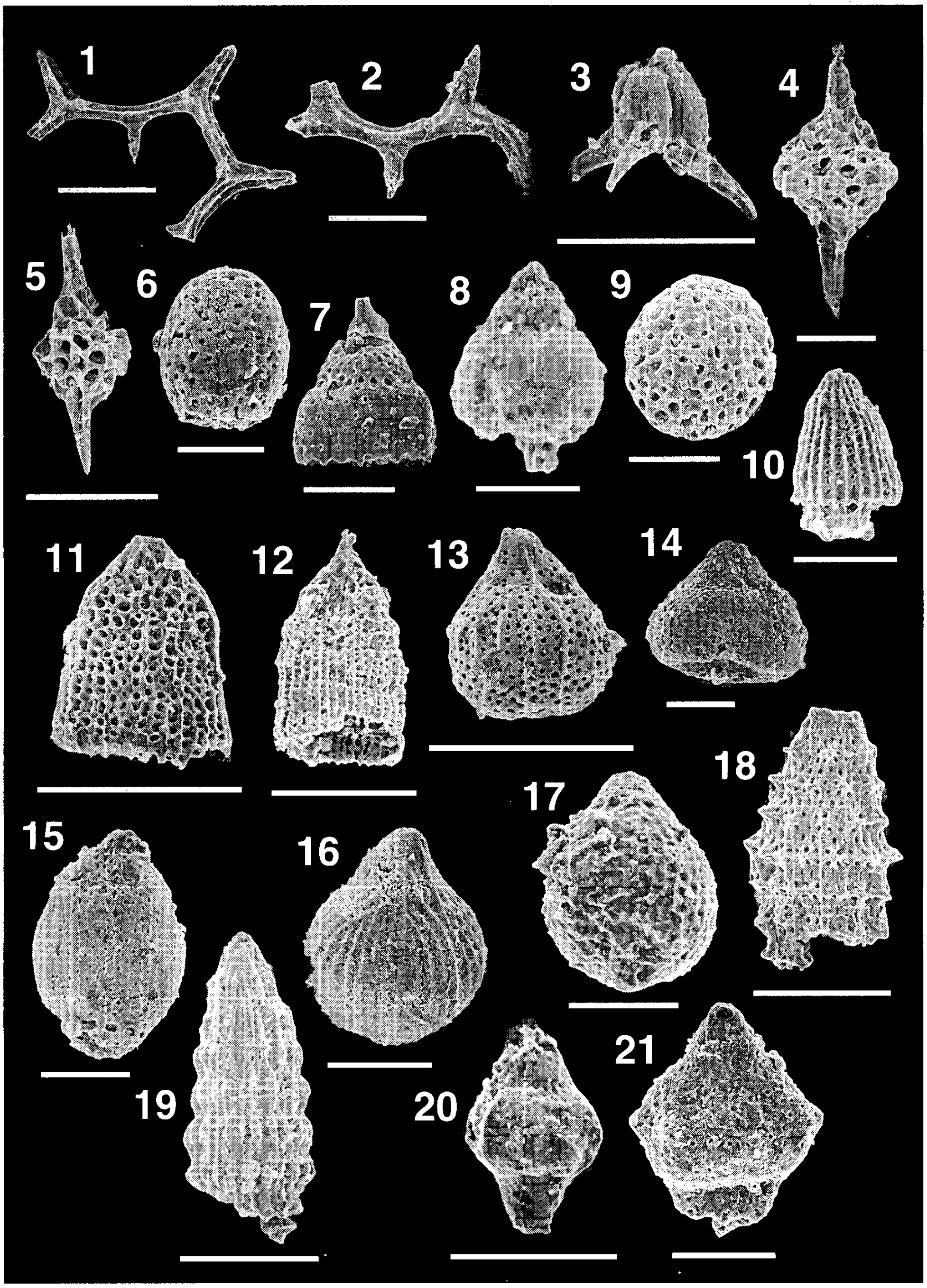

Fig. 9 Photomicrographs of radiolarians from felsic tuff (1–13) and gray siltstone (14–21). Fossil localities are shown in Figs. 2 to 4. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. Scale bars: 1–3, 5, 11–13 and 18–20 indicate 0.1 mm. 4, 6–10, 14–17 and 21 indicate 0.05 mm. 1: *Hexasaturnalis hexagonus* (Loc. 33, 69394), 2: *Hexasaturnalis* sp. cf. *H. tetraspinus* (Loc. 33, 69379), 3: *Saitoum* sp. (Loc. 33, 69388), 4: *Trillus* sp. cf. *T. elkhornensis* (Loc. 33, 69374), 5: *Trillus* sp. (Loc. 33, 69384), 6: *Archicapsa* (?) *pachyderma* (Loc. 23, 69174), 7: *Eucyrtidiellum disparile* (Loc. 33, 69397), 8: *Eucyrtidiellum* sp. (Loc. 23, 71087), 9: *Stypolarcus* sp. cf. *S. laboriosus* (Loc. 33, 69382), 10: *Archaeodictyomitra* sp. (Loc. 33, 69392), 11: *Parahsuum* sp. cf. *P. parvum* (Loc. 23, 69175), 12: *Parahsuum* sp. (Loc. 33, 69377), 13: *Unuma* sp. (Loc. 23, 69172), 14: *Stichocapsa japonica* (Loc. 13, 69191), 15: *Tricolocapsa* (?) *fusiformis* (Loc. 13, 69521), 16: *Tricolocapsa plicarum* s.l. (Loc. 13, 69177), 17: *Tricolocapsa* sp. (Loc. 13, 68981), 18: *Parvicingula* sp. cf. *P. dhimenaensis* (Loc. 13, 69178), 19: *Transhsuum* sp. (Loc. 13, 69526), 20: *Unuma* sp. cf. *U. latusicostatum* (Loc. 13, 69532), 21: Nassellaria gen. et sp. indet C group (Loc. 13, 69187).

