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Middle and Late Jurassic Radiolarian Biostratigraphy in the Sakawa and Adjacent Areas, Shikoku, Southwest Japan

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(With 10 Figures and 9 Plates)

Abstract

Three radiolarian zones of Middle and Late Jurassic age are set up on the basis of stratigraphic works along several continuous outcrops of chert → siliceous mudstone → mudstone sequence in the Sakawa and adjacent areas, Kochi Prefecture, Southwest Japan. *Tricolocapsa plicarum* Zone, *Tricolocapsa conexa* Zone and *Stylocapsa* (?) *spiralis* Zone in ascending order, are defined by biohorizons reflecting evolutionary lineages. Eight new species of nassellarians are described.

Introduction

Biostratigraphic usefulness of Mesozoic and Paleozoic radiolarian fossils has been documented through recent investigations in many areas of the world. Concerning works on Mesozoic radiolarian biostratigraphy, most deal with radiolarian succession of Late Jurassic and younger age, while investigations on biostratigraphy of Early and Middle Jurassic age are in stage of accumulation of modern data (PESSAGNO and BLOME, 1980, 1982; PESSAGNO and WHALEN, 1982; YAO, 1982, etc.).

In Japan, many Jurassic radiolarian assemblages have been quite recently proposed by several investigators (YAO *et al.*, 1980; YAO, 1982; YAO *et al.*, 1982; MIZUTANI *et al.*, 1981; MIZUTANI, 1981; YOSHIMURA *et al.*, 1982; KIDO *et al.*, 1982; MATSUOKA, 1982b; KISHIDA and SUGANO, 1982; NISHIZONO *et al.*, 1982, etc.). But in many cases, stratigraphic relation among radiolarian assemblages hvae not been adequately clarified except for the studies made on continuous sequences.

Three zones of Middle and Late Jurassic age, namely *Unuma echinatus* Assemblage-zone, *Lithocampe* (?) *nudata* Assemblage-zone and *Gongylothorax sakawaensis-Stichocapsa* sp. C Assemblage-zone in ascending order, were established based on assemblage analysis of several continuous outcrops in the Sakawa and Niyodo areas, Kochi Prefecture, Southwest Japan (MATSUOKA, 1982b). In the previous paper, I pointed out that zonal boundaries should be defined by biohorizons based on morphologic change reflecting phylogeny.

Through investigation of many stratigraphic sections of the Sakawa and adjacent areas, I have recognized some successive morphologic changes which can be utilized for the biostratigraphic division. In this paper, two biohorizons based on phylogeny are

determined and three radiolarian zones of Middle and Late Jurassic age are newly defined. Furthermore, paleontologic description is given on selected radiolarian group; two-, three-, four-segmented nassellarians with constricted distal end. Paleontologic study on some other radiolarian groups will be reported in the near future.

Acknowledgment

I wish to thank Prof. K. ICHIKAWA of Department of Geosciences, Osaka City University for his kind guidance, encouragement and critical reading of the manuscript. My sincere thanks are also due to Dr. A. YAO of the same Department for his continuous encouragement and valuable advice. I am also much obliged to Associate Prof. K. NAKASEKO of Institute of Geological Sciences, College of General Education, Osaka University and Prof. S. MIZUTANI of Department of Earth Sciences, Nagoya University for their useful suggestions.

Lithostratigraphy and Biostratigraphy

The material treated in this paper came from the Nishiyama Formation, the Togano Formation (KURATA, 1940) and their equivalent, which are characterized by repitition of chert beds and clastic beds. According to MATSUOKA (in prep.), the chert beds are Middle Triassic to Middle Jurassic in age and the clastic beds are Middle and Late Jurassic in age based mainly on radiolarian fossils. Lithologically chert changes gradually

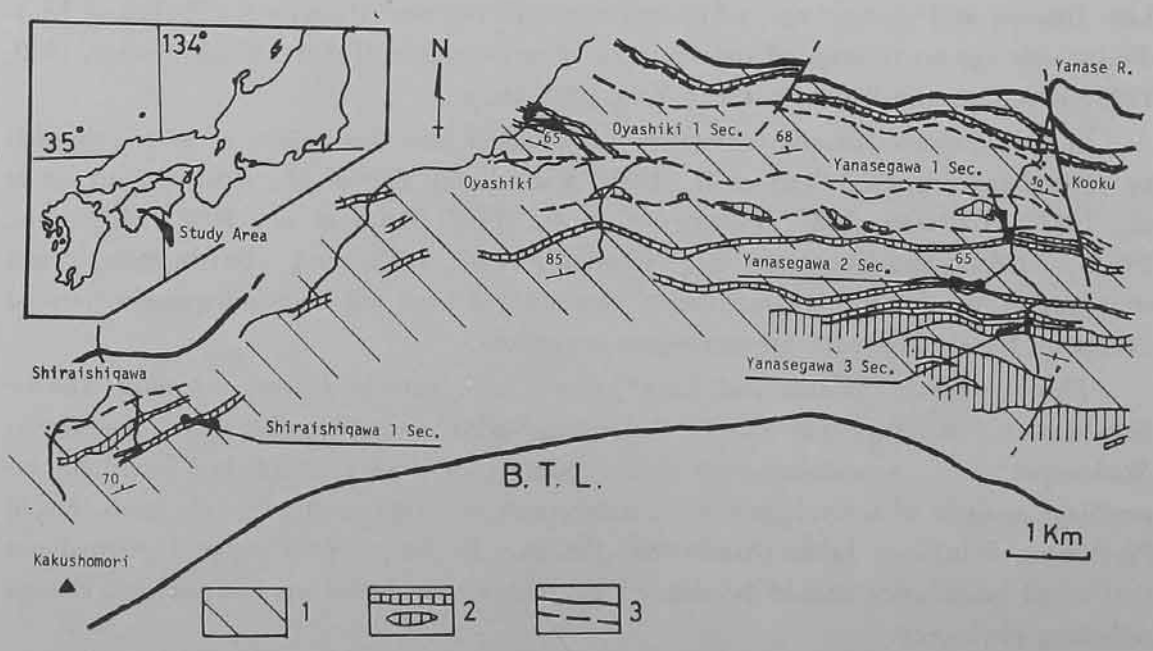

Fig. 1. Index map of the study sections.
1: Nishiyama Formation, Togano Formation (KURATA, 1940) and their equivalent.
2: Chert 3: Fault

upward into Middle or Late Jurassic siliceous mudstone and in some cases further into mudstone. Siliceous mudstone and mudstone are overlain by sandstone-rich alternating beds of sandstone and mudstone or massive sandstone. Chert, siliceous mudstone, mudstone and sandstone-rich alternation (or massive sandstone) form a stratigraphic unit and the zonal arrangement of chert beds and clastic beds seems to result from tectonic repetition of the unit.

Study sections, shown in Fig. 1, are relatively thin strata (less than 60 m) composed of chert, siliceous mudstone, mudstone, acidic tuff and sandstone. Radiolarian fossils were obtained from chert, siliceous mudstone and mudstone.

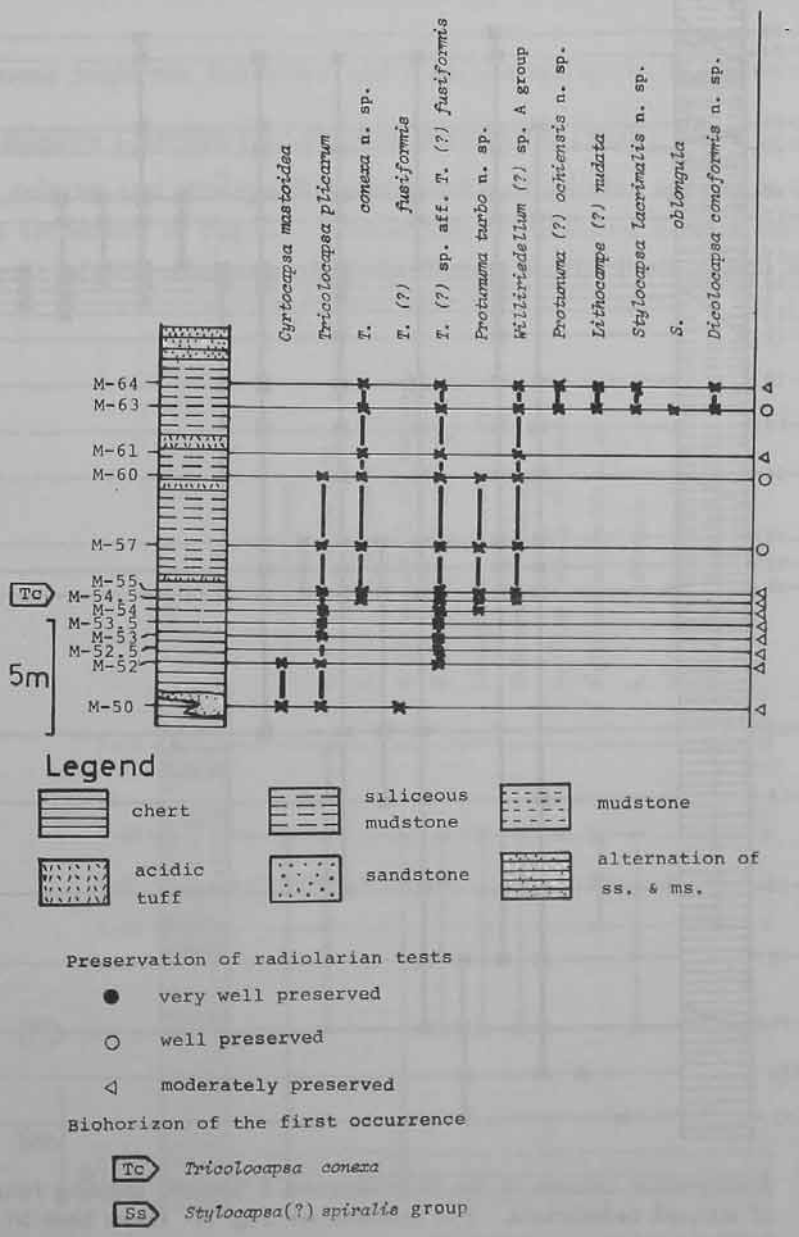

Fig. 2. Stratigraphic column of the Oyashiki 1 Section, showing range chart of selected radiolarians.

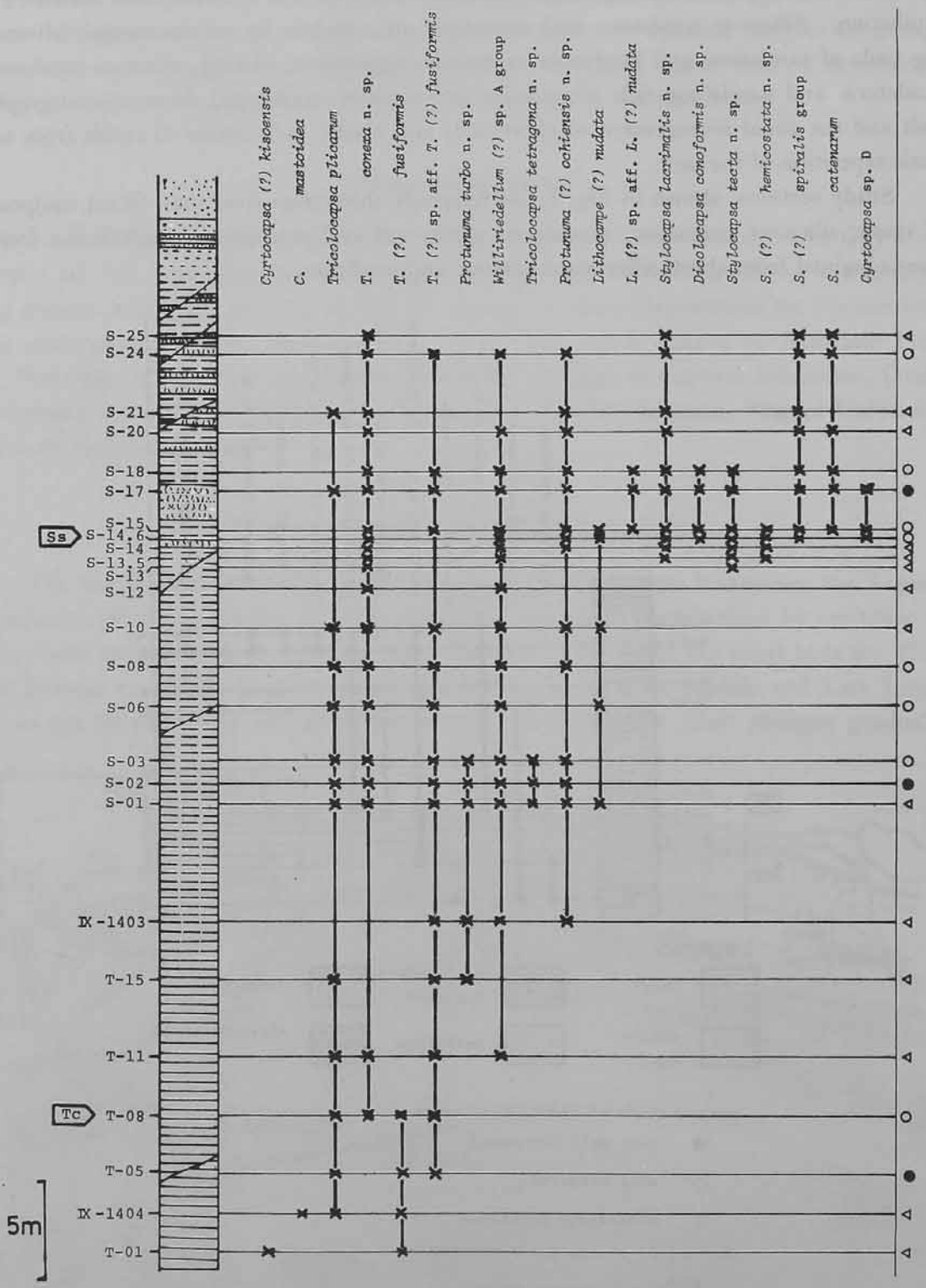

Fig. 3. Stratigraphic column of the Shiraishigawa 1 Section, showing range chart of selected radiolarians. For symbols see Fig. 2. Cross lines in the columnar section are minor faults.

1) Oyashiki 1 Section

Lithologic column and stratigraphic distribution chart of selected species in the Oyashiki 1 Section are given in Fig. 2. This section, located 0.8 km northeast of Oyashiki, Ochi Town, Kochi Prefecture, is a road cutting. Strata of this section are composed of bedded chert, siliceous mudstone, acidic tuff and sandstone-rich alternating beds of sandstone and mudstone. Bedded chert grades upward into siliceous mudstone. Siliceous mudstone is intercalated with acidic tuff layers of 0.3 to 0.9 m thick and is conformably overlain by sandstone-rich alternating beds of sandstone and mudstone.

