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Takahashi, Osamu
Department of Astronomy and Earth Sciences, Tokyo Gakugei University

Ishii, Atsushi
Department of Astronomy and Earth Sciences, Tokyo Gakugei University

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Radiolarian Assemblage-zones in the Jurassic and Cretaceous Sequence in the Kanto Mountains, Central Japan

Osamu TAKAHASHI* and Atsushi ISHII*

Abstract

Nineteen radiolarian assemblage-zones have been established in the Jurassic to Cretaceous sequences in the Kanto Mountains, central Japan. They consist of the *Parahsuum simplum* (Hettangian - Pliensbachian), *Parvicingula gigantocornis* (Toarcian), *Hsuum hisuikyoense* (Aalenian), *Unuma echinatus* (early - middle Bajocian), *Dictyomitrella*(?) *kamoensis* (emended herein: late Bajocian - early Bathonian), *Guexella nudata* (emended herein: middle - late Bathonian), *Mirifusus guadalupensis* (emended herein: early Callovian), *Stylocapsa*(?) *spiralis*(newly defined: late Callovian - early Oxfordian), *Tricolocapsa yaoi* (middle - late Oxfordian), *Pseudodictyomitra primitiva* (Kimmeridgian - middle Tithonian), *Pseudodictyomitra carpatica* (late Tithonian - early Valanginian), *Sethocapsa uterculus* (emended herein: Valanginian), *Eucyrtis tenuis* (emended herein: Hauterivian - early Barremian), *Thanarla conica* (newly defined: Barremian), *Holocryptocanium barbui* (late Albian - Cenomanian), *Dictyomitra formosa* (newly defined: Coniacian - Santonian), *Amphipyndax enesseffi* (emended herein: early - middle Campanian), *Amphipyndax tylotus* (late Campanian - early Maastrichtian), and *Clathrocyclas*(?) *gravis* (emended herein: Maastrichtian) Assemblage-zones in ascending order.

As a result, significant stratigraphic gaps are recognized in the Aptian - Middle Albian and the Turonian. It is noteworthy that these mid-Cretaceous time-stratigraphic hiatuses are widely observed not only in the Kanto Mountains but also in the Outer Zone of Southwest Japan.

These stratigraphic gaps may be ascribed to the global mass extinctions and the deteriorated accretion or accretionary hiatus due to the change of movement directions of subducting plates.

I. Introduction

Jurassic and Cretaceous radiolarian assemblages found in the Japanese Islands, especially in Southwest Japan, differ in diversity from those in Europe (*e.g.*, BAUMGARTNER, 1984, 1987) and North America (*e.g.*, PESSAGENO, 1976, 1977a, 1977b), except for some elements of cosmopolitan species. The characteristic radiolarian assemblages of Japan are thought to reflect the

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* Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Tokyo 184, Japan

Northwest-Pacific intermediate water-mass. Therefore, we believe that the establishment of distinct radiolarian zonations and to reveal components of radiolarian assemblages of Japanese Mesozoic are essentially important in paleoceanographical and paleontological viewpoints.

A detailed system of radiolarian zonations in Japan has been proposed for Mesozoic strata through the intensive studies by YAO (1984), MATSUOKA and YAO (1986), AITA (1987), and many other workers, but only a few works have been done on the radiolarian zonation in the Jurassic and Cretaceous sequence in the Kanto Mountains (*e.g.,* KISHIDA and HISADA, 1986; SASHIDA, 1988). In particular, the Cretaceous zonation in the Kanto Mountains has not been established as yet.

Furthermore, since the first discovery of the Triassic conodonts (IGO, 1972), it has been confirmed with microfossil data that Mesozoic sediments are widely distributed in the Chichibu and Shimanto belts in the Kanto Mountains (*e.g.,* SASHIDA *et al.,* 1982) and has been believed that the sediments in those belts constitute tectonically complexed accretionary prisms (*e.g.,* OZAWA and KOBAYASHI, 1985). In order to clarify the stratigraphy and structure of highly complicate accretionary prisms, as suggested by a preliminary study by ISHII and TAKAHASHI (1993), detailed radiolarian zonations are very useful.

In this paper, we will describe some distinctive elements of the radiolarian assemblages and will establish the radiolarian zonation in the Jurassic to Cretaceous sequence of Kanto Mountains, central Japan.

II. Geologic Setting of the Study Area

The Kanto Mountains, located at about 50km northwest of Tokyo, are

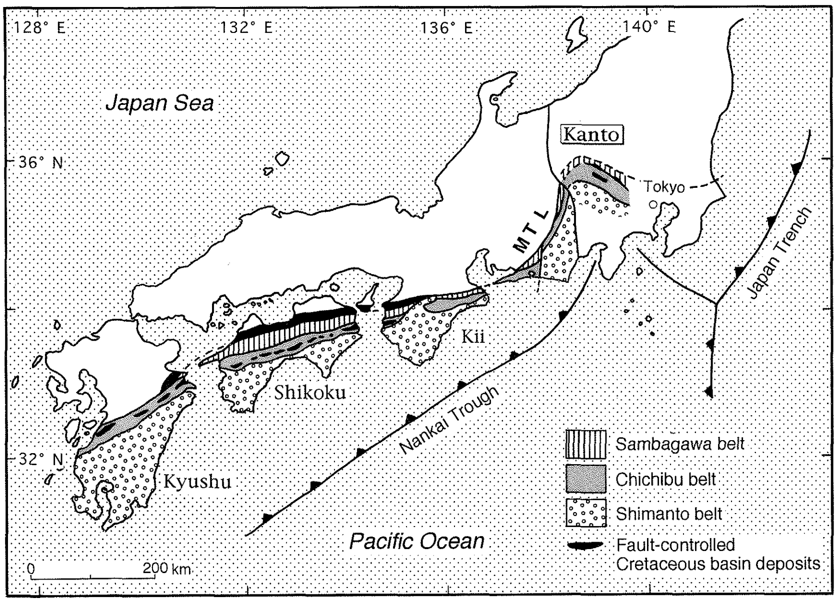

Fig.1. Index map of Southwest Japan showing the distribution of the Sambagawa, Chichibu, and Shimanto belts, together with fault-controlled Cretaceous basin deposits.
MTL: Median Tectonic Line.

geologically divided into the Sambagawa metamorphic belt, the Chichibu belt, and the Shimanto belt from north to south. Such a zonal arrangement of geologic units is common in the Outer Zone of Southwest Japan (Fig.1).

It has been confirmed with radiolarian biostratigraphic data that most of the rocks in the Chichibu and Shimanto belts are now interpreted to be the Early Jurassic to Paleogene accretionary complexes (OWADA and SAKA, 1982; SASHIDA *et al.,* 1982; HISADA, 1984; TAKASHIMA and KOIKE, 1984; OZAWA and KOBAYASHI, 1985; HISADA and KISHIDA, 1986; SAKAI, 1987; IWASAKI *et al.,* 1989; TAKAHASHI *et al.,* 1989; ISHII *et al.,* 1990; YASUDA, 1989; KAMATA *et al.,* 1991; SASHIDA, 1992; TAKAHASHI and ISHII, 1992; ISHII and TAKAHASHI, 1993; and IYOTA *et al.,* 1994). These belts are characterized by a swarm of thrust sheets striking to the northwest direction and dipping to the north.

In this study, five typical sections of the Itsukaichi, Oku-tama, Chichibu, Shomaru, and Saku areas were selected to make clear the tectonic history of the accretionary complexes during the Mesozoic time. These areas are situated in the southern part of the Chichibu belt and the northern part of the Shimanto belt (Fig.2). Radiolarians were recovered from these five sections in order to determine the age of accretion processes of each complex.

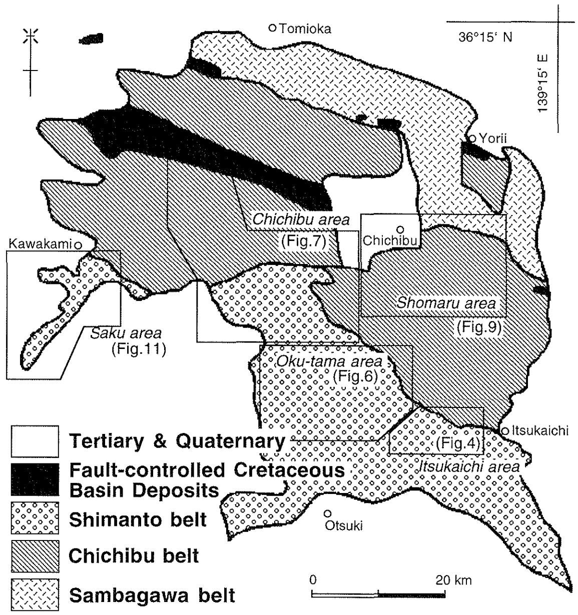

Fig.2. Map showing the tectonic divisions of the Kanto Mountains. Five boxes indicate the selected study areas.

A. Itsukaichi area (Figs.3 and 4)

This area is divided into two different geologic domains by the "Itsukaichi-Kawakami Tectonic Line" (YABE, 1925). The northern part of this area consists of the Middle Jurassic to the Late Cretaceous accretionary complexes. On the other hand, the southern part of the area consists of the Late Cretaceous accretionary complex "Kobotoke Group"(FUJIMOTO, 1931; MAKINO, 1973; SAKAI, 1987).

These complexes correspond to the stratigraphic divisions referred to the Unazawa, Hikawa, and Gozenyama Formations by FUJIMOTO (1939), the Nakayama and Kosode Formations by FUJIMOTO and SUZUKI (1957), the Kawai Formation by OWADA and SAKA (1982), and the Mitsuzawa, Fukazawa, and Ozawa Formations by TAKASHIMA and KOIKE (1984).

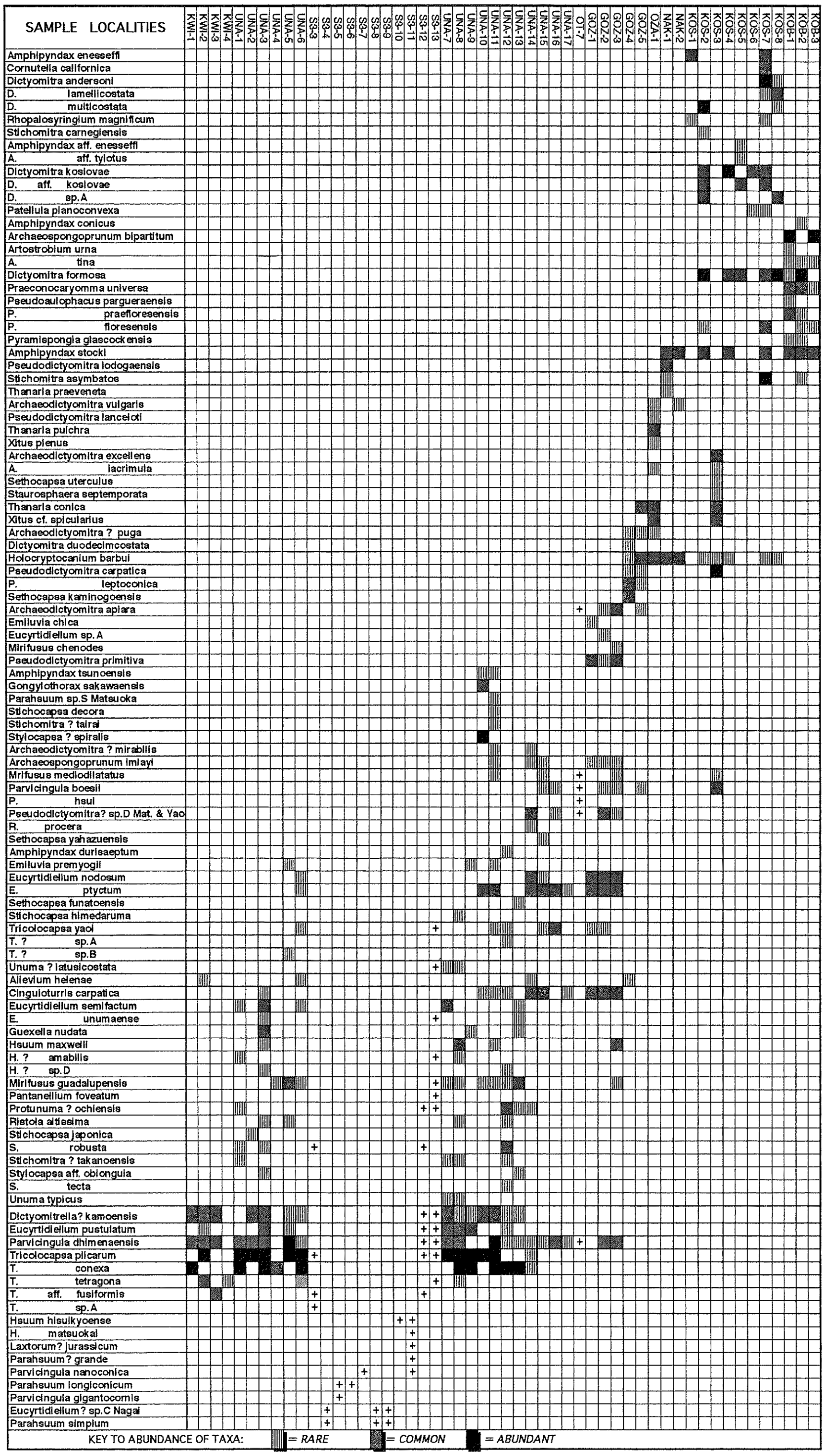

Fig.3. Occurrence and relative abundance of radiolarians in the Itsukaichi area. Plus (+) means presence, but difficult estimation of abundance.