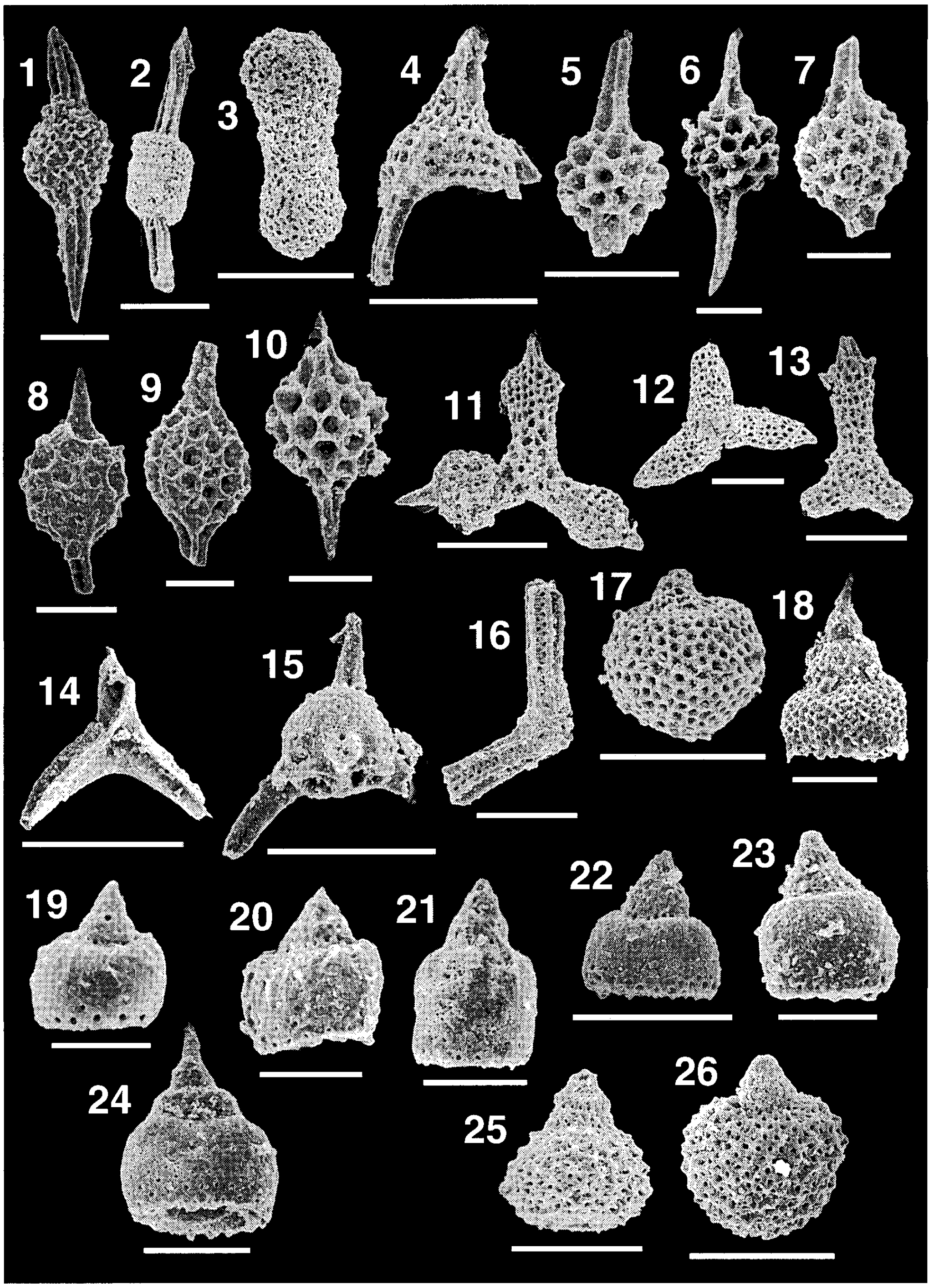

Fig. 10 Photomicrographs of radiolarians from black mudstone. Fossil localities are shown in Figs. 2 to 4. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. Scale bars: 2–5, 11–17, 22, 25 and 26 indicate 0.1 mm. 1, 6–10, 18–20, 21, 23 and 24 indicate 0.05 mm. 1–2: *Archaeospongoprunum* sp. (1: Loc. 1, 69109; 2: Loc. 25, 69935), 3: *Bistarkum* sp. (Loc. 25, 69939), 4: *Napora* sp. (Loc. 28, 69727), 5: *Pachyoncus* sp. cf. *P. kamiasoensis* (Loc. 28, 69742), 6: *Pachyoncus* sp. (Loc. 18, 69221), 7: *Pantanellium* sp. cf. *P. foveatum* (Loc. 6, 69590), 8–10: *Pantanellium* sp. (8–9: Loc. 1, 69095, 69110; 10: Loc. 28, 69728), 11: *Paronaella* sp. cf. *P. mulleri* (Loc. 25, 69927), 12: *Paronaella* sp. cf. *P. pygmaea* (Loc. 25, 69933), 13: *Paronaella* sp. (Loc. 20, 69877), 14: *Pterotrabs* sp. (Loc. 18, 69218), 15: *Saitoum* sp. (Loc. 28, 69690), 16: *Tritrabs* sp. (Loc. 26, 69632), 17: *Cryptamphorella* (?) sp. cf. *C.* (?) *geodora* (Loc. 27, 69674), 18: *Eucyrtidiellum gujoensis* (Loc. 25, 71154), 19–21: *Eucyrtidiellum semifactum* (19: Loc. 4, 69564; 20; Loc. 9, 69131; 21: Loc. 32, 71282), 22–23: *Eucyrtidiellum unumaense* (22: Loc. 4, 69062; 23: Loc. 11, 69039), 24: *Eucyrtidiellum* sp. aff. *E. unumaense* of Nagai (1986) (Loc. 31, 69401), 25: *Sethocapsa kodrai* (Loc. 28, 71178), 26: *Sethocapsa* sp. cf. *S. funatoensis* (Loc. 4, 69118).