Besides species shown in Fig. 2, the followings are obtained from the lowermost horizon.

M-50: *Protunuma fusiformis* ICHIKAWA and YAO, *Zartus* sp. in MATSUOKA (1982b).

2) Shiraishigawa 1 Section (=Loc. A in MATSUOKA, 1982b)

Lithologic column and stratigraphic distribution of selected species in the Shiraishigawa 1 Section are shown in Fig. 3. This section is exhibited along a road cutting, located 1.5 km east of Shiraishigawa, Niyodo Town, Kochi Prefecture. Strata of this

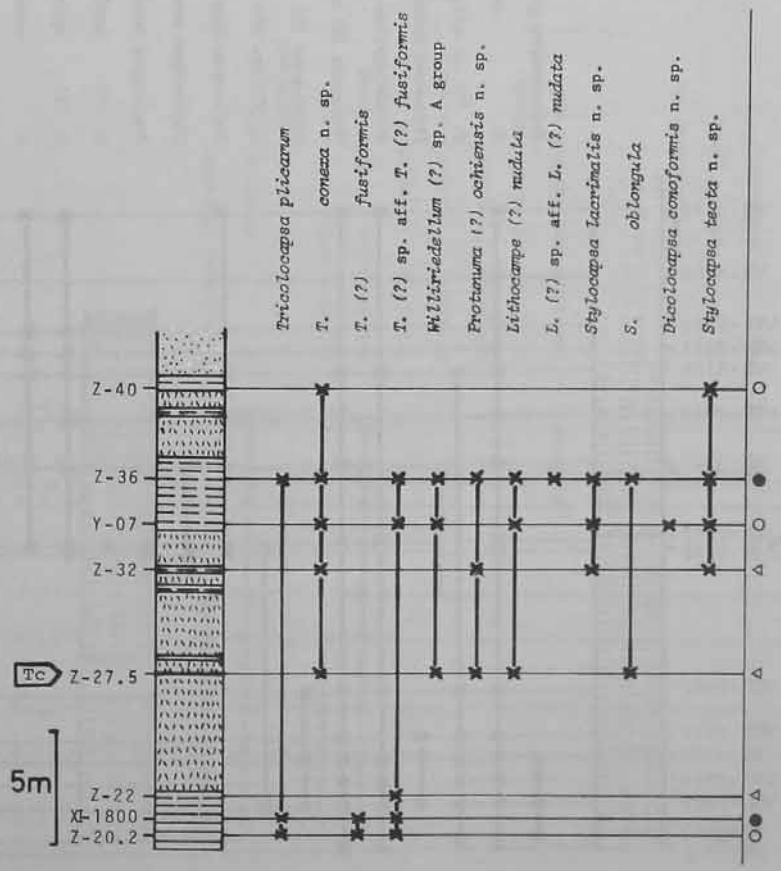

Fig. 4. Straigraphic column of the Yanasegawa 1 Section, showing range chart of selected radiolarians. For symbols see Fig. 2.

section consist of bedded chert, siliceous mudstone, mudstone, acidic tuff and sandstone. Bedded chert changes gradually through siliceous mudstone into mudstone. Acidic tuff layers of 0.2 to 1.7 m thick are intercalated within siliceous mudstone and mudstone. Mudstone is intercalated with fine-grained sandstone in uppermost part and is conformably overlain by massive, medium sandstone.

Besides species shown in Fig. 3, the followings are obtained from the lowermost horizon.

T-01: *Unuma echinatus* ICHIKAWA and YAO, *Unuma typicus* ICHIKAWA and YAO, *Zartus* sp. in MATSUOKA (1982b).

List of additional species from this section is given in MATSUOKA (1982b, Fig. 2).

3) Yanasegawa 1 Section

Lithologic column and stratigraphic distribution of selected species in the Yanase-

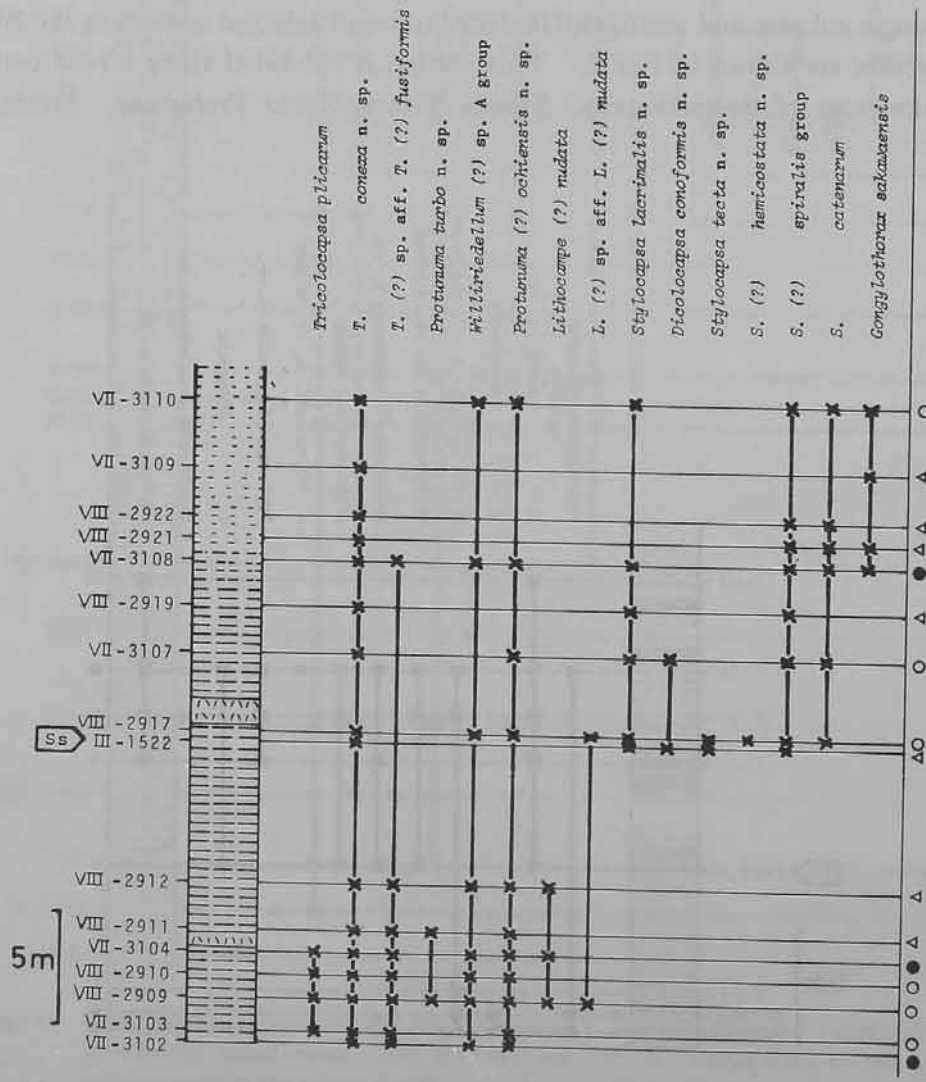

Fig. 5. Stratigraphic column of the Yanasegawa 2 Section, showing range chart of selected radiolarians. For symbols see Fig. 2.

gawa 1 Section are shown in Fig. 4. This section, located 1.0 km south of Kooku, Sakawa Town, Kochi Prefecture, is a road cutting. Strata of this section consist of bedded chert, siliceous mudstone, acidic tuff and sandstone. Bedded chert changes gradually upward into siliceous mudstone which is intercalated with acidic tuff layers of 0.6 to 5.6 m thick. Siliceous mudstone is overlain by massive, medium sandstone.

4) Yanasegawa 2 Section (= Loc. C in MATSUOKA, 1982b)

Lithologic column and stratigraphic distribution of selected species in the Yanasegawa 2 Section are shown in Fig. 5. This section, located 0.6 km southwest of Yanasegawa 1 Section, is a road cutting. Strata of this section are composed of siliceous mudstone, mudstone and acidic tuff. Siliceous mudstone is intercalated with acidic tuff layers of about 1 m thick and grades upward into mudstone.

List of additional species from this section is given in MATSUOKA (1982b, Fig. 4).

5) Yanasegawa 3 Section

Lithologic column and stratigraphic distribution of selected species in the Yanasegawa 3 Section are shown in Fig. 6. This section, located 1.0 km south of the Yanase-

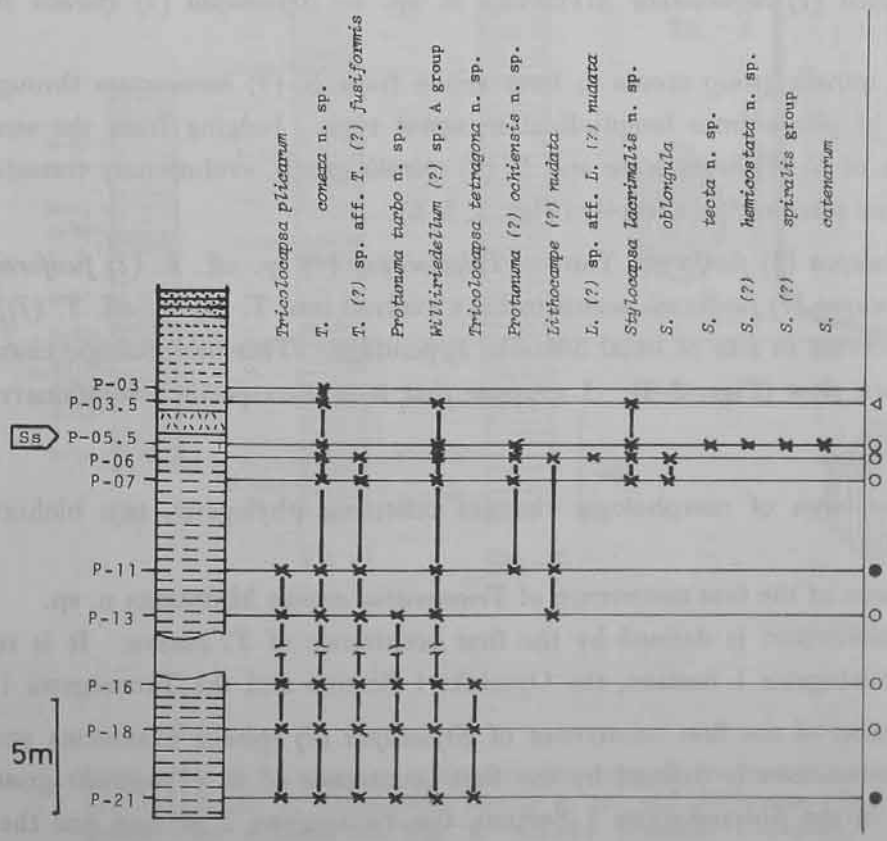

Fig. 6. Stratigraphic column of the Yanasegawa 3 Section, showing range chart of selected radiolarians. For symbols see Fig. 2.

gawa 1 Section, is exposed along a tributary of the Yanase River. Strata of this section are composed of siliceous mudstone, mudstone, acidic tuff and sandstone-rich alternating beds of sandstone and mudstone. Siliceous mudstone is intercalated with acidic tuff layers of about 1 m thick and changes gradually upward into mudstone. Mudstone is conformably overlain by sandstone-rich alternating beds of sandstone and mudstone.

Phylogeny, Biohorizon and Zonation

1) Phylogeny and Evolutionary trend

Through the investigation of five sections treated in this paper and other sections of the Sakawa and adjacent areas, several morphologic changes reflecting phylogeny or evolutionary trend have been recognized. Three of them are briefly reported in this chapter. Further discussion will be given in the Systematic Chapter of this paper.

i) *Tricolocapsa plicarum* YAO — *Tricolocapsa conexa* MATSUOKA n. sp.

T. conexa seems to have arisen from *T. plicarum* by addition of transverse ridges between two neighboring longitudinal plicae. *T. plicarum* and *T. conexa* coexisted over a considerable time span after divergence (Figs. 2–6).

ii) *Stylocapsa* (?) *hemicostata* MATSUOKA n. sp. — *Stylocapsa* (?) *spiralis* MATSUOKA group

S. (?) *spiralis* group seems to have arisen from *S.* (?) *hemicostata* through change in pattern of plicae from longitudinal to spiral type. Judging from the stratigraphic distribution of *S.* (?) *hemicostata* and *S.* (?) *spiralis* group, evolutionary transition seems to have taken place rather abruptly (Figs. 3, 5, 6).

iii) *Tricolocapsa* (?) *fusiformis* YAO — *Tricolocapsa* (?) sp. aff. *T.* (?) *fusiformis* YAO

Tricolocapsa (?) *fusiformis* seems to have evolved into *T.* (?) sp. aff. *T.* (?) *fusiformis* through decrease in size of basal dish-like appendage. This morphologic change seems to have been slow (Figs. 2–4). I suppose that it is intraspecific evolutionary trend.

2) Biohorizon

On the basis of morphologic changes reflecting phylogeny, two biohorizons are determined.

i) Biohorizon of the first occurrence of *Tricolocapsa conexa* MATSUOKA n. sp.

This biohorizon is defined by the first occurrence of *T. conexa*. It is recognized in the Shiraishigawa 1 Section, the Oyashiki 1 Section and the Yanasegawa 1 Section.

ii) Biohorizon of the first occurrence of *Stylocapsa* (?) *spiralis* MATSUOKA group

This biohorizon is defined by the first occurrence of *S.* (?) *spiralis* group. It is recognized in the Shiraishigawa 1 Section, the Yanasegawa 2 Section and the Yanasegawa 3 Section.

Above-mentioned two biohorizons are shown in Figs. 2–6.