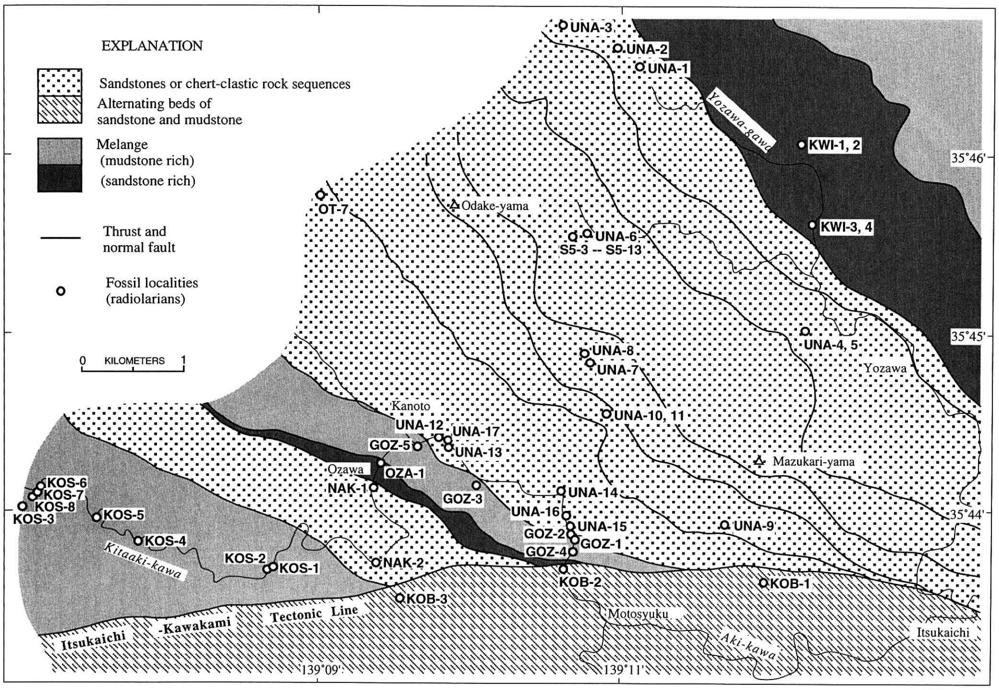

Fig.4. Geological map of the Itsukaichi area showing the localities of radiolarian fossils.

B. Oku-tama area (Figs.5 and 6)

The Latest Jurassic to the Late Cretaceous accretionary complexes are distributed in this area. These complexes correspond to the stratigraphic divisions referred to the Unazawa, Hikawa, and Gozenyama Formations by FUJIMOTO (1939), the Nakayama, Kosode, and Kurakake Formations by FUJIMOTO and SUZUKI (1957).

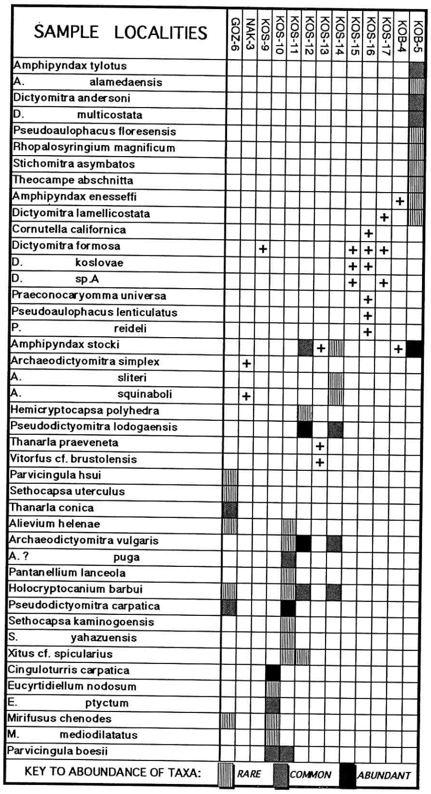

Fig.5. Occurrence and relative abundance of radiolarians in the Oku-tama area. Plus (+) means presence, but difficult estimation of abundance.

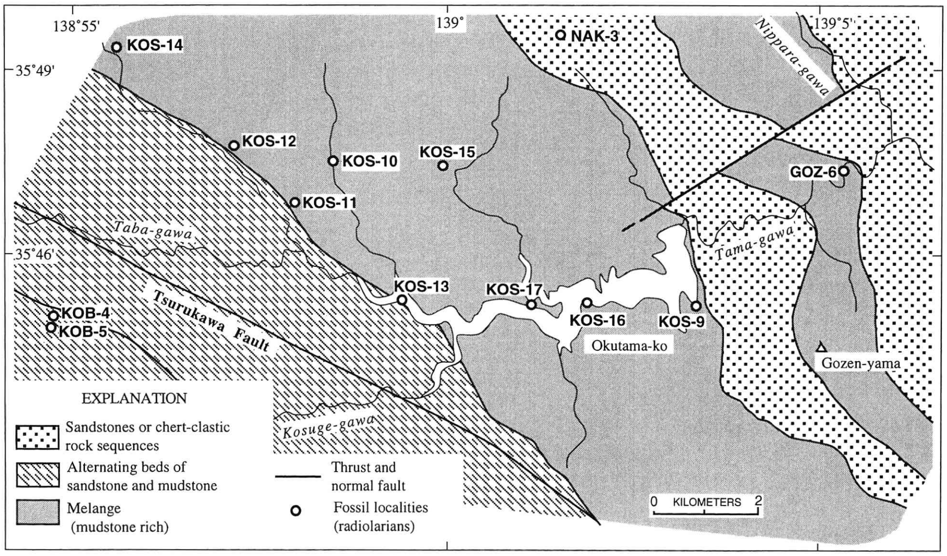

Fig.6. Geological map of the Oku-tama area showing the localities of radiolarian fossils.

C. Chichibu area (Figs.7 and 8)

In this area, the Early Jurassic to the Late Cretaceous accretionary complexes are widely exposed. At the northern and eastern margins of the area, these complexes show the fault contact with the "Sanchu Cretaceous" and are

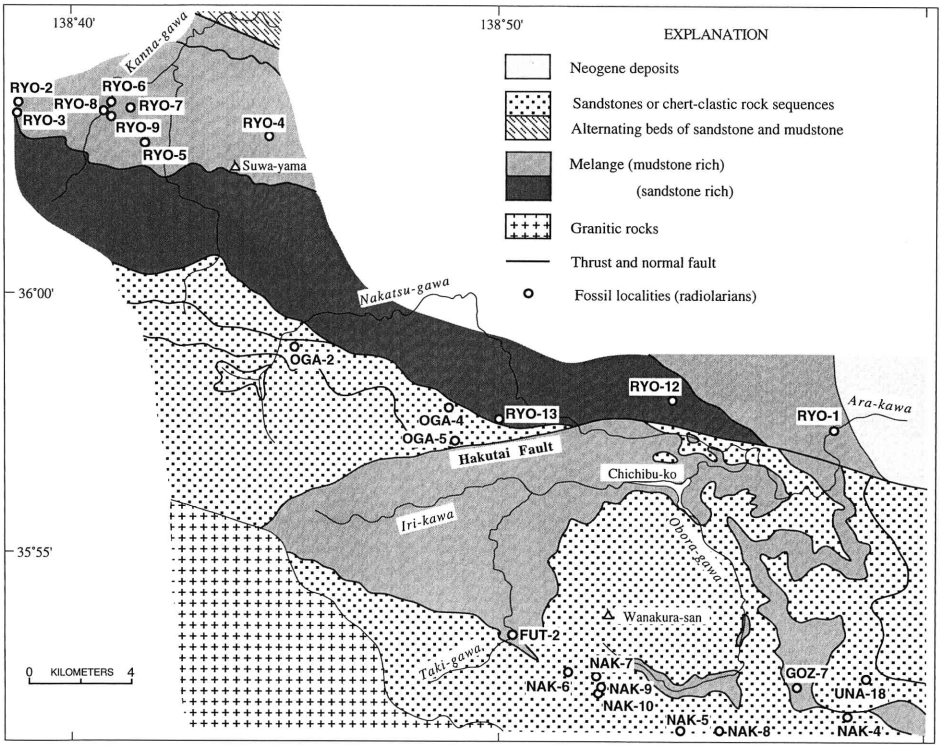

Fig.7. Geological map of the Chichibu area showing the localities of radiolarian fossils.

unconformably overlain by the "Chichibu Tertiary," respectively.

This area is separated into two different geologic domains by the EW trending high-angle fault called the Hakutai Fault (Chichibu Geologic Research Group, 1965; ISHII and TAKAHASHI, 1989). In the north of the fault, the Early to Middle Jurassic accretionary complexes are distributed, on the other hand, the south of the fault exposes the Late Jurassic to the Late Cretaceous accretionary complexes. These complxes correspond to the stratigraphic divisions referred to the Otchizawa Formation by OKUBO and HORIGUCHI (1969), the Suwayama and Daijyakurasawa Formations by FUJIMOTO (1937), the Mitsumine Formation by FUJIMOTO *et al.* (1950) and ISHII and TAKAHASHI (1989), the Ryokami, Ishifune, and Ogamata Formations by FUJIMOTO *et al.* (1957) and ISHII (1962), the Kawanori and Kurasawa Formations by HISADA (1984), the Zone I by HISADA and KISHIDA (1986), and the Wanakura-san, Koreisan, Futase, and Kawamata Formations by WATANABE *et al.* (1958).

SAMPLE LOCALITIES	RYO-1	RYO-2	RYO-3	RYO-4	RYO-5	RYO-6	RYO-7	RYO-8	RYO-9	RYO-12	RYO-13	OGA-2	OGA-4	OGA-5	UNA-18	GOZ-7	NAK-4	NAK-5	NAK-6	NAK-7	NAK-8	NAK-9	NAK-10	FUT-2
Archaeospongoprunum bipartitum																						A		
Artostrobium tina																							R	
A. urna																						R		
Cornutella californica																						R		
Dictyomitra formosa																						R		
D. koslovae																							R	
Patellula planoconvexa																						R		
Praeconocaryomma universa																						R	R	
Pseudoaulophacus lenticulatus																						R	R	
P. cf. praefloresensis																							R	
Pyramispongia glascockensis																						R		
Amphipyndax stocki																					C	C	C	
Archaeodictyomitra simplex																					R			
A. sliteri																					R			
Hemicryptocapsa polyhedra																						R		
Pseudodictyomitra pentacolaensis																					R			
P. pseudomacrocephala																					R			
Thanarla praeveneta																					R			
Vitorfus cf. brustolensis																						R		
Xitus plenus																					R			
Acaeniotyle umbilicata																				R				
Archaeodictyomitra lacrimula																				C				
Eucyrtis tenuis																				C				
Thanarla conica																				C				
Archaeodictyomitra vulgaris																					C			
Holocryptocanium barbui																+	+				A			
Pseudodictyomitra carpatica																				C				
Archaeospongoprunum imlayi																			+					
Emiluvia orea																			+					
Eucyrtidiellum ptyctum																			+					
Mirifusus mediodilatatus																+								
Parvicingula boesii																+								
Eucyrtidiellum pustulatum														R										
Hsuum maxwelli												C		C										
H. ? amabilis														C										
Mirifusus guadalupensis												R		C										
Protunuma ? ochiensis														C										
Ristola altissima														R										
Tricolocapsa tetragona														R										
Eucyrtidiellum ptyctum											+													
E. unumaense											+		+											
Guexella nudata													+											
Parvicingula dhimenaensis								+				C		C										+
Tricolocapsa conexa									+					A	+									
Cyrtocapsa mastoidea				+		+	+																	
Sethocapsa robusta							+																	
Tricolocapsa plicarum				+	+	+		+	+					A										
Hsuum hisuikyoense		+	+																					
Stichocapsa japonica		+																						
Unuma echinatus		+		+	+	+																		
Archicapsa pachyderma						+				R														
Dictyomitrella? kamoensis				+	+	+								R										
Eucyrtidillum disparile										C														
Hsuum matsuokai			+							R														
H. sp.A										C														
H. sp.B										C														
H. sp.C										C														
Parvicingula gigantocornis										A														
P. nanoconica										A														
Trillus sp.A										R														
T. sp.B										R														
T. sp.C										C														
Bagotum pseudoerraticum	+																							
Parahsuum simplum	+																							
P. takarazawaense	+																							

KEY TO ABOUNDANCE OF TAXA: R =RARE, C =COMMON, A =ABUNDANT

Fig.8. Occurrence and relative abundance of radiolarians in the Chichibu area.
Plus (+) means presence, but difficult estimation of abundance.

