Mem. Fac. Sci. Shimane Univ.,
26, pp. 145–170 Dec. 25, 1992

Late Ordovician Radiolarians from the Lachlan Fold Belt, Southeastern Australia

Hirokazu GOTO*, Masaki UMEDA**
and Hiroaki ISHIGA**

**Tokushu Plant Industry Co. Ltd., 2-1-18 Shikitsu-nishi, Naniwa-ku, Osaka, 558 JAPAN*
***Department of Geology, Faculty of Science, Shimane University Matsue, 690 JAPAN*
(Received September 10, 1992)

Late Ordovician well-preserved radiolarians occurred from black organic mudstones and calcareous mudstones of the Malongulli Formation of the Lachlan Fold Belt, southeastern Australia. Paleontological study provides significant informations for evaluation of origin of radiolaria, and their evolution in Early Paleozoic. This also may render an additional data on the nature of well diversified Early Paleozoic radiolarians, and record first appearence of ancestoral *Ceratoikiscum* of Albaillellaria and some forms of Palaeoscenidiidae.

Radiolarians described herein are grouped into 14 genera and 26 species. They consist of *Entactinia, Entactinosphaera, Haplentactinia, Haplotaeniatum Kalimnasphaera, Inanigutta, Secuicollacta, Palaeoscenidium, Palaeotripus, Palaeotrifidus,* and proposed one new genera related to *Ceratoikiscum* and undescribed forms.

1 Introduction

Radiolarian biostratigraphy of the Late Paleozoic to Mesozoic has progressed through examination of siliceous deposits of the accreted terranes in Circum Pacific regions, and has also been verified itself through accumulation of investigated zonation and correlation to other biozones. Radiolarites and related siliceous sediments are important as a representative of accreted oceanic materials (pelagic sediments) and may be related to frequency of oceanic plate genesis and transgression. Investigation of the Early Paleozoic terranes along the southeastern margin of the Gondwanaland is necessary to reveal early history of the Lachlan orogen, and will be a principal trigger of tectonic process and paleoenvironmental investigation in comparison with other well documented orogen.

Diversified radiolarian faunas from the Lachlan Fold Belt points presumed blooming of marine planktons caused by worldwide transgression, which brought about the oceanic anoxic event or "Ashgill graptolites mass mortality" in Late Ordovician time (see Berry et al., 1990).

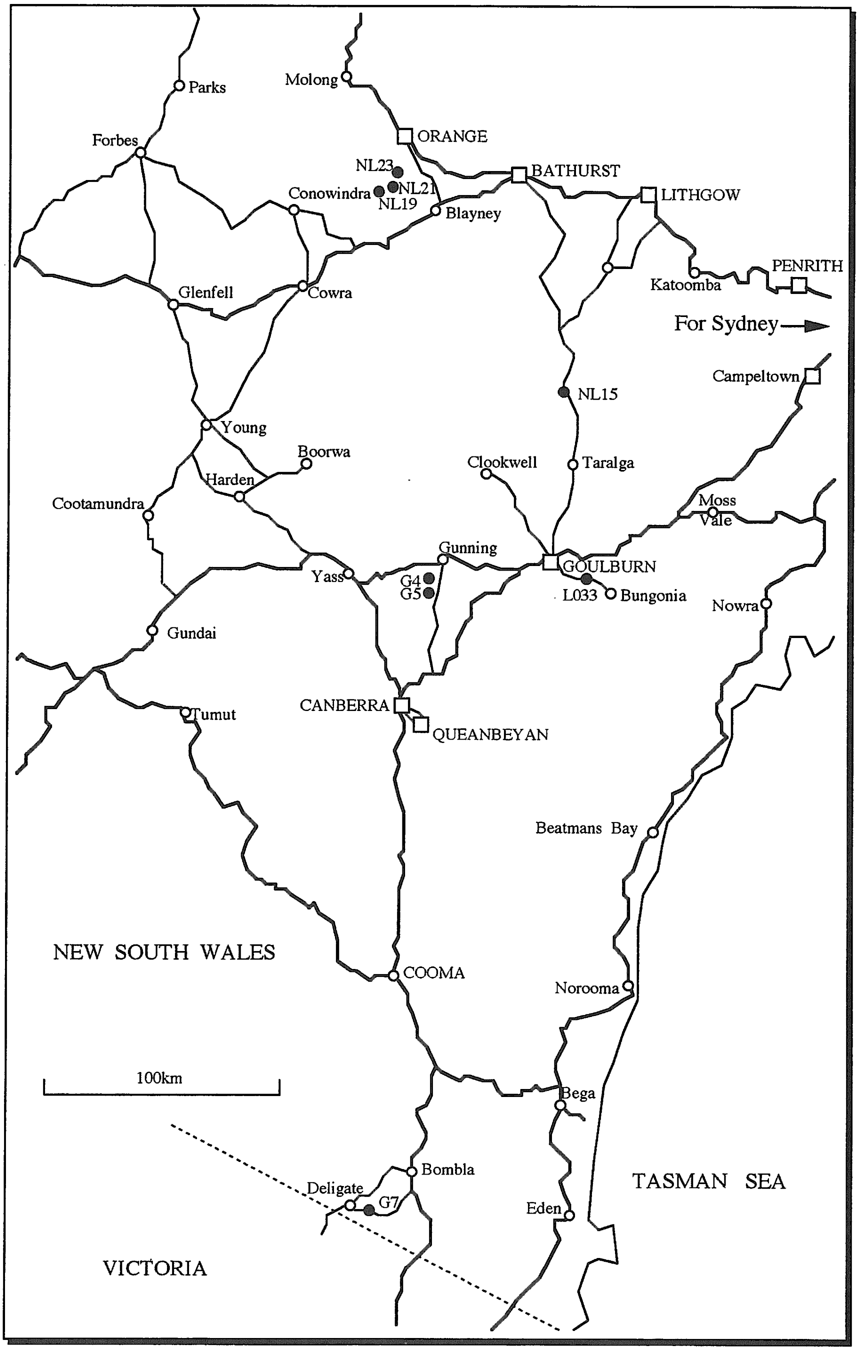


Figure 1. Index of the examined sections in New South Wales, southeastern Australia.

2 Lithologic feature and location of radiolarian bearing rocks

Brief outline of geology of the Lachlan Fold Belt and examination of Ordovician radiolarians are to be referred to Umeda et al. (1992). Localities of well preserved radiolarians are indicated in Fig. 1 and their grid reference is also indicated in Fig. 2.

sample number	locality	grid referrence	map name (1:100,000)
L33	E 149' 50", S 34' 49"	55HGB604426	Goulburn
NL 15 (G1)	E 149' 44", S 34' 13"	55HGC115526	Taralga
G2	E 149' 44", S 34' 11"	55HGC142522	Taralga
NL 21	E 148' 56", S 33' 28"	55HFB902361	Gunning
NL23	E 148' 57", S 33' 26"	55HFC809960	Molong
G4, 5	E 149' 05", S 34' 54"	55HFC814985	Molong
G7	E 148' 58", S 37' 03"	55HFU758982	Bendoc

Figure 2. Grid References of the localities.

L33: Roadside outcrop along the road leading from Goulburn to Bungonia. Bedded grey cherts are exposed, and are slightly recrestalized. Bedded cherts gradually change into siliceous shales.

NL 15, G1, G2: Outcrop along the Goulburn road, at about 30 km northwest from Taralga was first named as NL15 and later collection was done as location G1 (Fig. 3, Fig. 4).

Black organic mudstones and siliceous siltstones and bedded cherts are distributed. Late Ordovician conodonts *Plectodina* sp. was discriminated. Well preserved radiolarians occurred from black organic mudstones with 3–7 cm thickness and radiolarian remains were coated or completely replaced by pyrite. G2 is situated approximately 2 km north of NL 15 and this location represents nearly same horizon to that of NL15.

NL21, NL23: Both locations are about 50 km southwest of Orange (Fig. 5). NL21 is located at along the road leading from Blayney to Four Mile Creek, and beded calcareous mudstones with 2–5 cm single bed thickness are distributed. NL23 is quarry, located along road about 500 m north from NL21 leading to the Canobolas state forest. Bedded black to grey calcareous mudstones are distributed and are intruded by dyke rock. This is supposed to be same horizon to the Malongulli Formation reported by Webby and Blom (1986).

G4, G5: Outcrop at 20 km south from Gunning. Grey to greenish grey bedded

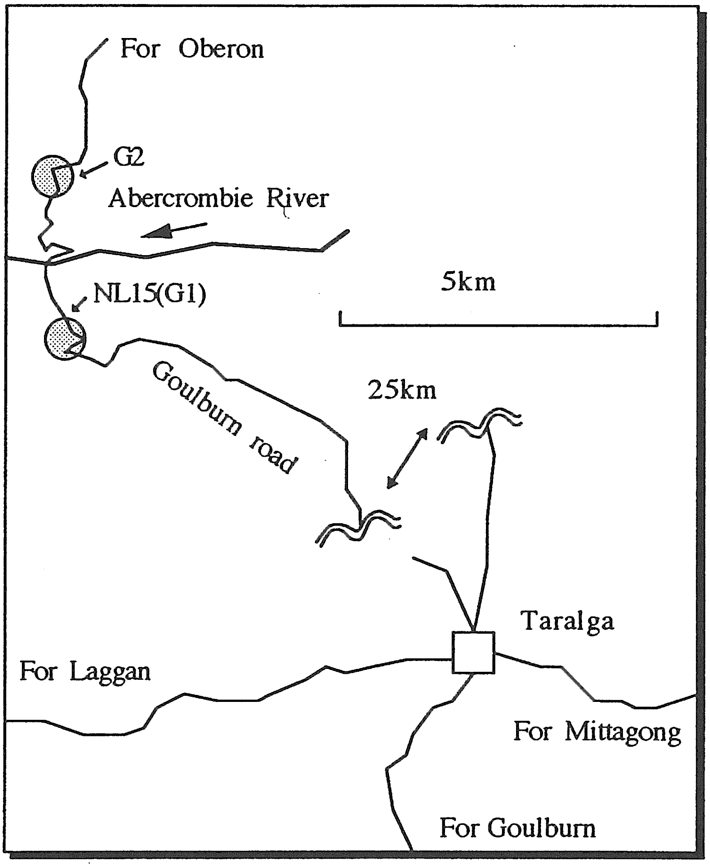


Figure 3. Index map showing localities NL 15 (G1) and G2 near Taralga.

cherts are distributed, which produced poorly preserved radiolarians.

G7: Outcrop about 100 m west from Green Creek, situated about 10 km east from Deligate. Grey bedded cherts and siltstones with 5–8 cm thickness of a single bed are distributed, which yeild radiolarians and cooccurred Middle Ordovician *Cyrtoniodus* sp.

3 Systematic Paleontology

Types and figured specimens were housed in the Department of Geology, Faculty of Science, Shimane University (DGSU PR), and will be shifted to be housed in Paleontological institution in Australia.

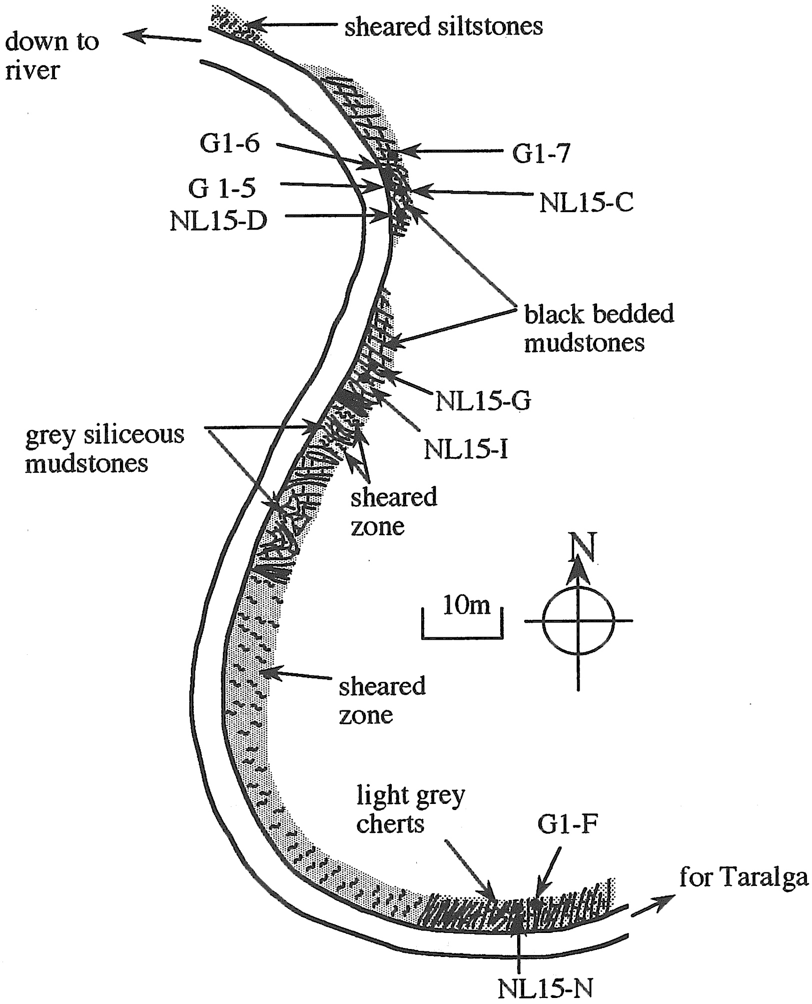


Figure 4. Route map showing lithology of the examined section and stratigraphic distribution of the collected samples at locality NL 15 (G1).

Subclass Radiolaria, Müller, 1858
Order Polycystina Ehrenberg, 1838; emend. Riedel, 1967
Systematic framework of the examined radiolarians were indicated in Fig. 6.

Family Entactiniidae Riedel, 1967: emend. Holdsworth, 1977: and Goodbody, 1986

Genus *Entactinia* Foreman, 1963

Remarks: *Entactinia* is characterized by internal six-rayed double spicules and a

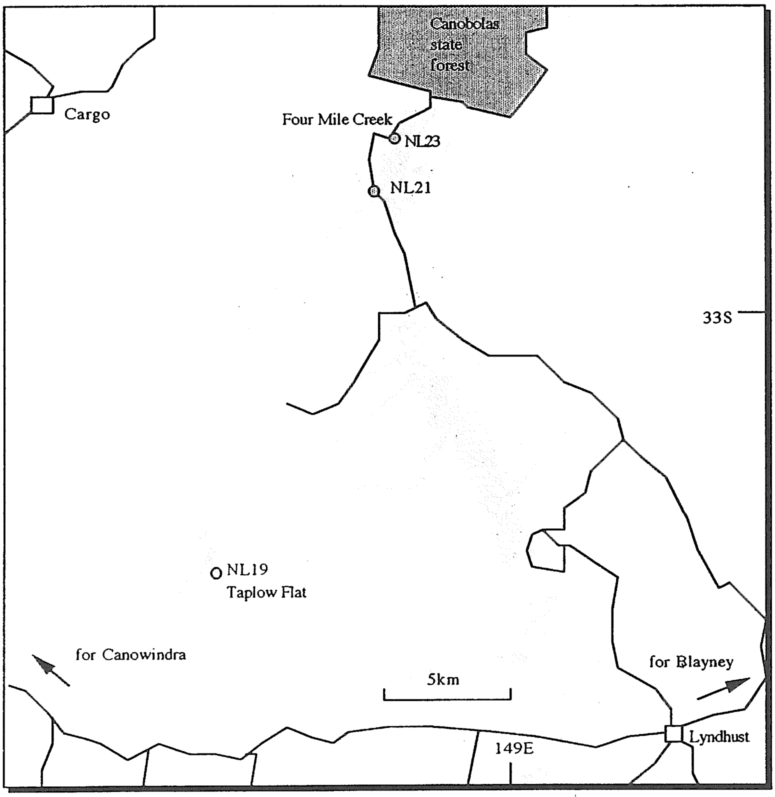


Figure 5. Index of localities NL 21, 23 near Lyndhust.