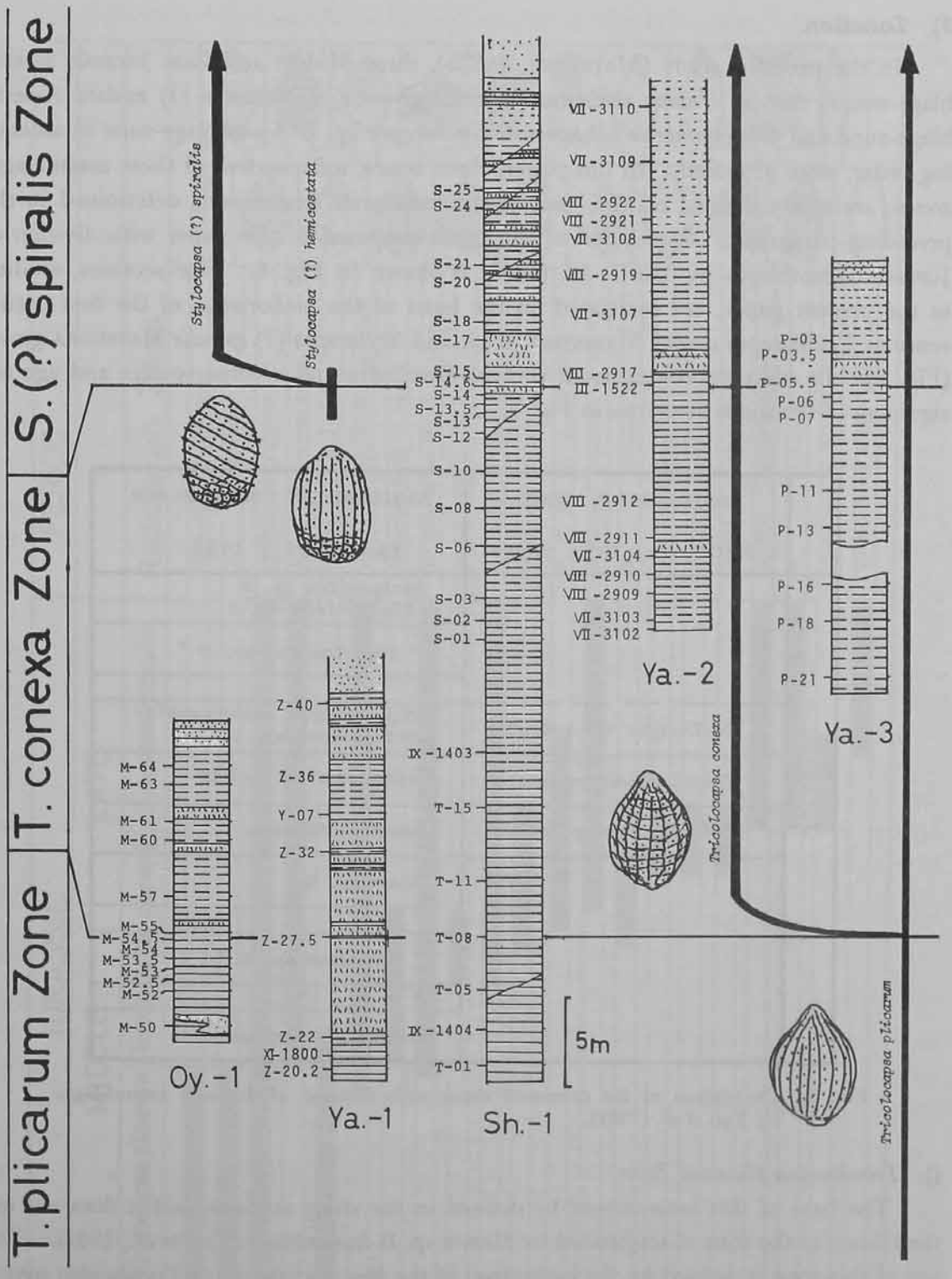

Fig. 7. Correlation of 5 columnar sections on the basis of the biohorizon of the first occurrence of *Tricolocapsa conexa* n. sp. and *Stylocapsa* (?) *spiralis* group. For symbols see Fig. 2. Oy.-1: Oyashiki 1 Section, Ya.-1: Yanasegawa 1 Section, Sh.-1: Shiraishigawa 1 Section, Ya.-2: Yanasegawa 2 Section, Ya.-3: Yanasegawa 3 Section.

3) Zonation

In the previous study (MATSUOKA, 1982b), three Middle and Late Jurassic assemblage-zones, namely *Unuma echinatus* Assemblage-zone, *Lithocampe* (?) *nudata* Assemblage-zone and *Gongylothorax sakawaensis-Stichocapsa* sp. C Assemblage-zone in ascending order, were proposed. In this paper, three zones, independent of these assemblage-zones, are newly defined on the basis of the radiolarian biohorizons determined in the preceding paragraph. Correlation of the zones proposed in this paper with division of Jurassic assemblages by YAO *et al.* (1982) is shown in Fig. 8. Five sections, studied in the present paper, are correlated on the basis of the biohorizons of the first occurrence of *Tricolocapsa conexa* MATSUOKA n. sp. and *Stylocapsa* (?) *spiralis* MATSUOKA group (Fig. 7). In addition, conceptional vertical distribution of selected species and age assignment of the zones are given in Fig. 9.

	RADIOLARIAN ZONE Matsuoka, this paper	RADIOLARIAN ASSEMBLAGE Yao *et al.*, 1982
Jurassic		*Dictyomitra* sp. A -*Dictyomitra* sp. B
		" *Tricolocapsa* sp. O "
	Stylocapsa (?) *spiralis*	*Gongylothorax sakawaensis* -*Stichocapsa* sp. C
	Tricolocapsa conexa	*Lithocampe* (?) *nudata*
	Tricolocapsa plicarum	*Unuma echinatus*
		Hsuum sp. B
		" *Parahsuum* sp. D "
		Parahsuum simplum

Fig. 8. Correlation of the proposed zones with division of Jurassic assemblages by YAO *et al.* (1982).

i) *Tricolocapsa plicarum* Zone

The base of this zone cannot be defined in the study sections, but it does not extend down to the zone characterized by *Hsuum* sp. B Assemblage (YAO *et al.*, 1982). The top of this zone is defined by the biohorizon of the first occurrence of *Tricolocapsa conexa* MATSUOKA n. sp. *Tricolocapsa plicarum* YAO, nominal species of this zone, is abundant in this zone and ranges up into the overlying *Tricolocapsa conexa* Zone and *Stylocapsa* (?) *spiralis* Zone. *Cyrtocapsa* (?) *kisoensis* YAO and *Cyrtocapsa mastoidea* YAO make their last occurrences near the top of this zone. *Tricolocapsa* (?) sp. aff. *T.* (?) *fusiformis*

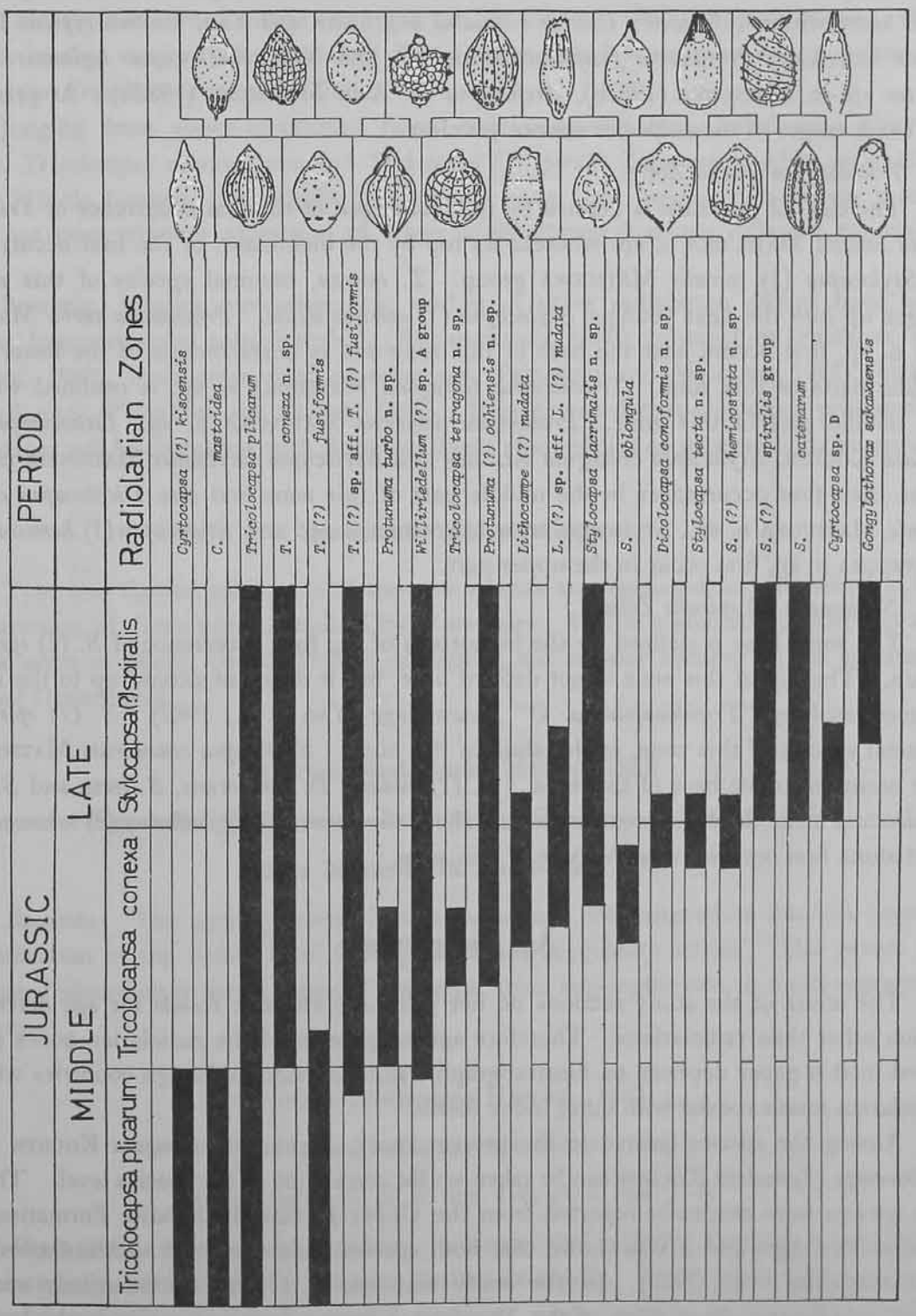

Fig. 9. Age assignment of the proposed zones and conceptional vertical distribution of radiolarian species treated in this paper.

YAO first occurs within this zone. Besides species shown in Fig. 9, the followings have their acme within this zone; *Unuma echinatus* ICHIKAWA and YAO, *Unuma typicus* ICHIKAWA and YAO, *Protunuma fusiformis* ICHIKAWA and YAO, *Stichocapsa tegiminis* YAO, *Zartus* sp. in MATSUOKA (1982b), *Archicapsa* sp. A in MATSUOKA (1982b). At present, the exact ranges of these species are not yet clear.

ii) *Tricolocapsa conexa* Zone

The base of this zone is defined by the biohorizon of the first occurrence of *Tricolocapsa conexa* MATSUOKA n. sp. whereas its top by the biohorizon of the first occurrence of *Stylocapsa* (?) *spiralis* MATSUOKA group. *T. conexa*, nominal species of this zone, ranges up into the next younger *Stylocapsa* (?) *spiralis* Zone. *Protunuma turbo* MATSUOKA n. sp. first occurs near the base of this zone and is characteristic of the lower and middle parts of this zone. *Tricolocapsa tetragona* MATSUOKA n. sp. is confined within the middle part of this zone. *Protunuma ochiensis* MATSUOKA n. sp., *Lithocampe* (?) *nudata* KOCHER, *Stylocapsa oblongula* KOCHER and *Stylocapsa lacrimalis* MATSUOKA n. sp. make their first occurrences in the middle part of this zone and also *Dicolocapsa conoformis* MATSUOKA n. sp., *Stylocapsa tecta* MATSUOKA n. sp. and *Stylocapsa* (?) *hemicostata* MATSUOKA n. sp. first occur in the upper part.

iii) *Stylocapsa* (?) *spiralis* Zone

The zonal base is defined by the biohorizon of the first occurrence of *S.* (?) *spiralis* group. The top of this zone is not defined here, but it does not extend up to the zone characterized by "*Tricolocapsa* sp. O" Assemblage (YAO *et al.*, 1982). *S.* (?) *spiralis*, nominal species of this zone, is abundant in this zone. *Stylocapsa catenarum* MATSUOKA first occurs near the base of this zone. *L.* (?) *nudata*, *D. conoformis*, *S. tecta* and *S.* (?) *hemicostata* make their last occurrences just above the base. *Gongylothorax* (?) *sakawaensis* MATSUOKA first occurs above the base of this zone.

Age assignment

The strata of the study sections do not yield any effective fossils for age determination other than radiolarians. Therefore age assignment of the radiolarian zones proposed in this paper depends on biostratigraphic studies made in foreign countries where radiolarian fossils coexist with other index fossils.

Among the species treated in the present study, *Stylocapsa oblongula* KOCHER and *Lithocampe* (?) *nudata* KOCHER can be taken up for correlation at the species level. These two species were originally reported from the Upper Jurassic Radiolarite Formation of Lombardian Alps and it was shown that both species became extinct within Oxfordian (BAUMGARTNER *et al.*, 1980). In the study sections, *L.* (?) *nudata* commonly occurs in the middle and upper parts of the *Tricolocapsa conexa* Zone and rarely in the lowermost part of the next younger *Stylocapsa* (?) *spiralis* Zone, whereas *S. oblongula* rarely occurs in the middle and upper parts of the *Tricolocapsa conexa* Zone.

The genus *Zartus* was originally introduced from the Middle Jurassic Snowshoe

Formation, Oregon and the Lower Jurassic Maude Formation, British Columbia and it was shown that *Zartus* became extinct in the late Bajocian (PESSAGNO and BLOME, 1980). In the studied sections, the species of *Zartus* make their last occurrences just below the top of the *Tricolocapsa plicarum* Zone.

Judging from above-mentioned facts, it is suggested that *Tricolocapsa plicarum* Zone, *Tricolocapsa conexa* Zone and *Stylocapsa* (?) *spiralis* Zone are roughly assigned to early Middle Jurassic, late Middle Jurassic and early Late Jurassic respectively though it is not clear whether extinction of taxon is simultaneous among different regions or not.

Recently, Jurassic biostratigraphic studies of other radiolarian groups have been made; hagiastrids and patulibracchids (BAUMGARTNER, 1980), pantanellids (PESSAGNO and BLOME, 1980), multi-segmented nassellarians (PESSAGNO and WHALEN, 1982), bizarre nassellarians (PESSAGNO and BLOME, 1982). It is expected that the zones proposed in this paper will be correlated with Europian stages after studies on other radiolarian groups.

Systematic paleontology

Type and figured specimens of the new species are registered and deposited in the Department of Geosciences, Osaka City University. In the systematic description and explanation of plates, the OCU MR number is the register number of the specimens in that Department.

Subclass **Radiolaria** MÜLLER 1858

Superorder **Polycystina** EHRENBERG 1838, emend. RIEDEL 1967

Order **Nassellaria** EHRENBERG 1875

Remarks: The genera treated in this paper are not assigned to families because classification of the family level is at present not adequately settled. The genera are arranged according to the number of segments, from two-segmented to multi-segmented genera.

Genus *Dicolocapsa* HAECKEL 1882

Dicolocapsa conoformis MATSUOKA, n. sp.

(pl. 1, figs. 1–3, pl. 5, figs. 1–6, pl. 6, figs. 1–4)

Description: Shell of two segments, turbinate, thin walled. Cephalis small, spherical internally, porous. Collar stricture distinct externally. Thorax funnel-shaped, porous with a small, circular, constricted aperture. Outer surface of cephalis somewhat rough, thorax smooth. Pores small, circular, uniform in size, densely distributed in cephalic surface, sparsely in thoracic surface where they are arranged diagonally.