D. Shomaru area (Figs.9 and 10)

In this area, the Early to Late Jurassic accretionary complexes are distributed. They consist of the Unazawa Formation by FUJIMOTO (1939), the Hanagiri and Kabasaka Formations by HORIGUCHI and TAKEUCHI (1982) and SASHIDA (1992), the Kawai Formation by OWADA and SAKA (1982), and the Hashidate Formation by HISADA (1984). Those formations are generally in thrust

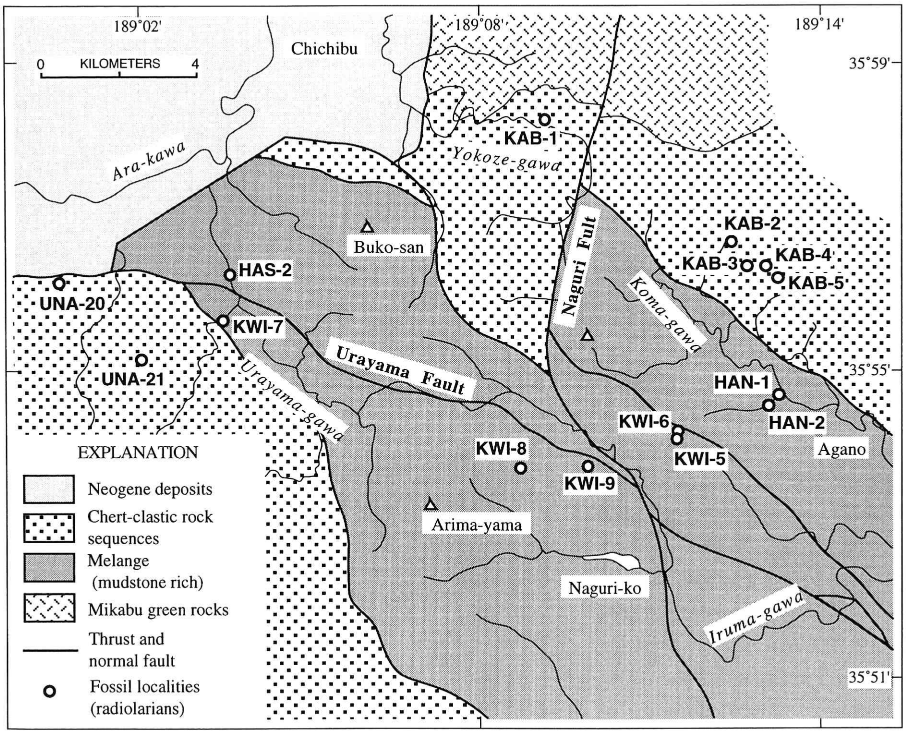

Fig.9. Geological map of the Shomaru area showing the localities of radiolarian fossils.

contact with each other, but are occasionally cut by NW normal faults, a set of young NS lateral-slip faults, and younger NE lateral-slip faults, which bound the "Chichibu Tertiary" on the northwest. On the other hand, the Kabasaka Formation has an conformable relationship with the underlying the Mikabu Green Rocks at the north of the area.

SAMPLE LOCALITIES	HAN-1	HAN-2	KWI-5	KWI-6	KWI-7	KWI-8	KWI-9	HAS-2	KAB-1	KAB-2	KAB-3	KAB-4	KAB-5	UNA-20	UNA-21
Archaeodictyomitra spp.						+	+	+				+	+		+
Dictyomitrella ? sp.										+					
Hsuum spp.							+		+		+	+		+	
Parvicingula dhimenaensis							+					+			
Protunuma sp.							+								
Stichocapsa spp.						+	+	+				+			
Archicapsa pachyderma				RARE											
Eucyrtidiellum disparile				ABUNDANT											
Hsuum hisuikyoense				COMMON											
H. matsuokai				RARE											
Parvicingula gigantocornis				RARE											
P. spp.				RARE								+			
Tricolocapsa spp.				COMMON	+	+	+	+	+	+	+	+	+		+
Eucyrtidiellum spp.			RARE					+				+			
Katroma spp.			COMMON												
Pantanellium sp.			RARE												
Parahsuum kanyoense			ABUNDANT												
P. longiconicum			RARE												
P. simplum			RARE												
P. takarazawaense	+														
P. spp.	+	+													
Poulpus sp.			RARE												
Trillus elkhornensis			RARE	COMMON											
KEY TO ABOUNDANCE OF TAXA:	RARE		COMMON			ABUNDANT									

Fig.10. Occurrence and relative abundance of radiolarians in the Shomaru area.
Plus (+) means presence, but difficult estimation of abundance.

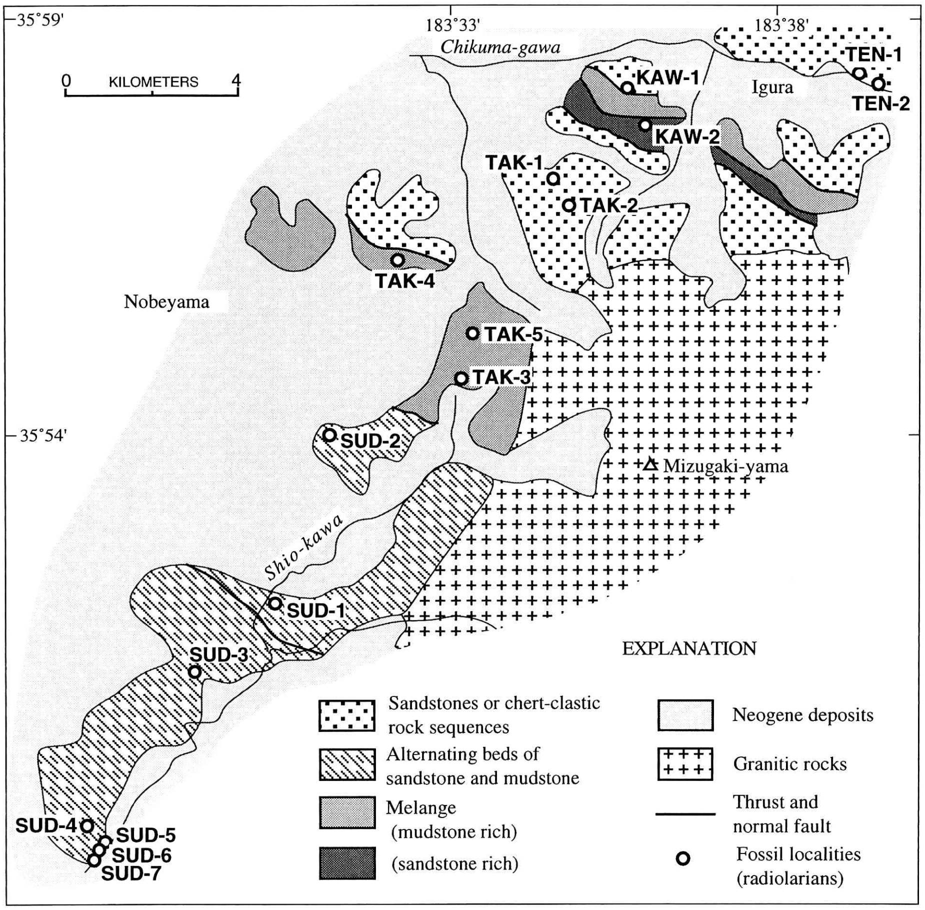

Fig.11. Geological map of the Saku area showing the localities of radiolarian fossils.

E. Saku area (Figs.11 and 12)

This area is largely overlain by Quaternary volcanic deposits and is intruded by Middle Miocene granitic rocks in the south. The Middle Jurassic to Latest Cretaceous accretionary complexes are exposed in this area, which correspond to the stratigraphic divisions referred to the Kawakami Formation by FUJIMOTO (1937), the Takatoyasan Formation by MAEDA (1953), the Tenguyama Formation by FUJIMOTO and SUZUKI (1958), the Zones IV and V by HISADA and KISHIDA (1986), the Sudama Formation by ISHII *et al.* (1990).

III. Methods of Study

The rock samples were treated in the following way:

1) Each sample was broken into small pieces (the total amount of about 200g) and washed well in water.

2) After that, the samples were treated with approximately 5% hydrofluoric acid solution for about 24 hours and washed through 50 μm and 200 μm screens.

3) The residue was dried, and was inspected under a binocular microscope to

SAMPLE LOCALITIES	TEN-1	TEN-2	KAW-1	KAW-2	TAK-1	TAK-2	TAK-3	TAK-4	TAK-5	SUD-1	SUD-2	SUD-3	SUD-4	SUD-5	SUD-6	SUD-7	SUD-8
Clathrocyclas? gravis													+	+	+	+	+
Mita regina													+				
Pterocodon ? anteclinata													+	+	+	+	+
Amphipyndax alamedaensis											R						
A. tylotus											C						
Dictyomitra andersoni											R						
Myllocercion acineton											R						
Praeconocaryomma dauerhafta											R						
Pseudoaulophacus floresensis											R						
Rhopalosyringium magnificum											R		+				
Stylosphaera cf. hastatus											R						
Theocampe abschnitta											C						
Amphipyndax enesseffi									+		R	R					
Cornutella californica								+			R	R					
Dictyomitra koslovae												R					
D. lamellicostata										R	C	R					
D. multicostata									+	C	C	C		+	+		+
Pseudoaulophacus pargueraensis									+								
Stichomitra asymbatos									+		R						
Pseudoaulophacus praefloresensis								+									
Amphipyndax stocki						C	R	+	+	C	A	C					
Archaeodictyomitra sliteri							R										
A. vulgaris						R											
Pseudodictyomitra lodogaensis						C	C	+									
Holocryptocanium barbui				R		C	C	+									
Pseudodictyomitra leptoconica				R													
Thanarla conica				C													
T. karpoffae				R													
Acaeniotyle diaphorogona					R												
A. umbilicata					R												
Pantanellum lanceola					A												
Eucyrtis tenuis					C												
Podobursa triacantha					R												
Pseudodictyomitra carpatica					R												
Staurosphaera septemporata					R												
Thanarla pulchra					R												
Xitus cf. spicularius					R												
Archaeospongoprunum imlayi			+														
Eucyrtidiellum ptyctum			+														
Pseudodictyomitra? sp.D Mat. & Yao			+														
Tricolocapsa yaoi			+														
Dictyomitrella? kamoensis		R															
Eucyrtidiellum unumaense		R															
Hsuum maxwelli	+	R															
Mirifusus guadalupensis		R															
Pantanellium foveatum	+	R															
Parvicingula dhimenaensis		R															
Tricolocapsa conexa	+	C															
KEY TO ABOUNDANCE OF TAXA:	R =RARE				C =COMMON					A =ABUNDANT							

Fig.12. Occurrence and relative abundance of radiolarians in the Saku area. Plus (+) means presence, but difficult estimation of abundance.

pick up radiolarians.

4) The collected radiolarians were mounted, gold coated, and photographed with a scanning electron microscope.

IV. Recognition of Radiolarian Assemblage-zones

Plenty of radiolarian fossils have been collected from the Chichibu and Shimanto belts. As described above, the Chichibu and Shimanto belts in the study area are characterized by tectonic complexes, and thus, repeated and complicated structures are resulted.

All radiolarian fossils are present in these complicated rock bodies. Strictly speaking, discontinuous and sporadic occurrences of radiolarians cannot provide complete assemblage-zones owing to their stratigraphic deficiency. Thus, the authors attempt to compare radiolarian assemblages with each other as to the similarity in components and systematic relationship among them. Then, the radiolarian assemblage-zones recognized in this study are correlated under the species level with those established by many other researchers (RIEDEL and SANFILIPPO, 1974; FOREMAN, 1975, 1977; PESSAGNO, 1976, 1977a, 1977b;

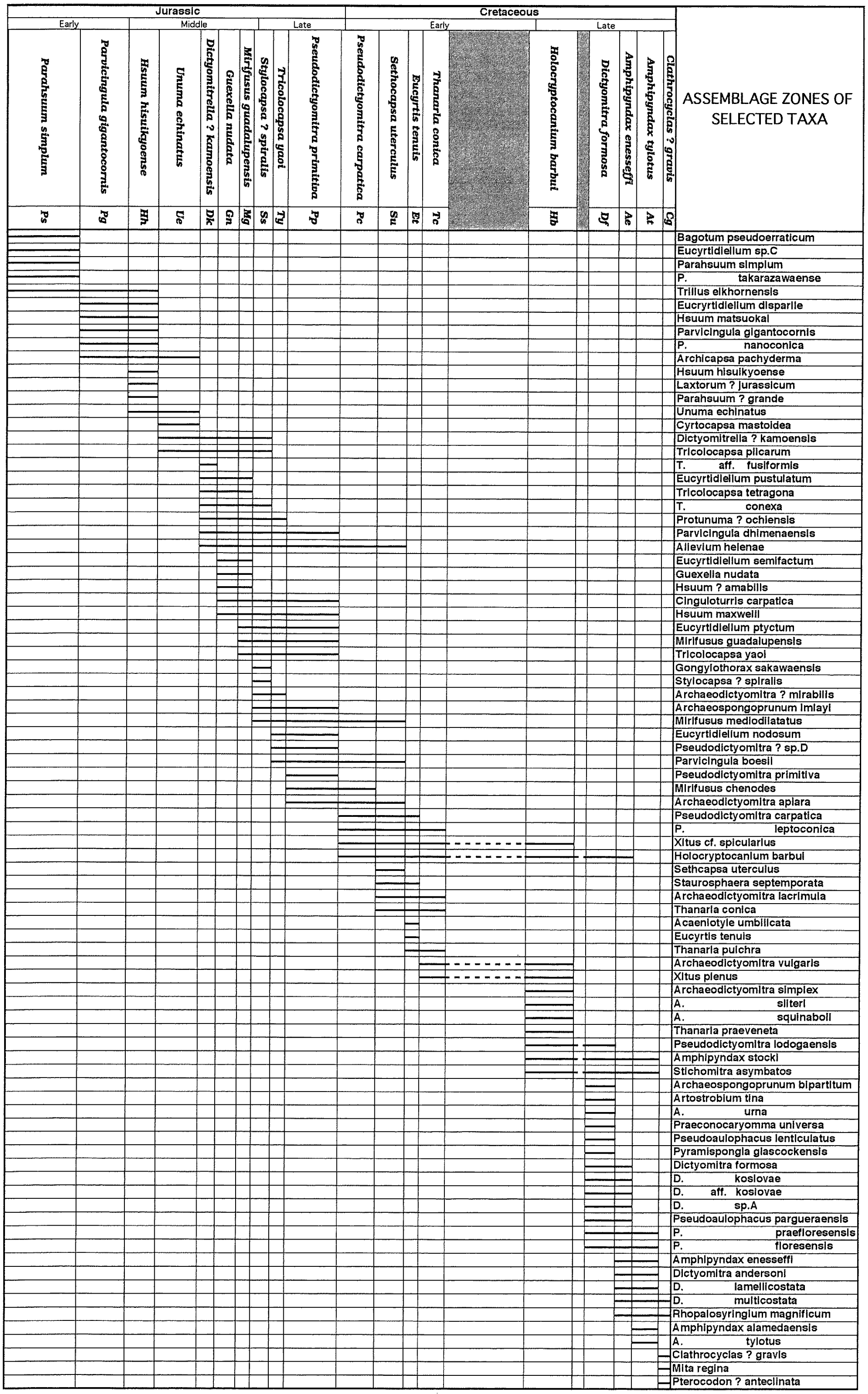

Fig.13. Relationship between the radiolarian assemblage-zone for the Jurassic to Cretaceous of the Kanto Mountains and the range chart for the selected taxa.