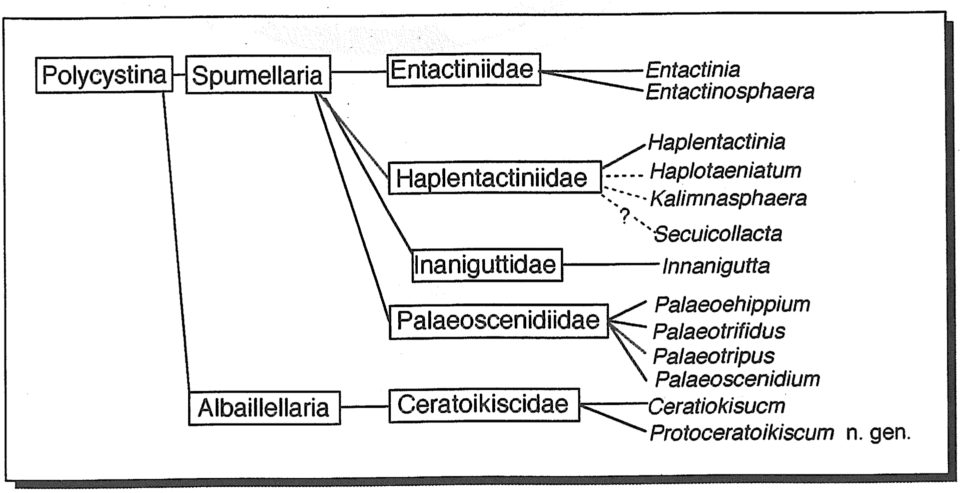


Figure 6. Systematics of the main Late Ordovician radiolarians described in this paper and related radiolarians.

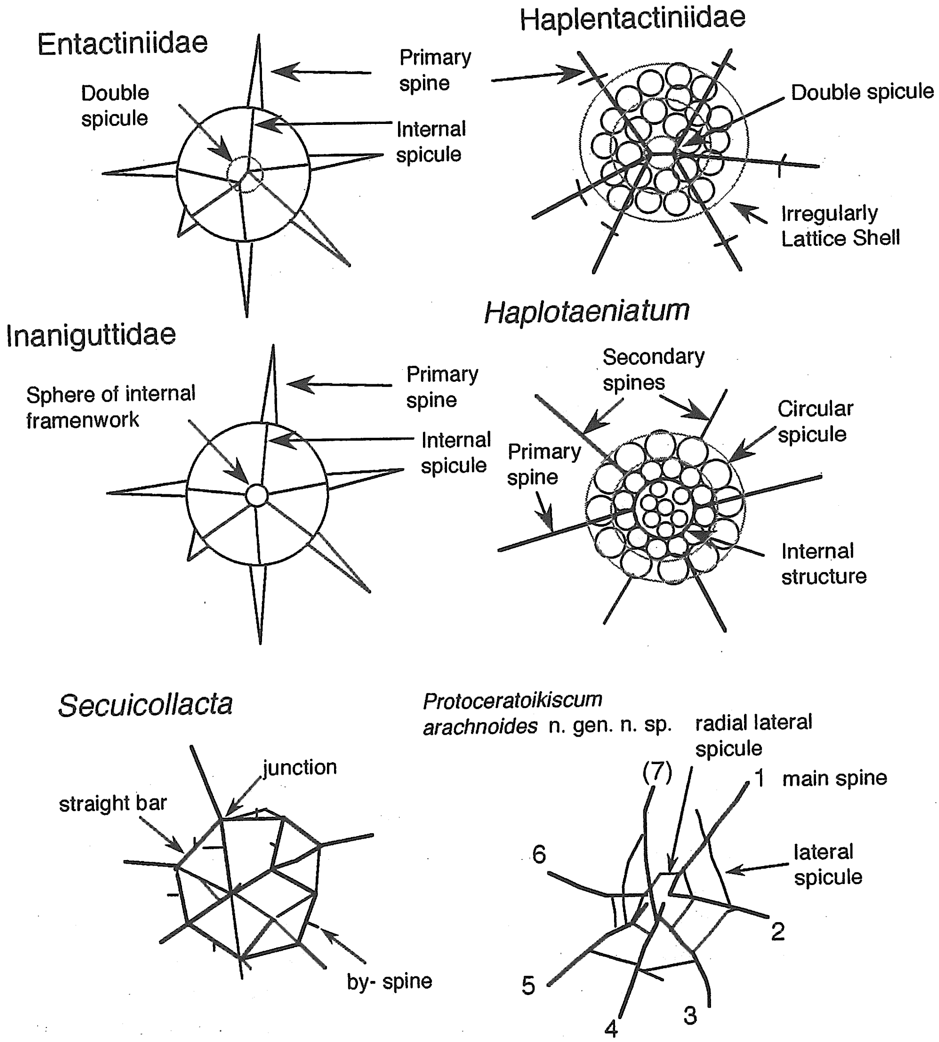


Figure 7. Illustration indicating shell structurure of selected Late Ordovician radiolarians.

single well-developed lattice or spongy shell. In some specimens, internally six-rayed double spicules and extra rays are observed. Spherical external shell produced pores.

Entactinia modesta Goto, Umeda and Ishiga n. sp. ver. 1
Plate 1, Figures 1, 2

Entactinia sp. D Goto and Ishiga, 1991, pl. 1, fig. e.

Material: Holotype is DGSU PR 1040 (Plate 1, Fig. 1) and paratype is DGSU PR

1041 (Plate 1, Fig. 2) from NL 15c, d and G18.

Etymology: From the Latin meaning modest.

Description: Test consists of rather small, thick-walled, single spherical shell, and shell surface yielded pores. Opening form is ellipse to angular and is small in size. Six primary spines are rather short and tapered at the distal end. These spines are extending from the shell and each two intimately occurred at three places of the shell surface. Internal spicules are originated from double spicule, and in some specimens they occurred from very short median bar (its looks as center point). This point is arranged at the eccentric position of spherical shell. No by-spines and apophyses are preserved.

Measurements: Based on more than 15 specimens in μm.
Diameter of sphere: 111–138 average 128
Pore diameter: 5–15 av. 12
Shell thickness: 15
Length of spines: 63–117 av. 70

Occurrence: Possibly Late Ordovician.

Entactinia modesta Goto Umeda, and Ishiga n. sp. ver. 2
Plate 1, Figure 3; Plate 3, Figure 1

aff. *Haplentactinia baltica* Nazarov, 1984

Material: Paratypes are DGSU PR 1040 (Plate 1, Fig. 3) and DGSU PR 1041 (Plate 2, Fig. 1) from NL15c, d G15, 6, 7 which are replaced by pyrite.

Description: Tests consist of rather small, spherical-subspherical, thick-walled, single shell with 4–6 thick rod-like primary spines. Primary spines are tapered at the distal end. On the surface, rough, thick long spicules connect to form angular-ellipse large pores forming roughly organized lattice shell. Primary spines are extending from internal spicules which are mostly straight. In some specimens primary spines are curved out of the external shell. Internal spicules are originated from double spicule or very short bar lying on eccentric position of the spherical shell.

Measurements: Based on more than 10 specimens in μm.
Diameter of sphere: 130–140 av. 135
Pore diameter: 20–35 av. 28
Shell thickness: 14–18
Length of spines: 105–190 av. 130

Remarks: *Entactinia modesta* n. sp. has the similar spherical shell in size with the other Ordovician *Entactinia* spp. In this study, *Entactinia modesta* is classified into the ver. 1 and ver. 2 according to the pore size. The ver. 1 has a peak at nearby 9–10, while ver. 2 has it at nearby 3–4 of L/P (where L is diameter of shell, P is diameter of pores).

Comparison: The ver. 1 shows similar form with *Palaeosphaera micra* Renz (1990), but differs from this species by the existence of internal structure, because no such structure has been indicated in *P. micra.* The ver. 2 has a resemble form to *Haplentactinia baltica* Nazarov. *H. baltica* is one of common species in the Late Ordovician at Kazakhstan (Nazarov, 1988) and this species have a lattice form constructed by a combination of slender spines and small spicule. But the ver. 2 seems to have formed subspherical in outline and is characterized by ornamentation of large pores. They mutually differ each other, and study of their relationship is problem to be revealed for morphological change in Early Paleozoic radiolaria.

Occurrence: Possibly Late Ordovician.

Entactinia leptura Goto Umeda, and Ishiga n. sp.
Plate 2, Figure 2, 3

Material: Holotype is DGSU PR 1044 (Plate 2, Fig. 2) and paratype is DGSU PR 1041 (Plate 2, Fig. 3) from NL15c, d, g G15, 6, 7, 8 NL21 NL23.

Etymology: From the Latin small or thin.

Description: Test consists of rather small, but thick-walled, single spherical shell with 4–6 thick, rod-like primary spines. Primary spines are gently tapered to distal end. Internal spicules originated from double spicule or very short bar which connect at the eccentrically or center position of spherical shell. Primary spines are rather thicker than internal spicule and extend to outside of the external shell irregularly. Well-developed by-spines extended at the junction of pore bars.

Remarks: *Entactinia modesta* and *Entactinia leptura* have similar form and size in each other. The main difference of them are much ornamentation of *Entactinia leptura,* namely thicker main spines, development of by-spines and large number of pores in *Entactinia leptura.*

Measurements: Based on more than 10 specimens in μm.
Diameter of sphere: 116–133 av. 122
Pore diameter: 10–20 av. 15
Shell thickness: 7–15
Length of spines: 50–75 av. 130 (not confirmed of poorly preservation)

Comparison: These specimens also show similarity to *Palaeosphaera micra* Renz 1991, but *P. Micra* has not internal structure.

Occurrence: Possibly Late Ordovician.

Entactinia micropora Goto Umeda, and Ishiga n. sp.
Plate 3, Figures 1–3

Material: Holotype is DGSU PR 1046 (Plate 3, Fig. 1) and paratypes are DGSU PR 1047 (Plate 3, Fig. 2) and DGSU PR 1048 (Plate 3, Fig. 3) from NL21, 23.

Etymology: From the Latin small and pore.

Description: Rather thick-walled, spherical shell is surrounded by circular or ellipse pores. Approximately 6 rod-like spines extend from internal double spicules and taper to distal end. The internal double spicules are rather smaller than outer primary spines. Internally this is arranged in an eccentrical position of spherical shell. Six primary spines are assignable to approximately isometric angle with each other. These spines are mostly straight but may be curved to the end. A part of specimens have by-spines which originated from the pore bar junction.

Remarks: This species from NL21, 23 of Malongulli formation resembles *E. subulata* Webby and Blom (1986), but differs from the latter in having smaller pores and larger numbers of pores.

Measurements: Based on more than 15 specimens in μm.
Diameter of sphere: 137–176 av. 140
Pore diameter: 8–15 av. 12
Shell thickness: 13–15
Length of spines: 125–180 av. 140

Occurrence: Possibly Late Ordovician.

Entactinia sp. A
Plate 4, Figures 1, 2

Material: Types are more than 5 specimens (DGSU PR 1049, Plate 4, Fig. 1; DGSU PR 1050, Plate 4, Fig. 2) from NL15c, which are replaced by pyrite.

Description: Very small, rather thick-walled spherical shell is surrounded by circular or ellipse pores. Six to ten rather thick rod-like short spines grow to outer side irregularly. These spines are tapered distally and/or curved. A part of specimens has by-spines oriented from junction of pore bars.

Remarks: Internal structure is not clearly observed. However, according to the fragments of this species, eccentrically arranged junction of internal spicules is observable.

Measurements: Based on 4 specimens in μm.
Diameter of sphere: 77–92 av. 83
Pore diameter: 8–15 av. 12
Shell thickness: 5–8
Length of spines: 70–92 av. 80

Comparison: This specimen resembles *Entactinia leptura* n. sp. described above, but *E. leptura* has 4–6 primary spines and spherical shell nearby 130 μm in diameter. This specimens are characterized by small shell that is nearly 80 μm measured at proximal part.

Occurrence: Possibly Late Ordovician.

Genus *Entactinosphaera*, Foreman 1963

Remarks: Entactinopshera is characterized by two or more spherical shell with double spicules. These specimens have triple shell, but internal double spicules are not clarified by recrystallization of inner shell. Therefore, this classification remains unsolved for lacking of detailed observation of inner shell structure.

Entactinosphaera sp. A
Plate 4, Figure 3

Entactinosphaera sp. A Goto and Ishiga, 1991, pl. 2, fig. a

Material: One specimen from NL15c (DGSU PR 1051). A part of spherical shell are replaced by pyrite

Description: Triple spherical shell has 6 primary spines consisting of main skeleton. Rather thick, rod-like spines grow up from most internal shell which has half diameter of external shell. Rather thin-walled secondary shell is ornamented by little circular pores. The secondary shell is supported by primary spines and hook-like spicules which rise from most internal shell near primary spines. This forms spongy like delicated shell. External shell with angular pores are supported by thin by-spines and spicule oriented from secondary shell.

Measurements: Based on one specimen in μm.
Diameter of most internal sphere: 33
Diameter of secondly sphere: 80
Diameter of external sphere: 100
Pore diameter: 5–10
Length of spines: 50–60

Comparison: This specimens shows variety of forms, and is able to compare with *Inanigutta* sp. Nazarov 1984. But it is hard to determine the specific assignment because of poor-preservation. And this evidence points appearence of radiolarians with two or more internal shells already occurred in Late Ordovician time.

Discussion: This specimens have suffered recrystallization and of which some parts are rather ill preserved, but parts replaced by pyrite, especially their outer surface of shell are excellently preserved. The specimen is characterized by small circular pores under 1/20 of L/P ratio. The type 1 illustrated in Plate 4, Figure 3 and type 2, not indicated are classified by following characters: namely type 1 has rather thick rod-like spines, while type 2 has rather large shell with well-developed by-spines.

Occurrence: Possibly Late Ordovician.

Family Inaniguttidae Nazarov and Ormiston, 1984
Genus *Inanigutta* Nazarov, 1984

Remarks: Genus *Inanigutta* has a hollow sphere and 6 primary spines. The species described below is characterized by hollow sphere and very long primary 6 rayed spines and also show same shell size to those previously described. And *Inanigutta* may be a synonym to Palaeocatinommids, informal grouped by Holdsworth (1977).

Fmily: Haplentactiniidae Nazarov and Nolvak, 1983
Genus: *Haplentactinia* Foreman, 1963

Remarks: *Haplentactinia* is first described by Foreman (1963) that have six rayed double spicule with branches arising at two levels along each ray and sometimes form an irregular lattice shell. These specimens have spongy meshwork and approximately 6 primary spines and also have similar form with *Haplentactinia armillata* Nazarov, 1980.