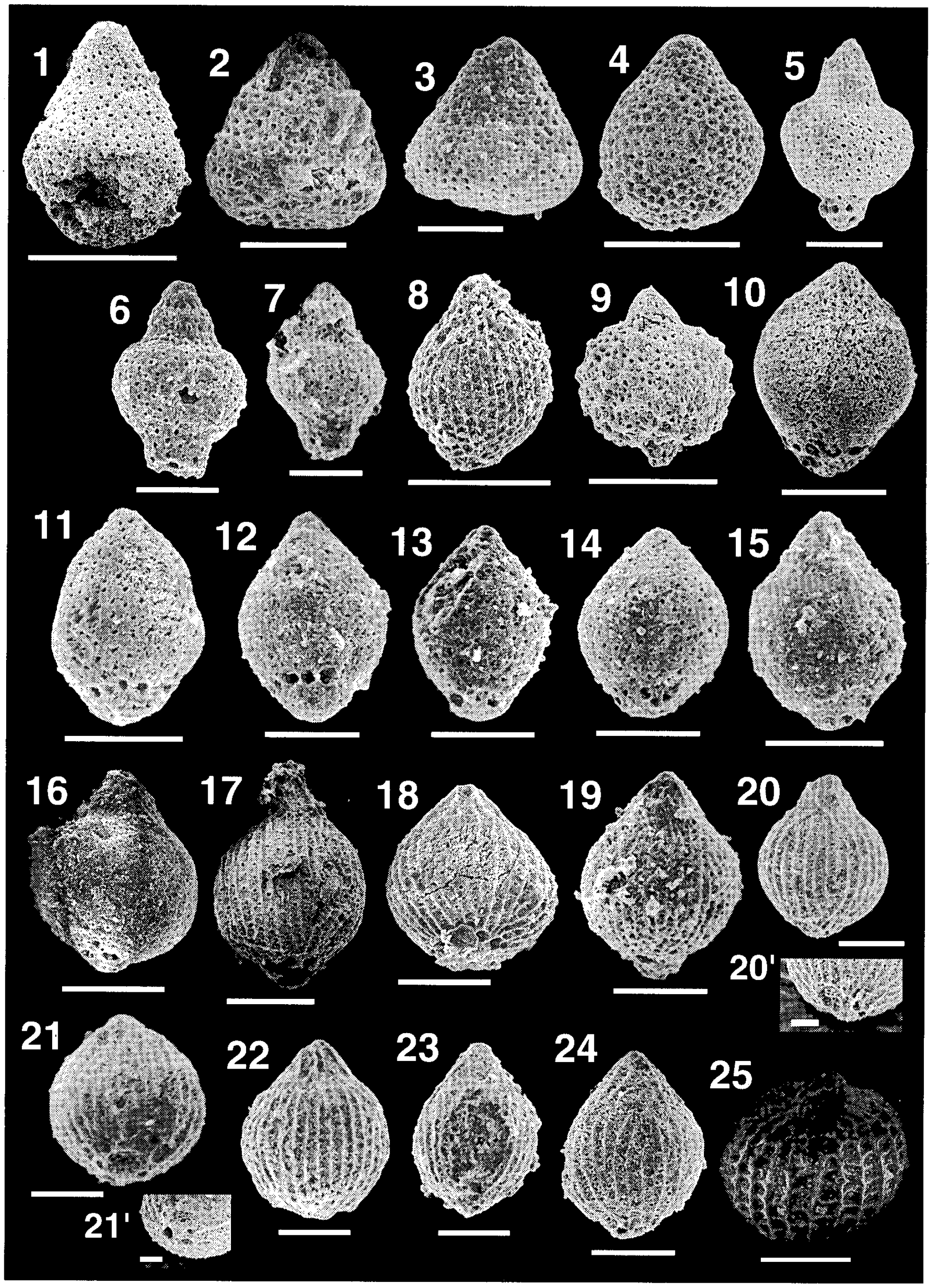

Fig. 11 Photomicrographs of radiolarians from black mudstone. Fossil localities are shown in Figs. 2 to 4. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. Scale bars: 1, 4, 8 and 9 indicate 0.1 mm. 2, 3, 5–7 and 10–25 indicate 0.05 mm. 20' and 21' indicate 0.02 mm. 1: *Stichocapsa convexa* (Loc. 18, 69211), 2: *Stichocapsa himedaruma* (Loc. 9, 69129), 3: *Stichocapsa japonica* (Loc. 32, 69430), 4: *Stichocapsa robusta* (Loc. 4, 69119), 5: *Stichocapsa* sp. b of Kido et al. (1982) (Loc. 32, 71254), 6–7: *Stichocapsa* sp. A (6: Loc. 4, 69063; 7: Loc. 32, 71247), 8: *Tricolocapsa conexa* (Loc. 26, 71195), 9: *Tricolocapsa formosa* (loc. 26, 69611), 10–14: *Tricolocapsa* (?) *fusiformis* (10: Loc. 18, 69214; 11: Loc. 28, 71168; 12: Loc. 29, 71212; 13: Loc. 25, 71145; 14: Loc. 28, 71176), 15–16: *Tricolocapsa* (?) sp. aff. *T.* (?) *fusiformis* of Matsuoka (1983) (15: Loc. 11, 69584; 16: Loc. 31, 69408), 17–19: *Tricolocapsa plicarum plicarum* (17: Loc. 18, 69215; 18: Loc. 1, 69090; 19: Loc. 25, 71146), 20–24: *Tricolocapsa plicarum* ssp. A of Baumgartner et al. (1995) (20: Loc. 4, 69545; 21: Loc. 6, 69596; 22: Loc. 26, 71184; 23: Loc. 28, 71180; 24: Loc. 29, 71206), 25: *Tricolocapsa tetragona* (Loc. 1, 69087). 20' and 21' show distal views of 20 and 21, respectively.