SANFILIPPO and RIEDEL, 1985; SCHAAF, 1985; MATSUOKA and YAO, 1986; BAUMGRARTNER, 1987; PESSAGNO *et al.,* 1993; MATSUOKA, 1992).

Thus nineteen radiolarian assemblages have been identified in the Jurassic to Cretaceous sequence in the Kanto Mountains, as shown in Fig.13. Most of them correspond to the previously established Mesozoic radiolarian assemblages, except for the *Dictyomitrella*(?) *kamoensis* (late Bajocian to early Bathonian), *Guexella nudata* (emended herein: middle to late Bathonian), *Mirifusus guadalupensis* (emended herein: early Callovian), and *Stylocapsa*(?) *spiralis* (late Callovian to early Oxfordian) Assemblages of the Jurassic; the *Sethocapsa uterculus* (emended herein: Valanginian), *Eucyrtis tenuis* (emended herein: Hauterivian to early Barremian), *Thanarla conica* (Barremian), *Dictyomitra formosa* (Coniacian to Santonian), *Amphipyndax enesseffi* (emended herein: early to middle Campanian), and *Clathrocyclas*(?) *gravis* (Maastrichtian) Assemblages of the Cretaceous.

Each of radiolarian zones are described here in ascending order. Faunal lists for each sample are presented in Figs.3, 5, 8, 10, and 12. Correlation of each radiolarian zone with that in other regions of Japan is indicated in Figs.14 and 15.

A. Jurassic radiolarian assemblage-zones

1. *Parahsuum simplum* (Ps) Assemblage-zone (YAO, 1982; emend. YAO, 1984)

Occurrence : This zone characterizes gray bedded-chert in the Itsukaichi area

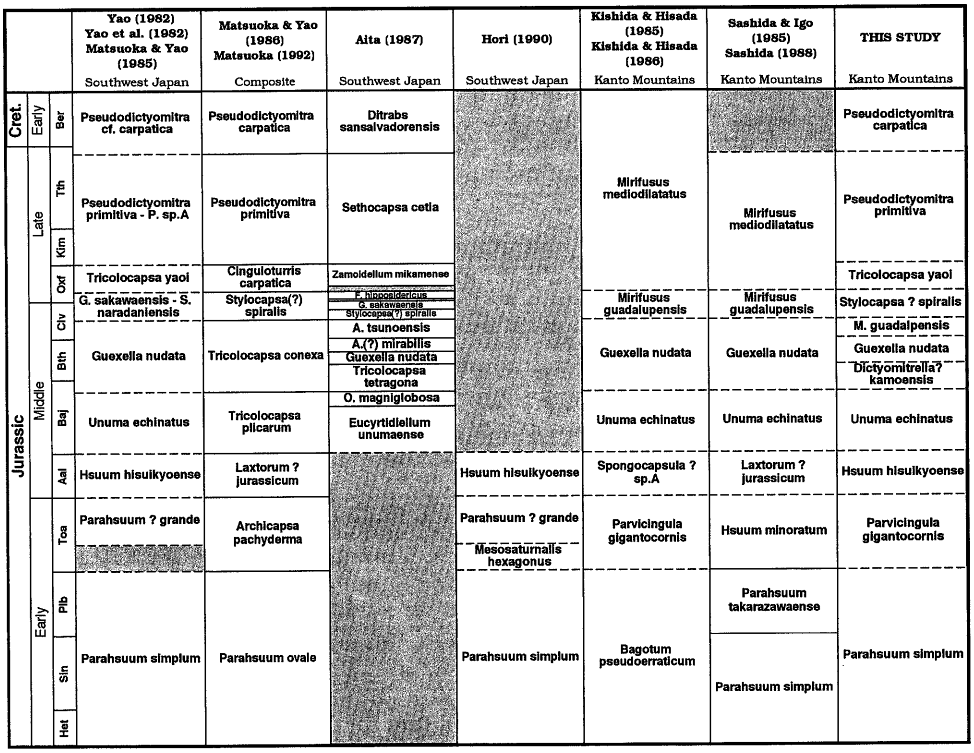

Fig.14. Correlation of radiolarian assemblage-zones for the Jurassic of Japan. Broken line indicates the boundary of assemblage-zones.

(sample numbers S3-4, S3-8, and S3-9), greenish chert blocks in the mélange facies in the Chichibu area (RYO-1), and mudstone matrix of the mélange facies in the Shomaru area (HAN-1 and KWI-5).

Content : This zone is characterized by the occurrence of *Parahsuum simplum.* The following species are included in this assemblage: *Parahsuum takarazawaense, P. kanyoense, P. longiconicum, Bagotum pseudoerraticum, Katoroma* sp., *Napora* sp., *Trillus elkhornensis,* and *Eucyrtidiellum* sp.C in NAGAI (1986).

Renarks : The definition of this zone follows YAO (1984).

Age : Approximately ranging from the Hettangian to the Pliensbachian (HORI, 1990).

2. *Parvicingula gigantocornis* (Pg) Assemblage-zone (KISHIDA and HISADA, 1985)

Occurrence : This zone occurs in gray bedded-chert in the Itsukaichi area (S3-5 and S3-6) and black mudstone matrix of the mélange facies in the Shomaru area (KWI-6), and greenish mudstone of the mélange facies in the Chichibu area (RYO-12).

Content : This zone is characterized by the occurrence of *Parvicingula gigantocornis.* The following species are included in this assemblage: *Parvicingula nanoconica, Parahsuum* sp. aff. *P. longiconicum, Hsuum*(?) sp.A, *H.*(?) sp.B, *H.* sp.C, *H. matsuokai, Archicapsa pachyderma, Trillus* sp.A, *T.* sp.B, *T.* sp.C, and *Eucyrtidiellum disparile.*

Remarks : The definition of this zone follows KISHIDA and HISADA (1985).

Age : Approximately the Toarcian (KISHIDA and HISADA, 1985).

3. *Hsuum hisuikyoense* (Hh) Assemblage-zone (YAO, 1984)

Occurrence : This zone occurs in gray bedded-chert in the Itsukaichi area (S3-10 and S3-11) and dark green mudstone matrix of the mélange facies in the Chichibu area (RYO-2 and RYO-3).

Content : This zone is characterized by the occurrence of *Hsuum hisuikyoense.* The following species are included in this assemblage: *Laxtorum*(?) *jurassicum, Parahsuum*(?) *grande, P.* sp. aff. *P. longiconicum, Hsuum matsuokai, Parvicingula gigantocornis, P. nanoconica, Archicapsa pachyderma, Eucyrtidiellum disparile, E. unumaense,* and *Trillus elkhornensis.*

Remarks : The definition of this zone follows YAO (1984).

Age : Approximately the Aalenian (YAO, 1990).

4. *Unuma echinatus* (Ue) Assemblage-zone (YAO et al., 1980)

Occurrence : This zone occurs in dark green mudstone matrix of the mélange facies in the Chichibu area (RYO-4, RYO-5, RYO-6, RYO-7, and RYO-13).

Content : This zone is characterized by the occurrence of *Unuma echinatus.* The following species are included in this assemblage: *Tricolocapsa plicarum, Stichocapsa robusta, S. japonica,* and *Cyrtocapsa mastoidea.*

Remarks : The definition of this zone follows YAO et al. (1980).

Age : Approximately the Early to Middle Bajocian (YAO, 1990; MATSUOKA, 1992).

5. *Dictyomitrella*(?) *Kamoensis* (Dk) Assemblage-zone (MIZUTANI *et al.*, 1981; emended herein)

Occurrence : This zone occurs in gray bedded-chert in the Itsukaichi area (S3-3 and S3-12) and black mudstone matrix of the mélange facies in the Chichibu area (RYO-8 and RYO-9) and the Itsukaichi area (KWI-1, KWI-2, KWI-3, and KWI-4).

Content : This zone is characterized by the occurrence of *Dictyomitrella*(?) *kamoensis*. The base of this zone is defined as the first occurrence of *Tricolocapsa* aff. *fusiformis, T. conexa, T. tetragona, Eucyrtidiellum pustulatum, Protunuma*(?) *ochiensis, Parvicingula dhimenaensis,* and *Alievium helenae.* The top of this zone is defined as the last occurrence of *T.* aff. *fusiformis* and the first occurrence of *G. nudata.*

Remarks : " *Dictyomitrella*" sp.A (= *D.*(?) *kamoensis*) - *Pantanellium* sp.A (=*P. foveatum*) Assemblage was described first by MIZUTANI *et al.* (1981) from the Mino area. The present samples, however, do not include *P. foveatum.* Therefore, the name of the assemblage is modified into the *Dictyomitrella*(?) *kamoensis* Assemblage in the Kanto Mountains.

Age : MATSUOKA and YAO (1986) described that the first appearance of *Tricolocapsa conexa* is defined as the base of the *T. conexa* Zone and *T. tetragona* first appears near the base of that zone. On the other hand, they noticed that *Guexella nudata* first occurs in the middle of the *T. conexa* Zone. *Guexella nudata* is not included in this assemblage. Accordingly, the *D.*(?) *kamoensis* Assemblage-zone of this paper is equivalent approximately to the lower part of the *Tricolocapsa conexa* Zone by MATSUOKA and YAO (1986), and probably ranges from the Late Bajocian to the Early Bathonian (MATSUOKA, 1992).

6. *Guexella nudata* (Gn) Assemblage-zone (MATSUOKA, 1982; emended herein)

Occurrence : This zone occurs in dark green mudstone matrix and gray chert blocks of the mélange facies in the Itsukaichi area (UNA-1, UNA-2, UNA-3, and UNA-9).

Content : This zone is characterized by the occurrence of *Guexella nudata.* The base of this zone is defined as the first occurrence of *G. nudata.* The top of this zone is defined as the first occurrence of *Mirifusus guadalupensis. Eucyrtidiellum semifactum, Hsuum maxwelli, H.*(?) *amabilis,* and *Cinguloturris carpatica* occur first in this zone. The following species are included in this assemblage: *Tricolocapsa conexa, T. plicarum, Dictyomitrella*(?) *kamoensis, Parvicingula dhimenaensis, Hsuum*(?) sp.D, *Stichomitra*(?) *takanoensis, Eucyrtidiellum unumaense, E. pustulatum, Protunuma*(?) *ochiensis, Stylocapsa* sp. aff. *S. oblongula, Stichocapsa robusta, S. japonica, Emiluvia premyogii,* and *Ristola altissima.*

Remarks : In the middle of the MATSUOKA's (1982) *L. nudata* (=*G. nudata*) Assemblage-zone, the first occurrence of *Mirifusus guadalupensis, Eucyrtidiellum ptyctum,* and *Tricolocapsa yaoi* has been confirmed. Therefore, we distinguish the *M. guadalupensis* Assemblage-zone (defined in the following section) from the *G. nudata* Assemblage-zone in the first occurrence of *M. guadalupensis.*

Age : *G. nudata* first occurs at the middle of the *T.* conexa Zone (MATSUOKA and YAO, 1986). Besides, *M. guadalupensis,* which appears from the Middle

Callovian (BAUMGARTNER, 1987), does not exist. Consequently, this assemblage-zone indicates probably from the Late Bathonian to the Early Callovian.

7. *Mirifusus guadalupensis* (Mg) Assemblage-zone (KISHIDA & HISADA, 1986; emended herein)

Occurrence : This zone occurs in dark green mudstone matrix and gray chert blocks of the mélange facies in the Itsukaichi (S3-13, UNA-4, UNA-5, UNA-6, UNA-7, UNA-8, UNA-12, and UNA-13) and Saku areas (TEN-1 and TEN-2).

Content : The base of this zone is defined as the first occurrence of *Mirifusus guadalupensis* and the top of this zone as the first occurrence of *Stylocapsa*(?) *spiralis* and *Gongylothorax sakawaensis* as well as the last occurrence of *Guexella nudata. Eucyrtidiellum semifactum, E. pustulatum, Tricolocapsa tetragona,* and *Hsuum*(?) *amabilis* occur last in this zone.

Remarks : *M. guadalupensis* Assemblage was first proposed in the eastern Kanto Mountains by KISHIDA and HISADA (1986). They pointed out that *M. guadalupensis* is not accompanied by *G. nudata,* and defined this zone as the first occurrence of *M. guadalupensis.* As discussed above, in this study the first occurrence of *M. guadalupensis* is marked in the middle of the MATSUOKA's (1982) *L. nudata* (= *G. nudata*) Assemblage-zone. Therefore, it seems appropriate to mark the base of the *M. guadalupensis* Assemblage-zone in the middle of the MATSUOKA's (1982) *L. nudata* (= *G. nudata*) Assemblage-zone.

Furthermore, the authors propose to introduce the *Stylocapsa*(?) *spiralis* Assemblage-zone, instead of the upper portion of KISHIDA and HISADA's (1986) *M. guadalupensis* Assemblage-zone, based on the first occurrence of *S.*(?) *spiralis* and *G. sakawaensis. S.*(?) *spiralis* Assemblage-zone is defined in the following section.

Age : The first appearance of *M. guadalupensis* was reported from the Middle Callovian by BAUMGARTNER (1987). In addition, this assemblage zone does not contain the Late Callovian species *S.*(?) *spiralis.* Therefore, this zone indicates approximately the Middle Callovian.