Haplentactinia sp. aff. *H. baltica* Nazarov and Nolvak, 1983
Plate 5, Figure 1

Material: One specimen from NL15c which is replaced by pyrite (DGSU PR 1058).
Description: Latticed subspherical shell with 6 rather thick primary spines taper to distal end. Primary spines grow from isometric interval with each other. By-spines are oriented from spicule which makes lattice shell junction.
Remarks: Internal and structure of latticea shell surface are not clear by poor preservation.
Measurements: Based on one specimen in μm.
Diameter of sphere (most short part of lattice shell): 64
Length of spines: 70
Comparison: *H. baltica* Nazarov and Nolvak (1983) has six slender primary spines and rude spongy or latticed shell structure. It is common in Late Ordovician at Kazakhstan (Nazarov and Nolvak, 1983). This specimen has similar form concerning structure of lattice shell and 6 spines. No clear internal structure has been observed.
Occurrence: *H. baltica* Nazarov and Nolvak was reported from Late Ordovician of Estonia (Nazarov and Nolvak, 1983) and specimen described here resembles to this species. Possibly Late Ordovician.

Haplentactinia attenuata Goto Umeda, and Ishiga n. sp.
Plate 5, Figures 2–3

Material: Holotype is DGSU PR 1059 (Plate 7, Fig. 2) and paratype is DGSU PR 1060 (Plate 7, Fig. 3) from NL15c which are replaced by pyrite.
Etymology: From the Lattin thin or point.
Description: Four to six rod-like primary spines gently taper to distal end and these grow up from central position of shell. Spines connect each other to support the

bubble shaped spongy outer shell. Shell comprises two or more spherical shell. Inner shell has 2/3 diameter of outer shell in size and extends from rather delicate structure formed by small circular spicule. Secondary or more shell ornamented on outer layer of the inner shell, and each pore is formed by connection of vertical or acute angled fine spicules. By-spine like spicule is extending from the surface of junction forming circular spicule.

Remarks: Internal structure of this specimens is very crowded by spicules, so it is not clear.

Measurements: Based on 2 specimens in μm.
Diameter of most internal sphere: 70–80
Diameter of external sphere: 93–117 av. 110
Circular spicule diameter: 10–20 av. 15
Length of spines: 24–40 av. 50
Length of by-spines: 8–15

Occurrence: Possibly Late Ordovician.

Genus *Haplotaeniatum* Nazarov, 1988
Type specimen: *Haplotaeniatum tegimentum* Nazarov (Nazarov and Ormiston, 1984)

Remarks: Two or more concentrically organized complicated shells consist of small circular spicules. Circular spicules are developed irregularly to outside forming bubble like fine and delicate structure. Primary spines if exsist, radiate from layers of some concentric shells, and the spines radiate from the inner shell which connect outer shells. This specimens doesn't have connecting node or double spicule.

Haplotaeniatum Nazarov might be proposed in Nazarov (1988) indicated by plates and description, although Nazarov cited the proposal in his previous work in Nazarov of Nazarov and Ormiston (1984), or Nazarov and Ormiston (1986).

Haplotaeniatum spinatum Goto Umeda, and Ishiga n. sp.
Plate 6, Figures 1–3

Gen. A sp. A, Goto and Ishiga, 1991, pl. 2, fig. c.
cfr. *Entactinia spongia* Renz, 1990, pl. 1, figs. 1–3.

Material: Holotype is DGSU PR 1067 (Plate 10, Fig. 1) and paratypes are DGSU PR 1068 (Plate 10, Fig. 2) and DGSU PR 1069 (Plate 10, Fig. 3). More than 20 specimens from NL15c which is replaced by pyrite.

Description: Tests are characterized by rather small shell and circular spicule. Circular spicule makes approximately two or more spherical shells. Most inner shell which made of spherical spicule with rather large circular pores and lies on eccentrically position. Unclear secondarly shell make from circular spicules which grow up vertical or acute angle like arch. Most outer shell are formed secondly shell. Two to four rod-like primary spines are emanated from most inner shell which have no structure in the most inner side of shell. Secondly spines extend from the second layered shell and in case grow from the most outer shell.

Measurements: Based on 20 specimens.
Diamter of most internal sphere: av. 40
Diamter of secondary sphere: av. 80
Diamter of external sphere: 104–170 av. 170
Diameter of circular spicule: 15–25 av. 20
Length of spines: 40–60 av. 50

Occurence: *Entactinia*? *spongia* was described from Caradocian (lower part of Upper Ordovician) of Nevada (Renz, 1990b). Poosibly Late Ordovician.

Haplotaeniatum fenestratum Goto Umeda, and Ishiga n. sp.
Plate 7, Figures 1–3

cfr. *Entactinia spongia* Renz, 1990b

Material: Holotype is DGSU PR 1070 (Plate 11, Fig. 1) and paratypes are DGSU PR 1071 (Plate 11, Fig. 2) and DGSU PR 1072 (Plate 10, Fig. 3) from NL15 which are replaced by pyrite.

Description: Rather small circular spicule makes unclearly inner shell which lies on the eccentric point of shell. Secondary or more layered shell was formed by the ornamentation of pores. Outer pores were arranged outside of the inner side of the pore frame. Spicules of the pores extend with vertical or acute angle, and grow up to rather large circular spicules than those of the inner ones. The circular spicules get larger and larger in diameter to outside. No primary spines are evident.

Measurements: Based on 2 specimens in μm.
Diameter of external sphere: av. 145
Diameter of circular spicule: 20–40 av. 30

Comparison: Basic shell construction of *H. fenestratus* n. sp. is made up of combination of babble shaped circular spicules. The specimens of this species varies in number of pores.

Occurrence: Possibly Late Ordovician.

Genus: *Kalimnasphaera* Webby and Blom, 1986

Remarks: Type species of this genus *Kalimnasphera maclosa* Webby and Blom, 1986 is characterized by two additional concentric shells which are delicate, smaller, and medullary shells. This form from the Ordovician can be assigned to *Kalimnasphaera* for the character described below.

Kalimnasphaera sp. aff. *K. maclosa* Webby and Blom, 1986
Plate 8, Figures 1–3

Material: More than 20 specimens from NL21, 23 (DGSU PR 1055, Plate 6, Fig. 1; DGSU PR 1056, Plate 6, Fig. 2; DGSU PR 1057, Plate 6, Fig. 3).

Description: Relative large, spherical or subspherical shell with circular or ellipse pores. Rod-like primary spines are grown from unknown internal position. At surface of shell, rod-like by-spines are extending and connect lateral spines. These construction of shell is the fundamental feature of this species.

Remarks: Internal structure is not clear.

Measurements: Based on more than 20 specimens in μm.
Diameter of internal sphere: 137–195
Diameter of external sphere: 250 (based on one specimen)
Length of spines: 342 (most long spine)
Length of by-spines: av. 40

Discussion: In Caradocian to Ashgilian stage of the Malongulli Formation, *Kalimnasphaera maclosa* Webby and Blom commonly occurred and is most abundant among the fauna from Nevada. At this stage, types from NL21, 23 indicate same feature to those from the Malongulli Formation. Besides, from the black mudstones at locality G2 also yielded radiolaria with affinity to *Kalimnasphaera*. Study of *Kalimnasphaera* form is a significant key for correlation of *Kalimnasphaera* radiolarian bearing assemblages in the Upper Ordovician.

Occurrence: Possibly Late Ordovician.

Inanigutta sp. aff. *I. complanata* Nazarov, 1975
Plate 9, Figures 1–3

Entactinia sp. A aff. *E. subulata* Webby and Blom, 1986- Goto and Ishiga, 1991, pl. 1, figs. a, b.

Material: More than 50 specimens from NL15a, c, d, g, t, G1f, h, 1, 2, 5, 6, 7, 8 2Gb, c. Types are 3 specimens from NL15c (DGSU PR 1052, Plate 5, Fig. 1; DGSU PR 1053, Plate 5, Fig. 2; DGSU PR 1054, Plate 5, Fig. 3). A part of them is replaced by pyrite.

Description: Large, two or more, spherical shell is ornamented by 4–6 slender and long primary spines which gently taper at the distal end. At least, length of spines exceeds four times of shell diameter. Circular or ellipse double stratified pores were developed to form thick-walled shell. Internal spicules are rather smaller than outer spines emanated from connecting nodes that lie at eccentrically or nearly center of spherical shell. This continues to outside. Six primary spines exend outside with approximately isometric interval of each other, and outer primary spines are mostly straight but may be curved at the proximal end. A part of them has by-spines which extend from the junction of pore bars.

Measurements: Based on more than 20 specimens in μm.
Diameter of sphere: 200–275 av. 228
Pore diameter: 8–20 av. 14
Shell thickness: 17
Length of spines: 400–1075 av. 500

Remarks: These specimens are characterized by large spherical shell with long primary spines. Indistinct internal structure has not been observed because of poor preservation. But some show that they are characterized by triple shell and internal spicule which form connecting node.

Comparison: This specimens resemble to Late Ordovician *Inanigutta complanata* Nazarov, 1975, because of the similarity of outer shell size. Observation of outer form of this species reveals that, *Entactinia subulata* Webby and Blom, 1986, *E. elongata* Nazarov, 1975 or, *E. daysys* Nazarov, 1976, are comparable to this species, but concerning the size, *E. subulata* is half of this and species of *Entactinia* are characterized by single spherical shell.

Occurrence: Possibly Late Ordovician.

Secuicollacta ornata Goto Umeda, and Ishiga n. sp.
Plate 10, Figures 1–3

Entactinia sp. D Goto and Ishiga 1991, pl. 1, fig. c.
aff. Rotasphaerids Holdsworth, 1977
aff. Pactarentinia holdsworthi Furutani, 1983
aff. Palaeosphaera micra Renz, 1990

Materials: Holotype is DGSU PR 1061 (Plate 10, Fig. 1) and paratypes are DGSU PR 1062 (Plate 10, Fig. 2) and DGSU PR 1063 (Plate 10, Fig. 3) from NL15c, which are replaced by pyrite.

Description: Small, lattice or spherical shell with 6–8 rather small rod-like primary spines that genetly tapered to distal end. One or two pairs of primary spines are connected to curved spicule at the surface of shell. Shell seems to lattice with development of angular or ellipse pores. Some specimens have by-spines which are oriented from junction of pore bars.

Remarks: Internal structure is not clear, but this may be absent.

Measurements: Based on more than two specimens in μm.
Diameter of sphere: 77–102
Pore diameter: 6–15 av. 10
Shell thickness: 7
Length of spines: 19–55 av. 40

Length of by-spines: 13–18 av. 15

Comparison: These specimens have similar form to Devonian *Pactarentinia* of Furutani (1983) from Mt. Yokokurayama, Japan and Silurian Rotasphaerids (Holdsworth, 1977 plate 2, figure 4). Limited observation of main spines shows all specimens resemble to each other. Because of the unclear internal structure, distinction of Entactiniidae from Palaeoscenidiidae may be hard at this stage. This indicates a difficulty of distinction of *Entactinia* with very eccentric position of internal structure, in case it lies underneath the shell surface, from *Pactarentinia* like palaeosceniids.

Occurrence: Possibly Late Ordovician.

Secuicollacta silex Goto Umeda, and Ishiga n. sp.
Plate 11, Figure 1

aff. Rotasphaerids Holdsworth, 1977
aff. *Palaeosphaera micra* Renz, 1990, pl. figs. 7–9.

Material: Holotype is DGSU PR 1064 (Plate 11, Fig. 1) from NL15c which is replaced by pyrite.

Etymology: From the Latin stone.

Description: Test consists small, rather thin lattice spherical shell with no internal structure. Eight rod-like primary spines gently taper to distal end, and extend irregularly. Primary spines have horizontally radiating 5–7 branches (spicules) at the shell surface and these fine spicules make lattice shell. Small by-spines are oriented from junction of these spicules.

Measurements: Based on more than two specimens in μm.

Diameter of sphere: 80 μm
Pore diameter: 6–15 av. 10
Shell thickness: 7
Length of spines: 60–83 av. 70
Length of by-spines: 3–7 av. 5

Remarks: This specimen is characterized by spherical lattice shell and eight main primary spines.

Occurrence: Possibly Late Ordovician.

Secuicollacta minuta Goto Umeda, and Ishiga n. sp.
Plate 11, Figures 2, 3

Secuicollacta sp. A Goto and Ishiga, 1991, pl. 2, fig. b.
aff. *Secuicollacta cassa* Nazarov and Ormiston, 1984
aff. *Secuicollacta vulgaris* Furutani, 1990
aff. *Secuicollacta stelligera* Renz, 1990b

Material: Holotype is DGSU PR 1066 (Plate 11, Fig. 3) and paratype is DGSU PR 1065 (Plate 11, Fig. 2) from NL15c which are replaced by pyrite.

Description: Very small lattice shell seems to some polyhedron solids because of the formation of small number of basic spicules constructing lattice. Lattice shell varies its form but approximately eight faces solids is fundamental structure. Six thick rod-like spines grow from external shell and branches of 5 spicules which make skeleton from each apexes of solids of eight faces. Branched spicules connect distally with each other, and rather long and thick by-spines are extending from junction of these branched spicules indicated in Figs. 2, 3 of Plate 9. No internal structure is evident.

Measurements: Based on 6 specimens in μm.

Diameter of sphere (most short part of lattice shell): 55–73 av. 60

Shell thickness (thickness of spicule): av. 6

Length of spines: 55–83 av. 60

Comparison: This specimens characterized by basic structure of octahedron with very small spicules can be comparative to *Secuicollacta cassa,* Nazarov 1980. And it is also compared to *S. stelligera* Renz 1990. They are characterized by 5 bars meeting at a junction of lattice shell at the apexes of octahedron. *S. cassa* and *S. stelligera* have similar structure with each other, but latter has no internal structure neither to this specimens.

Occurrence: Possibly Late Ordovician.

Family Palaeosceniniidae Riedel, 1967b; emend. Holdsworth, 1977; Nazarov and Rudenko, 1981; Goodbody, 1982; Furutani, 1983 and Goodbody , 1986

Remakrs: The family is characterized by basal and apical radiating spines from central point or short median bar which is one of characteristics of fundametanl structure of Palaeoscenidiidae.

Following feature is a diagnostic among the palaeosceniids.

Palaeoephippium (2 apical spines and 4 basal spines)

Palaeotrifidus (2 apical spines and 3 basal spines)

Palaeotripus (3 apical spines and 3 basal spines).

Palaeotrifidus sp. A

Plate 12, Figure 1

Material: One specimens (DGSU PR 1075) from NL21b and other specimens not indicated, were obtained from G1-6.

Description: Two apical spines radiate from a small bar or center point. Three strong spines radiate with curve at approximately one quarter of the distance from the small center bar. At the curved point, encircling girdle are formed.

Measurement: Based on one specimen in μm.

Lenth of apical spine: 81
Length of basal spines: 239
Occurrence: Possibly Late Ordovician.

Palaeotrifidus sp.
Plate 12, Figure 2

Material: One specimen (DGSU PR 1076) from G2c and others not indicated were also obtained from G1-7.

Description: Two apical spines are rather small, and 3 basal spines radiate from probable small center bar. At the top of basal spines, spines are covered by well developed wall like structure.

Measurement: Based on one specimen in μm.
Length of apical spine: 26
Length of basal spines: 131
Length of center bar: 17
Occurrence: Possibly Lte Ordovician.

Palaeoscendium sp.
Plate 12, Figure 3

Material: One specimen from G1-F.

Description: Four apical spines which bifurcate to the distal end, radiate from short median bar. Four basal spines show bifurcation at point of one quarter of the distance from the median bar. At the bifurcated point, secondly spines form an encircling girdle.

Remarks: Two apical spines are lacking by poorly-preserved.

Measurement: Based on one specimen in μm.
Length of apical spine: 33
Length of basal spines: 150
Length of center bar: 17
Occurrence: Possibly Late Ordovician.