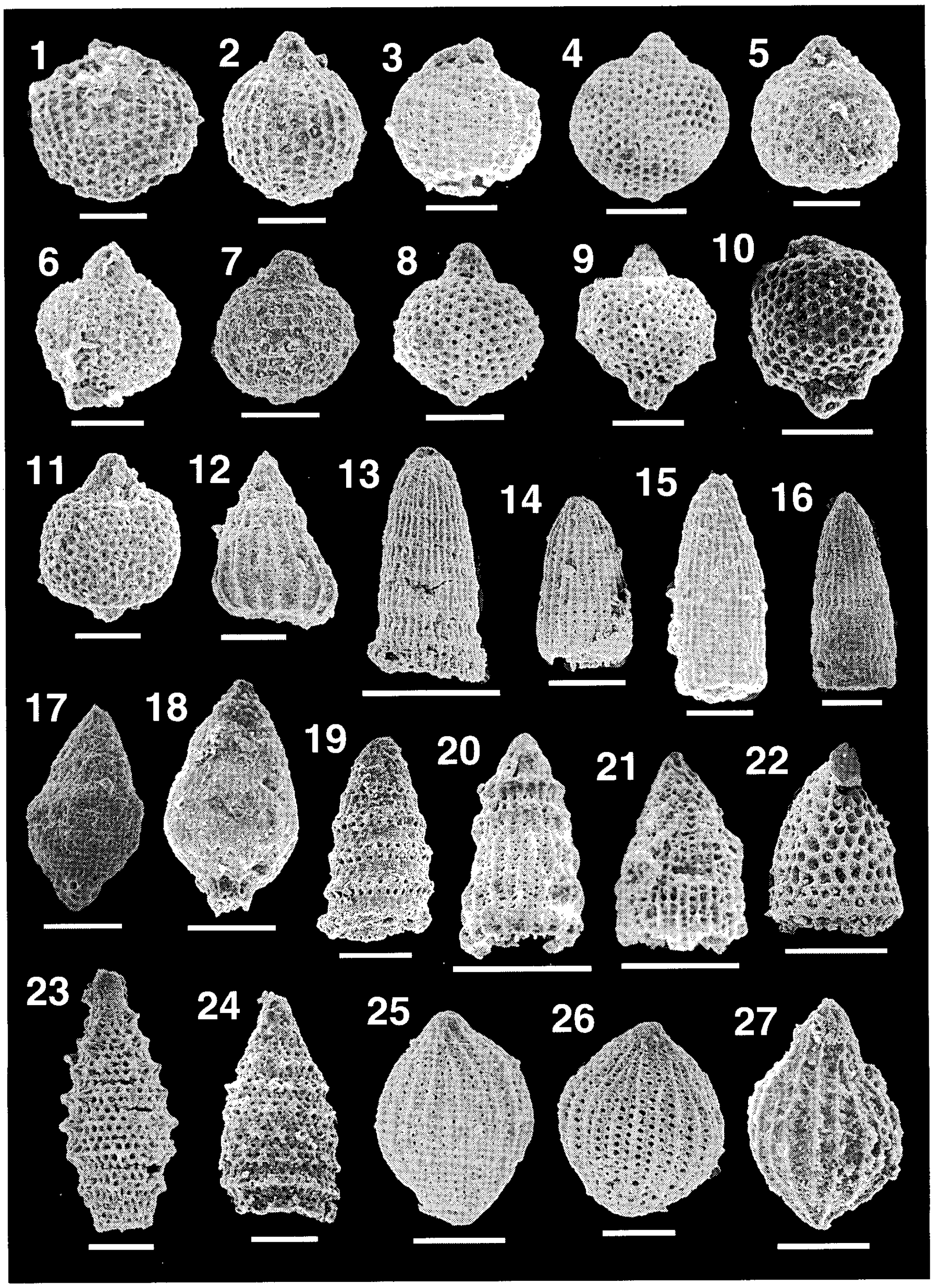

Fig. 12 Photomicrographs of radiolarians from black mudstone. Fossil localities are shown in Figs. 2 to 4. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. Scale bars: 16, 20 and 21 indicate 0.1 mm. 1–15, 17–19 and 22–27 indicate 0.05 mm. 1–3: *Tricolocapsa tetragona* (1: Loc. 6, 71073; 2: Loc. 26, 71204; 3: Loc. 27, 69677), 4–7: *Tricolocapsa* spp. (4–5: Loc. 4, 69059, 69060; 6: Loc. 11, 69037; 7: Loc. 21, 69801), 8: *Williriedellum carpathicum* (Loc. 4, 69556), 9: *Williriedellum* (?) *marcuccii* (Loc. 21, 69813), 10: *Williriedellum* (?) sp. cf. *W.* (?) *marcuccii* (Loc. 7, 68936), 11: *Williriedellum* sp. (Loc. 4, 69112), 12: *Archaeodictyomitra* (?) *amabilis* (Loc. 4, 69539), 13: *Archaeodictyomitra* sp. cf. *A. spelae* (Loc. 26, 69606), 14–16: *Archaeodictyomitra* spp. (14: Loc. 18, 68988; 15: Loc. 20, 69875; 16: Loc. 25, 69882), 17–18: *Cyrtocapsa mastoidea* (17: Loc. 1, 69096; 18: Loc. 21, 71225), 19: *Dictyomitrella* (?) *kamoensis* (Loc. 26, 69619), 20: *Droltus* (?) sp. of Kobayashi (1998; Plate 5-8) (Loc. 32, 71253), 21: *Parahsuum* sp. (Loc. 4, 69566), 22: *Parvicingula cappa* (Loc. 18, 69209), 23: *Parvicingula dhimenaensis* (Loc. 27, 69679), 24: *Parvicingula* sp. (Loc. 21, 69823), 25: *Protunuma* sp. cf. *P. fusiformis* (Loc. 4, 69537), 26: *Protunuma* (?) *ochiensis* (Loc. 26, 69643), 27: *Protunuma turbo* (Loc. 26, 71190).