8. *Stylocapsa*(?) *spiralis* (Ss) Assemblage-zone (defined herein)

Occurrence : This zone occurs in black mudstone matrix of the mélange facies in the Itsukaichi area (UNA-10 and UNA-11).

Content : The base of this zone is defined as the first occurrence of *Stylocapsa*(?) *spiralis* in association with *Gongylothorax sakawaensis.* The top of this zone is defined as the last occurrence of *Tricolocapsa plicarum, T. conexa, S.*(?) *spiralis,* and *G. sakawaensis,* and the first occurrence of *Pseudodictyomitra*(?) sp.D of MATSUOKA and YAO (1985), *Ristola boesii,* and *Eucyrtidiellum nodosum.*

Remarks : The fossil assemblage of this zone corresponds with the *G. sakawaensis* - *S. naradaniensis* Assemblage by MATSUOKA (1982). The present zone, however, does not contain *S. naradaniensis,* and so, the name of the assemblage is modified here into the *S.*(?) *spiralis* Assemblage.

Age : According to YAO (1990) and Matsuoka (1992), this zone approximately ranges from the Late Callovian to the Early Oxfordian.

9. *Tricolocapsa yaoi* (Ty) Assemblage-zone (YAO, 1984)

Occurrence : This zone occurs in black mudstone matrix of the mélange facies in the Itsukaichi (UNA-14, UNA-15, UNA-16, and UNA-17) and Saku areas (KAW-1).

Content : This zone is characterized by the occurrence of *Tricolocapsa yaoi.* The following species are included in this assemblage: *Pseudodictyomitra*(?) sp.D in MATSUOKA and YAO (1985), *Archaeodictyomitra*(?) *mirabilis, Protunuma*(?) *ochiensis, Cinguloturris carpatica, Parvicingula dhimenaensis, P. boesii, Mirifusus mediodilatatus, Ristola procera, Eucyrtidiellum nodosum, E. ptyctum, Sethocapsa yahazuensis, Archaeospongoprunum imlayi,* and *Alievium helenae.*

Remarks : The definition of this zone follows YAO (1984).

Age : Approximately ranging from the Middle to Late Oxfordian (YAO, 1990; MATSUOKA, 1992).

10. *Pseudodictyomitra primitiva* (Pp) Assemblage-zone (YAO et al., 1982)

Occurrence : This zone occurs in black mudstone matrix of the mélange facies in the Itsukaichi area (GOZ-1, GOZ-2, and GOZ-3).

Content : This zone is characterized by the occurrence of *Pseudodictyomitra primitiva.* The following species are included in this assemblage: *Pseudodictyomitra*(?) sp. D in MATSUOKA and YAO (1985), *Tricolocapsa yaoi, Parvicingula dhimenaensis, P. boesii, Mirifusus chenodes, M. guadalupensis, M. mediodilatatus, Archaeodictyomitra apiara, Hsuum maxwelli, Cinguloturris carpatica, Eucyrtidiellum ptyctum, E. nodosum, E.* sp.A, *Emiluvia chica,* and *Archaeospongoprunum imlayi.*

Remarks : The definition of this zone follows YAO *et al.* (1982).

Age : Approximately ranging from the Kimmeridgian to the Middle Tithonian (YAO, 1990; MATSUOKA, 1992).

B. Cretaceous radiolarian zones

1. *Pseudodictyomitra carpatica* (Pc) Assemblage-zone (MATSUOKA and YAO, 1985)

Occurrence : This zone occurs in greenish mudstone matrix of the mélange facies in the Itsukaichi (GOZ-5) and Chichibu areas (GOZ-7).

Content : This zone is characterized by the occurrence of *Pseudodictyomitra carpatica.* The following species are included in this assemblage: *Pseudodictyomitra leptoconica, Archaeodictyomitra*(?) *puga, Parvicingula boesii, Dictyomitra duodecimcostata, Xitus* sp. cf. *X. spicularius, Mirifusus mediodilatatus, Sethocapsa kaminogoensis, S. yahazuensis, Holocryptocanium barbui japonicum,* and *Alievium helenae.*

Remarks : In this study, the *P. carpatica* Assemblage-zone is regarded as synonymous with the *P.* cf. *carpatica* Assemblage-zone of MATSUOKA and YAO (1985) and the *Dictyomitra* cf. *carpatica* Assemblage-zone of YAO (1990). The definition of this zone follows MATSUOKA and YAO (1985).

Age : RIEDEL and SANFILIPPO (1974) defined the base of their *Sphaerostylus lanceola* Zone as the first appearance of *S. lanceola* and the top as the first appearance of *Staurosphaera septemporata.* The *P. carpatica* Assemblage of this paper contains *Pantanellium lanceola* (=*S. lanceola*), but *S. septemporata* is absent.

BAUMGARTNER (1987) described that *Alievium helenae* and *P. carpatica* appear at the same time, when is regarded as the base of his Zone D. In addition, the characteristic species *Sethocapsa uterculus* and *Cecrops septemporatus* (= *S.*

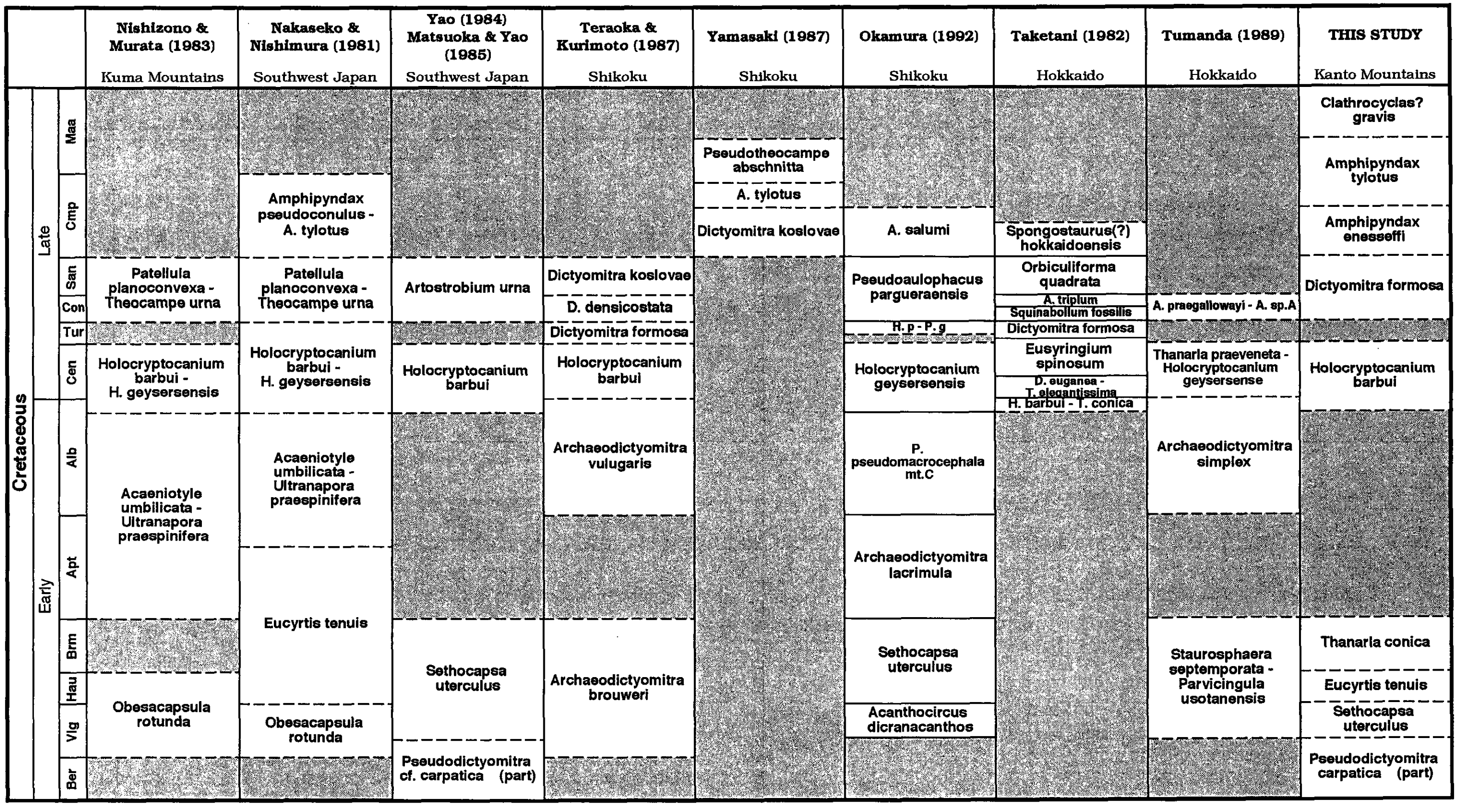

Fig.15. Correlation of radiolarian assemblage-zones for the Cretaceous of Japan. Broken line indicates the boundary of assemblage-zones.

septemporata) from his Zone E are not included in our *P. carpatica* Assemblage.

Moreover, AITA (1987) mentioned that *Sethocapsa kaminogoensis* and *P. carpatica,* which are common in our *P. carpatica* Assemblage, appear nearly at the base of his *Ditrabs sansalvadorensis* Zone.

MATSUOKA (1992) defined his *P. carpatica* Zone on the basis from the first appearance of *P. carpatica* to the first appearance of *Cecrops septemporatus* (= *S. septemporata*).

Taking these biostratigraphic data into consideration, the age of this zone ranges probably from the Late Tithonian to the Early Valanginian.

2. *Sethocapsa uterculus* (Su) Assemblage-zone (YAO, 1984; emended herein)

Occurrence : This zone occurs in greenish mudstone matrix of the mélange facies in the Itsukaichi (GOZ-4) and Oku-tama areas (GOZ-6), and greenish chert block of the mélange facies in the Itsukaichi area (KOS-3).

Content : This zone is characterized by the occurrence of *Sethocapsa uterculus.* The base of this zone is defined as the first occurrence of *Sethocapsa uterculus* and *Staurosphaera septemporata* associated with *Archaeodictyomitra lacrimula* and *Thanarla conica.* The top of this zone is defined by the last occurrence of *S. uterculus* and *Mirifusus mediodilatatus* associated with *Parvicingula boesii, Archaeodictyomitra apiara,* and *Alievium helenae.* The following species are included in this assemblage: *Pseudodictyomitra leptoconica, P. carpatica, Archaeodictyomitra*(?) *puga, A. excellens, Xitus* sp. cf. *X. spicularius, Parvicingula hsui,* and *Holocryptocanium barbui japonicum.*

Remarks : *S. uterculus* Assemblage-zone was first proposed in the Kii-Yura area by YAO (1984). In this study, as discussed below, we distinguish the *Eucyrtis tenuis* Assemblage-zone from the upper portion of YAO's (1984) *S. uterculus* Assemblage-zone by the occurrence of *Eucyrtis tenuis.* Thus, the *S. uterculus* Assemblage-zone is shorter than that of YAO (1984).

This assemblage is nearly synonymous with the *Obesacapsula rotunda* Assemblage of NAKASEKO and NISHIMURA (1981).

Age : RIEDEL and SANFILIPPO (1974) defined the base of their *S. septemporata* Zone by the first appearance of *S. septemporata,* and the top of the zone by the first appearance of *Stichocapsa tenuis* (= *Eucyrtis tenuis*). The *S. uterculus* Assemblage-zone in this paper characteristically contains *S. septemporata* and the components of RIEDEL and SANFILIPPO's (1974) *S. septemporata* Zone, but *Eucyrtis tenuis* is absent.

On the other hand, SANFILIPPO and RIEDEL (1985), SCHAAF (1985), and MATSUOKA (1992) reported that the top of their *S. septemporata* Zone and the base of their *Dibolachras tytthopora* Zone are defined as the first appearance of *D. tytthopora.* In the Kanto Mountains, *D. tytthopora* has not been found, and so, the definition and age of the *S. septemporatus* Zone of RIEDEL & SANFILIPPO (1974) are followed in this study.

BAUMGARTNER (1987) defined the approximate base of his Zone E as the presence of *S. uterculus* and *C. septemporatus* (= *S. septemporata*). These two diagnostic species are contained in the present *S. uterculus* Assemblage.

Judging from those stratigraphic data, this zone is assigned approximately to the Valanginian.

3. *Eucyrtis tenuis* (Et) Assemblage-zone (NAKASEKO and NISHIMURA, 1981; emended herein)

Occurrence : This zone occurs in red chert block of the mélange facies in the Saku (TAK-1) and Chichibu areas (NAK-7).

Content : This zone is characterized by the occurrence of *Eucyrtis tenuis.* The base of this zone is defined as the first occurrence of *E. tenuis, Acaeniotyle umbilicata,* and *Thanarla pulchra* and the top of this zone as the last occurrence of *E. tenuis, A. umbilicata, P. carpatica,* and *S. septemporata.* The following species are included in this assemblage: *Thanarla conica, Archaeodictyomitra lacrimula, Xitus* sp. cf. *X. spicularius, Pantanellium lanceola, Acaeniotyle diaphorogona,* and *Podobursa triacantha.*

Remarks : The *E. tenuis* Assemblage was first proposed in the Shimanto belt in Southwest Japan by NAKASEKO and NISHIMURA (1981).

Age : The first appearance of *E. tenuis* is defined at the base of the *Stichocapsa tenuis* (= *E. tenuis*) Zone by RIEDEL and SANFILIPPO (1974). Moreover, the characteristic species from *S. tenuis* (= *E. tenuis*) Zone are involved in this assemblage from the Saku and Chichibu areas, and so, this assemblage can be compared with that of the *S. tenuis* (= *E. tenuis*) Zone of RIEDEL and SANFILIPPO (1974).