Measurements (in μm, based on 16 specimens): Total height (TH), 100–120 (mean,

Table 1. Measurements of *Dicolocapsa conoformis* MATSUOKA, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	DA
OCU MR						
2538	5	5	110	81	—	—
2539	6	1	103	68	—	—
2540			118	76	—	7
2541	5	2	110	85	20	—
2542	6	4	105	72	14	6
2543	5	6	110	78	19	5
2544	5	4	—	82	18	—
2545	6	2	113	79	20	—
2546	6	3	110	80	—	8
2547	5	1	111	79	14	6
2548	5	3	114	79	16	6
2549	1	2	120	75		—
2550			110	75		—
2551	1	1	115	70		—
2552	1	3	—	80		5
2553			100	65		—

111); maximum width of shell (MW), 65–85 (mean, 77); diameter of cephalis (DC), 14–20 (mean, 17); of aperture (DA), 5–8 (mean, 6).

Remarks: This species is distinguished from the species hitherto referred to *Dicolocapsa*, such as *Dicolocapsa murina* RÜST (1885, p. 307, pl. 37, fig. 1), by having funnel-shaped thorax.

Type-specimens: Holotype, OCU MR 2548 (pl. 5, figs. 3a, 3b); Paratype, OCU MR 2543 (pl. 5, figs. 6a, 6b), OCU MR 2552 (pl. 1, figs. 3a, 3b).

Genus *Gongylothorax* FOREMAN 1968, emend. DUMITRICA 1970

Gongylothorax sakawaensis MATSUOKA

(pl. 1, fig. 4, pl. 5, figs. 7a, 7b)

1982a *Gongylothorax sakawaensis* MATSUOKA — p. 74–75, pl. 1, figs. 1–10.
1982 *Gongylothorax sakawaensis* MATSUOKA — YAO *et al.*, pl. 4, figs. 8–9.
1982b *Gongylothorax sakawaensis* MATSUOKA — MATSUOKA, pl. 3, figs. 1–2.
1983 *Gongylothorax sakawaensis* MATSUOKA — YAO, p. 371, fig. 3_{-11}.

Genus *Stylocapsa* PRINCIPI 1909

Stylocapsa tecta MATSUOKA, n. sp.

(pl. 1, figs. 5–11, pl. 5, figs. 8–14)

1982b *Stylocapsa* sp. E — MATSUOKA, pl. 3, fig. 7.

Description: Shell of two segments, pyriform, widest at about 3/4 portion of total

Table 2. Measurements of *Stylocapsa tecta* MATSUOKA, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	DA
OCU MR						
2554			139	82	—	—
2555			151	82	12	9
2556			148	80	—	—
2557			128	73	—	7
2558			152	100	13	—
2559			130	77	—	—
2560	5	9	174	90	—	10
2561	5	11	145	82	19	—
2562	5	10	192	88	—	6
2563	5	14	129	86	19	—
2564			123+	90	16	8
2565			170	102	—	—
2566			132	85	—	8
2567	5	8	180	85	—	8
2568	5	13	170	92	—	—
2569			152	89	19	—
2570	5	12	147	88	13	7
2571			150	75	11	—
2572			154	82	12	8
2573			146	96	—	9
2574			140	72		—
2575	1	9	156	85		—
2576			131	86		—
2577	1	10	—	86		—
2578			—	88		—
2579			147	75		—
2580	1	6	172	96		—
2581	1	8	152	85		—
2582	1	5	165	88		—
2583			150	90		—

length from the apical end. Cephalis spherical internally, hidden in staut apical horn. Apical horn consisting of numerous blades and grooves. Thorax oboidal with a circular, constricted aperture. Pores of thoracic shell tapering externally and arranged longitudinally. Thirteen to 15 longitudinal rows of pores visible in lateral view. Pores on upper part of thorax set in small, circular to rounded polygonal pits which become obscure distally. Outer surface of upper part of thorax rough due to longitudinally arranged pits, that of lower part smooth.

Measurements (in μm, based on 30 specimens): Total height (TH), 128–192 (mean, 152); maximum width of shell (MW), 72–102 (mean, 86); diameter of cephalis (DC), 11–19 (mean, 15); of aperture (DA), 6–10 (mean, 8).

Remarks: Concerning the outer surface of thorax, proportion of the area with smooth surface to that with rough surface varies among specimens. Smooth surface changes gradually to rough surface proximally. This indicates that coating of shell surface decreases in apical direction during ontogeny in this species. This is a inverse pattern of lamellar model suggested by PESSAGNO and WHALEN (1982).

Stylocapsa tecta n. sp. is distinguished from *S. oblongula* KOCHER by possessing an apical horn which consists of numerous blades and grooves.

Type-specimens: Holotype, OCU MR 2567 (pl. 5, figs. 8a, 8b); Paratype, OCU MR 2562 (pl. 5, figs. 10a, 10b), OCU MR 2574 (pl. 1, fig. 11).

Stylocapsa lacrimalis MATSUOKA, n. sp.

(pl. 1, figs. 12–13, pl. 7, figs. 3–10)

Description: Shell of two segments, inflated drop-like shaped. Cephalis small, spherical internally, encased in wall, with small pointed apical end externally. Thorax subspherical with thick wall. Aperture, small, circular, constricted. A well-defined circular depression situated near aperture. Pores in the depression larger than those on outer surface of shell, densely distributed. Outer surface of shell with tetragonal, pentagonal and hexagonal frames surrounding one pore or rarely a few pores. Pores small, circular, uniform in size.

Measurements (in μm, based on 13 specimens): Total height (TH), 98–119 (mean, 107); maximum width of shell (MW), 76–100 (mean, 88), diameter of cephalis (DC), 11–15 (mean, 13), of aperture (DA), 6–9 (mean, 7).

Remarks: This species does not bear a prominent apical horn but pointed apical end. Some specimens possess rather rounded apical end. Ornament on outer shell

Table 3. Measurements of *Stylocapsa lacrimalis* MATSUOKA, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	DA
OCU MR						
2587	7	9	102	94	12	—
2588	7	5	100	80	15	—
2589	7	7	115	90	11	8
2590	7	8	119	100	15	—
2591			100	90	—	—
2592	7	6	115	91	—	6
2593			110	88	—	—
2594			99	83	15	—
2595	7	10	98	80	—	—
2596	7	4	109	90	—	6
2597	7	3	105	86	11	—
2598	1	12	106	76		—
2599	1	13	108	93		9

surface varies among specimens. Some specimens are ornamented with tetragonal frames which are arranged longitudinally. Some others are covered with hexagonal and pentagonal frames. Most specimens have ornament in combination of the above-mentioned two types.

Stylocapsa lacrimalis n. sp. is similar to *Tricolocapsa conexa* n. sp. described below, in outline of shape, ornament of outer shell surface and presence of circular depression near aperture, but differs from the latter in its smaller size and in number of segments. Judging from morphological similarity, *S. lacrimalis* n. sp. seems to be related phylogenetically to *T. conexa* n. sp.

Type-specimens: Holotype, OCU MR 2587 (pl. 7, figs. 9a, 9b); Paratype, OCU MR 2588 (pl. 7, figs. 5a, 5b), OCU MR 2599 (pl. 1, figs. 13a, 13b).

Stylocapsa (?) *hemicostata* Matsuoka, n. sp.

(pl. 2, figs. 1–4, pl. 6, figs. 8–13)

Description: Shell of two segments, oval. Cephalis small, spherical internally, partly encased in thoracic wall and cavity. Collar stricture indistinct externally. Thorax oval with a small, constricted aperture. Small projection(s) at proximal end of some specimens. Ornament on outer surface of shell differentiated between proximal and distal parts. Proximal part with 17 to 20 longitudinal plicae in lateral view; one row of pores between neighboring two longitudinal plicae. Distal part with polygonal frames. One pore present in the center of each depression surrounded by the polygonal frames. Longitudinal plicae changing distally to polygonal frames by adding perpendicular or oblique ridges to the longitudinal plicae. Pores on outer surface of shell small, circular

Table 4. Measurements of *Stylocapsa* (?) *hemicostata* Matsuoka, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	DA
OCU MR						
2600	6	9	129	108	—	—
2601	6	8	148	114	—	—
2602	6	12	140	110	19	—
2603	6	13	143	101	18	—
2604			139	101	—	—
2605	6	10	142	111	—	—
2606	6	11	138	100	18	—
2607			133	106	—	—
2608	2	4	130	102		—
2609			—	99		8
2610			125	95		—
2611	2	1	132	102		5
2612	2	2	125	102		—
2613	2	3	—	113		6

and uniform in size.

Measurements (in μm, based on 14 specimens): Total height (TH), 125–148 (mean, 135); maximum width of shell (MW), 95–114 (mean, 105); diameter of cephalis (DC), 18–19 (mean, 18); of aperture (DA), 5–8 (mean, 6).

Remarks: This species does not bear a prominent apical horn, but small projection(s) are present in some specimens (pl. 2, fig. 1). Therefore this species is doubtfully assigned to *Stylocapsa*. On outer surface, proportion of the area with longitudinal plicae to that with polygonal frames varies among specimens.

Stylocapsa (?) *hemicostata* n. sp. differs from *Stylocapsa* (?) *spiralis* MATSUOKA by possessing longitudinal plicae.

Type-specimens: Holotype, OCU MR 2601 (pl. 6, figs. 8a, 8b); Paratype, OCU MR 2600 (pl. 6, figs. 9a, 9b), OCU MR 2611 (pl. 2, fig. 1).

Stylocapsa (?) *spiralis* MATSUOKA group

(pl. 2, figs. 5–9, pl. 6, figs. 14–15)

1982a *Stylocapsa* (?) *spiralis* MATSUOKA, — p. 77–78, pl. 3, figs. 1–8.
1982 *Stylocapsa* (?) *spiralis* MATSUOKA, — YAO *et al.*, pl. 4, figs. 11–12.
1982b *Stylocapsa* (?) *spiralis* MATSUOKA, — MATSUOKA, pl. 3, figs. 8–9.

Remarks: Various forms are included under this name. There are several varieties in ornamentation of outer surface of shell. Some have regular spiral arrangement of plicae (*S.* (?) *spiralis* s.s., pl. 2, figs. 8–9, pl. 6, figs. 14–15). Some others have chevron-like arrangement of plicae (pl. 2, fig. 7). The remaining ones have ornament with combination of longitudinal, spiral and chevron-like plicae (pl. 2, figs. 5–6). *Stylocapsa* (?) *spiralis* group include all intermediate forms between *Stylocapsa* (?) *hemicostata* n. sp. and *Stylocapsa* (?) *spiralis* s.s. in addition to *S.* (?) *spiralis* s.s. These intermediate forms occur abundantly at the horizon of the first occurrence of *S.* (?) *spiralis* group. *Stylocapsa* (?) *spiralis* group seems to be derived from *Stylocapsa* (?) *hemicostata* through change in plicae arrangement from longitudinal pattern to spiral pattern. Judging from stratigraphic distribution of *S.* (?) *hemicostata* and *S.* (?) *spiralis* group, it seems that the morphologic change took place rapidly and *S.* (?) *spiralis* s.s. survived without remarkable morphologic change.

Stylocapsa catenarum MATSUOKA

(pl. 2, fig. 10, pl. 7, figs. 1–2)

1982a *Stylocapsa catenarum* MATSUOKA — p. 75–76, pl. 2, figs. 1–11.
1982 *Stylocapsa catenarum* MATSUOKA — YAO *et al.*, pl. 4, fig. 10.
1982b *Stylocapsa catenarum* MATSUOKA — MATSUOKA, pl. 3, figs. 3–4.

Remarks: Some specimens entirely lack apical horn (pl. 7, figs. 2a, 2b), but are otherwise similar to the specimens with apical horn. Whether apical horn is present

or not, is not a diagnostic criterion for identification of this species.

Stylocapsa oblongula KOCHER

(pl. 6, figs. 5–7)

1980 *Stylocapsa oblongula* KOCHER — BAUMGARTNER *et al.*, p. 62, pl. 6, fig. 1.
1982 *Stylocapsa oblongula* KOCHER — AITA, pl. 1, figs. 18a, 18b.

Genus *Tricolocapsa* HAECKEL 1887

Tricolocapsa (?) *fusiformis* YAO

(pl. 2, fig. 11, pl. 8, fig. 1)

1979 *Tricolocapsa* (?) *fusiformis* YAO — p. 33–34, pl. 4, figs. 12–18, pl. 5, figs. 1–4.
1982 *Tricolocapsa* (?) *fusiformis* YAO — WAKITA and OKAMURA, pl. 7, fig. 10.
1982 *Tricolocapsa* (?) *fusiformis* YAO — KOJIMA, pl. 2, fig. 2.
1982 *Tricolocapsa* (?) *fusiformis* YAO — WAKITA, pl. 3, fig. 4.
1982 *Tricolocapsa* (?) *fusiformis* YAO — KIDO *et al.*, pl. 5, fig. 3.
1982b *Tricolocapsa* (?) *fusiformis* YAO — MATSUOKA, pl. 1, figs. 17–19.

Remarks: I pointed out that dish-like basal appendage of *T.* (?) *fusiformis* YAO becomes systematically small in size from *Unuma echinatus* Assemblage-zone through *Lithocampe* (?) *nudata* Assemblage-zone to *Gongylothorax sakawaensis-Stichocapsa* sp. C Assemblage-zone (MATSUOKA, 1982b). I use the ratio of maximum width of the shell (MW) to appendage width (AW) as indicator of the relative size of appendage in this paper (see Fig. 10). In figured-specimens of *T.* (?) *fusiformis* YAO (YAO, 1979, pl. 4, figs. 12–18, pl. 5, figs. 1–4), the ratio (MW/AW) ranges between 1.4 and 1.9. I assign specimens with the ratio (MW/AW) of less than 2.0 (inclusive) to *T.* (?) *fusiformis* YAO and specimens with the ratio (MW/AW) of more than 2.0 to *T.* (?) sp. aff. *T.* (?) *fusiformis* YAO. According to this criterion, *T.* (?) *fusiformis* changes gradually into *T.* (?) sp. aff. *T.* (?) *fusiformis* near the biohorizon of the first occurrence of *Tricolocapsa conexa* n. sp. (see Fig. 9).

Fig. 10. *Tricolocapsa* (?) *fusiformis* YAO
MW: maximum width of the shell, AW: width of the basal appendage.