Palaeotripus ramalinus Goto, Umeda and Ishiga n. sp.
Plate 13, Figures 1–3

Material: Holotype is DGUS PR 1073 (Plate 13, Fig. 1) and paratypes are DGUS PR 1074 (Plate 13, Fig. 2) and DGUS PR 1075 (Plate 13, Fig. 3) from NL21b NL23, d, e and G1F.

Etymology: From the Latin branch.

Description: Three apical spines are thick and short, and radiate from central point.

These spines are curved in middle to distal portion, and make branches distally. Three strong basal spines are recurved, with thick branches extending to form roughly organized mesh structure.

Remarks: This species differs from *Palaeotripus sexabrachiatus* Renz, for the latter is characterized by spherical shaped basal spicules (called encircling girdle by Renz, 1990). And *P. ramalinus* is characterized by recurved thick basal spines, while *P. sexabrachiatus* is by nearly straight, basal spines. If the formation of basal spherical structure is taking into account, Triassic *Parentactinia inerme* Dumitrica may be important to discuss the formational process of encircling girdle. As *Parentactinia inerme* seems to be primitive and ancestral form to *Parentactinia pygnax* Dumitrica, *Palaeotripus ramalinus* described here is primitive form to *P. sexabrachiatus.*

Measurements: Based on one specimen in μm.

Length of apical spine: 58

Length of basal spines: 188

Occurrence: Possibly Late Ordovician.

Plalaeoephippium plattum Goto Umeda, and Ishiga n. sp.

Plate 14, Figures 1–3; Plate 15, Fig. 1

Material: Holotype is DGUS PR 1084 (Plate 14, Fig. 1) and paratypes are DGUS PR 1085 (Plate 14, Fig. 2), DGUS PR 1086 (Plate 14, Fig. 3) and DGUS PR 1087 (Plate 15, Fig. 1) from NL15c, G1-5 and G1-6.

Etymology: From the Latin flat.

Description: Slender and flattened four basal spines and small two apical spines, radiating from very short median bar or central point. Among four basal spines, two are shorter than the other, and these two are recurved downward (clearly observed in Figure 3 of Plate 14). Other longest spine is main basal spine which also is recured, but in a horizontal plane. The fourth spine curved downward, with small spicules and nodes distally and spines slightly thickened by such ornamentation.

Remakrs: Much ornamented form is discriminated among the specimens from NL15c of Balaratt. Three basal spines are arranged in nearly horizontal plane and usually straight, except main (?) basal spine, which is curved in horizontal plane. Basal spines are ornamented by short spines and nodes, which are grown up to form granuale in distal portion.

Measurements: Based on 4 specimens in μm.

Length of skeleton: 208–416 av. 300

Discussion: This specimens are relatively similar form with *Palaeoscenidium* and show very simple shell construction. So this specimens is conjectured ancestor of *Palaeoscenidiidae*.

Occurrence: Possibly Late Ordovician.

Palaeotrippus simplum Goto Umeda, and Ishiga n. sp.
Plate 15, Figures 2, 3

Material: Holotype is DGUS PR 1088 (Plate 15, Fig. 2) and paratype is DGUS PR 1089 (Plate 17, Fig. 3) from NL15c.

Etymology: From the Latin simple.

Description: Three branched slender spicules are radiating in horizontal plane. The longest spine, straight and thick, may be main spine and other two, named as secondary spines are shorter and rather thinned. Main spine is ornamented with nodes and granules which are irregularly arranged. Right secondary spine is shorter than left basal spine (when specimens are observed from upper view, right and left are attempted). These three form symmetric arrangement, if main spine may be axis of the rotation. Angles between main spine to other spine are 125° and 135° in Figures 2 and 3 respectively. Left basal spine is slightly curved. Apical spines may be two, but they are small and hard to be observed clearly among the extracted specimens.

Measurements: Based on one specimen (Fig. 3 in Plate 15) in μm.
Length of skeleton: 214

Occurrence: Possibly Late Ordovician.

Suborder Albaillellaria
Family Ceratoikiscidae

Genus *Protoceratoikiscum* Goto, Umeda and Ishiga n. gen.
Type species: *Protoceratoikiscum chinocryostallus* Goto Umeda, and Ishiga n. sp.

Description: Seven rod like spines are radiating from the central part of the shell in horizontal plane, and two of these curve distally with clockwise roation. In this attitude, spines being numbered from first to seventh, two spines (first or top and fourth or bottom spines) are nearly straight and sitting opposite site, and form intersecter or main spine. Third and seventh spines extending both sides of main spines, distally curved. Second spine is sitting on right side and fifth and sixth spines sitting left side. By spines connect these spines and form "spider web" like shell.

Remarks: Small triangle like shell at central portion constructed by three paired spines indicates close relation to basic structure of *Ceratoikiscum*.

Protoceratoikiscum arachnoidus Goto Umeda, and Ishiga n. sp.
Plate 16, Figures 1–3

Gen B sp. A Goto and Ishiga, 1991, pl. 2, fig. d.
cfr. ?*Ceratoiliskum* sp. Renz, 1990, pl. 1, fig. 5.

Material: Holotype is DGSU PR 1078 (Plate 16, Fig. 1) and paratypes are DGUS

PR 1079 (Plate 16, Fig. 2) and DGUS PR 1080 (Plate 16, Fig. 3) and more than 30 specimens from NL15c and NL21. A part of them is replaced by pyrite.

Etymology: From the Latin spider web.

Description: Test consists 7 rod-like spicules spreading at plain (see Figure 7). The first and fourth main spines are extending and sitting opposite side each other. These may connect each other at central portion of shell. The second and 6th spines nearly straight and are extending in opposite side. Third and seventh spines, both of which are curved in clockwide rotation. Lateral spines connect these seven spines and form at least 2 rows of incomplete circles. Because of absence of seventh spines (see Plate 16 Figures, 1, 2) curved lateral spines or by-spines occur to connect fifth or sixth spines and first spines.

Measurements: Based on 7 specimens in μm.
Length of skeleton: 263–458 av. 420
Length of first spine: 170–340 av. 231

Remarks: Unfortunately Figure 1 in Plate 16 is reversed attitude of the species. Comparison of the extracted specimens revealed that *Protoceratoikiscum* described below may rather complicated form than that of *P. arachnoides,* for they are chracterized by usual seven staight spines and densely rotated three or more rows of circles by lateral spicules.

Occurrence: Possibly Late Ordovician.

Protoceratoikiscum chinocrystallum Goto Umeda, and Ishiga n. sp.
Plate 17, Figures 1–3

Gen B sp. A Goto and Ishiga, 1991, pl. 3, fig. e.

Material: Holoytpe is DGUS PR 1081 (Plate 17, Fig. 1) and paratypes are DGUS PR 1082 (Plate 17, Fig. 2) and DGUS PR 1083 (Plate 17, Fig. 3) and more than 30 specimens from NL15c and NL21.

Etymology: From the Latin snow crystal.

Description: *Protoceratoikiscum* with straight seven spines and three or more incomplete circles formed by lateral spicules. Both radiating spines and lateral spicules show same thickness and they are thicker than those of *Protoceratoikiscum arachnoides* n. sp. described above.

Measurements: Based on 7 specimens in μm.
Length of skeleton: 263–458 av. 420
Length of first spine: 170–340 av. 231

Occurrence: Possibly Late Ordovician.

Acknowledgements

The authors would like to appreciate Dr. Ian Stwart of Monash University for useful advices on conodont and Dr. Chris Fergusson of Wollongong University for encouradgements of this study. This work has been financially supported by Japanese Ministry of Science, Culture and Education.

References

Aitchison, J., 1990. Significance of Devonian-Carboniferous Radiolarians from accretionary terranes of New England Orogen, Eastern Australia. *Marine Micropaleont.*, **15**, 365–378.

Bergstrom, S. M., 1979. First report of the enigmatic Ordovician Microfossil Konyrium North America. *Jour. of Paleont.*, **53**, 320–327.

Berry, W. B. N., Wilde, P. and Quinby-Hunt, M., 1990. Late Ordovician graptolite mass mortality and subsequent early Silurian re-radiation. *In* Kauffman E. G. and Walliser, O. H.(eds) *Extinction Events in Earth History. Lecture Notes in Earth Sci.*, **30**, 115–132.

Cheng, Yen-Nien, 1986. Taxonomic studies on Upper Paleozoic Radiolaria. Special Publications, no. 1, National Museum of Natural Science, Taiwan. R.O.C. 311 pp.

Dunham, J. B. and Murphy M. A., 1976. An occurrence of well preserved radiolaria from the upper Ordovician (Caradocian), Eureka county, Nevada. *Jour. Paleont.*, **50**, 882–887.

Fergusson, C. L., 1987. Early Paleozoic back-arc deformation in the Lachlan Fold Belt, southeastern Australia. implications for terrane translations in eastern Gondwanaland. *In* Terrane Accretion and Orogenic Belt. *Am. Geophy. Un. Geodyn. Ser.*, **19**, 39–56.

Fergusson, C. L. and VandenBerg, A. H. M., 1990. Middle Paleozoic thrusting in the eastern Lachlan Fold Belt, southeastern Australia. *Jour. Struct. Geol.*, 12, 577–589.

Foreman, H. P. 1963. Upper Devonian radiolaria from the Huron Member of the Ohio Shale. *Micropaleont.* **9**, 267–304.

Fortey, R. A. and Holdsworth, B. K. 1971. The oldest known well-preserved radiolaria. *Bollettino della Societa paleontological Italiana.* **10**: 1, 35–41.

Furutani, H., 1983. Middle Paleozoic Palaeoscenidiidae (radiolaria) from Mt. Yokokura, Shikoku, Japan, Part 1. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, **130**, 96–116.

Furutani, H., 1990. Middle Paleozoic radiolarians from Fukuji area, Gifu Prefecture, Central Japan, *Jour. Earth Sci., Nagoya Univ.* **37**, 1–56.

Goodbody, Q. H., 1986. Wenlock Palaeoscenidiidae and Entactiniidae (radiolaria) from the Cape Phillips Formation of the Canadian Arctic Archipelago. *Micropaleont.* **32**, 129–157.

Goto, H. and Ishiga, H., 1991. Study of late Ordovician radiolarians from the Lachlan Fold Belt, Southwestern Australia. *Geol. Rept. Shimane Univ.*, **10**, 57–62 (in Japanese with English abstract).

Holdsworth, B. K., 1977. Paleozoic radiolaria: Distribution in Atlantic Borderlands. *In*: Swain, F. M., ed., The stratigraphic micropaleontology of Atlantic basin and borderland. *Development in Paleontology and Stratigraphy* **6**, Elsevier, 167–184.

Nazarov, B. B., 1975. Radiolyarii nizhnego-srednego paleozoya Kazakhstana (metody issledovanii, sistematika, stratigraficheskoe znachenie). Trudy Akademiya Nauk SSSR, Geologicheskii Institut, **275**, 1–203 (in Russian).

Nazarov, B. B. and Nolvak, YA., 1983. Radiolarians from the Upper Ordovician of Estonia. Eesti Nsv Teaduste Akadeemia Toimetised, 32 Koide Geoloogia 1983, Nr. 1 (in Russian with English abstract).

Nazarov, B. B. and Ormiston, A. R., 1984. Vozmozhnaya Sistema Radiolyariy Paleozoya. *In* M. Petushevskaya (ed.,) Morfologiya, Ekologiya i Evolyutsia Radiolyariy, Zoologicheskii Institut, Leningrad, Nauka, Leningrad, 64–87 (in Russian).

Nazarov, B. B. and Ormiston, A. R., 1986. Trend in the development of Paleozoic radiolaria. *Marine Micropaleont.*, **11**, 3–32.

Nazarov, B. B., 1988. Paleozoic radiolaria. Practical manual of microfauna U.S.S.R., vol. 2. Leningrad, Nedra -232 p.

Renz ,G. W., 1988. Silurian radiolarians of the genus *Ceratoikiscum* from the Canadian Arctic. *Micropaleont.*, **34**, 260–267.

Renz, G. W., 1990a. Ordovician radiolaria from Nevada and Newfoundland, a comparison at the family level. *Marine Micropleont.*, **15**, 393–402.

Renz, G. W., 1990b. Late Ordovician (Caradocian) radiolarians from Nevada. *Micropaleont.* **36**, no. 4, 367–377.

Ruedemann, R. and Wilson, T. Y., 1936. Eastern New York Ordovician cherts. *Bull. Geol. Soc. Amer.* **74**, 1335–1586.

Umeda, M., Goto, H. and Ishiga, H., 1992. Middle Ordovician radiolarians from the Lachlan Fold Belt, Southeastern Australia. *Mem. Fac. Sci. Shimane Univ.*, **26**, 131–140.

Wakamatsu, H., Sugiyama, K. and Furutani, H., 1990. Silurian and Devonian radiolarians from the Kurosegawa Tectonic Zone, southwest Japan. *Jour. Earth Sci. Nagoya Univ.*, **37**, 157–192.

Webby, B. D. and Blom, W. M., 1986. The first well-preserved radiolarians from the Ordovician of Australia. *Jour. Paleont.*, **60**, 145–157.

Explanation of Plates

All figures are stereoscopic pairs. Scale bars in Plates 1–4, 6–17 50 μm. Scale bars in Plate 5, 100 μm.

Plate 1
Figures 1, 2 *Entactinia modesta* Goto, Umeda and Ishiga n. sp. ver. 1.
Figure 3 *Entactinia modesta* Goto, Umeda and Ishiga n. sp. ver 2
Figures 1–3 from NL 15C.

Plate 2
Figure 1 *Entactinia modesta* Goto, Umeda and Ishiga n. sp. ver. 2
Figures 2, 3 *Entactinia leptura* Goto, Umeda and Ishiga n. sp.
Figure 1 from G2 C, Figures 2, 3 from NL 15C.

Plate 3
Figure 1–3 *Entactinia micropora* Goto, Umeda and Ishiga n. sp.
Figure 1 from NL 21A, Figure 2 from G1 6, Figure 3 from NL 21B.

Plate 4
Figures 1, 2 *Entactinia* sp. A
Figure 3 *Entactinosphaera* sp. A
Figures 1–3 from NL 15C.

Plate 5
Figure 1 *Haplentactinia* sp. aff. *H. baltica* Nazarov, 1984
Figures 2, 3 *Haplentactinia attenuata* Goto, Umeda and Ishiga n. sp.
Figures 1–3 from NL 15C.

Plate 6
Figures 1–3 *Haplotaeniatum spinatum* Goto, Umeda and Ishiga n. sp.
Figures 1–3 from NL 15C.

Plate 7
Figures 1–3 *Haplotaeniatum fenestratum* Goto, Umeda and Ishiga n. sp.
Figures 1–3 from NL 15C.

Plate 8
Fugures 1–3 *Kalimnasphaera* sp. aff. *K. maclosa* Webby and Blom, 1986
Figures 1, 2 from NL 21C, Figure 3 from NL 21A.

Plate 9
Figures 1–3 *Inanigutta* sp. aff. *I. complanata* Nazarov, 1975
Figure 1 from NL 15C, Figure 2 from G1 8, Figure 3 from NL 15G.

Plate 10
Figures 1–3 *Secuicollacta orenata* Goto, Umeda and Ishiga n. sp.
Figures 1–3 from NL 15C, Figures 1–3.

Plate 11
Figure 1 *Secuicollacta silex* Goto, Umeda and Ishiga n. sp.
Figures 2–3 *Secuicollacta minuta* Goto, Umeda and Ishiga n. sp.
Figures 1–3 from NL 15C.

Plate 12
Figure 1, 2 *Palaeotrifidus* sp. A
Figure 3 *Palaeoscenidium* sp. A
Figure 1 from G2 C, Figure 2 from G1 7, Figure 3 from NL 21B.