Additionally, the *E. tenuis* Assemblage contains *Staurosphaera septemporata,* which disappears at the Early Barremian, according to RIEDEL and SANFILIPPO (1974), FOREMAN (1975), SCHAAF (1985), and SANFILIPPO and RIEDEL (1985), and *Thanarla pulchra* which disappears at the Middle Barremian, according to SCHAAF (1985) and SANFILIPPO and RIEDEL (1985). On the basis of these data, the *E. tenuis* Assemblage-zone is assigned approximately to the Hauterivian to the Early Barremian.

4. *Thanarla conica* (Tc) Assemblage-zone (defined herein)

Occurrence : This zone occurs in black mudstone matrix of the mélange facies in the Itsukaichi (OZA-1) and Saku areas (KAW-2).

Content : This zone is characterized by the occurrence of *Thanarla conica* and *Holocryptocanium barbui japonicum.* The base of this zone is defined as the first occurrence of *Archaeodictyomitra vulgaris* and *Xitus plenus* and the top as the last occurrence of *Pseudodictyomitra leptoconica, Archaeodictyomitra lacrimula, Thanarla conica,* and *T. pulchra.* The following species are included in this assemblage: *Pseudodictyomitra lanceloti, Archaeodictyomitra*(?) *puga, A. vulgaris, Thanarla karpoffae, Xitus* sp. cf. *X. spicularius.*

Remarks : This assemblage was referred to the *Pseudodictyomitra leptoconica* Assemblage by ISHII *et al.* (1990). In this study, this assemblage is renamed as the *Thanarla conica* Assemblage. The *T. conica* Assemblage-zone is correlated to the *Archaeodictyomitra pseudoscalaris* Assemblage-zone in eastern Shikoku by ISHIDA and HASHIMOTO (1991).

Age : The last appearance of *P. leptoconica* and *A. lacrimula* is reported from the Early Aptian by SCHAAF (1985). SANFILIPPO and RIEDEL (1985) also described that the last appearance of *A. lacrimula* is at the Early Aptian. As described above, *T. pulchra* disappeared at the Middle Barremian (SCHAAF, 1985; SANFILIPPO and RIEDEL, 1985).

Moreover, ISHIDA & HASHIMOTO (1991) considered that their *A. pseudoscalaris* Assemblage-zone indicates approximately the Barremian, taking into account the occurrence of Barremian ammonites.

Judging from these data and the stratigraphic position overlain by the *E. tenuis* Assemblage-zone, the age of the present zone is probably the Barremian.

5. *Holocryptocanium barbui* (Hb) Assemblage-zone (emend. YAO, 1984)

Occurrence : This zone occurs in black mudstone matrix of the mélange facies in the Itsukaichi (NAK-1 and NAK-2), Oku-tama (NAK-3), Chichibu (NAK-4), and Saku areas (TAK-2), greenish mudstone of the mélange facies in the Chichibu area (NAK-8), and gray chert block of the mélange facies in the Saku area (TAK-3).

Content : This zone is characterized by the occurrence of *Holocryptocanium barbui s.l.* The following species are included in this assemblage: *Holocryptocanium barbui barbui, H. barbui japonicum, Hemicryptocapsa polyhedra, Pseudodictyomitra pseudomacrocephala, P. pentacolaensis, P. lodogaensis, Archaeodictyomitra vulgaris, A. squinaboli, A. simplex, A. sliteri, Thanarla praeveneta, Stichomitra asymbatos, Amphipyndax stocki,* and *Xitus plenus.*

Remarks : The definition of this zone follows YAO (1984).

Age : Approximately ranging from the Late Albian to the Cenomanian (YAO, 1984).

6. *Dictyomitra formosa* (Df) Assemblage-zone (defined herein)

The components of this assemblage are very different from the *Holocryptocanium barbui* Assemblage. Many species are found at the base of this zone.

Occurrence : This zone occurs in black mudstone of the coherent facies in the Itsukaichi area (KOB-1, KOB-2, and KOB-3), and black mudstone of the mélange matrix in the Chichibu (NAK-9 and NAK-10) and Saku areas (TAK-4), and greenish mudstone of the mélange facies in the Oku-tama area (KOS-9, KOS-15, and KOS-16), and gray chert blocks of the mélange facies in the Itsukaichi area (KOS-4, KOS-5, and KOS-6).

Content : This zone is characterized by the occurrence of *Dictyomitra formosa.* The base of this zone is defined as the first occurrence of such species as: *Archaeospongoprunum bipartitum, Artostrobium tina, A. urna, Praeconocaryomma universa, Pseudoaurophacus lenticulatus, P. praefloresensis, P. paragueraensis, P. floresensis, Pyramispongia glascockensis, Dictyomitra formosa, D. koslovae,* and *Stichomitra asymbatos.* The top of this zone is defined as the last occurrence of *A. bipartitum, A. tina, A. urna, P. universa, P. lenticulatus, P. praefloresensis,* and *P. glascockensis* as well as the first occurrence of *Amphipyndax enesseffi, Dictyomitra andersoni, D. lamellicostata, D. multicostata,* and *Rhopalosyringium magnificum.* The following species are included in this assemblage: *Dictyomitra* sp. aff. *D. koslovae, Vitorfus* sp. cf. *V. brustolensis, Holocryptocanium barbui japonicum, Amphipyndax stocki, A. conicus, A.* sp. aff. *A. enesseffi, A.* sp. aff. *A. tylotus,* and *Patellula planoconvexa.*

Remarks : This assemblage corresponds with the *Patellula planoconvexa - Theocampe urna* (=*Artostrobium urna*) Assemblage of NAKASEKO and NISHIMURA

(1981) and NISHIZONO and MURATA (1983), and the *A. urna* Assemblage of YAO (1984). In the Kanto Mountains, this assemblage rarely contains *A. urna* and *P. planoconvexa.* Thus, this assemblage-zone is defined as the *D. formosa* Assemblage-zone.

Age : The first appearance of *A. urna* defines the base of the *A. urna* (=*Theocampe urna*) Zone, according to RIEDEL and SANFILIPPO (1974), FOREMAN (1975), YAO (1984), SANFILIPPO and RIEDEL (1985), and SCHAAF (1985), and the top of that zone is defined by the first appearance of *Amphipyndax pseudoconulus* (=*A. enesseffi*).

Although SANFILIPPO and RIEDEL (1985) and SCHAAF (1985) reported *P. lenticulatus* and *D. koslovae* from the Campanian, FOREMAN (1975) and YAO (1984) reported that these species appear first in the middle of their *A. urna* Zone or *A. urna* Assemblage-zone near at the beginning of Santonian.

Thus, the age of this assemblage-zone may be assigned to the interval between the Coniacian and the Santonian.

7. *Amphipyndax enesseffi* (Ae) Assemblage-zone (NAKASEKO and NISHIMURA, 1981; emended herein)

Occurrence : This zone occurs in black mudstone of the coherent facies in the Saku area (SUD-1 and SUD-3), and black mudstone of the mélange matrix in the Itsukaichi (KOS-1, KOS-2, KOS-7, and KOS-8), Oku-tama (KOS-17), Chichibu (NAK-9 and NAK-10), and Saku areas (TAK-5), gray chert blocks of the mélange in the Oku-tama area (KOB-4).

Content : This zone is characterized by the occurrence of *Amphipyndax enesseffi.* The base of this zone is defined as the first occurrence of *A. enesseffi.* It is found near the horizon of the first occurrence of *Dictyomitra multicostata, D. andersoni, D. lamellicostata,* and *Rhopalosyringium magnificum.* The top of this zone is defined as the first occurrence of *Amphipyndax tylotus* (TAKAHASHI and ISHII, 1993). The following species are included in this assemblage: *Amphipyndax stocki, A.* sp. aff. *A. tylotus, Dictyomitra formosa, D. koslovae, D.* sp. aff. *D. koslovae, D.* sp. A, *Stichomitra asymbatos, S.*(?) *carnegiensis, Cornutella californica, Archaeospongoprunum stocktonensis, Holocryptocanium barbui japonicum, Pseudoaulophacus floresensis, P. praefloresensis,* and *P. pargueraensis.*

Remarks : This zone is correlated to the *Dictyomitra koslovae* Assemblage-zone of YAMASAKI (1987). He described that *A. enesseffi* and *A. tylotus* appear at the same time in the late Campanian. Although those species are found in the western Kanto Mountains, the *A. enesseffi* Assemblage-zone is recognized by the presence of its nominal species alone (TAKAHASHI and ISHII, 1993).

Age : The first appearance of *A. enesseffi* defines the base of the *A. pseudoconulus* (= *A. enesseffi*) Zone, according to RIEDEL and SANFILIPPO (1974), FOREMAN (1977), SANFILIPPO and RIEDEL (1985), and SCHAAF (1985), and the top of that zone is defined by the first appearance of *Amphipyndax tylotus* (FOREMAN, 1977; SANFILIPPO and RIEDEL, 1985).

In addition, the components of this zone are common with those of the PESSAGNO's (1976) *Curucella espartoensis* Zone which is assigned to the Early to Middle Campanian.

On the basis of these data, this zone is assigned to the Early to Middle

Campanian.

8. *Amphipyndax tylotus* (At) Assemblage-zone (NAKASEKO and NISHIMURA, 1981; emend. TAKAHASHI and ISHII, 1993)

Occurrence : This zone occurs in black mudstone of the coherent facies in the Oku-tama (KOB-5) and Saku areas (SUD-2).

Content : This zone is characterized by the occurrence of *Amphipyndax tylotus.* The following species are included in this assemblage: *Amphipyndax enesseffi, A. stocki, A. alamedaensis, Dictyomitra lamellicostata, Theocampe abschnitta, Myllocercion acineton, Rhopalosyringium magnificum,* and *Pseudoaulophacus praefloresensis.*

Remarks : The definition of this zone follows TAKAHASHI and ISHII (1993).

Age : Approximately ranging from the Late Campanian to the Early Maastrichtian (TAKAHASHI and ISHII, 1993).

9. *Clathrocyclas*(?) *gravis* (Cg) Assemblage-zone (ISHII *et al.*, 1990; emended herein)

Occurrence : This zone occurs in gray chert layer of the coherent facies in the Saku area (SUD-4, SUD-5, SUD-6, SUD-7, and SUD-8).

Content : This zone is characterized by the occurrence of *Clathrocyclas*(?) *gravis.* The base of this zone is defined as the first occurrence of *C.*(?) *gravis, Mita regina,* and *Pterocodon anticlinata. Dictyomitra multicostata, Rhopalosyringium magnificum,* and many other indeterminable species are included in this assemblage.

Remarks : This assemblage was reported by ISHII et al. (1990). The components of the assemblage are different from those of other Cretaceous assemblages.

Age : VISHNEVSKAYA (1986) discovered *C.*(?) *gravis* in the Late Campanian to Maastrichtian strata in the Bering region. *C.*(?) *gravis* is accompanied with *M. regina* and *D. multicostata that* are in common with the Maastrichtian assemblage from California by FOREMAN (1968) and PESSAGNO (1976). Consequently, this assemblage-zone indicates probably the Maastrichtian.

V. Discussion

As described above, this study has confirmed that the Aptian to Middle Albian and the Turonian radiolarian zones are missing in the Cretaceous sequence of the Kanto Mountains. In other areas of the Japanese Islands, such as in Kyushu (NISHIZONO and MURATA, 1983), Shikoku (YAO, 1984; TERAOKA and KURIMOTO, 1987; OKAMURA, 1992), and Hokkaido (TUMANDA, 1989), either one or the two zones are also lacking (Fig.15).

With regard to the absence of the Aptian to Middle Albian and the Turonian radiolarian zones in the Japanese Islands, there seem to be the following two interpretations:

First, the absence of these zones might have reflected the global mass extinctions at the Aptian - Albian and the Cenomanian - Turonian boundaries (*e.g.,* RAUP and SEPKOSKI, 1986) perhaps due to the worldwide regressions (VAIL *et al.,*

1977) and/or the anoxic events (JENKYNS, 1980). In fact, decreasing in diversity and significant specific changes of radiolarians in those geologic times have been reported by SANFILIPPO and RIEDEL (1985), SCHAAF (1985), TAKETANI (1995), and others. Thus, radiolarians in those times in the Japanese Cretaceous were too simple in fauna and too scarce in population to establish the Aptian - Middle Albian and the Turonian radiolarian zones.

Second, the absence of particular radiolarian zones may have been caused by deterioration in accretionary processes or accretionary hiatus in the mid-Cretaceous due to the change of movement directions of oceanic plates (MASUDA, 1984; MARUYAMA and SENO, 1986).

The fault-controlled basins in the Kanto Mountains seem to present the key to resolve this problem, because the development of these basins was obviously synchronized with the events of the mid-Cretaceous accretionary hiatuses.

In this context, HOWELL and VEDDER (1981) suggested that the mid-Cretaceous and late Paleocene accretionary hiatuses in the northern California Continental Borderland may have been simultaneous with transform faulting that interrupted subduction. The relationship between the subduction-style, subduction complex, and development of strike-slip basins in California is very similar to those in the Kanto Mountains of central Japan.

The relationship between the fault-controlled basins and the accretionary complex of the mid-Cretaceous time in Kyushu was previously reported by SAKAI *et al.* (1990). They inferred that the missing of the Shimanto accretionary complex was caused by transform movement or oblique subduction of the Izanagi Plate against the Eurasian Plate. Thus, it is important to point out that the close relationship between the lack of accretionary complexes and the development of strike-slip basins is recognizable not only in the Kanto Mountains but also in Kyushu at the same time.

VI. Summary

The following results are summarized in this study: (1) Nineteen Jurassic and Cretaceous radiolarian assemblage-zones are established in the Kanto Mountains. They are the *Parahsuum simplum, Parvicingula gigantocornis, Hsuum hisuikyoense, Unuma echinatus, Dictyomitrella*(?) *kamoensis, Guexella nudata, Mirifusus guadalupensis, Stylocapsa*(?) *spiralis, Tricolocapsa yaoi, Pseudodictyomitra primitiva, Pseudodictyomitra carpatica, Sethocapsa uterculus, Eucyrtis tenuis, Thanarla conica, Holocryptocanium barbui, Dictyomitra formosa, Amphipyndax enesseffi, Amphipyndax tylotus,* and *Clathrocyclas*(?) *gravis* Assemblage-zones in ascending order.