Tricolocapsa (?) sp. aff. *T.* (?) *fusiformis* YAO

(pl. 2, figs. 12–13, pl. 8, figs. 2–3)

1982 *Tricolocapsa* (?) aff. *fusiformis* YAO — YAO *et al.*, pl. 4, fig. 7.
1982 *Tricolocapsa* (?) *fusiformis* YAO — OWADA and SAKA, pl. 2, fig. 13.
1982 *Tricolocapsa* (?) sp. cf. *T.* (?) *fusiformis* YAO — KIDO *et al.*, pl. 5, fig. 4.
1982b *Tricolocapsa* (?) aff. *fusiformis* YAO — MATSUOKA, pl. 2, fig. 15.
1982 *Tricolocapsa fusiformis* YAO — KISHIDA and SUGANO, pl. 11, figs. 10–11.

Remarks: This name is used according to the criterion mentioned under *Tricolocapsa* (?) *fusiformis* YAO.

Tricolocapsa plicarum YAO

(pl. 3, figs. 1–2)

1973 "*Artocapsa*" sp. A — ICHIKAWA and YAO, pl. 5, figs. 1a, 1b.
1979 *Tricolocapsa plicarum* YAO — p. 32–33, pl. 4, figs. 1–11.
cf. 1982 *Tricolocapsa* sp. cf. *T. plicarum* YAO — YOSHIMURA *et al.*, pl. 6, fig. 4.
1982 *Tricolocapsa plicarum* YAO — WAKITA and OKAMURA, pl. 7, fig. 9.
1982 *Tricolocapsa plicarum* YAO — YAO *et al.*, pl. 3, fig. 12.
1982 *Tricolocapsa plicarum* YAO — SASHIDA *et al.*, pl. 2, fig. 1.
cf. 1982 *Tricolocapsa plicarum* YAO — OWADA and SAKA, pl. 2, fig. 15.
1982 *Tricolocapsa plicarum* YAO — KOJIMA, pl. 2, fig. 1.
1982 *Tricolocapsa plicarum* YAO — WAKITA, pl. 3, fig. 3.
1982 *Tricolocapsa plicarum* YAO — KIDO *et al.*, pl. 5, fig. 1.
cf. 1982 *Tricolocapsa plicarum* YAO — IMOTO *et al.*, pl. 2, figs. 1–2.
1982 *Tricolocapsa plicarum* YAO — AITA, pl. 1, fig. 17.
1982 *Tricolocapsa plicarum* YAO — KISHIDA and SUGANO, pl. 12, figs. 1–2.
1982 *Tricolocapsa plicarum* YAO — NISHIZONO *et al.*, pl. 2, fig. 16.
non 1982 *Tricolocapsa plicarum* YAO — SASHIDA *et al.*, pl. 1, fig. 2.

Remarks: Dish-like basal appendage of *T. plicarum* becomes smaller in stratigraphically higher horizon as in the case of *Tricolocapsa* (?) *fusiformis* YAO. Some specimens possess a circular depression near aperture (pl. 3, fig. 2).

Tricolocapsa conexa MATSUOKA, n. sp.

(pl. 3, figs. 3–7, pl. 7, figs. 11–14)

1982 *Tricolocapsa plicarum* YAO — SASHIDA *et al.*, pl. 1, fig. 2.
1982 *Tricolocapsa* sp. a — KIDO *et al.*, pl. 5, fig. 5.
1982b *Tricolocapsa* aff. *plicarum* YAO — MATSUOKA, pl. 3, fig. 15.
1982 *Tricolocapsa* sp. E — AITA, pl. 2, figs. 5a, 5b; non fig. 4.
1982 *Gongylothorax* ? sp. — KISHIDA and SUGANO, pl. 8, fig. 22; non fig. 21.

Description: Shell of three segments, drop-like shaped. Cephalis spherical internally. Thorax truncate conical. Lumber stricture slightly recognizable or indistinct externally. Abdomen subspherical with a constricted aperture and a circular depres-

sion near aperture. Aperture shifted slightly off-center by presence of circular depression. Aperture covered by pored, small, thin-walled appendage in well-preserved specimens (pl. 3, fig. 6). Circular depression near aperture possessing densely spaced pores which are larger in diameter than pores on main part of outer shell surface. Outer surface of shell ornamented with continuous longitudinal plicae and transverse ridges connecting adjacent two longitudinal plicae; plicae and ridges forming tetragonal frames. Pores at the center of the tetragonal frames small, circular and uniform in zise.

Table 5. Measurements of *Tricolocapsa conexa* MATSUOKA, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	HT	HA
OCU MR							
2614			105	90	—	—	—
2615			109	88	—	—	—
2616			132	103	—	—	—
2617			132	110	—	—	—
2618	7	13	142	106	—	—	—
2619			130	117	16	—	—
2620			129	93	—	—	—
2621			128	101	17	32	80
2622	7	12	130	102	18	25	90
2623	7	11	138	120	18	30	98
2624			152	114	20	30	108
2625			145	112	20	28	110
2698	7	14	150	114	19	30	108
2626			130	102			
2627			157	120			
2628	3	7	—	100			
2629			—	100			
2630			153	120			
2631			146	104			
2632			—	106			
2633			—	115			
2634	3	6	—	123			
2635	3	3	143	107			
2696	3	4	128	112			
2697	3	5	—	118			

Measurements (in μm, based on 25 specimens): Total height (TH), 105–157 (mean, 129); maximum width of shell (MW), 88–123 (mean, 103); diameter of cephalis (DC), 16–20 (mean, 18); height of thorax (HT), 25–32 (mean, 29); of abdomen (HA), 80–108 (mean, 99).

Remarks: This species is very similar to *T. plicarum* YAO in outer shape, proportion among the segments, longitudinal plicae and dish-like basal appendage, but differs

from the latter by possessing transverse ridges connecting adjacent two longitudinal plicae.

Judging from morphological features and vertical distribution of *T. plicarum* and *T. conexa* (Fig. 9), it is conceivable that the former is ancestral to the latter species.

Type-specimens: Holotype OCU MR 2635 (pl. 2, fig. 3); Paratype OCU MR 2622 (pl. 7, figs. 12a, 12b), OCU MR 2618 (pl. 7, figs. 13a, 13b).

Tricolocapsa tetragona MATSUOKA, n. sp.

(pl. 3, figs. 8–12, pl. 8, figs. 4–10)

1982b *Tricolocapsa* sp. N — MATSUOKA, pl. 2, figs. 13, 17.
1982 *Tricolocapsa* sp. E — AITA, pl. 2, fig. 4; non figs. 5a, 5b.

Description: Shell of three segments. Cephalis spherical internally, rounded ex-

Table 6. Measurements of *Tricolocapsa tetragona* MATSUOKA, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	HT	HA	DA
OCU MR								
2636	8	5	131	120	—	—	110	—
2637			140	114	15	—	—	—
2638	8	9	115	91	12	25	88	—
2639	8	7	128	113	—	22	106	—
2640			128	127	—	—	—	—
2641	8	8	150	130	13	28	120	—
2642			128	123	—	—	—	—
2643	8	4	119	105	—	—	—	—
2644	8	6	—	112	—	—	—	—
2645			128	116	—	—	—	—
2646	8	10	129	117	—	15	100	—
2647			—	102				—
2648			128	105				—
2649			136	115				—
2650	3	10	—	115				5
2651			—	119				7
2652			—	110				—
2653			135	107				—
2654			130	98				—
2655			130	120				—
2656	3	9	—	132				—
2657			—	124				—
2658	3	8	136	125				—
2659	3	11	—	123				—
2660	3	12	—	118				—

ternally, imperforate. Thorax cylindrical with small, circular pores. Lumber stricture distinct. Abdomen spherical with a small constricted aperture. Shell surface of abdomen ornamented with longitudinal plicae and transverse ridges connecting adjacent two longitudinal plicae. Thirteen to 14 longitudinal plicae visible in lateral view. The plicae and transverse ridges forming tetragonal frames, which change distally to pentagonal and hexagonal frames. Small, circular pores present at the center of the frames.

Measurements (in μm, based on 25 specimens): Total height (TH), 115–150 (mean, 131); maximum width of shell (MW), 91–132 (mean, 115); diameter of cephalis (DC), 12–15 (mean, 13); height of thorax (HT), 15–28 (mean, 23); of abdomen (HA), 88–120 (mean, 105), diameter of aperture (DA), 5–7 (mean, 6).

Remarks: Ornament of outer shell surface varies among specimens. Besides type specimens with characteristic tetragonal frames, some specimens have only longitudinal plicae on the upper hemisphere of abdomen, where tetragonal frames are not formed (pl. 3, figs. 9, 12).

Tricolocapsa tetragona n. sp. is similar to *Tricolocapsa* sp. cf. *T. ruesti* Tan (Yao, 1979, p. 30–31, pl. 3, figs. 8–10, 12–20; non fig. 11) in proportion of each segment, but differs from the latter by having tetragonal frames on abdominal surface. This species is distinguished from *T. conexa* n. sp. by having distinct lumber stricture, more widely spaced longitudinal plicae and transverse ridges and by lacking dish-like basal appendage.

Type-specimens: Holotype, OCU MR 2636 (pl. 8, figs. 5a, 5b); Paratype, OCU MR 2641 (pl. 8, figs. 8a, 8b), OCU MR 2658 (pl. 3, fig. 8).

Genus *Williriedellum* Dumitrica 1970

Williriedellum sp. A group

(pl. 4, figs. 1–3, pl. 8, figs. 11–15)

1982 *Tricolocapsa* sp. I — Yao *et al.*, pl. 4, fig. 14.
1982b *Tricolocapsa* sp. I — Matsuoka, pl. 2, fig. 14, pl. 3, fig. 14.
1982 *Williriedellum carpathicum* Dumitrica — Aita, pl. 3, fig. 6.
?1982 *Tricolocapsa* sp. D — Kishida and Sugano, pl. 12, fig. 10.

Description: Shell of three segments, with two polar prominences: one upper given by the cephalo-thoracic couple, the other lower given by the basal appendage. Abdomen barrel-shaped with or without small spines. Outer surface of shell covered with hexagonal (rarely pentagonal) frames. One, small, circular pore present in the center of the frames. Ornament of outer shell surface varing in prominence from distinct to obscure according to degree of occlusion.

Remarks: Various forms are included under this name. There are several factors in variation; degree of occlusion of outer shell surface, degree of encasement of thorax into abdomen and degree of prominence of apical horn and spines on abdomen. This group may be divided into some species.

Genus *Cyrtocapsa* HAECKEL 1881

Cyrtocapsa (?) *kisoensis* YAO

(pl. 9, fig. 9)

1979 *Cyrtocapsa* (?) *kisoensis* YAO — p. 37–39, pl. 8, figs. 9–16.
1982 *Cyrtocapsa* (?) *kisoensis* YAO — YAO *et al.*, pl. 3, fig. 13.
1982b *Cyrtocapsa* (?) *kisoensis* YAO — MATSUOKA, pl. 1, figs. 4, 20.

Cyrtocapsa mastoidea YAO

(pl. 9, fig. 8)

1973 "*Cyrtocapsa*" sp. — ICHIKAWA and YAO, pl. 4, figs. 1–3.
1979 *Cyrtocapsa mastoidea* YAO — p. 36–37, pl. 8, figs. 1–8.
1982 *Cyrtocapsa mastoidea* YAO — MIZUTANI and KOIKE, pl. 1, fig. 9.
1982 *Cyrtocapsa mastoidea* YAO — WAKITA, pl. 3, fig. 9.
1982 *Cyrtocapsa mastoidea* YAO — KIDO *et al.*, pl. 4, fig. 7.
1982b *Cyrtocapsa mastoidea* YAO — MATSUOKA, pl. 1, fig. 7.
?1982 *Tricolocapsa* cfr. *fusiformis* YAO — SASHIDA *et al.*, pl. 2, fig. 12.

Cyrtocapsa sp. D

(pl. 9, figs. 10–11)

1982b *Cyrtocapsa* sp. D — MATSUOKA, pl. 3, fig. 17; non fig. 16.

Description: Shell of four segments, elongate spindle-shaped. Cephalis small, spherical internally with a staut apical horn which possesses several longitudinal grooves. Thorax truncate conical. Abdomen cylindrical. The fourth segment inverse conical with a constricted aperture. Longitudinal plicae present on cephalic, thoracic and rarely abdominal surface. Pores small, circular, uniform in size, distributed uniformly on outer surface of shell except for apical horn. Outer surface of shell smooth except for plication.

Remarks: This species is similar to *Cyrtocapsa* (?) *kisoensis* YAO and also to *Lithocampe* (?) sp. aff. *L.* (?) *nudata* KOCHER described below but differs from them by bearing a staut apical horn which possesses longitudinal grooves.

Genus *Protunuma* ICHIKAWA and YAO 1976

Protunuma turbo MATSUOKA, n. sp.

(pl. 4, figs. 4–7, pl. 8, figs. 16–18, pl. 9, figs. 1–2)

1982 *Protunuma* sp. J — YAO *et al.*, pl. 4, fig. 5.
1982b *Protunuma* sp. J — MATSUOKA, pl. 2, fig. 5.
?1982 *Protunuma fusiformis* ICHIKAWA and YAO — WAKITA, pl. 4, fig. 3.

Description: Shell of three segments, spindle-shaped. Cephalis spherical internal-

ly, rounded externally, without pores. A very small apical horn possibly present, but usually absent. Thorax truncate conical, perforate. Junction between thorax and abdomen represented externally by a narrow zone of imperforate or sporadically pored wall. Abdomen subspherical with longitudinal plicae, numerous pores and a small, constricted aperture. Seven to 9 longitudinal plicae visible in lateral view, increasing in number through insertion and extending to thoracic and often cephalic surface. One row to four rows of pores present between neighboring two longitudinal plicae. Pores small, circular, uniform in size, arranged diagonally.

Table 7. Measurements of *Protunuma turbo* MATSUOKA, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	HT	HA	DA
OCU MR								
2661	9	1	125	90	16	20	91	6
2662	8	18	120	90	20	—	—	4
2663	8	17	115	78	13	28	78	3
2664			105	78	—	—	—	3
2665			112	84	14	—	—	3
2666	8	16	127	87	13	22	90	4
2667			125	92	—	—	—	4
2668			113	88	19	—	—	7
2669			102	71	15	—	—	5
2670			126	82	19	20	96	—
2671			119	82	18	21	83	4
2672	9	2	130	95	16	27	94	5
2673	4	5	113	84				—
2674	4	7	—	80				—
2675	4	4	115	92				—
2676			112	81				—
2677	4	6	120	78				—
2678			124	86				—
2679			—	75				—

Measurements (in μm, based on 19 specimens): Total height (TH), 102–130 (mean, 118); maximum width of shell (MW), 71–95 (mean, 84); diameter of cephalis (DC), 13–20 (mean, 16); height of thorax (HT), 20–28 (mean, 23); of abdomen (HA), 78–96 (mean, 89); diameter of aperture (DA), 3–7 (mean, 4).