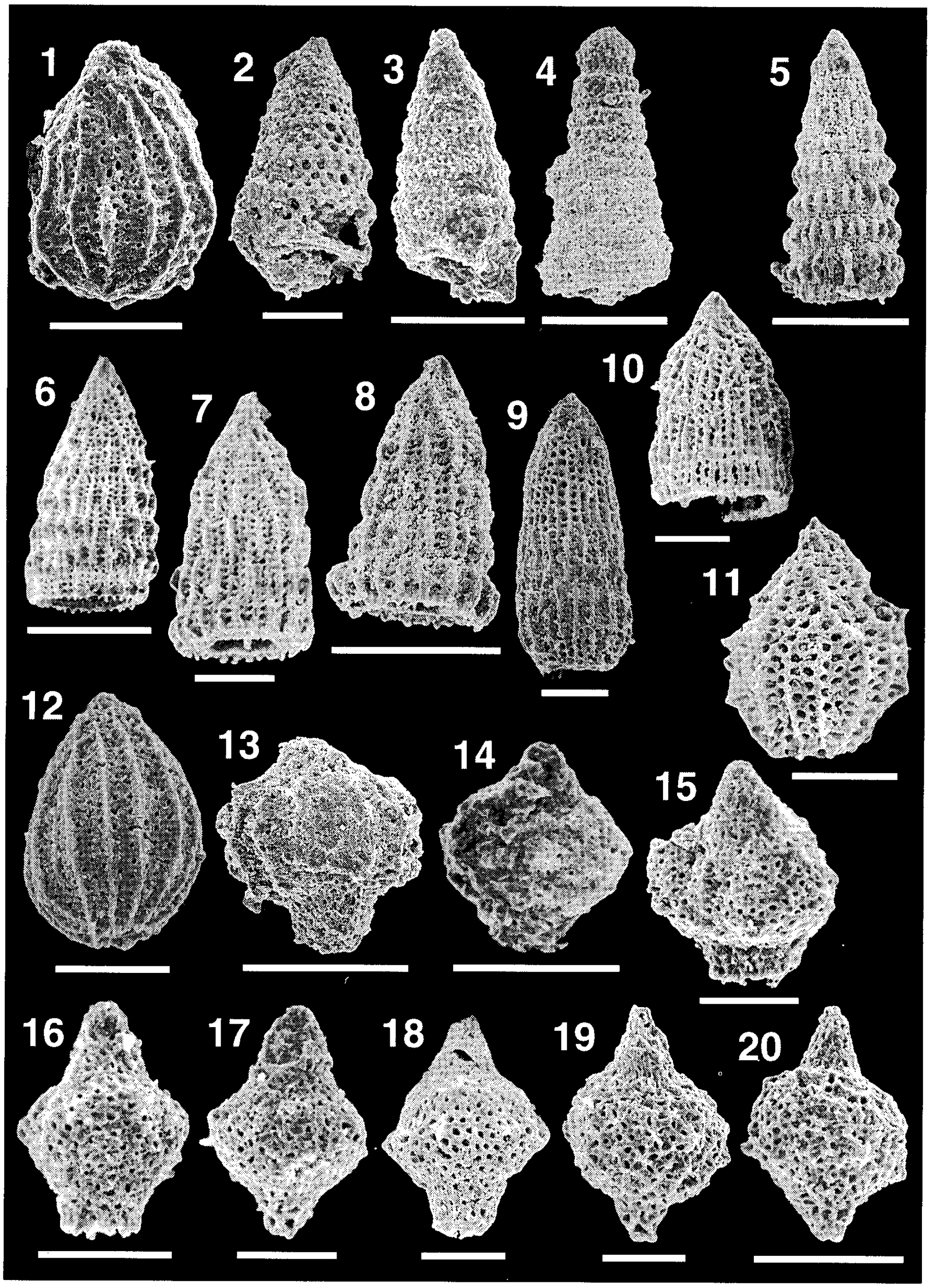

Fig. 13 Photomicrographs of radiolarians from black mudstone. Fossil localities are shown in Figs. 2 to 4. Numbers in five figures represent sequential number of SEM photograph registered in the Rad File, Nagoya University Museum. Scale bars: 3–6, 8, 13–14 and 20 indicate 0.1 mm. 1–2, 7, 9–12 and 15–19 indicate 0.05 mm. 1: *Protunuma* sp. B of Hull (1997) (Loc. 1, 69093), 2: *Ristola* sp. cf. *R. decora* (Loc. 30, 69968), 3: *Spongocapsula* sp. (Loc. 11, 69115), 4: *Stichomitra* (?) sp. cf. *S.* (?) *takanoensis* (Loc. 26, 69621), 5: *Transhsuum* sp. cf. *T. brevicostatum* (Loc. 28, 69685), 6: *Transhsuum maxwelli* (Loc. 32, 71271), 7: *Transhsuum* sp. cf. *T. maxwelli* (Loc. 28, 69692), 8: *Transhsuum* sp. cf. *T. parasolense* (Loc. 28, 69709), 9–10: *Transhsuum* spp. (Loc. 25, 69917, 71134), 11: *Unuma* (?) sp. (Loc. 32, 71270), 12: *Unuma* sp. cf. *U. gorda* (Loc. 4, 69117), 13: *Unuma* sp. cf. *U. latusicostatum* (Loc. 29, 69849), 14–18: Nassellaria gen. et sp. indet C group (14: Loc. 6, 69595; 15: Loc. 25, 71141; 16: Loc. 28, 71165; 17: Loc. 29, 71216; 18: Loc. 32, 71261), 19–20: Nassellaria gen. et sp. indet D (19: Loc. 21, 71223; 20: Loc. 26, 71191).

1995a). *Tricolocapsa plicarum plicarum* is assigned to the Tp Zone (Matsuoka, 1995a, b). Meanwhile, *Tricolocapsa* (?) *fusiformis* and *Tricolocapsa plicarum plicarum* from this locality have smaller basal appendages than *Tricolocapsa* (?) *fusiformis* and *Tricolocapsa plicarum* described by Yao (1979), respectively. Because basal appendages of *Tricolocapsa* (?) *fusiformis* and *Tricolocapsa plicarum* become smaller in stratigraphically higher horizon (Matsuoka, 1983), the co-occurrence of the two species with small basal appendages suggests assignment to the middle to upper part of the Tp Zone. Thus, the age of the black mudstone in Loc. 25 is restricted during late Bajocian to early Bathonian.

Loc. 26: Radiolarian assemblage includes *Protunuma* (?) *ochiensis* (Fig. 12.26), *Protunuma turbo* (Fig. 12.27), *Tricolocapsa conexa* (Fig. 11.8), *Tricolocapsa plicarum* ssp. A of Baumgartner et al. (1995) (Fig. 11.22) and *Tricolocapsa tetragona* (Fig. 12.2). Their co-occurrence suggests assignment to the lower part of the Tc Zone (Matsuoka, 1983, 1995a, b). Thus, the age of the black mudstone in Loc. 26 is restricted to late Bathonian.

Loc. 27: Radiolarian assemblage includes *Tricolocapsa tetragona* (Fig. 12.3). *Tricolocapsa tetragona* ranges from the uppermost part of the Tp Zone to the lower part of the Tc Zone (Matsuoka, 1995a). Thus, the age of the black mudstone in Loc. 27 is restricted to Bathonian.

Locs. 28 and 29: Radiolarian assemblages include *Tricolocapsa* (?) *fusiformis* (Figs. 11.11, 11.12 and 11.14) and *Tricolocapsa plicarum* ssp. A of Baumgartner et al. (1995) (Figs. 11.23 and 11.24). The co-occurrence of *Tricolocapsa* (?) *fusiformis* and *Tricolocapsa plicarum* ssp. A of Baumgartner et al. (1995) suggests assignment to the middle to upper part of the Tp Zone (Matsuoka, 1983, 1995a, b). Thus, the age of the black mudstones in Locs. 28 and 29 is restricted during late Bajocian to early Bathonian.