(2) Significant stratigraphic gaps are recognized in Aptian - middle Albian and Turonian times in the Kanto Mountains. These stratigraphic gaps were probably mainly due to the deteriorated accretion or accretionary hiatus in those times and partly due to the global mass extinctions.

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Explanation of Plate 1

Scanning electron micrographs of radiolarians. Scale bars indicate 100 μm.
Scale A : Figs.5,8,9,11,12,14,24,26,28
Scale B : Figs.1-4,7,10,13,16-19,21-23,25,27,29-32
Scale C : Figs.6,15,20

Figs.1-5 *Parahsuum simplum* Assemblage
1. *Parahsuum simplum* YAO (S3-8)
2. *Parahsuum takarazawaense* SASHIDA (RYO-1)
3. *Bagotum pseudoerraticum* KISHIDA & HISADA (RYO-1)
4. *Trillus elkhornensis* PESSAGNO & BLOME (KWI-5)
5. *Eucyrtidiellum* sp.C in NAGAI (1986) (S3-8)

Figs.6-8 *Parvicingula gigantocornis* Assemblage
6. *Eucyrtidiellum disparile* NAGAI & MIZUTANI (RYO-2)
7. *Parvicingula gigantocornis* KISHIDA & HISADA (RYO-2)
8. *Hsuum matsuokai* ISOZAKI & MATSUDA (RYO-2)

Figs.9-13 *Hsuum hisuikyoense* Assemblage
9. *Hsuum hisuikyoense* ISOZAKI & MATSUDA (KWI-6)
10. *Archicapsa pachyderma* (TAN SIN HOK) (KWI-6)
11. *Laxtorum*(?) *jurassicum* ISOZAKI & MATSUDA (S3-11)
12. *Parahsuum* (?) *grande* HORI (S3-11)
13. *Parvicingula nanoconica* HORI & OTSUKA (S3-11)

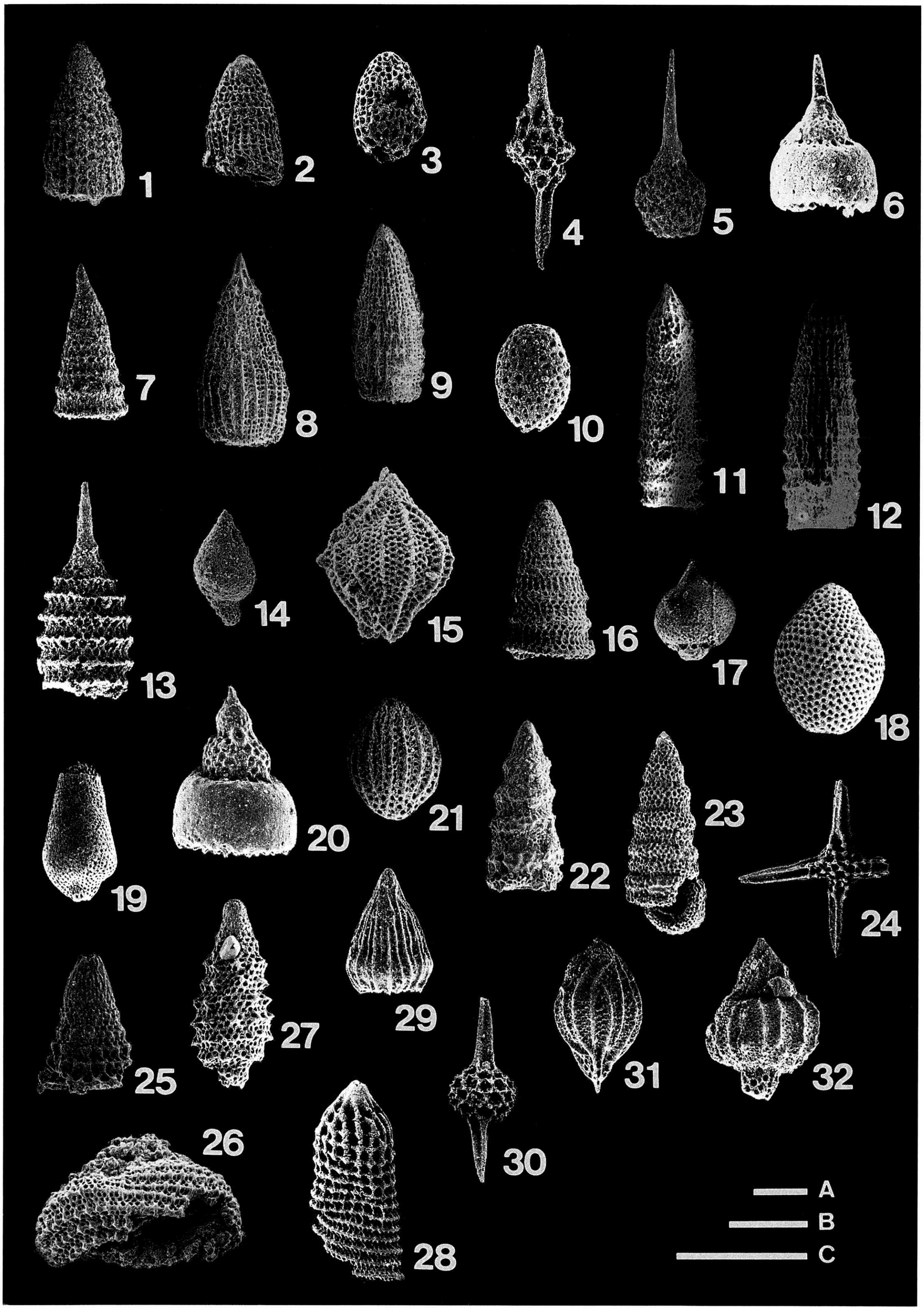
Figs.14,15 *Unuma echinatus* Assemblage
14. *Cyrtocapsa mastoidea* YAO (RYO-7)
15. *Unuma echinatus* ICHIKAWA & YAO (RYO-7)

Figs.16,17 *Dictyomitrella*(?) *kamoensis* Assemblage
16. *Dictyomitrella*(?) *kamoensis* MIZUTANI & KIDO (S3-12)
17. *Tricolocapsa*(?) sp. aff. *T. fusiformis* YAO (S3-3)

Figs.18-22,24 *Guexella nudata* Assemblage
18. *Stichocapsa robusta* MATSUOKA (UNA-3)
19. *Guexella nudata* (KOCHER) (UNA-3)
20. *Eucyrtidiellum unumaense* (YAO) (UNA-3)
21. *Protunuma*(?) *ochiensis* MATSUOKA (UNA-1)
22. *Cinguloturris carpatica* DUMITRICA (UNA-3)
24. *Emiluvia premyogii* BAUMGARTNER (UNA-9)

Figs.25-32 *Mirifusus guadalupensis* Assemblage
25. *Mirifusus guadalupensis* PESSAGNO (UNA-7)
26. *Mirifusus guadalupensis* PESSAGNO (UNA-4)
27. *Parvicingula dhimenaensis* BAUMGARTNER (S3-13)
28. *Ristola altissima* (RÜST) (UNA-5)
29. *Hsuum*(?) *amabilis* AITA (S3-13)
30. *Pantanellium foveatum* MIZUTANI & KIDO (S3-13)
31. *Unuma typicus* ICHIKAWA & YAO (UNA-8)
32. *Unuma*(?) *latusicostata* (AITA) (S3-13)

Fig.23 *Stylocapsa*(?) *spiralis* Assemblage
23. *Cinguloturris carpatica* DUMITRICA (UNA-11)



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Explanation of Plate 2

Scanning electron micrographs of radiolarians. Scale bars indicate 100 μm.
Scale A : Figs.17,18,20,23
Scale B : Figs.3,7-16,19,21,22,24-28
Scale C : Figs.1,2,4-6

Figs.1-6 *Mirifusus guadalupensis* Assemblage
1. *Tricolocapsa plicarum* YAO (UNA-7)
2. *Tricolocapsa conexa* MATSUOKA (UNA-4)
3. *Tricolocapsa tetragona* MATSUOKA (UNA-8)
4. *Tricolocapsa yaoi* MATSUOKA (S3-12)
5. *Eucyrtidiellum pustulatum* BAUMGARTNER (UNA-7)
6. *Eucyrtidiellum semifactum* NAGAI & MIZUTANI (UNA-7)

Figs.7,10-14 *Stylocapsa(?) spiralis* Assemblage
7. *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO) (UNA-11)
10. *Stylocapsa(?) spiralis* MATSUOKA (UNA-10)
11. *Gongylothorax sakawaensis* MATSUOKA (UNA-10)
12. *Archaeodictyomitra(?) mirabilis* AITA (UNA-11)
13. *Hsuum maxwelli* PESSAGNO (UNA-11)
14. *Alievium helenae* SCHAAF (UNA-11)

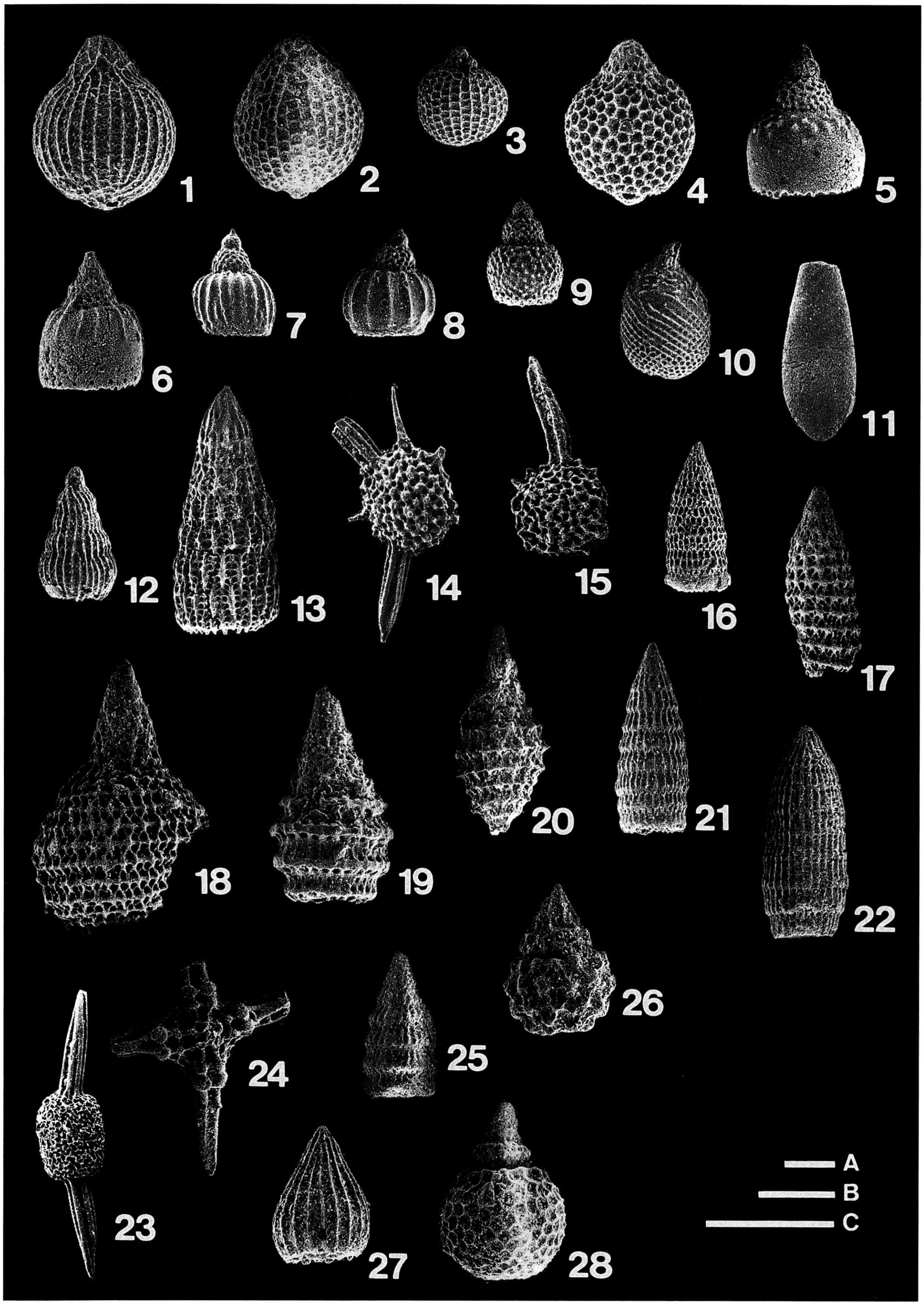
Fig.15 *Dictyomitrella(?) kamoensis* Assemblage
15. *Alievium helenae* SCHAAF (KWI-2)

Figs.16-19 *Tricolocapsa yaoi* Assemblage
16. *Pseudodictyomitra(?)* sp.D in MATSUOKA & YAO (1985)(UNA-14)
17. *Ristola procera* (PESSAGNO) (UNA-14)
18. *Mirifusus mediodilatatus* (RÜST) (UNA-15)
19. *Parvicingula boesii* (PARONA) (UNA-16)

Figs.8,9,20-24 *Pseudodictyomitra primitiva* Assemblage
8. *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO) (GOZ-2)
9. *Eucyrtidiellum nodosum* WAKITA (GOZ-3)
20. *Mirifusus chenodes* (RENZ) (GOZ-3)
21. *Pseudodictyomitra primitiva* MATSUOKA & YAO (GOZ-3)
22. *Archaeodictyomitra apiara* (RÜST) (GOZ-3)
23. *Archaeospongoprunum imlayi* PESSAGNO (GOZ-1)
24. *Emiluvia chica* FOREMAN (GOZ-1)