Remarks: This species differs from *Protunuma fusiformis* ICHIKAWA and YAO (1976, p. 116, pl. 2, figs. 1–4) by consisting of three segments and from *Tricolocapsa plicarum* YAO by possessing more than two rows of pores between two neighboring longitudinal plicae and by lacking basal appendage.

Type-specimens: Holotype, OCU MR 2663 (pl. 8, figs. 17a, 17b); Paratype, OCU MR 2672 (pl. 9, figs. 2a, 2b), OCU MR 2675 (pl. 4, fig. 4).

Protunuma (?) *ochiensis* MATSUOKA, n. sp.

(pl. 4, figs. 8–11, pl. 9, figs. 3–7)

1982 *Protunuma* sp. B — YAO *et al.*, pl. 4, fig. 6.
1982 *Protunuma* sp. B — MATSUOKA, pl. 2, figs. 6, 7, 18.
?1982 *Unuma* sp. A — WAKITA, pl. 4, fig. 1.
?1982 *Protunuma* sp. — SATO *et al.*, pl. 4, fig. 6.

Description: Shell of four segments, spindle-shaped, without aperture. Cephalis spherical internally, bearing somewhat pointed proximal end externally. Some specimens possessing a small apical horn (pl. 9, figs. 3a, 3b). Thorax truncate conical. Abdomen large, barrel-shaped with inverse subconical last segment. Longitudinal plicae running continuously through segments; some of them extending from proximal end to distal end, others edging out or converging to adjacent plicae proximally and distally. Nine to 13 longitudinal plicae visible in lateral view. One row to 3 rows of pores present between neighboring two longitudinal plicae. Pores relatively large, circular, arranged diagonally and increasing in size distally.

Table 8. Measurements of *Protunuma* (?) *ochiensis* MATSUOKA, n. sp.

Specimen	Pl.	Fig.	TH	MW	DC	HT	HA	HF
OCU MR								
2680	9	7	166	112	14	30	77	45
2681			150	95	—	—	—	40
2682	9	4	160	112	14	22	85	48
2683	9	6	176	116	16	28	95	33
2684			183	120	—	—	—	55
2685	9	5	130	85	12	30	48	38
2686	9	3	158	110	—	—	—	50
2687			—	105				
2688			118	97				
2689	4	11	129	100				
2690			129	110				
2691			126	91				
2692	4	10	147	106				
2693			—	105				
2694	4	8	145	97				
2695			130	99				
2699	4	9	160	126				
2700			162	97				

Measurements (in μm, based on 18 specimens): Total height (TH), 118–183 (mean, 148); maximum width of shell (MW), 85–126 (mean, 105); diameter of cephalis (DC), 12–16 (mean, 14); height of thorax (HT), 22–30 (mean, 28); of abdomen (HA), 48–95 (mean, 76); of fourth segment (HF), 33–55 (mean, 44).

Remarks: This species is doubtly assigned to *Protunuma* by reason of lacking aper-

ture.

This species is distinguished from *Protunuma fusiformis* ICHIKAWA and YAO (1976, p. 116, pl. 2, figs. 1–4) and *Protunuma turbo* n. sp. by lacking aperture, by consisting of four segments and by possessing pores increasing in size distally.

Type-specimens: Holotype, OCU MR 2683 (pl. 9, figs. 6a, 6b); Paratype, OCU MR 2682 (pl. 9, figs. 4a, 4b), OCU MR 2694 (pl. 4, figs. 8a, 8b).

Genus *Lithocampe* EHRENBERG 1838

Lithocampe (?) *nudata* KOCHER

(pl. 9, figs. 12–14)

1980 *Lithocampe* (?) *nudata* KOCHER — BAUMGARTNER *et al.*, p. 55, pl. 6, fig. 3.
1982 *Lithocampe* (?) *nudata* KOCHER — YAO *et al.*, pl. 4, figs. 1–2.
1982b *Lithocampe* (?) *nudata* KOCHER — MATSUOKA, pl. 2, figs. 1–2.
aff. 1982 *Lithocampe* (?) *nudata* KOCHER — AITA, pl. 1, figs. 19a–19c.
non 1982 *Lithocampe* (?) sp. cf. *L.* (?) *nudata* KOCHER — KIDO *et al.*, pl. 4, fig. 6.

Lithocampe (?) sp. aff. *L.* (?) *nudata* KOCHER

(pl. 4, figs. 12–13, pl. 9, fig. 15)

1982b *Cyrtocapsa* sp. D — MATSUOKA, pl. 3, fig. 16; non fig. 17.
1982 *Lithocampe* (?) *nudata* KOCHER — AITA, pl. 1, figs. 19a–19c.

Description: Shell of four segments, elongate ellipsoidal. Cephalis spherical internally, with numerous small spines externally. Thorax and abdomen truncate conical. Fourth segment inversely subconical, with a constricted aperture. Outer surface of shell smooth except for proximal end and longitudinal plication. Pores small, circular to ellipsoidal, arranged diagonally. Longitudinal plicae running from cephalic surface to thoracic or abdominal surface and rarely extending to the surface of fourth segment. Pores on distal part somewhat larger than those on main part of outer shell surface.

Remarks: This species is very similar to *Lithocampe* (?) *nudata* KOCHER in number of segments, external shape and proportion of the segments, but differs from the latter by its slender form and presence of longitudinal plicae.

Judging from stratigraphic distribution and morphological similarity, it is concievable that *L.* (?) sp. aff. *L.* (?) *nudata* KOCHER is phylogenetically related to *Lithocampe* (?) *nudata* KOCHER.

This species is rare in the study area. Therefore species name is not proposed here pending more comprehensive observation of additional specimens.

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Plate 1

Explanation of Plate 1

All figures ×300

Figs. 1–3. *Dicolocapsa conoformis* Matsuoka, n. sp. ..... Page 13

1. S-17-43, 2/8 (1060) OCU MR 2551
2. S-17-36, 2/5 (849) OCU MR 2549
3. S-17-43, 5/10, OCU MR 2552 Paratype
   a: oblique lateral view (1094)
   b: basal view (1095)

Fig. 4. *Gongylothorax sakawaensis* Matsuoka ..... Page 14

VII-0503-17, 1/6 (143) OCU MR 2488 Holotype

Figs. 5–11. *Stylocapsa tecta* Matsuoka, n. sp. ..... Page 14

5. S-17-36, 2/9 (846) OCU MR 2582
6. S-17-36, 4/4 (867) OCU MR 2580
7. S-17-36, 6/1 (879) OCU MR 2586
8. S-17-36, 2/4 (840) OCU MR 2581
9. S-17-35, 1/1 (751) OCU MR 2575
10. S-17-37, 10/6 (951) OCU MR 2577
    oblique basal view of broken specimen, showing large, narrowly spaced pores, which taper externally on the inner surface of thorax.
11. S-15-39, 2/1 (960) OCU MR 2574 Paratype

Figs. 12–13. *Stylocapsa lacrimalis* Matsuoka, n. sp. ..... Page 16

12. S-17-36, 6/5 (807) OCU MR 2598
13. S-17-36, 6/5 (960) OCU MR 2599 Paratype
    a: lateral view (1072)
    b: basal view, showing a constricted aperture and a circular depression near aperture. (1073)

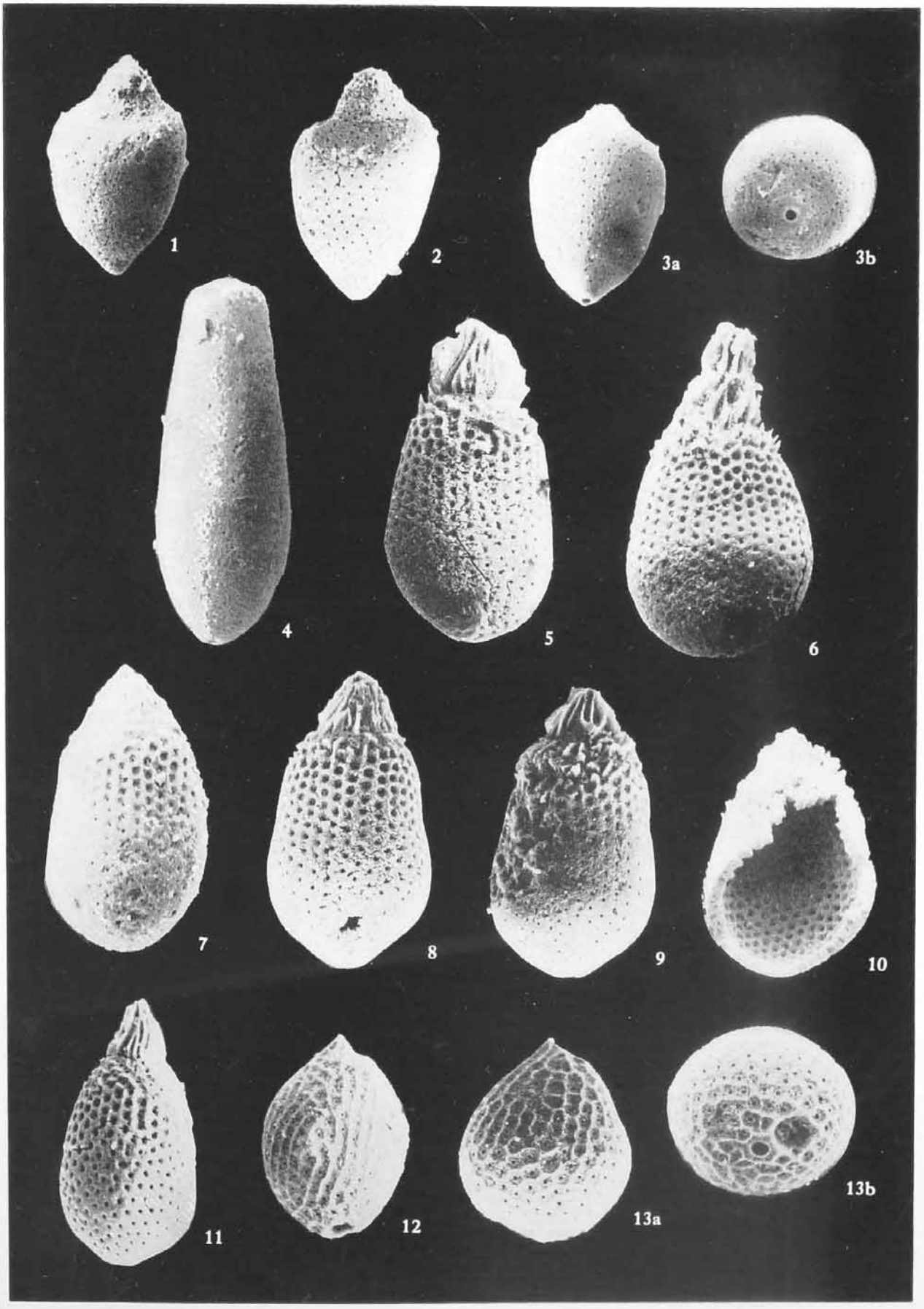
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Plate 2

Explanation of Plate 2

All figures ×300

Figs. 1–4. *Stylocapsa* (?) *hemicostata* MATSUOKA, n. sp. ..... Page 17
1. S-15-41, 1/2 (1037) OCU MR 2611 Paratype
2. S-15-39, 7/1 (987) OCU MR 2612
3. S-15-40, 10/1 (1029) OCU MR 2613
   oblique basal view, showing a constricted aperture
4. S-15-40, 6/10 (1018) OCU MR 2608

Figs. 5–9. *Stylocapsa* (?) *spiralis* MATSUOKA group ..... Page 18
5. S-15-39, 8/2 (998)
6. S-15-40, 1/10 (1004)
7. S-15-40, 10/4 (1020)
8. S-17-43, 1/3 (1062) *S.* (?) *spiralis* s.s.
9. S-17-36, 4/9 (864) *S.* (?) *spiralis* s.s.

Fig. 10. *Stylocapsa catenarum* MATSUOKA ..... Page 18
VII-0503-17, 3/5 (151) OCU MR 2508

Fig. 11. *Tricolocapsa* (?) *fusiformis* YAO ..... Page 19
T-05-32, 7/8 (561)

Figs. 12–13. *Tricolocapsa* (?) sp. aff. *T.* (?) *fusiformis* YAO ..... Page 20
12. S-02-44, 4/2 (1133)
13. S-17-43, 4/1 (1088)

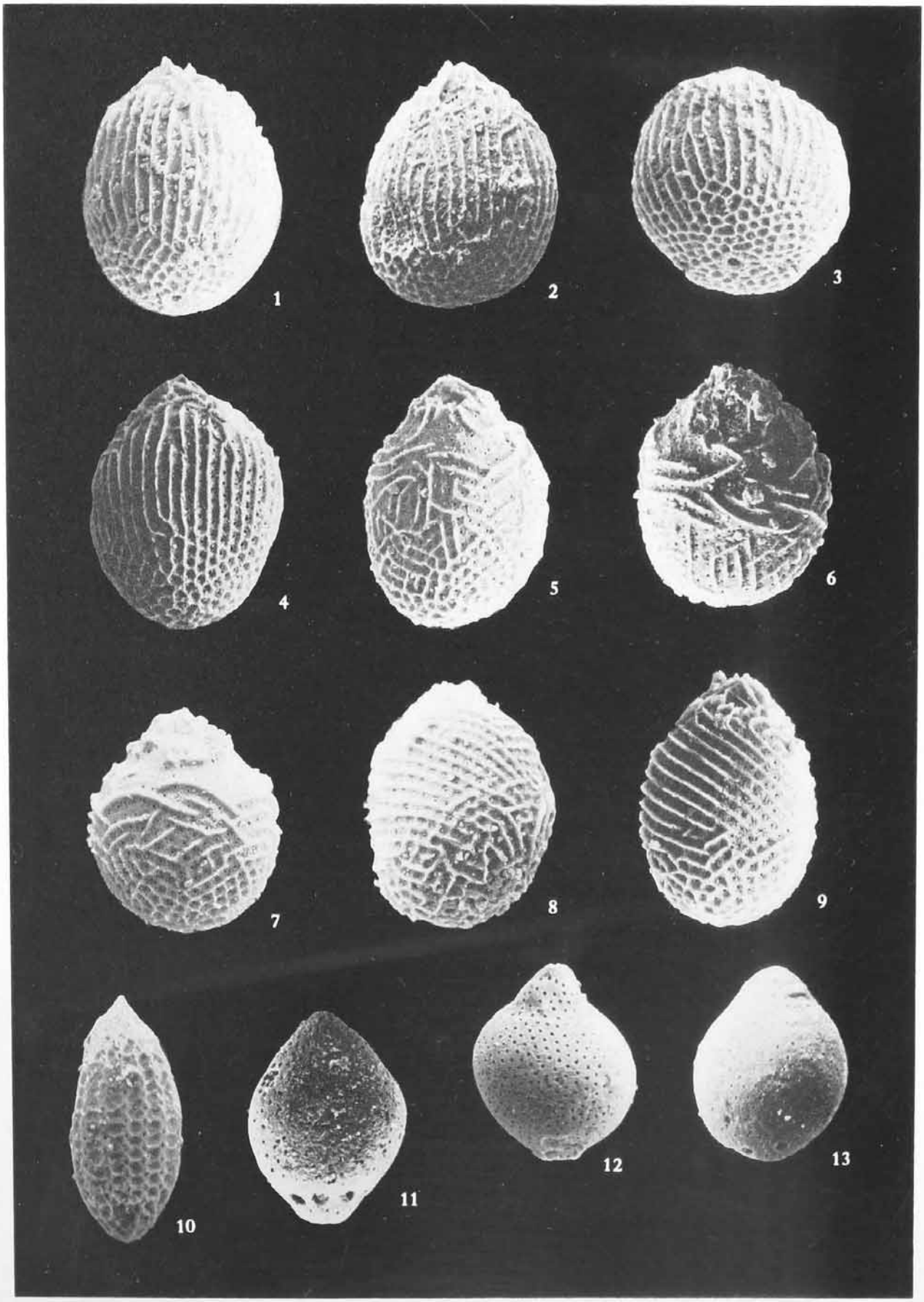
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Plate 3

Explanation of Plate 3

All figures ×300

Figs. 1–2. *Tricolocapsa plicarum* YAO ..... Page 20

1. T-05-30, 14/5 (487)
2. T-05-30, 6/4 (435)
   oblique basal view, showing a circular depression near aperture which is covered with basal appendage.