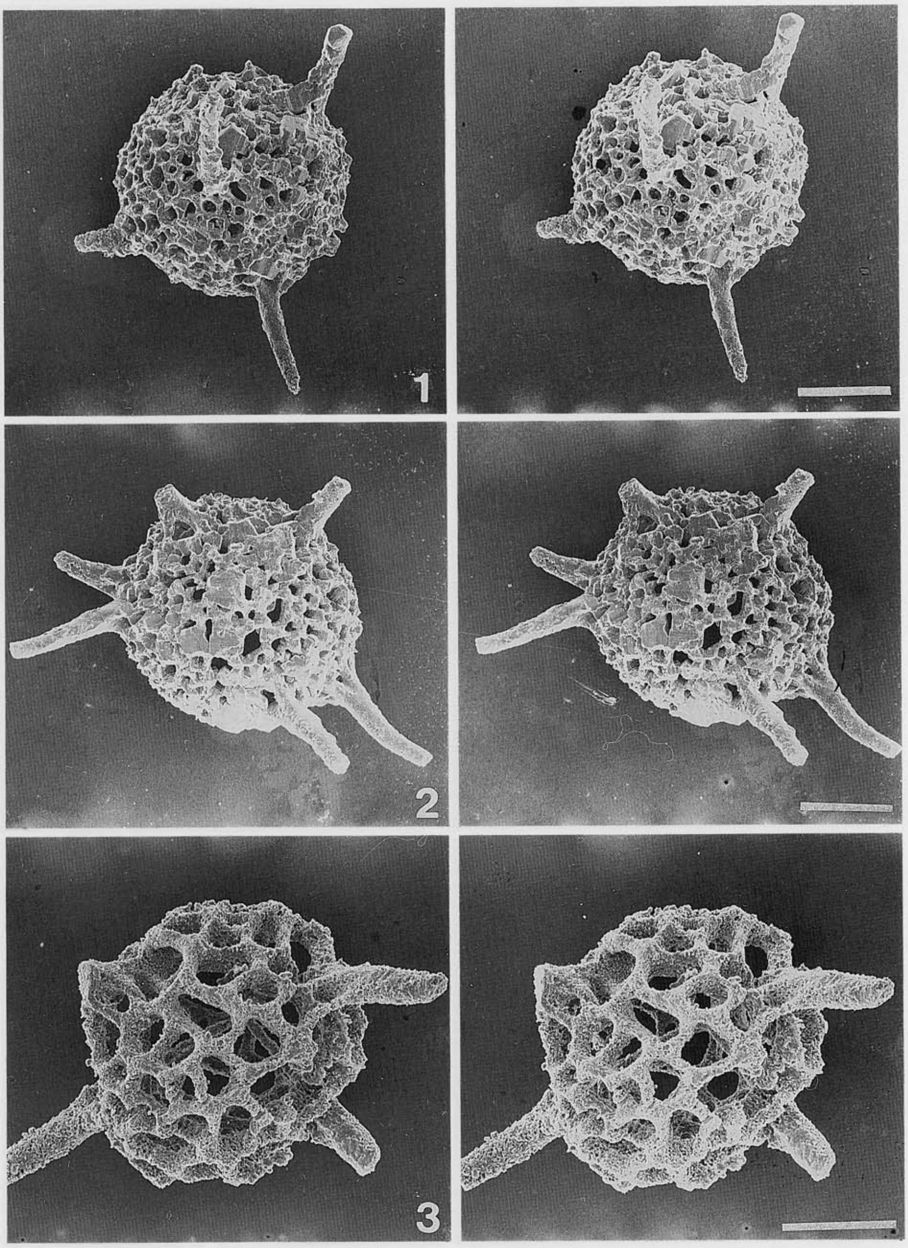
Plate 13
Figures 1–3 *Palaeotripus ramalinus* Goto, Umeda and Ishiga n. sp.
Figures 1–3 from G1 F.

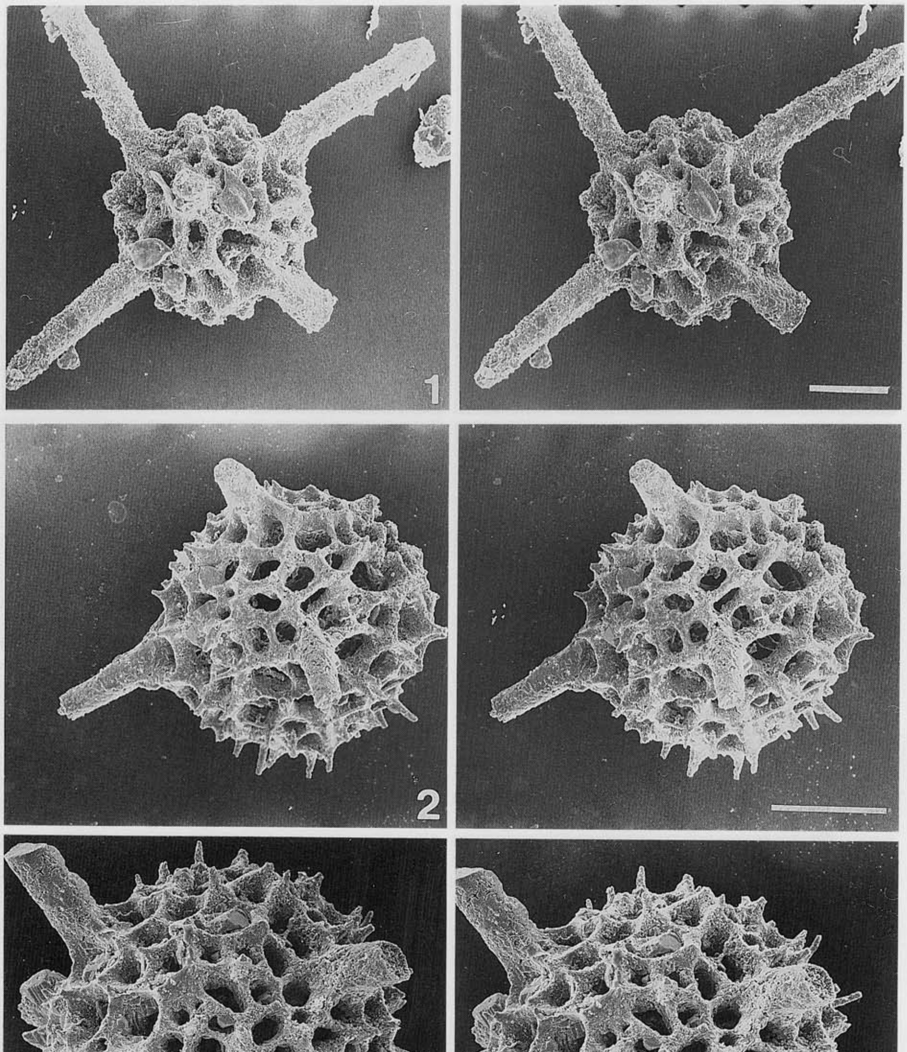
Plate 14
Figures 1–3 *Palaeoephippium plattum* Goto, Umeda and Ishiga n. sp.
Figures 1, 2 from G1 6, Figure 3 G1 5.

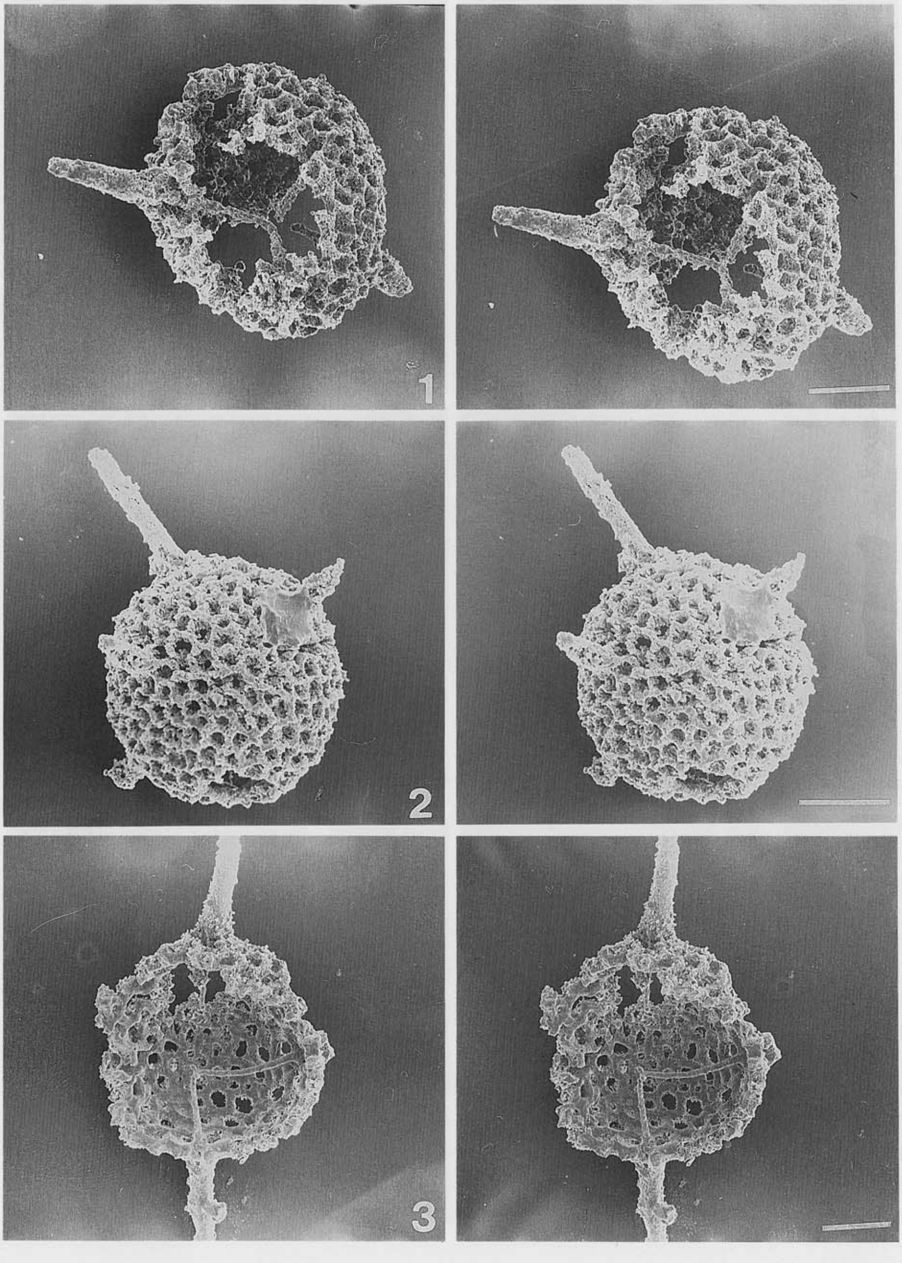
Plate 15
Figure 1 *Palaeoephippium plattum* Goto, Umeda and Ishiga n. sp.
figures 2, 3 *Palaeotrippus simplum* Goto, Umeda and Ishiga n. sp.
Figure 1 from G1 6, Figure 2 from G1 7, Figure 3 from G2 B.

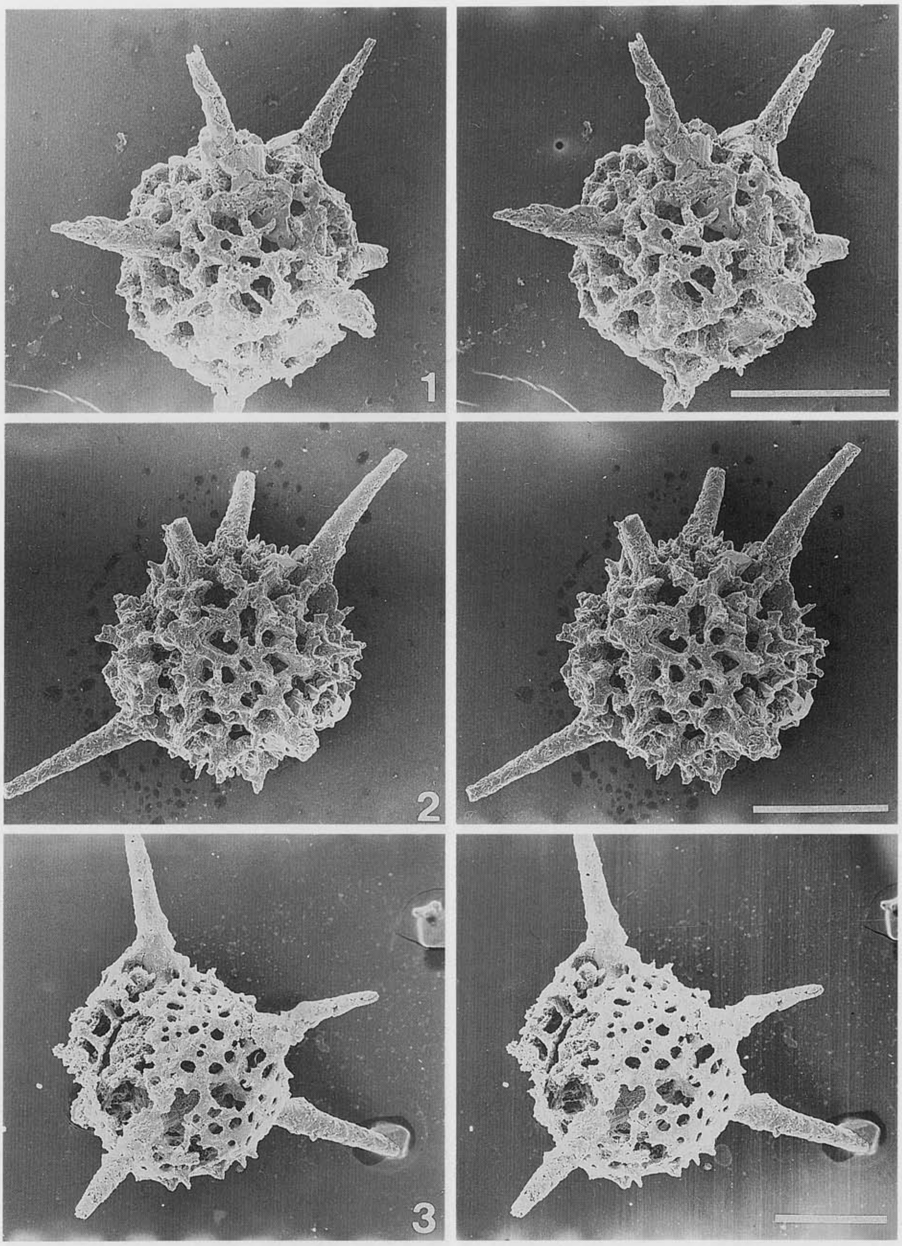
Plate 16
Figures 1–3 *Protoceratoikiscum arachnoides* Goto, Umeda and Ishiga n. sp.
Figures 1, 2 from G1 5, Figure 3 from G1 6.