Loc. 31: Radiolarian assemblage includes *Eucyrtidiellum* sp. aff. *E. unumaense* of Nagai (1986) (Fig. 10.24) and *Tricolocapsa* (?) sp. aff. *T. fusiformis* of Matsuoka (1983) (Fig. 11.16). *Eucyrtidiellum* sp. aff. *E. unumaense* of Nagai (1986) suggests assignment to the lower part of the range zone of *Eucyrtidiellum unumaense* (Nagai, 1986) which ranges from the Tp to Tc Zone (Matsuoka, 1995a). *Tricolocapsa* (?) sp. aff. *T. fusiformis* of Matsuoka (1983) ranges from the uppermost part of the Tp Zone to the Ss Zone (Matsuoka, 1983). Therefore, the co-occurrence of *Eucyrtidiellum* sp. aff. *E. unumaense* of Nagai (1986) and *Tricolocapsa* (?) sp. aff. *T. fusiformis* of Matsuoka (1983) suggests assignment to the upper part of the Tp Zone. On the basis of their co-occurrence, the age of the black mudstone in Loc. 31 is restricted during late Bajocian to early Bathonian.

Loc. 32: Radiolarian assemblage includes *Eucyrtidiellum semifactum* (Fig. 10.21). *Eucyrtidiellum semifactum* ranges from the upper part of the Tp Zone to the lower part of the Tc Zone (Matsuoka, 1995a). Thus, the age of the black mudstone in Loc. 32 is restricted to Bathonian.

From above-mentioned radiolarian analysis, the age of black mudstone in the Hirayu Complex is confined between Bajocian and Callovian. The newly obtained radiolarians clearly show that the melange matrix is younger in age than the clasts of brownish siliceous mudstone, red mudstone and chert. The age of the gray siltstone is included in the age interval of the black mudstone.