Figs. 3–7. *Tricolocapsa conexa* MATSUOKA, n. sp. ..... Page 20

3. S-17-43, 2/1 (1075) OCU MR 2635 Holotype
4. S-17-36, 4/6 (866) OCU MR 2696
5. S-17-43, 6/5 (1097) OCU MR 2697
6. S-17-44, 1/6 (1105) OCU MR 2634
   basal view
7. S-15-40, 2/3 (1006) OCU MR 2628

Figs. 8–12. *Tricolocapsa tetragona* MATSUOKA, n. sp. ..... Page 22

8. S-02-44, 1/3 (1103) OCU MR 2658 Paratype
9. S-02-44, 1/8 (1107) OCU MR 2656
   oblique apical view
10. S-03-34, 12/1 (696) OCU MR 2650
    oblique basal view, showing a constricted aperture.
11. S-02-44, 2/5 (1113) OCU MR 2659
    apical view
12. S-02-44, 2/3 (1115) OCU MR 2660
    oblique apical view

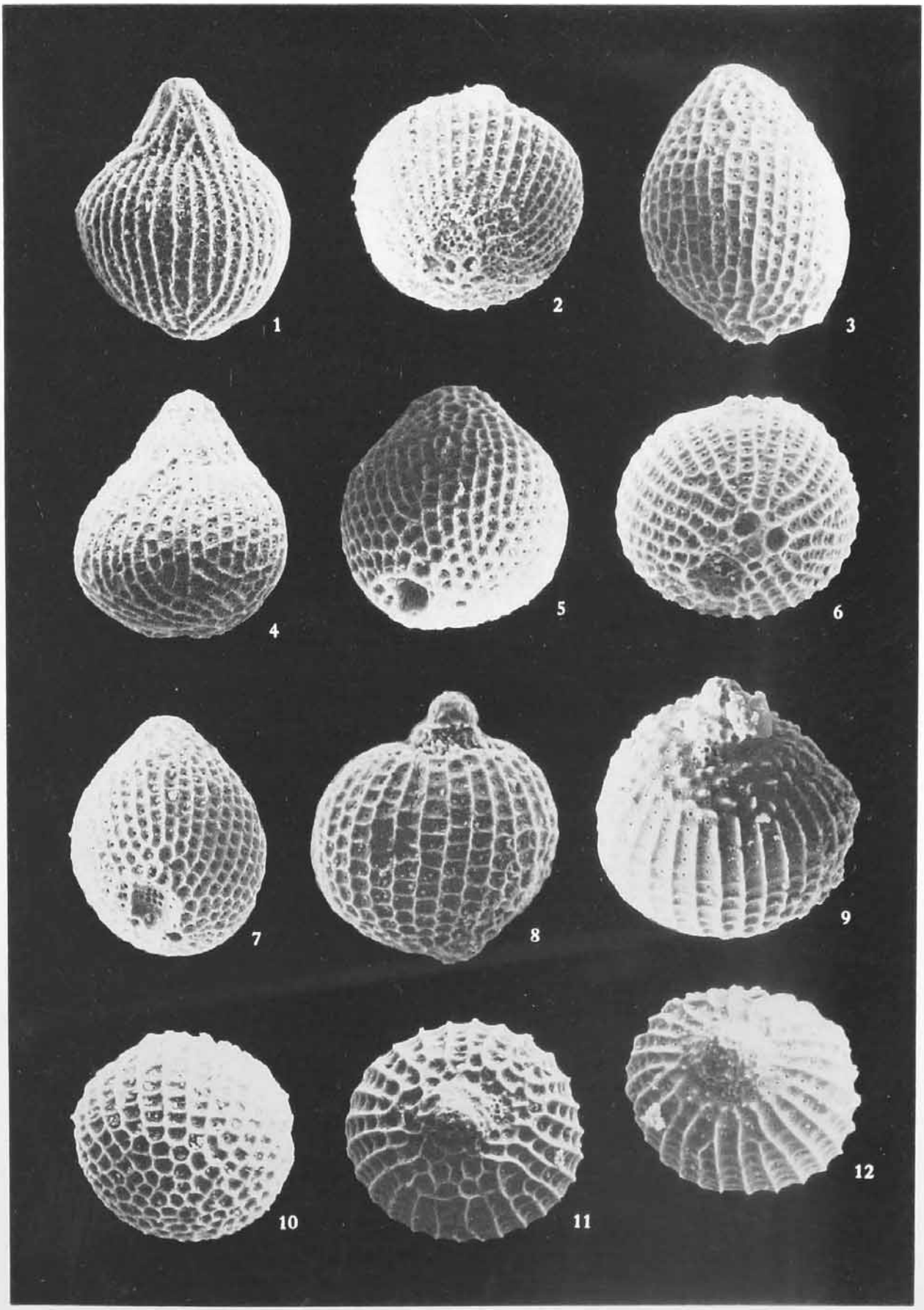
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Plate 4

Explanation of Plate 4

All figures ×300

Figs. 1–3. *Williriedellum* sp. A group ..... Page 23
1. S-15-40, 3/2 (1000)
2. S-15-41, 5/5 (1053)
3. S-17-35, 5/6 (799)
oblique basal view of broken specimen, showing encasement of thorax in abdominal cavity.

Figs. 4–7. *Protunuma turbo* MATSUOKA, n. sp. ..... Page 24
4. S-02-44, 4/8 (1127) OCU MR 2675 Paratype
5. S-02-44, 2/8 (1111) OCU MR 2673
6. S-02-44, 2/7 (1112) OCU MR 2677
7. S-02-44, 3/5 (1121) OCU MR 2674
oblique apical view

Figs. 8–11. *Protunuma* (?) *ochiensis* MATSUOKA, n. sp. ..... Page 26
8. S-17-43, 5/2, OCU MR 2694 Paratype
a: oblique basal view (1090)
b: lateral view (1089)
9. S-17-37, 8/5 (942) OCU MR 2699
10. S-17-43, 4/4 (1086) OCU MR 2692
12. S-02-44, 4/4 (1110) OCU MR 2689

Figs. 12–13. *Lithocampe* (?) sp. aff. *L.* (?) *nudata* KOCHER ..... Page 27
12. S-15-41, 3/7 (1040)
13. S-17-43, 3/6 (1081)

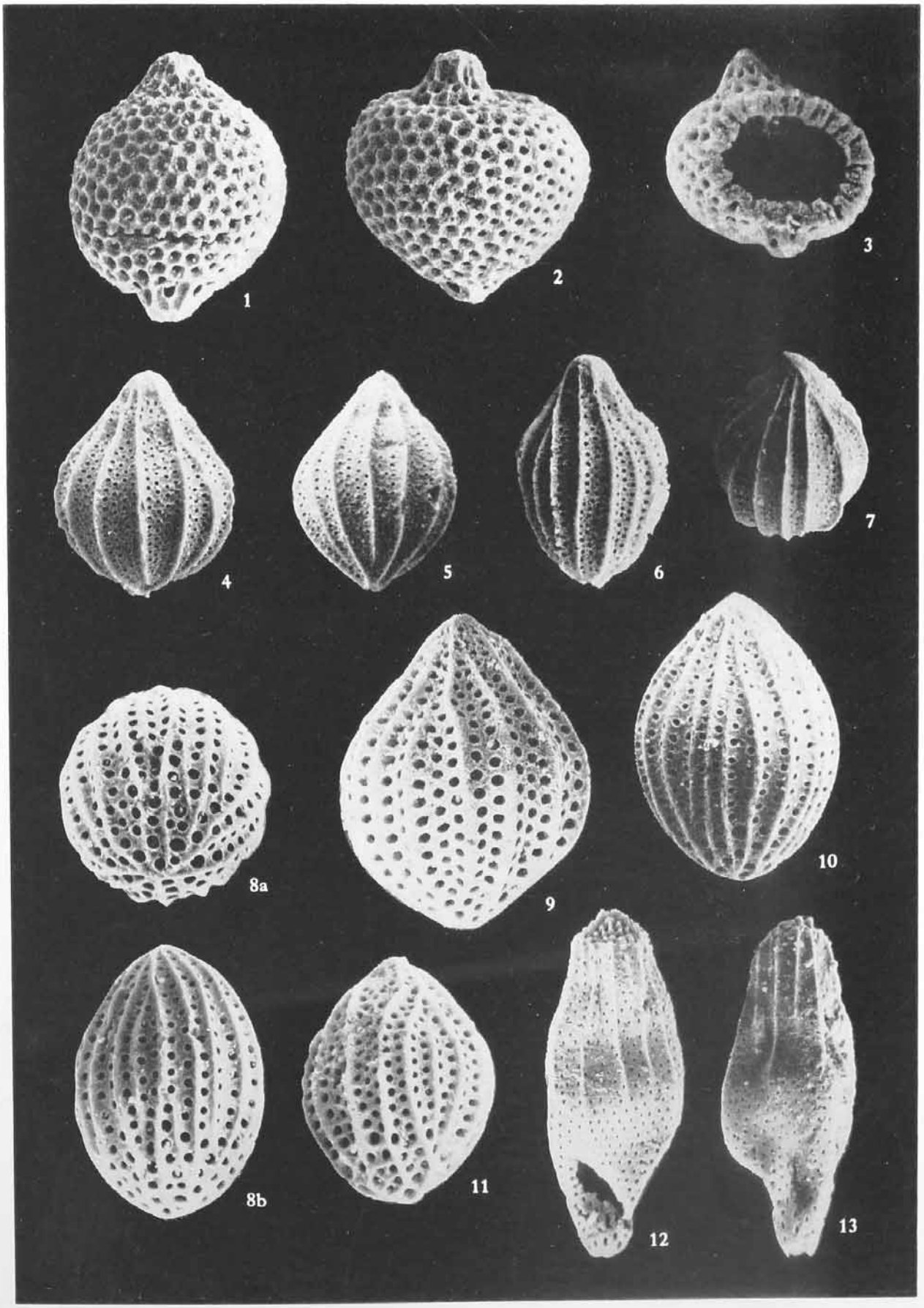
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Plate 5

Explanation of Plate 5

All figures ×200

Figs. 1–6. *Dicolocapsa conoformis* MATSUOKA, n. sp. ..... Page 13

1.	S-17-2, 104.2/40 (58-9)	OCU MR 2547	
2.	S-17-3, 96.5/35 (60-27, 28)	OCU MR 2541	
3.	S-17-6, 95.3/42.5 (65-7, 8)	OCU MR 2548	Holotype
4.	S-17-2, 105/33 (58-6)	OCU MR 2544	
5.	S-17-1, 99/36.2 (46-11, 12)	OCU MR 2538	
6.	S-17-2, 104/40.5 (58-10, 11)	OCU MR 2543	Paratype

Figs. 7a, 7b. *Gongylothorax sakawaensis* MATSUOKA ..... Page 14

	VII-0503-29, 83.2/35.7 (35-4, 5)	OCU MR 2482	Holotype

Figs. 8–14. *Stylocapsa tecta* MATSUOKA, n. sp. ..... Page 14

8.	S-17-3, 93.5/49 (60-33,34)	OCU MR 2567	Holotype
9.	S-17-1, 94.8/26.2 (47-9)	OCU MR 2560	
10.	S-17-3, 91.3/44 (60-35, 36)	OCU MR 2562	Paratype
11.	S-17-2, 97.6/48.5 (58-31, 32)	OCU MR 2561	
12.	S-17-2, 97.2/41.8 (58-33, 34)	OCU MR 2570	
13.	S-17-2, 93/44 (59-21, 22)	OCU MR 2568	
14.	S-17-2, 88.5/21.5 (59-37, 38)	OCU MR 2563	