Figs.25,26 *Pseudodictyomitra carpatica* Assemblage
25. *Pseudodictyomitra leptoconica* (FOREMAN) (GOZ-5)
26. *Sethocapsa kaminogoensis* AITA & OKADA (GOZ-5)

Figs.27,28 *Sethocapsa uterculus* Assemblage
27. *Thanarla conica* (ALIEV) (KOS-3)
28. *Sethocapsa uterculus* (PARONA) (KOS-3)



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Explanation of Plate 3

Scanning electron micrographs of radiolarians. Scale bars indicate 100 μm.
Scale A : Figs.3-6,8,14,17,18,22,27
Scale B : Figs.1,2,7,9-13,15,16,19-21,23-26

Figs.1,2 *Sethocapsa uterculus* Assemblage
1. *Pseudodictyomitra carpatica* (LOZYNIAK) (KOS-3)
2. *Archaeodictyomitra excellens* (TAN SIN HOK) (KOS-3)

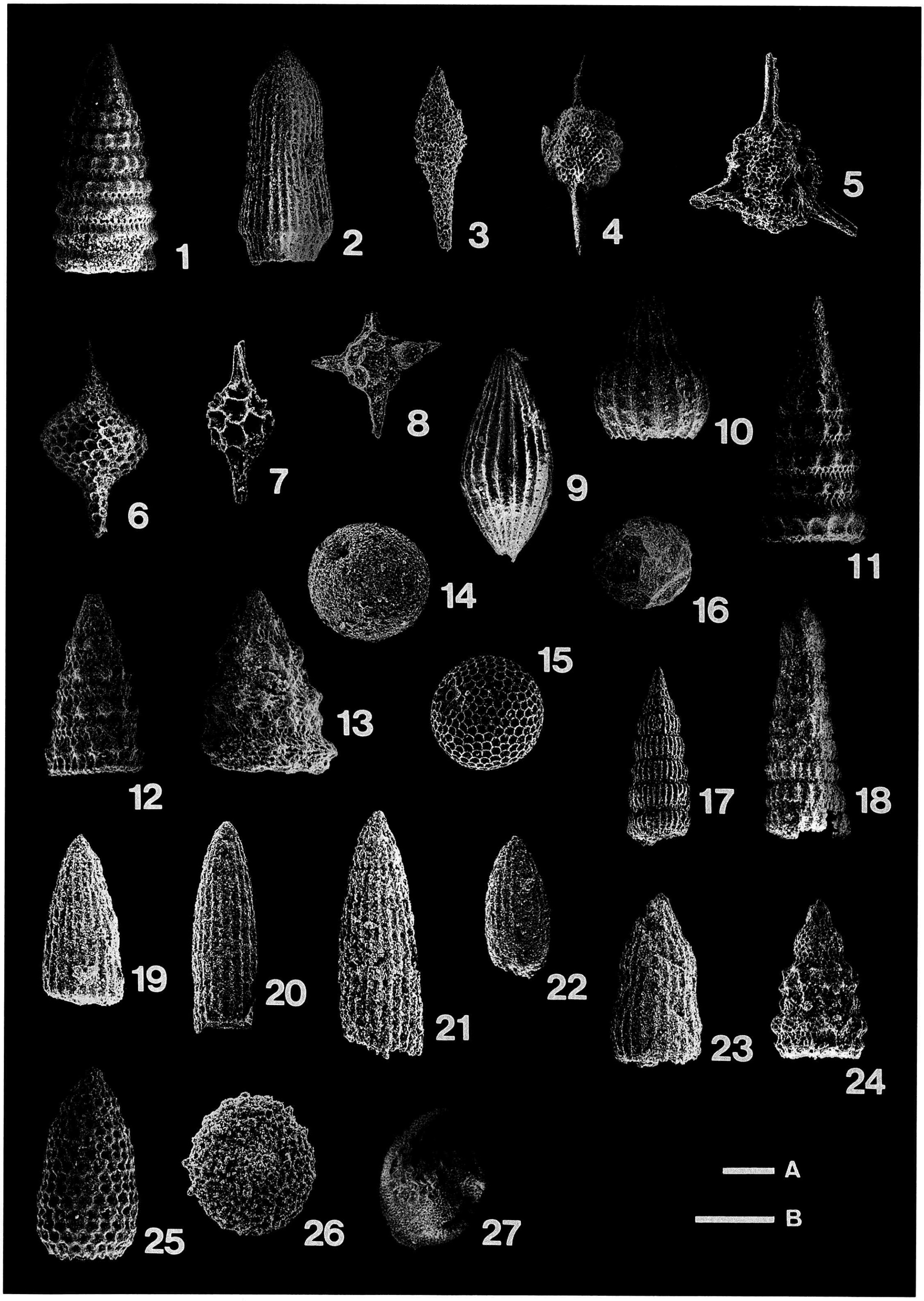
Figs.3-8 *Eucyrtis tenuis* Assemblage
3. *Eucyrtis tenuis* (RÜST) (TAK-1)
4. *Acaeniotyle umbilicata* (RÜST) (TAK-1)
5. *Acaeniotyle diaphorogona* FOREMAN (TAK-1)
6. *Podobursa triacantha* (FIFHLI) (TAK-1)
7. *Pantanellium lanceola* (PARONA) (TAK-1)
8. *Staurosphaera septemporata* PARONA (TAK-1)

Figs.9-13 *Thanarla conica* Assemblage
9. *Archaeodictyomitra lacrimula* (FOREMAN) (OZA-1)
10. *Thanarla pulchra* (SQUINABOL) (OZA-1)
11. *Pseudodictyomitra lanceloti* SCHAAF (OZA-1)
12. *Xitus plenus* PESSAGNO (OZA-1)
13. *Xitus* sp. cf. *X. spicularius* (ALIEV) (OZA-1)

Figs.14,16-24 *Holocryptocanium barbui* Assemblage
14. *Holocryptocanium barbui barbui* DUMITRICA (NAK-8)
16. *Hemicryptocapsa polyhedra* DUMITRICA (KOS-12)
17. *Pseudodictyomitra lodogaensis* PESSAGNO (NAK-1)
18. *Pseudodictyomitra pseudomacrocephala* (SQUINABOL) (NAK-8)
19. *Archaeodictyomitra vulgaris* PESSAGNO (NAK-8)
20. *Archaeodictyomitra sliteri* PESSAGNO (NAK-8)
21. *Archaeodictyomitra simplex* PESSAGNO (NAK-8)
22. *Archaeodictyomitra squinaboli* PESSAGNO (NAK-3)
23. *Thanarla praeveneta* PESSAGNO (NAK-8)
24. *Stichomitra asymbatos* FOREMAN (NAK-1)

Figs.25-27 *Dictyomitra formosa* Assemblage
25. *Amphipyndax conicus* NAKASEKO & NISHIMURA (KOB-2)
26. *Pseudoaulophacus lenticulatus* (WHITE) (NAK-9)
27. *Patellula planoconvexa* (PESSAGNO) (KOS-6)

Fig.15 *Amphipyndax enesseffi* Assemblage
15. *Holocryptocanium barbui japonicum* DUMITRICA (KOS-7)



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Explanation of Plate 4

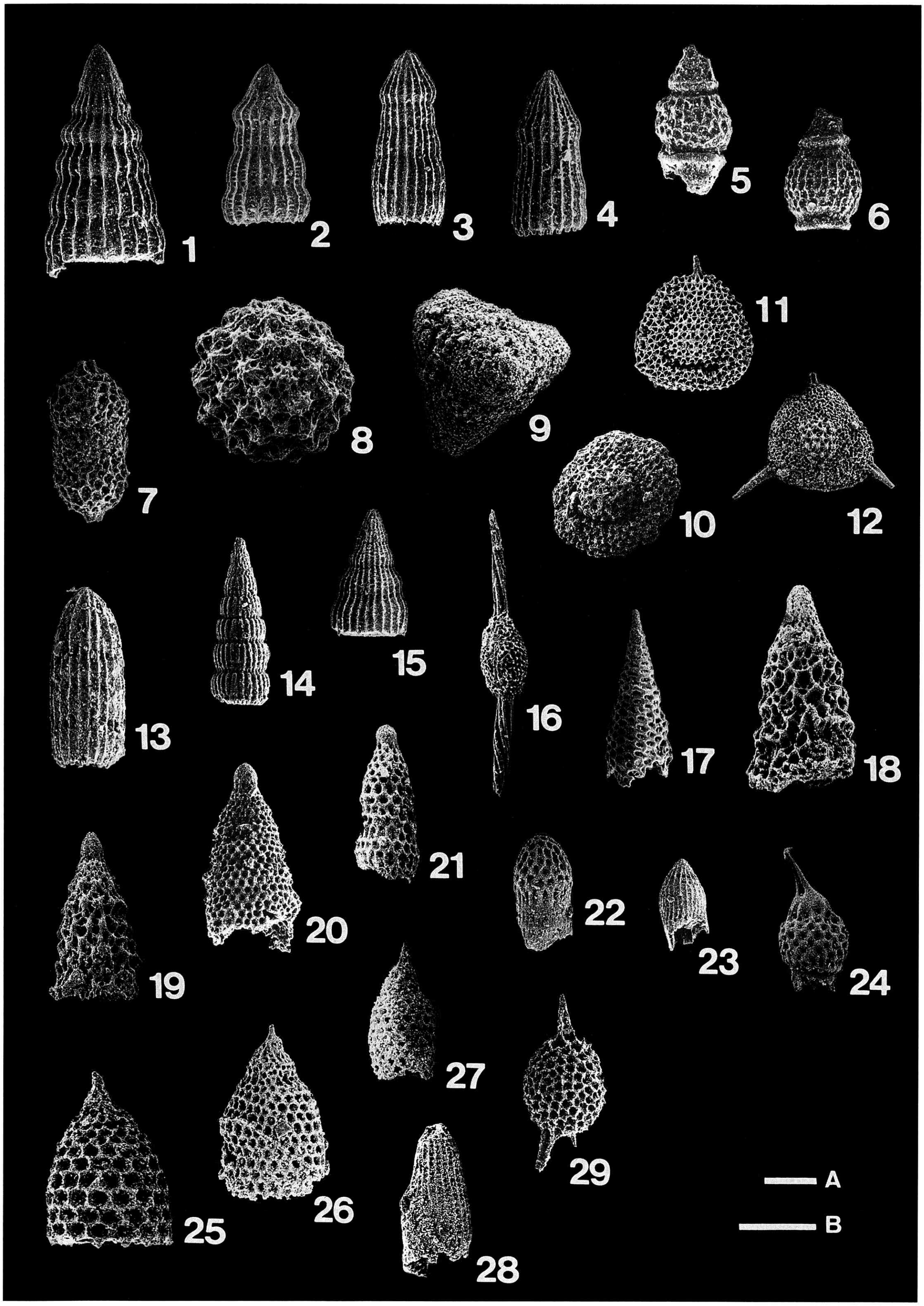
Scanning electron micrographs of radiolarians. Scale bars indicate 100 μm.
Scale A : Figs.9-12,25-27
Scale B : Figs.1-8,13-24,28,29

Figs.1-3,5-9 *Dictyomitra formosa* Assemblage
1. *Dictyomitra formosa* SQUINABOL (KOB-2)
2. *Dictyomitra koslovae* FOREMAN (KOS-6)
3. *Dictyomitra* sp. aff. *D. koslovae* FOREMAN (KOS-5)
5. *Artostrobium urna* FOREMAN (KOB-1)
6. *Artostrobium tina* FOREMAN (KOB-1)
7. *Archaeospongoprunum bipartitum* PESSAGNO (KOB-3)
8. *Praeconocaryomma universa* PESSAGNO (KOB-2)
9. *Pyramispongia glascockensis* PESSAGNO (NAK-9)

Figs.10,11,14-17 *Amphipyndax enesseffi* Assemblage
10. *Pseudoaulophacus pargueraensis* PESSAGNO (TAK-5)
11. *Pseudoaulophacus floresensis* PESSAGNO (KOS-2)
14. *Dictyomitra andersoni* (CAMPBELL & CLARK) (KOS-7)
15. *Dictyomitra multicostata* ZITTEL (KOS-2)
16. *Archaeospongoprunum stocktonensis* PESSAGNO (KOS-7)
17. *Cornutella californica* CAMPBELL & CLARK (KOS-7)

Figs.12,13,18-24 *Amphipyndax tylotus* Assemblage
12. *Pseudoaulophacus praefloresensis* PESSAGNO (SUD-2)
13. *Dictyomitra lamellicostata* FOREMAN (KOB-5)
18. *Amphipyndax tylotus* FOREMAN (SUD-2)
19. *Amphipyndax enesseffi* FOREMAN (SUD-2)
20. *Amphipyndax stocki* (CAMPBELL & CLARK) (SUD-2)
21. *Amphipyndax alamedaensis* (CAMPBELL & CLARK) (SUD-2)
22. *Theocampe abschnitta* (EMPSON-MORIN) (SUD-2)
23. *Myllocercion acineton* FOREMAN (SUD-2)
24. *Rhopalosyringium magnificum* CAMPBELL & CLARK (SUD-2)

Figs.25-29 *Clathrocyclas*(?) *gravis* Assemblage
25. *Clathrocyclas*(?) *gravis* VISHNEVSKAYA (SUD-8)
26. Gen. sp. indet. (SUD-4)
27. *Pterocodon*(?) *anteclinata* FOREMAN (SUD-4)
28. *Mita regina* (CAMPBELL & CLARK) (SUD-4)
29. *Stylosphaera* cf. *hastatus* (CAMPBELL & CLARK) (SUD-4)



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