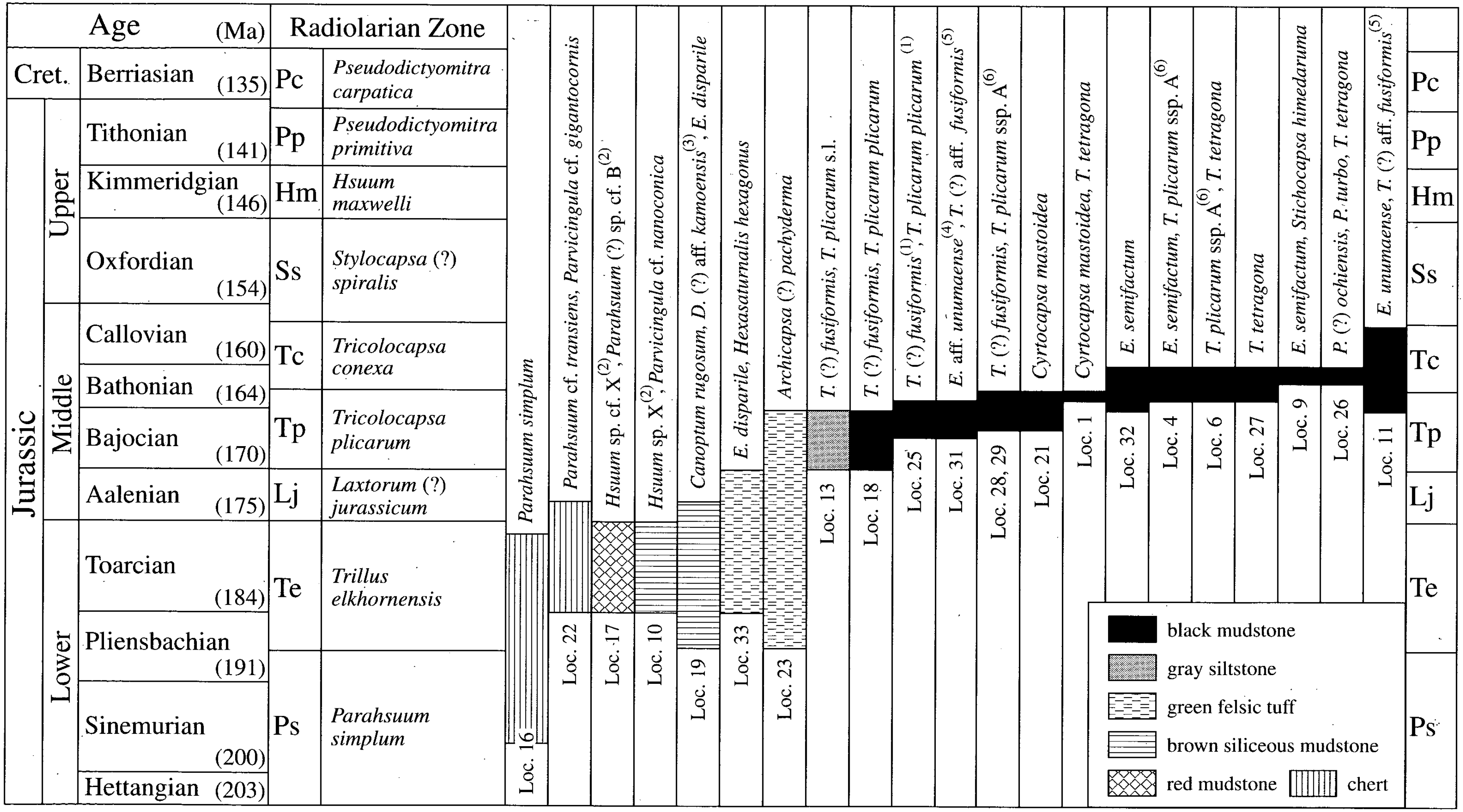

Fig. 14 Jurassic radiolarian ages with index fossils of mudstone, felsic tuff and siliceous mudstone. Fossil localities are shown in Figs. 2 to 5. Radiolarian zones and their age assignments are from Matsuoka (1995a). (1) having small basal appendage, (2) Hori and Otsuka (1989), (3) Kobayashi (1998), (4) Nagai (1986), (5) Matsuoka (1983), (6) Baumgartner et al. (1995). *D.*: *Dictyomitrella*, *E.*: *Eucyrtidiellum*, *P.*: *Protunuma*, *T.*: *Tricolocapsa*.

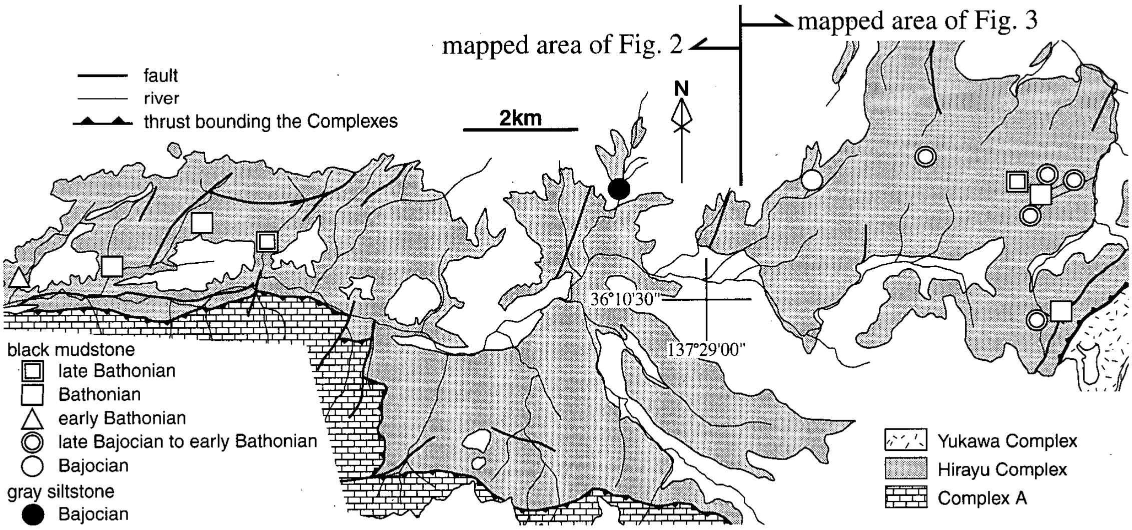

Fig. 15 Simplified geological map showing the radiolarian localities of black mudstone and gray siltstone. Detailed age of each locality is also shown.

The black mudstone samples are divided into the following five groups based on their radiolarian ages: (1) the sample from Loc. 18, assigned to Bajocian in age, (2) the samples from Locs. 21, 25, 28, 29 and 31, assigned to late Bajocian to early Bathonian in age, (3) the sample from Loc. 1, assigned to early Bathonian in age, (4) the samples from Locs. 4, 6, 27 and 32, assigned to Bathonian in age, and (5) the samples from Locs. 9 and 26, assigned to late Bathonian in age (Figs. 14 and 15).

SUMMARY

This study is focused on the radiolarian age of the Hirayu Complex which is a part of the accretionary complexes of the Mino Belt, central Japan. The Hirayu Complex in the Nyukawa-Hirayu area is characterized by a melange including various kinds of clasts in a muddy matrix. Radiolarians obtained from clasts of green felsic tuff, brownish siliceous mudstone, red mudstone and bedded chert, and from a melange matrix of black mudstone and gray siltstone are examined in this study. The results are as follows.

(1) Six samples of the bedded chert clasts include radiolarians showing the detailed age. The age of each sample is as follows: Late Carboniferous? to Middle Permian, late Middle to Late Permian, late Middle Permian to Early Triassic, early Anisian of Triassic, middle Sinemurian to Toarcian of Jurassic, and Toarcian to early Aalenian of Jurassic.

(2) Radiolarian assemblages from the clasts of red mudstone, brownish siliceous mudstone and green felsic tuff are first reported in this area. The assemblages indicate that the ages of red mudstone, brownish siliceous mudstone and green felsic tuff are Toarcian, late Pliensbachian to early Aalenian and late Pliensbachian to Bajocian, respectively.

(3) Radiolarian assemblage from the gray siltstone of the melange matrix is first

reported in this area. The assemblage indicates that the age of the gray siltstone is Bajocian.

(4) Radiolarian ages from the black mudstone of the melange matrix are confined between Bajocian and Callovian. Radiolarians show that the melange matrix is younger in age than the clasts of brownish siliceous mudstone, red mudstone and chert. The ages of the black mudstone is divided into the following five groups based on the radiolarian ages: Bajocian, late Bajocian to early Bathonian, early Bathonian, Bathonian and late Bathonian.

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