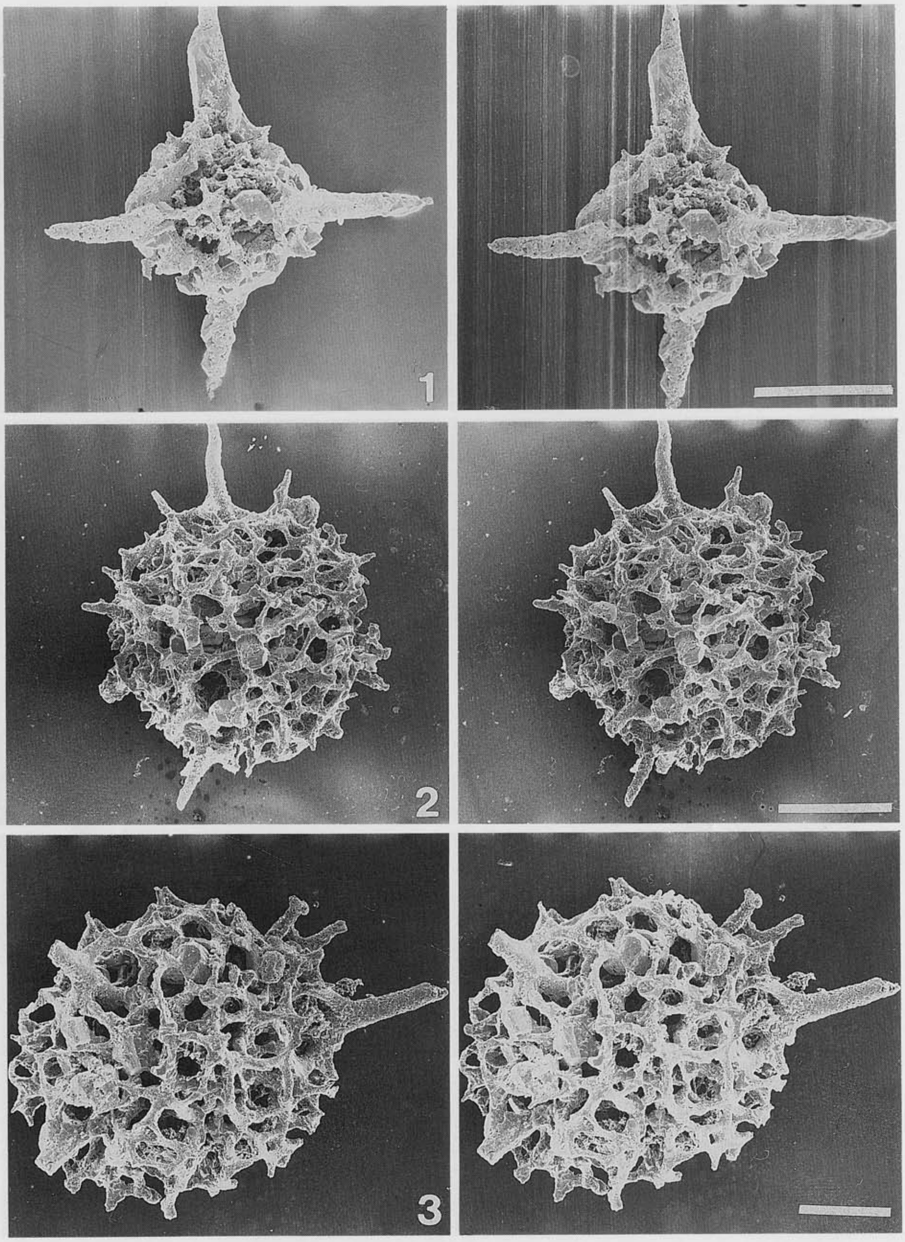
Plate 17
Figures 1–3 *Protoceratoikiscum chinocrystallum* Goto, Umeda and Ishiga n. sp.
Figure 1 from G1 6, Figures 2, 3 from G1 5.

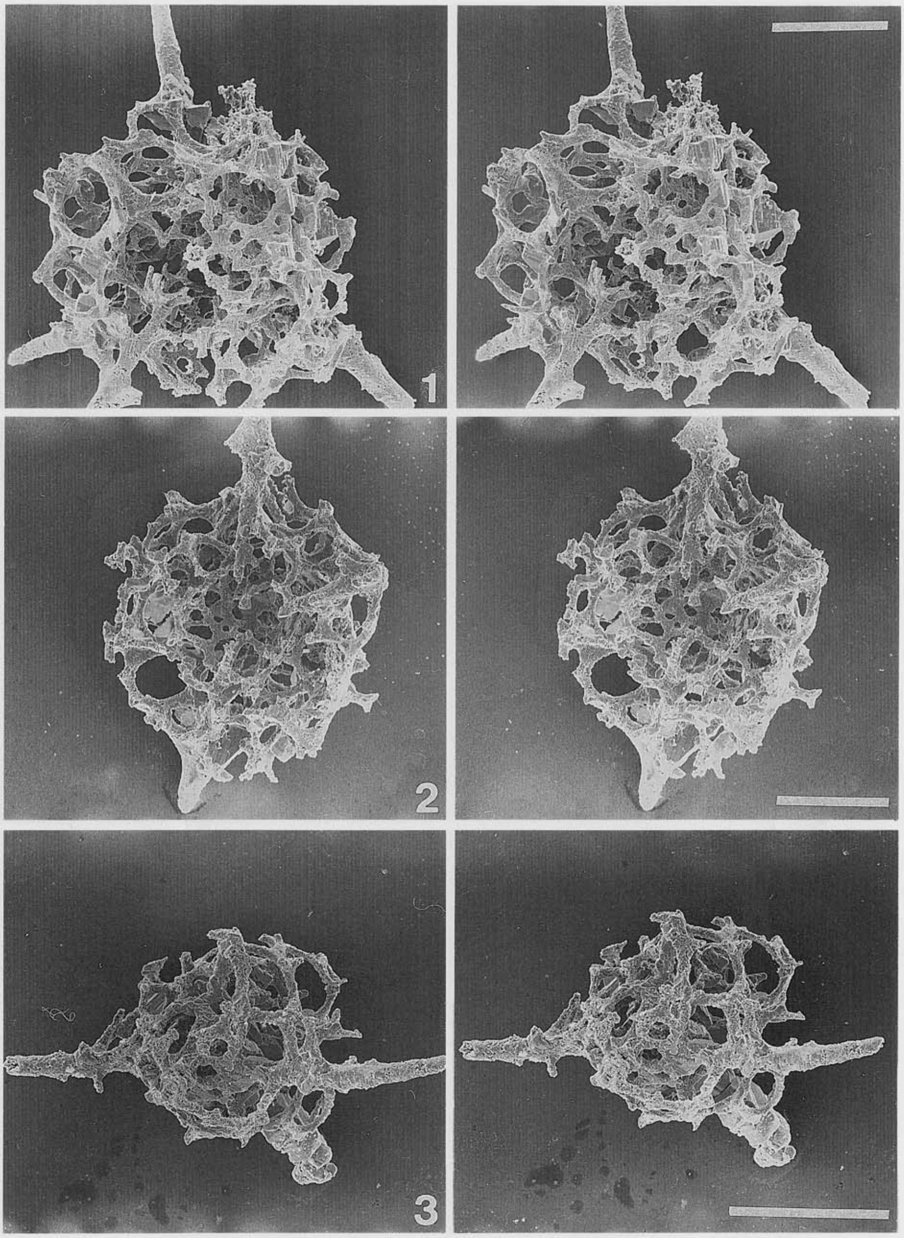

1
2
3

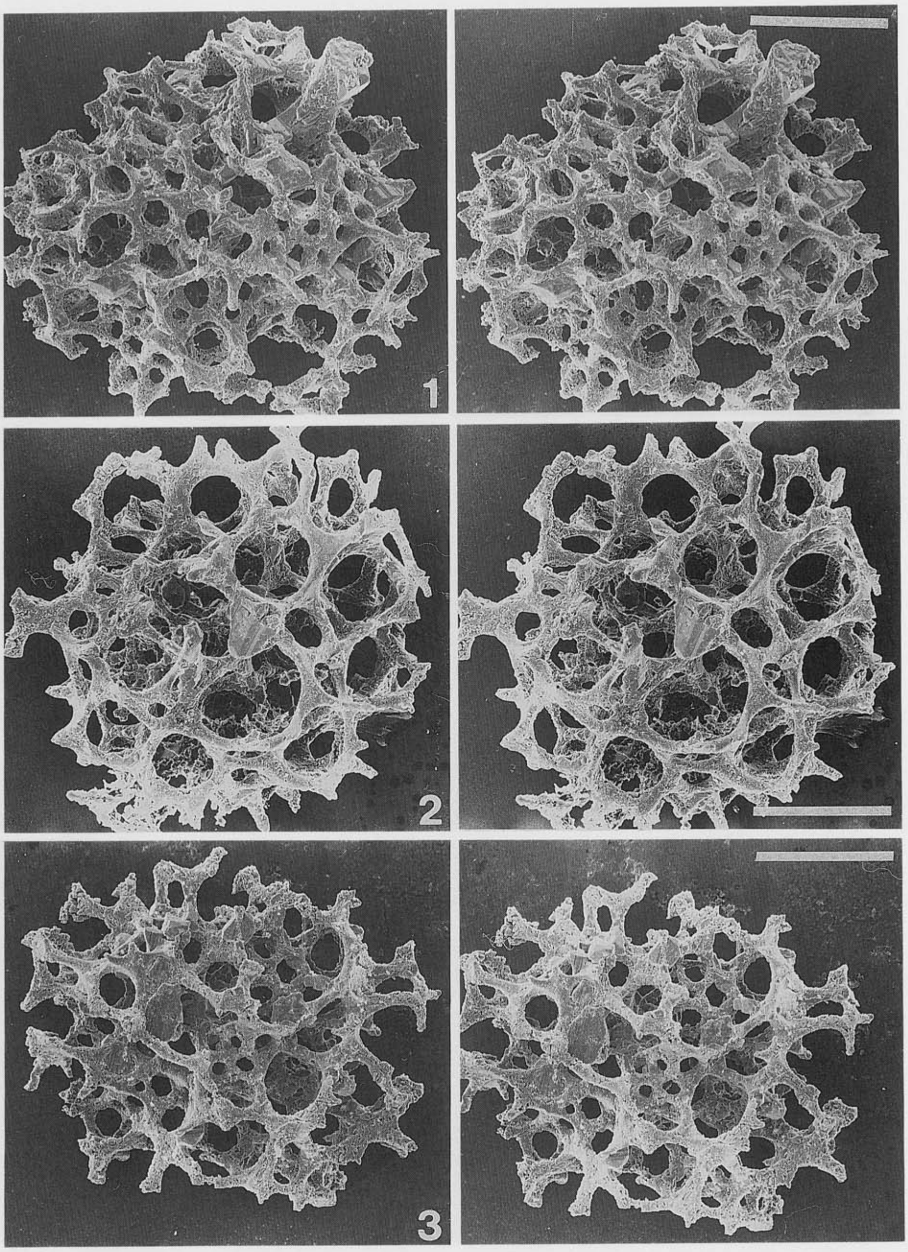

1
2
3

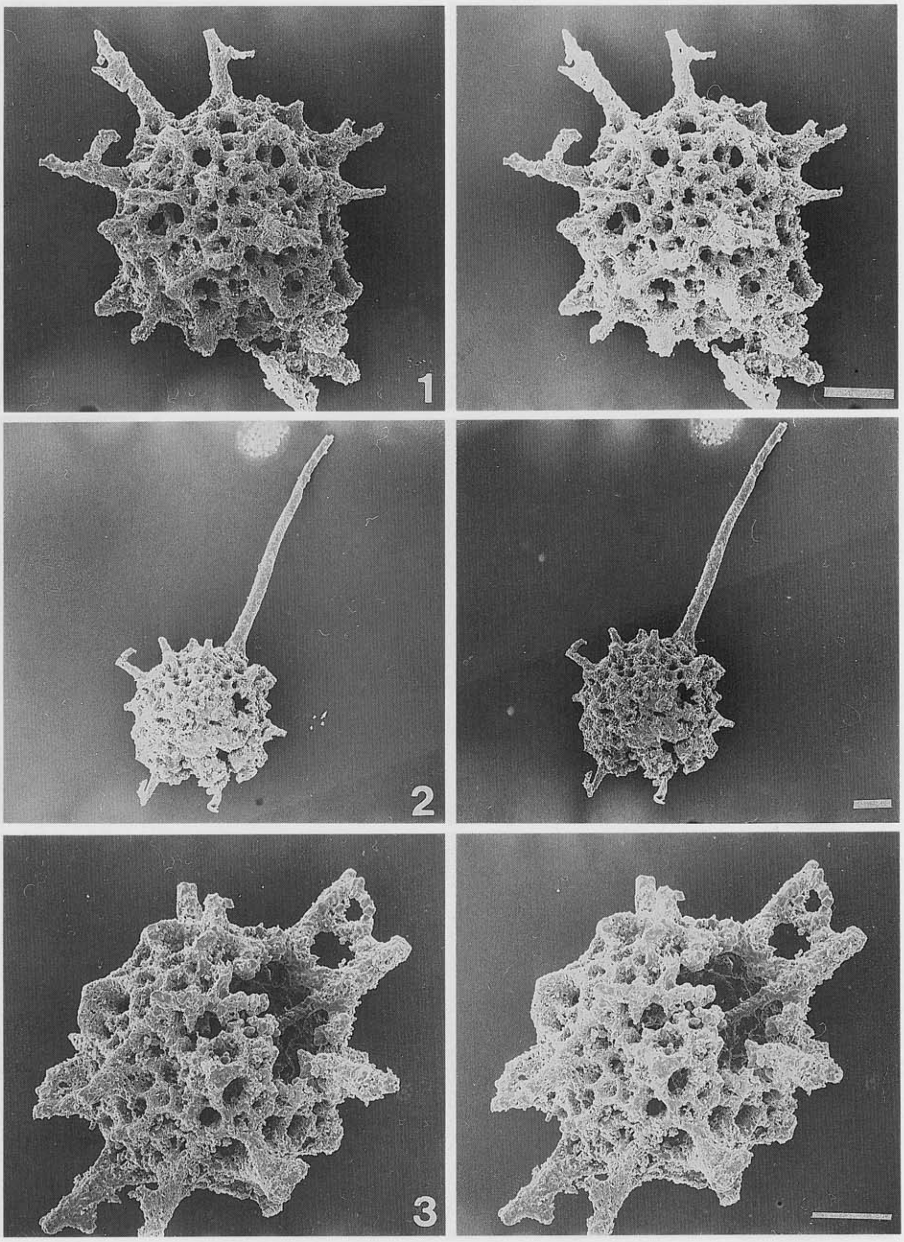

1
2
3

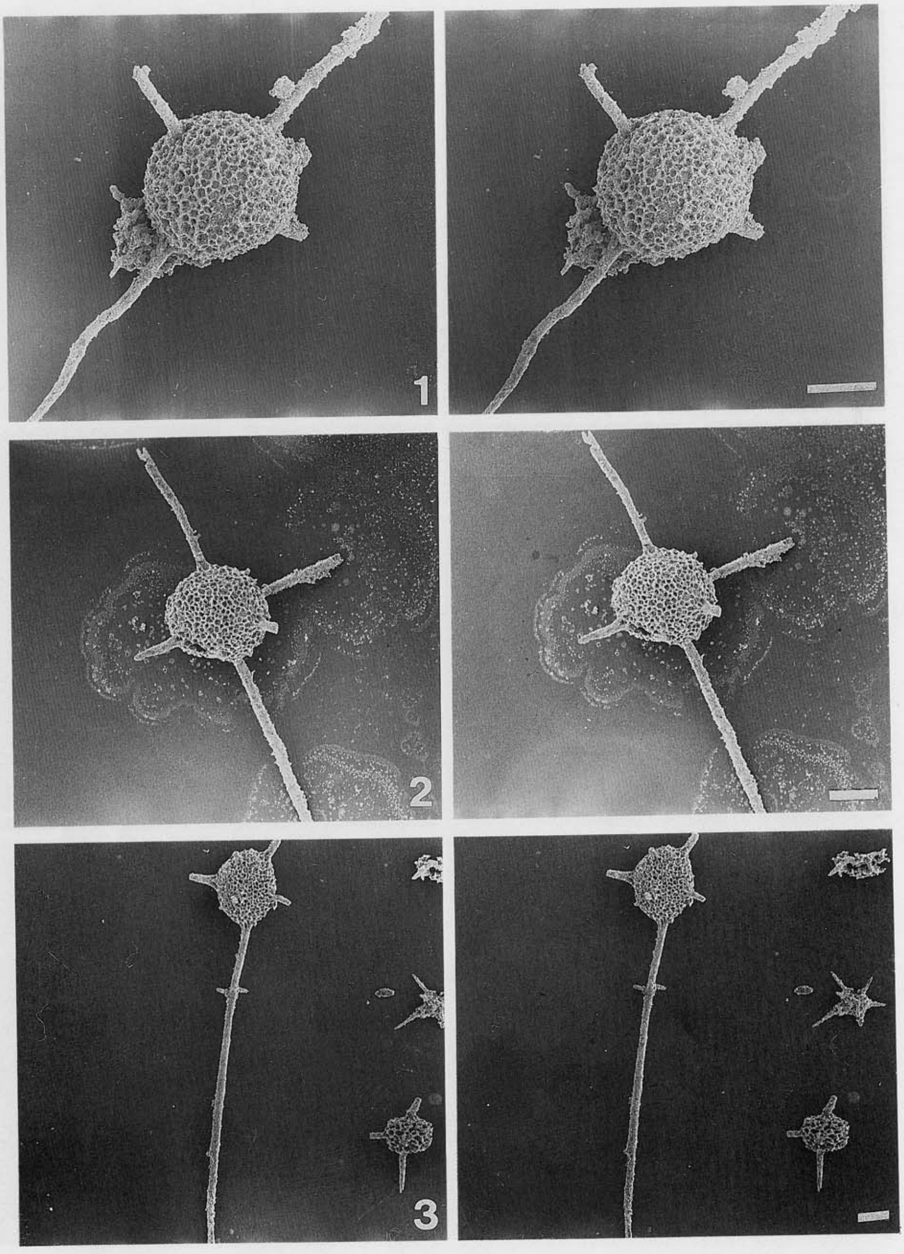

1
2
3

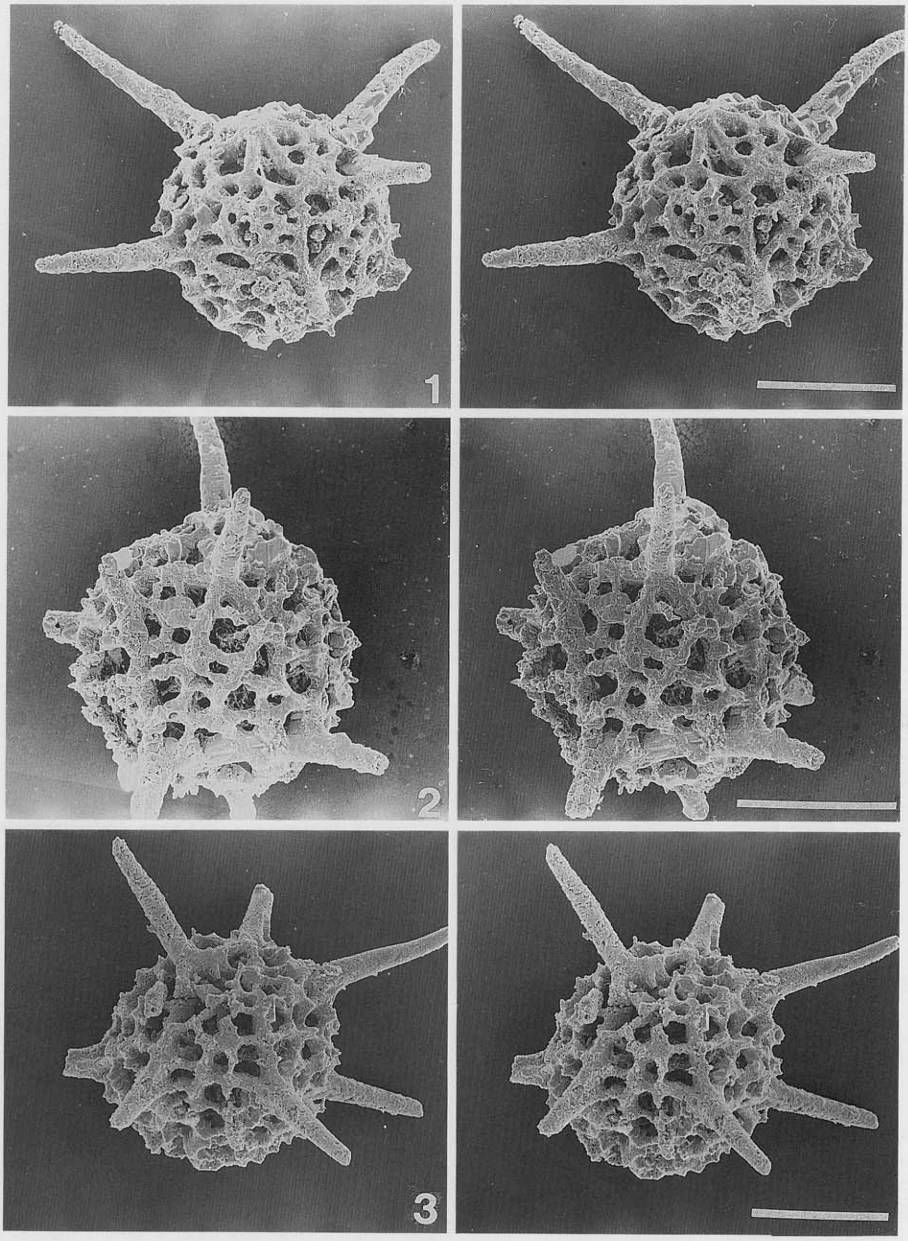

1
2
3

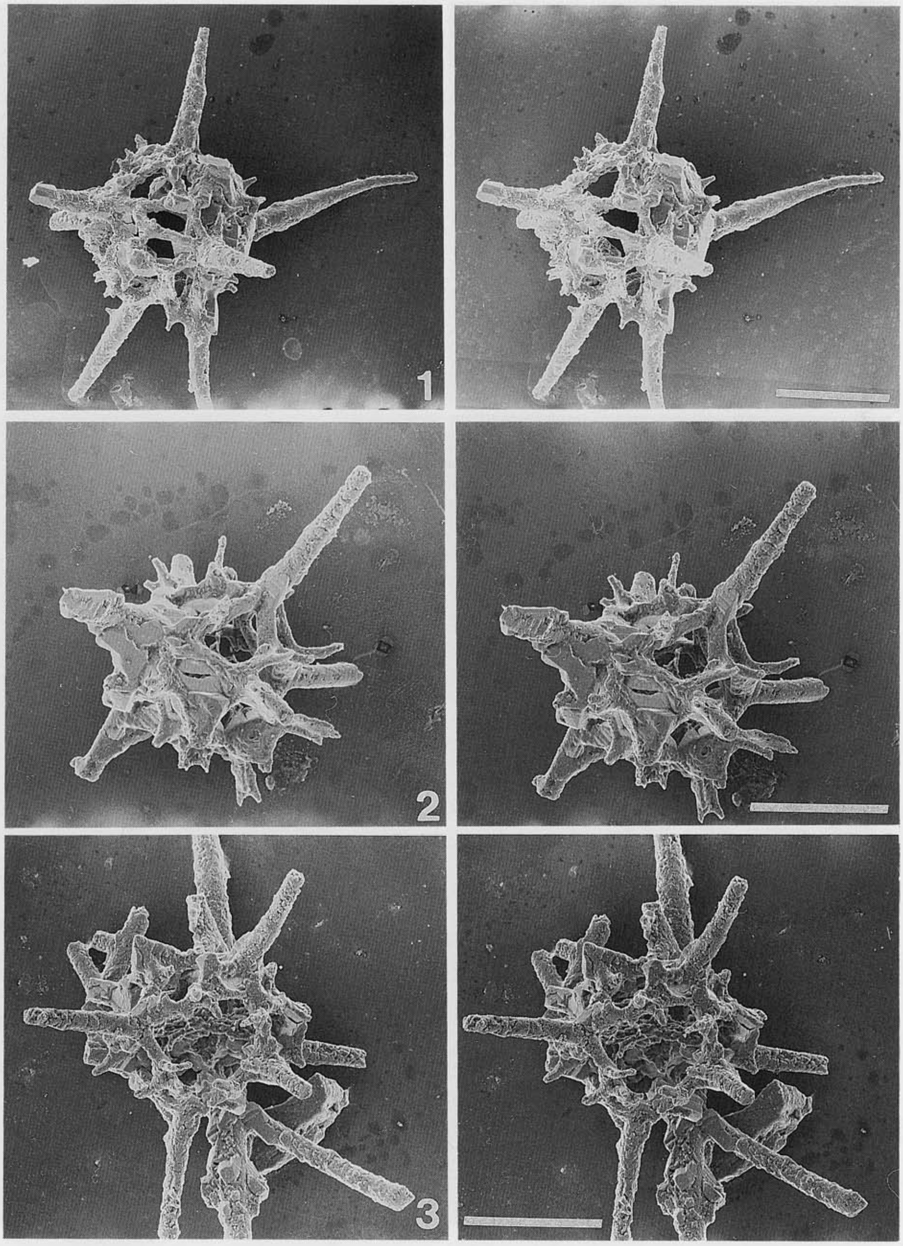


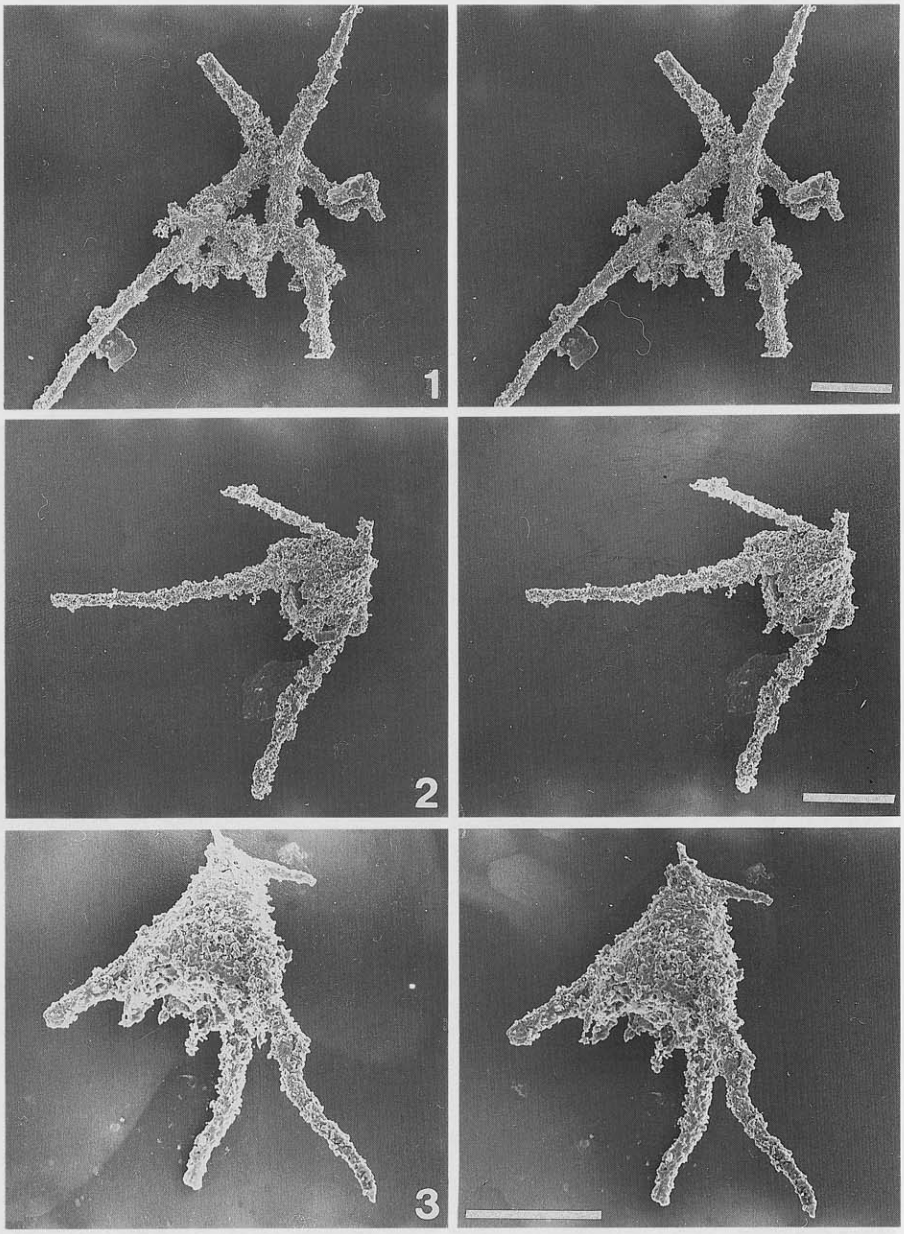

1
2
3

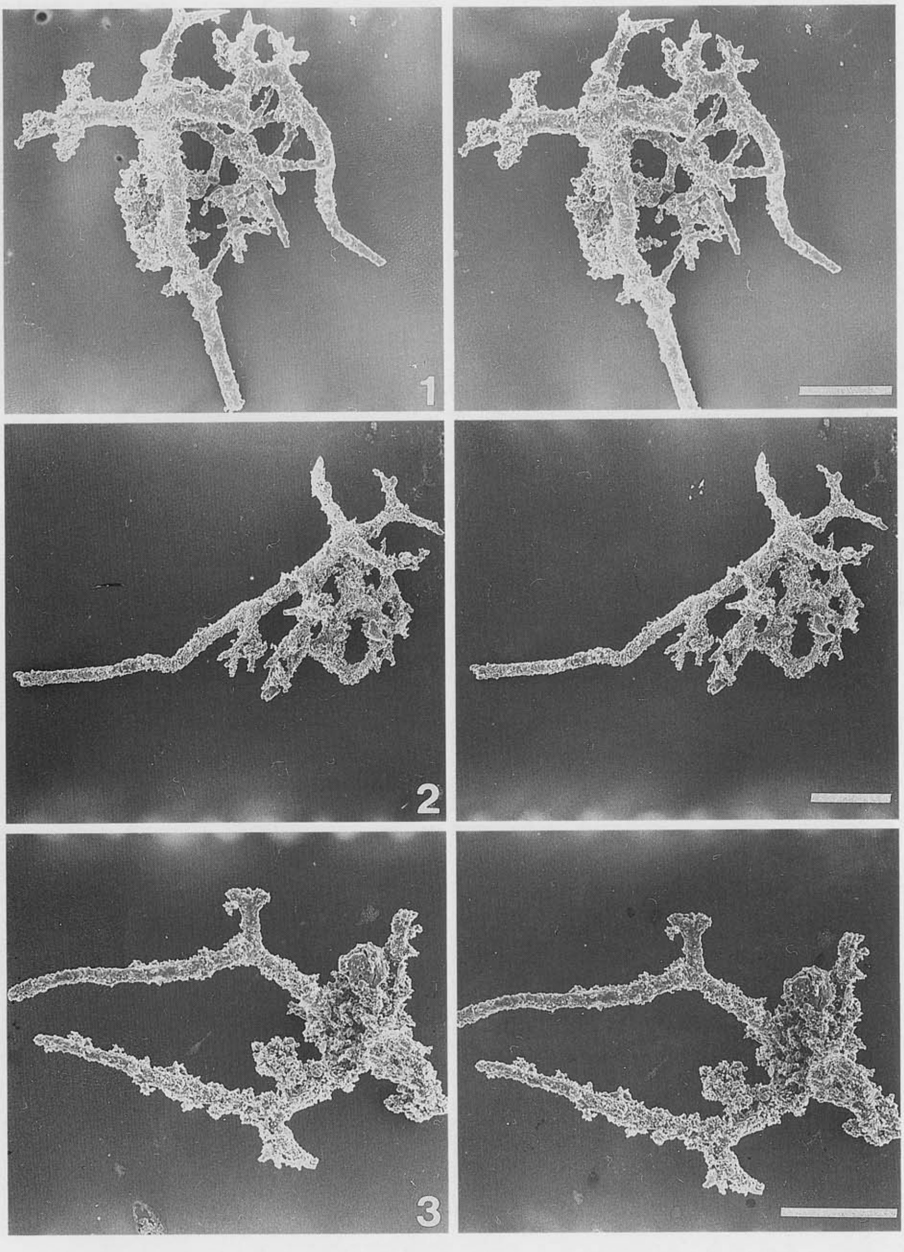

1
2
3

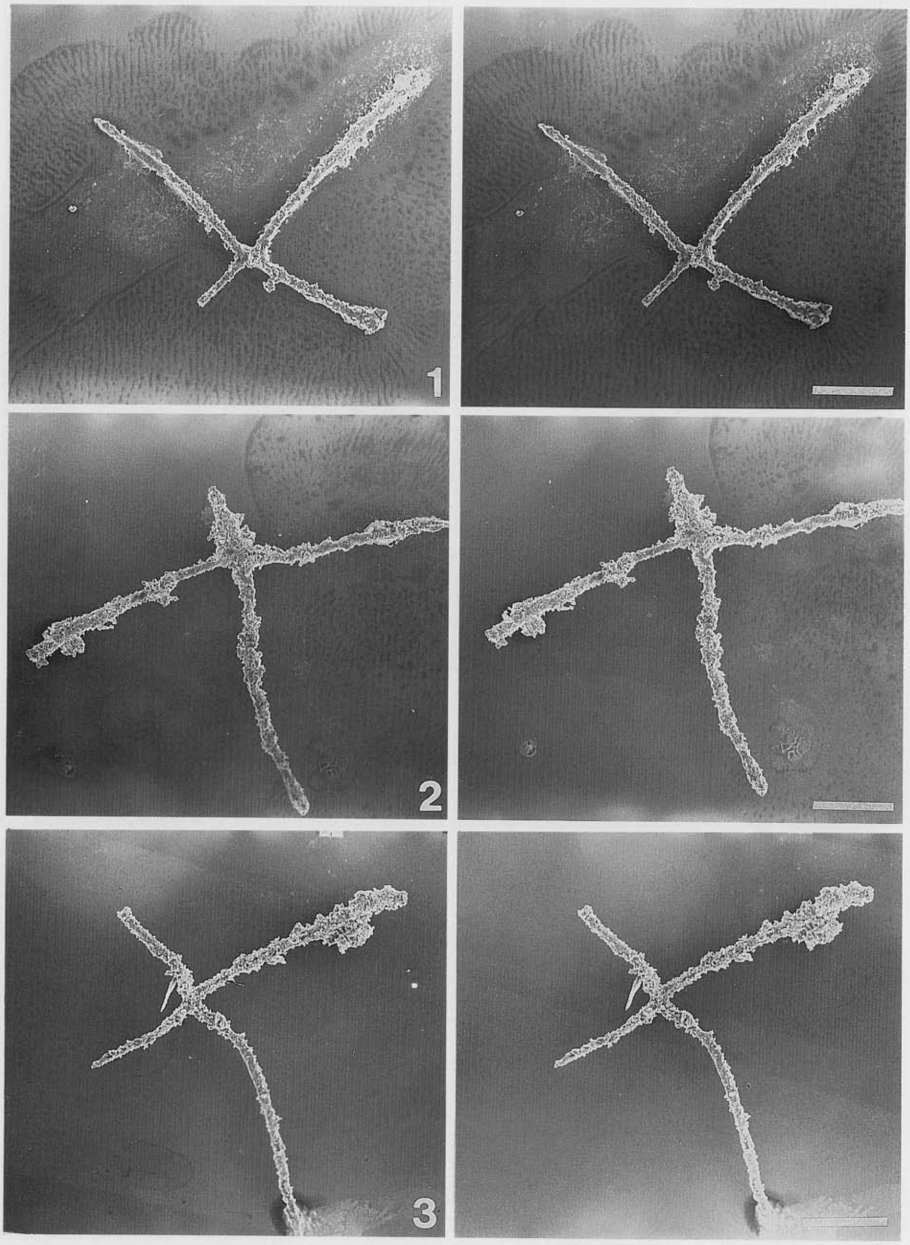

1
2
3

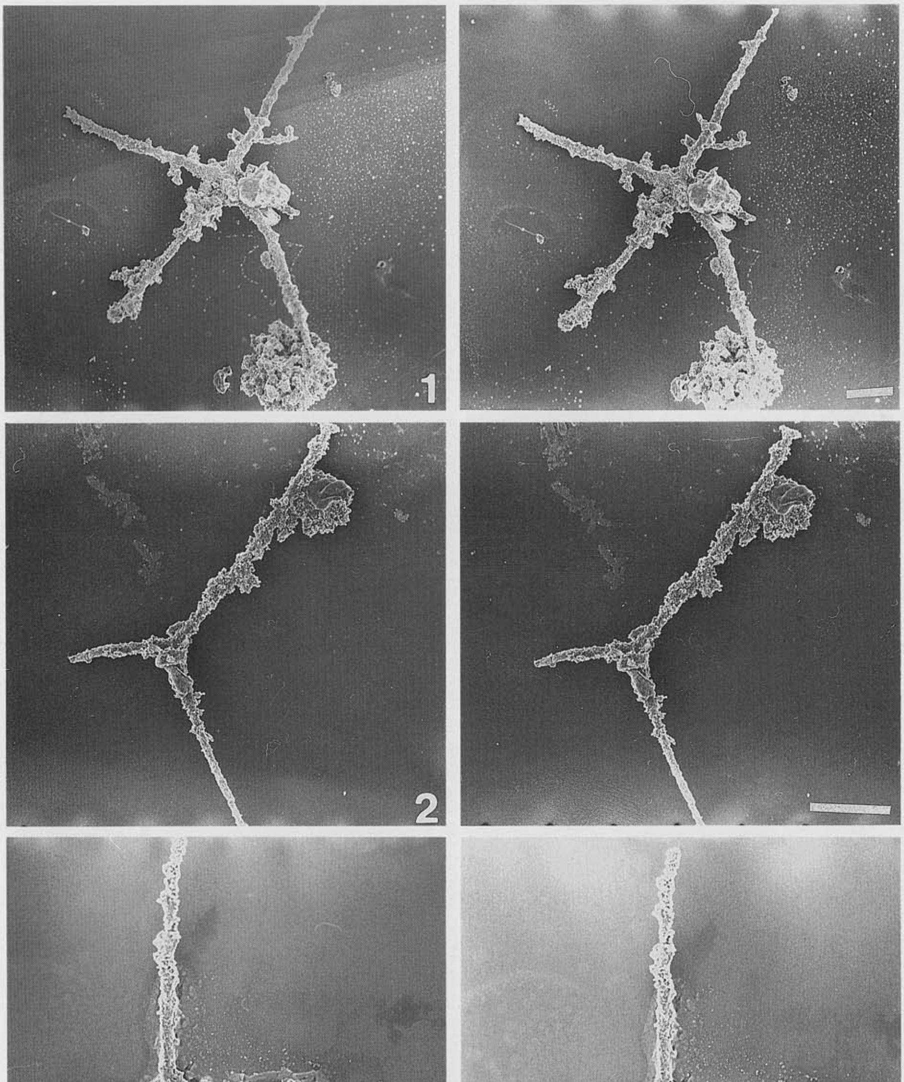

1
2
3

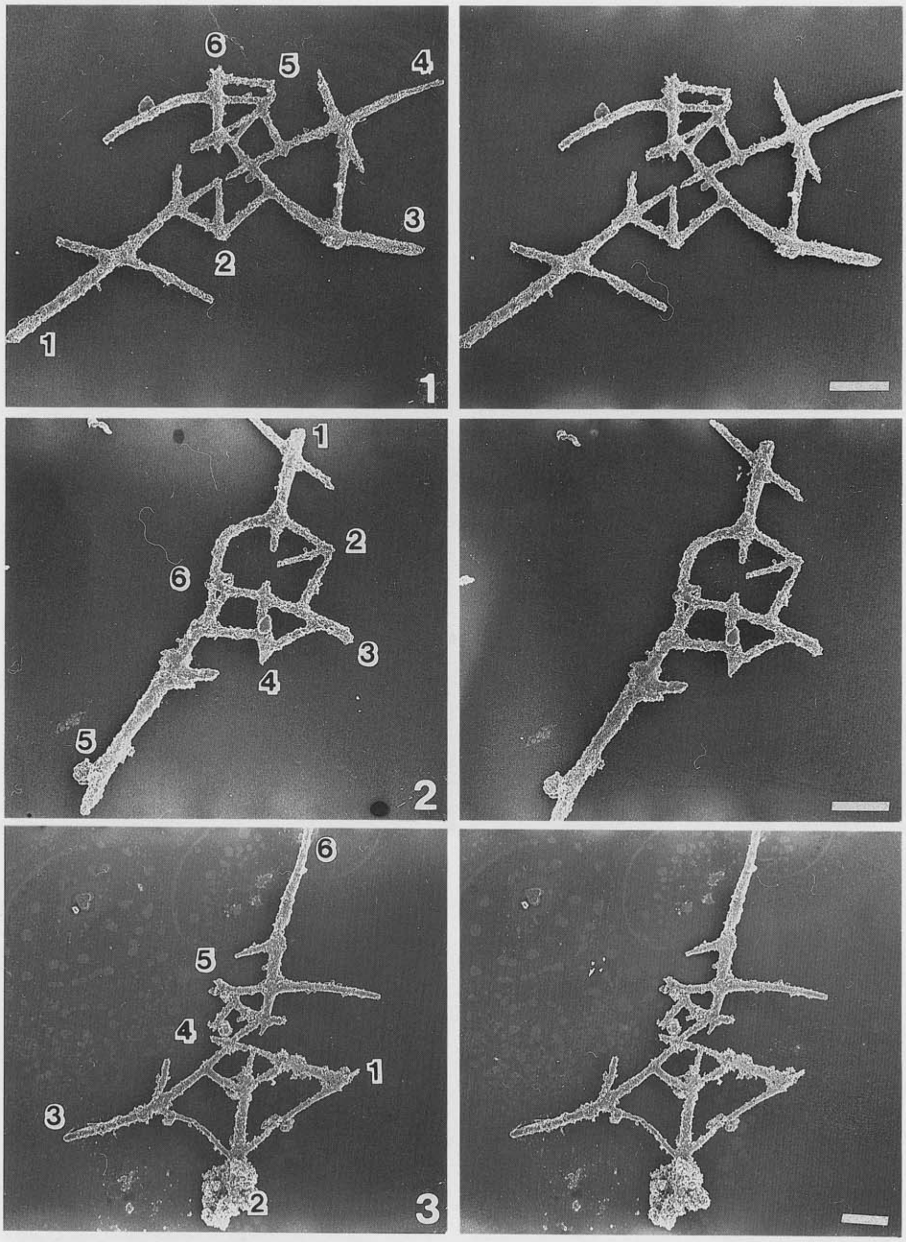

1
2
3

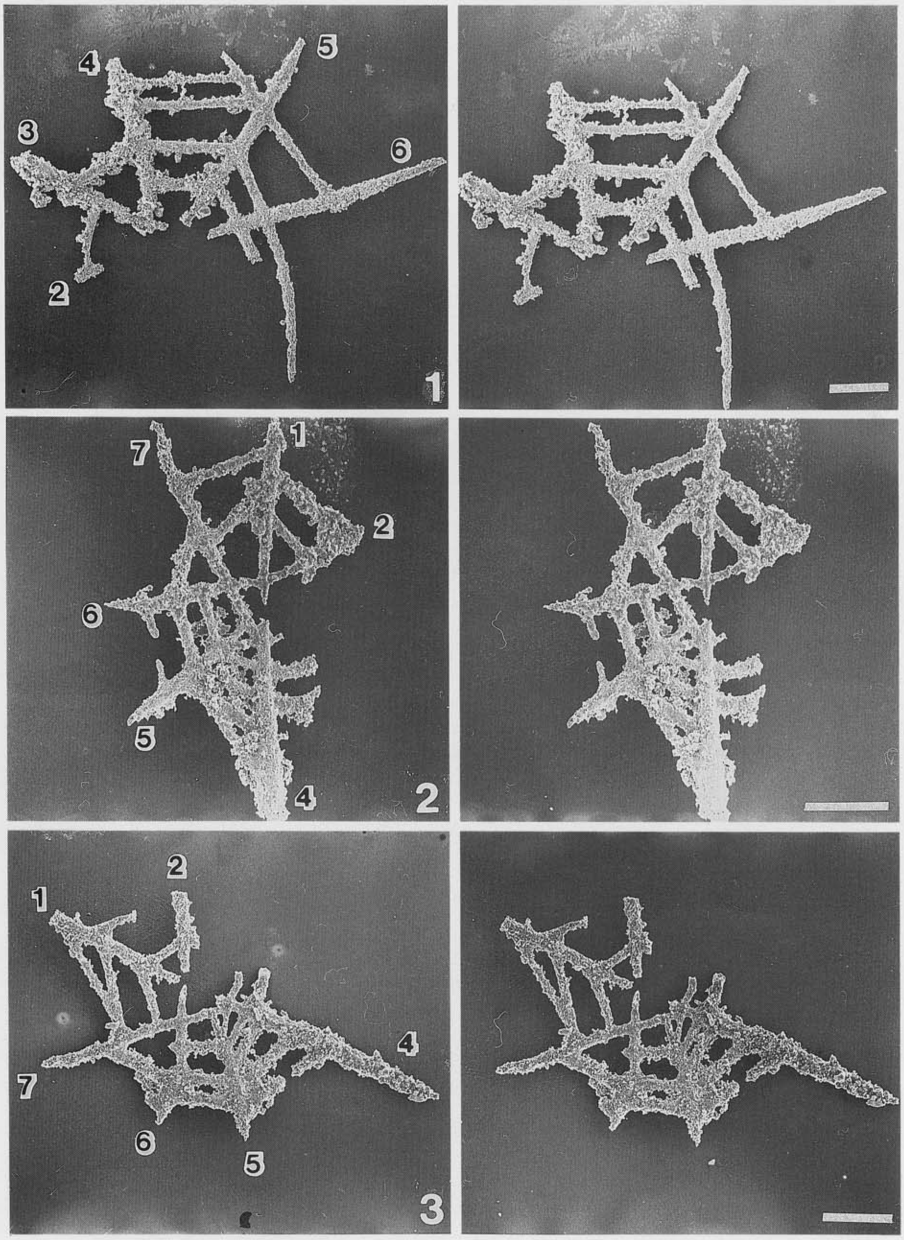

1
2
3


1
2
3


1
2
3


1
2
3


6
5
4
3
2
1
1
1
2
6
3
4
5
2
6
5
4
1
3
2
3



4
5
3
6
2
1
7
1
2
6
5
4
2
2
1
4
7
6
5
3