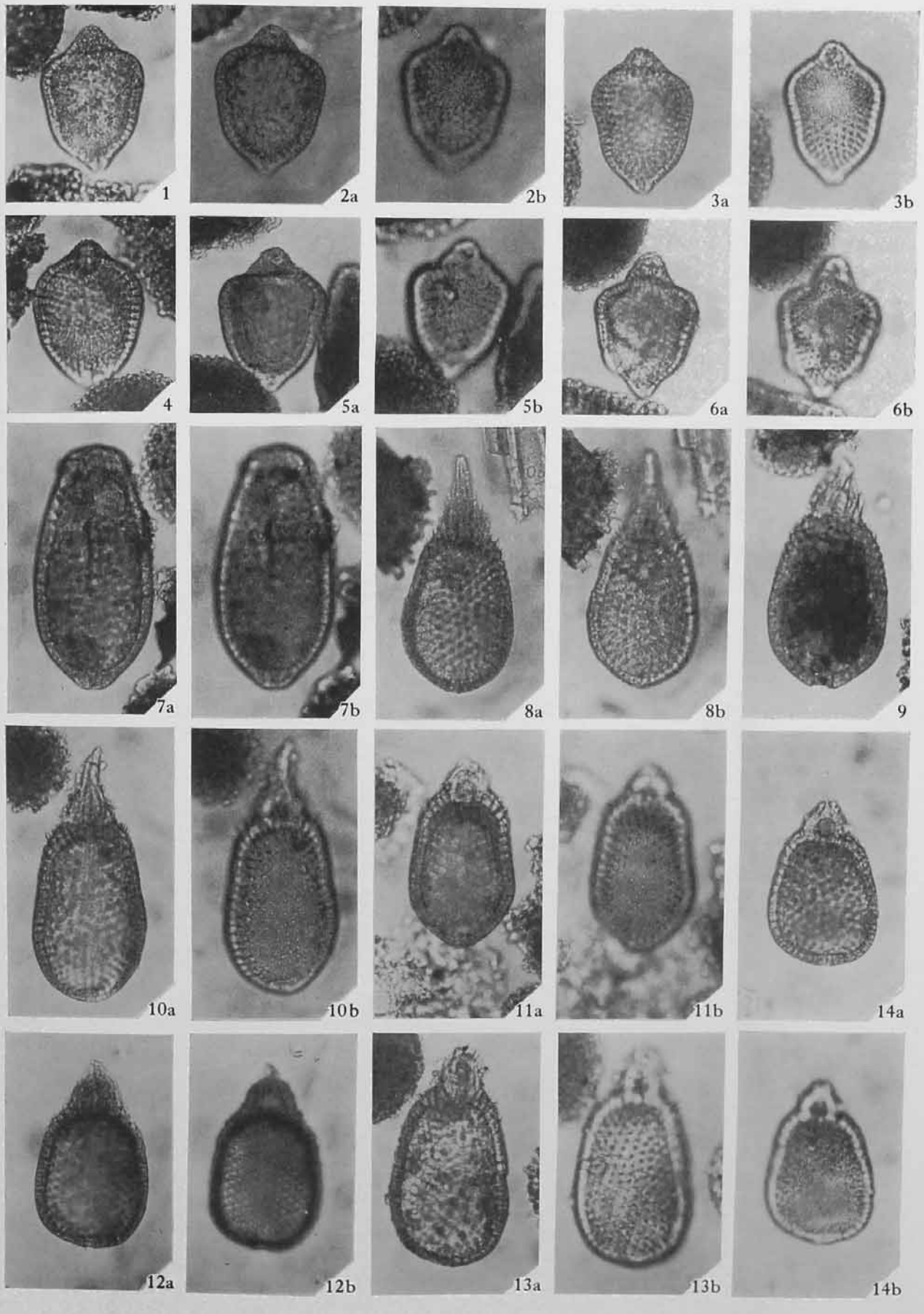
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Plate 6

Explanation of Plate 6

All figures ×200

Figs. 1–4. *Dicolocapsa conoformis* MATSUOKA, n. sp. ..... Page 13
1. S-17-1, 97/43 (46-29) OCU MR 2539
2. S-17-2, 102.5/33 (58-19) OCU MR 2545
3. S-17-2, 96.5/28.7 (59-4) OCU MR 2546
4. S-17-2, 92/45 (59-31) OCU MR 2542

Figs. 5–7. *Stylocapsa oblongula* KOCHER..... Page 19
5. M-64-1, 92/45.3 (56-5)
6. P-07-1, 96.5/41 (65-37)
7. P-07-1, 89/41 (65-35, 36)

Figs. 8–13. *Stylocapsa* (?) *hemicostata* MATSUOKA, n. sp. ..... Page 17
8. S-15-3, 95.2/29.8 (65-23, 24) OCU MR 2601 Holotype
9. S-15-3, 100.6/20 (65-17, 18) OCU MR 2600 Paratype
10. S-15-5, 99.8/34 (65-30, 31) OCU MR 2605
11. S-15-5, 84/45 (65-32, 33) OCU MR 2606
12. S-15-3, 102/31.6 (65-15, 16) OCU MR 2602
13. S-15-3, 95.2/27.8 (65-21, 22) OCU MR 2603

Figs. 14–15. *Stylocapsa* (?) *spiralis* MATSUOKA s.s. ..... Page 18
14. S-17-2, 103/35 (58-16, 17)
15. S-17-1, 89.8/30 (47-30, 31)

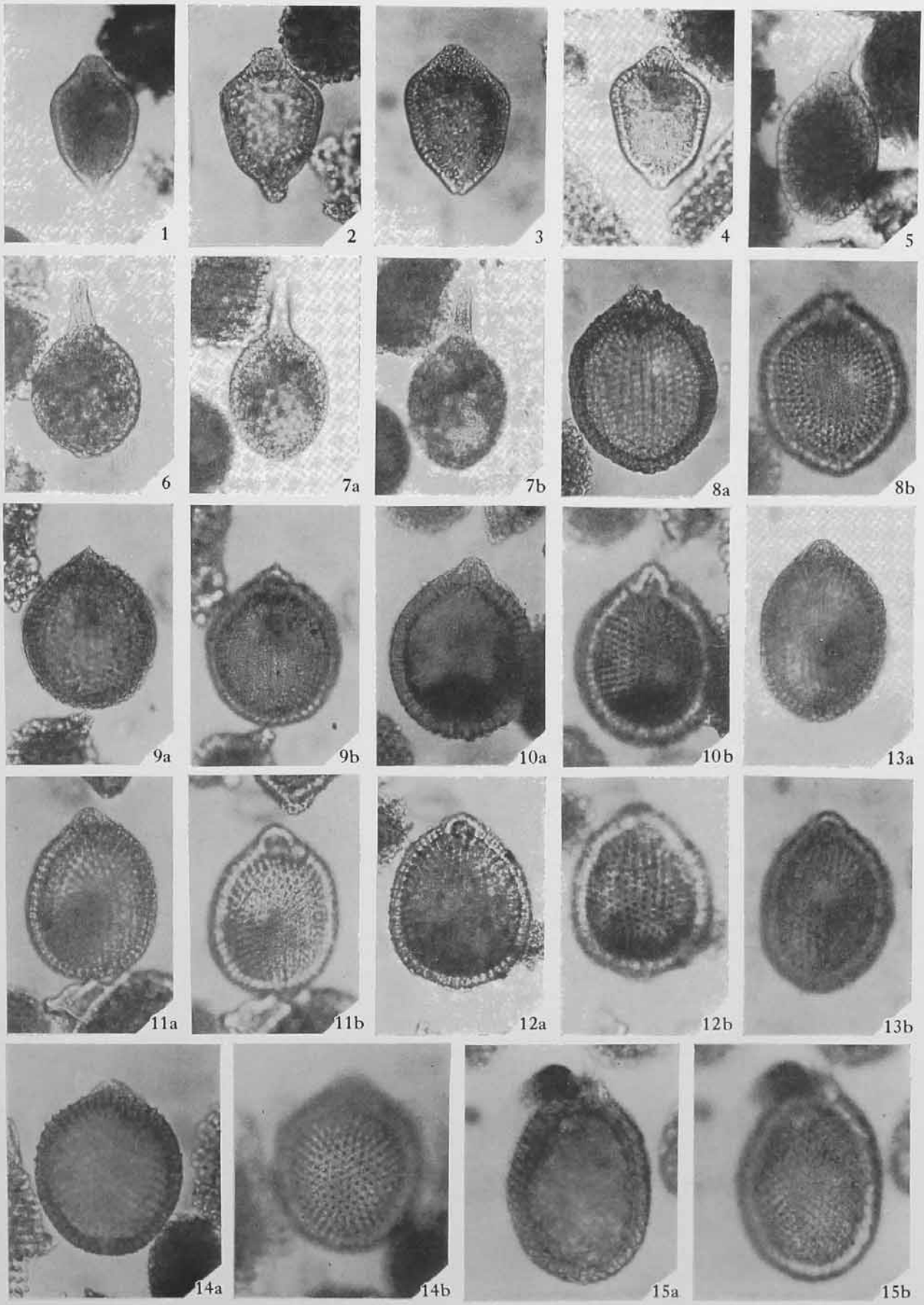
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Plate 7

Explanation of Plate 7

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Figs. 1–2. *Stylocapsa catenarum* MATSUOKA ..... Page 18
1. VII-0503-29, 95.2/30 (35-11, 12) OCU MR 2498 Holotype
2. S-17-2, 84.3/44.8 (60-10, 11)

Figs. 3–10. *Stylocapsa lacrimalis* MATSUOKA, n. sp. ..... Page 16
3. S-17-4, 88.5/29.5 (64-29, 30) OCU MR 2597
4. S-17-3, 97/22 (60-24) OCU MR 2596
5. S-17-3, 96.5/25.5 (65-19, 20) OCU MR 2588 Paratype
6. S-17-2, 85/46.8 (60-8, 9) OCU MR 2592
7. S-17-3, 96.2/35.5 (65-27) OCU MR 2589
8. S-17-2, 82.5/42.2 (60-14, 15) OCU MR 2590
9. S-17-3, 90/34.2 (65-25, 26) OCU MR 2587 Holotype
10. S-17-2, 94.3/43 (59-17) OCU MR 2595

Figs. 11–14. *Tricolocapsa conexa* MATSUOKA, n. sp. ..... Page 20
11. S-17-4, 93.2/49.2 (64-16, 17) OCU MR 2623
12. S-17-4, 104.5/32.2 (64-4. 5) OCU MR 2622 Paratype
13. S-17-1, 97.1/32 (46-26, 27) OCU MR 2618 Paratype
14. S-17-4, 93/44.3 (64-20, 22) OCU MR 2698

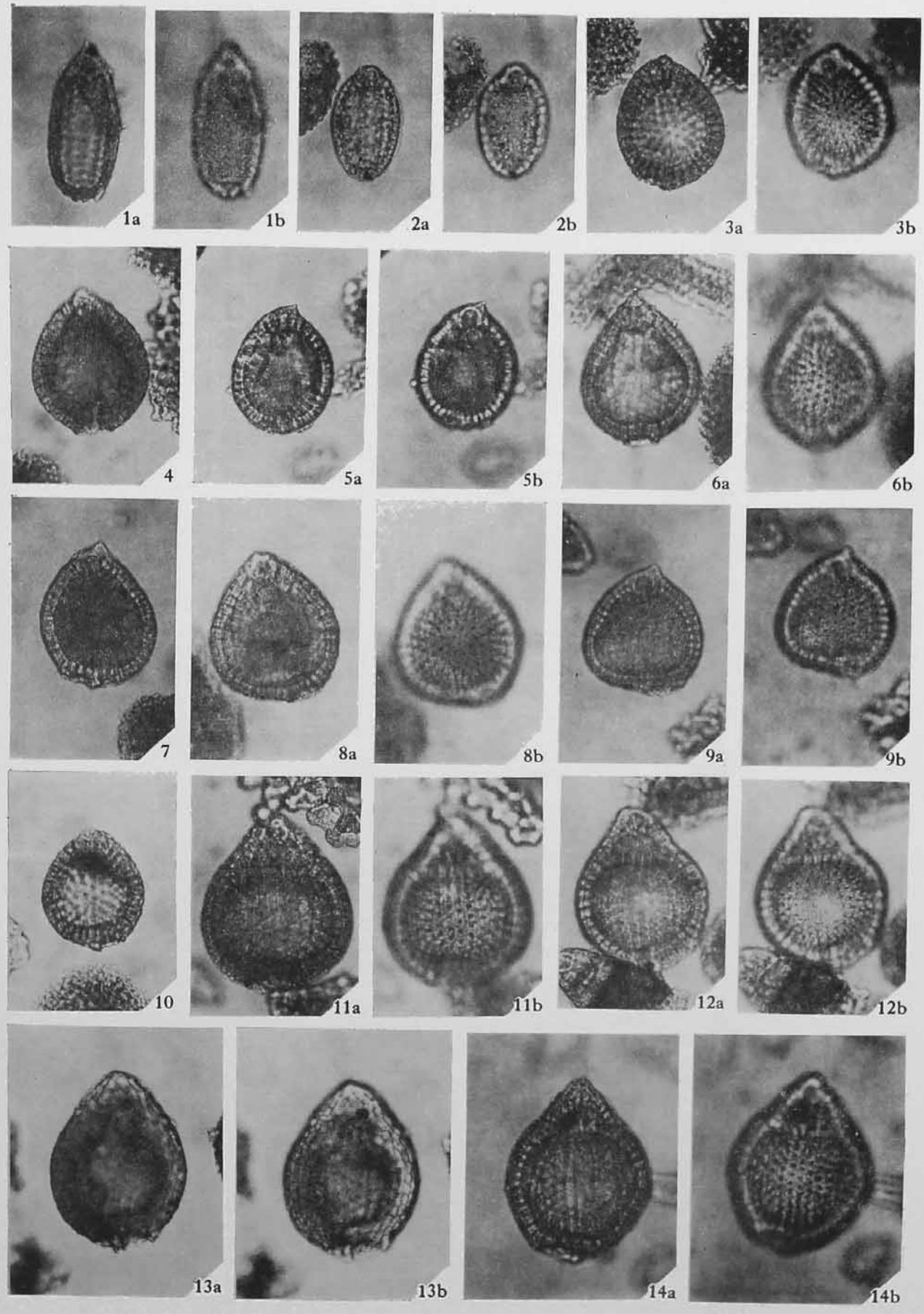
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Plate 8

Explanation of Plate 8

All figures ×200

Fig. 1. *Tricolocapsa* (?) *fusiformis* YAO ..... Page 19
T-05-1, 101.1/42 (51-20)

Figs. 2–3. *Tricolocapsa* (?) sp. aff. *T.* (?) *fusiformis* YAO ..... Page 20
2. S-02-3, 92.5/25.5 (61-30, 31)
3. VII-3104-1, 100.2/40.8 (30-20, 21)

Figs. 4–10. *Tricolocapsa tetragona* MATSUOKA, n. sp. ..... Page 22

4.	S-02-5, 90.3/26 (63-32)	OCU MR 2646	
5.	S-03-1, 95/30.5 (49-29, 30)	OCU MR 2636	Holotype
6.	S-03-3, 92.5/27.5 (61-24, 25)	OCU MR 2644	
7.	S-02-5, 89.2/30 (63-33)	OCU MR 2639	
8.	S-02-4, 90/26 (62-22, 23)	OCU MR 2641	Paratype
9.	S-02-2, 96.8/34.2 (61-4, 5)	OCU MR 2638	
10.	S-02-3, 100/29.5 (61-18)	OCU MR 2643	

Figs. 11–15. *Williriedellum* sp. A group ..... Page 23
11. S-17-4, 102/47 (64-10, 11)
12. S-17-2, 96.1/21.5 (58-37, 38)
13. S-02-4, 84/47.2 (62-30)
14. S-02-3, 92.5/25.5 (61-22, 23)
15. S-02-4, 94.8/36 (62-20, 21)

Figs. 16–18. *Protunuma turbo* MATSUOKA, n. sp. ..... Page 24

16.	S-02-3, 95.3/32.7 (61-20)	OCU MR 2666	
17.	S-02-5, 89.1/41 (63-35, 36)	OCU MR 2663	Holotype
18.	S-02-4, 95.5/46.8 (62-11, 12)	OCU MR 2662	

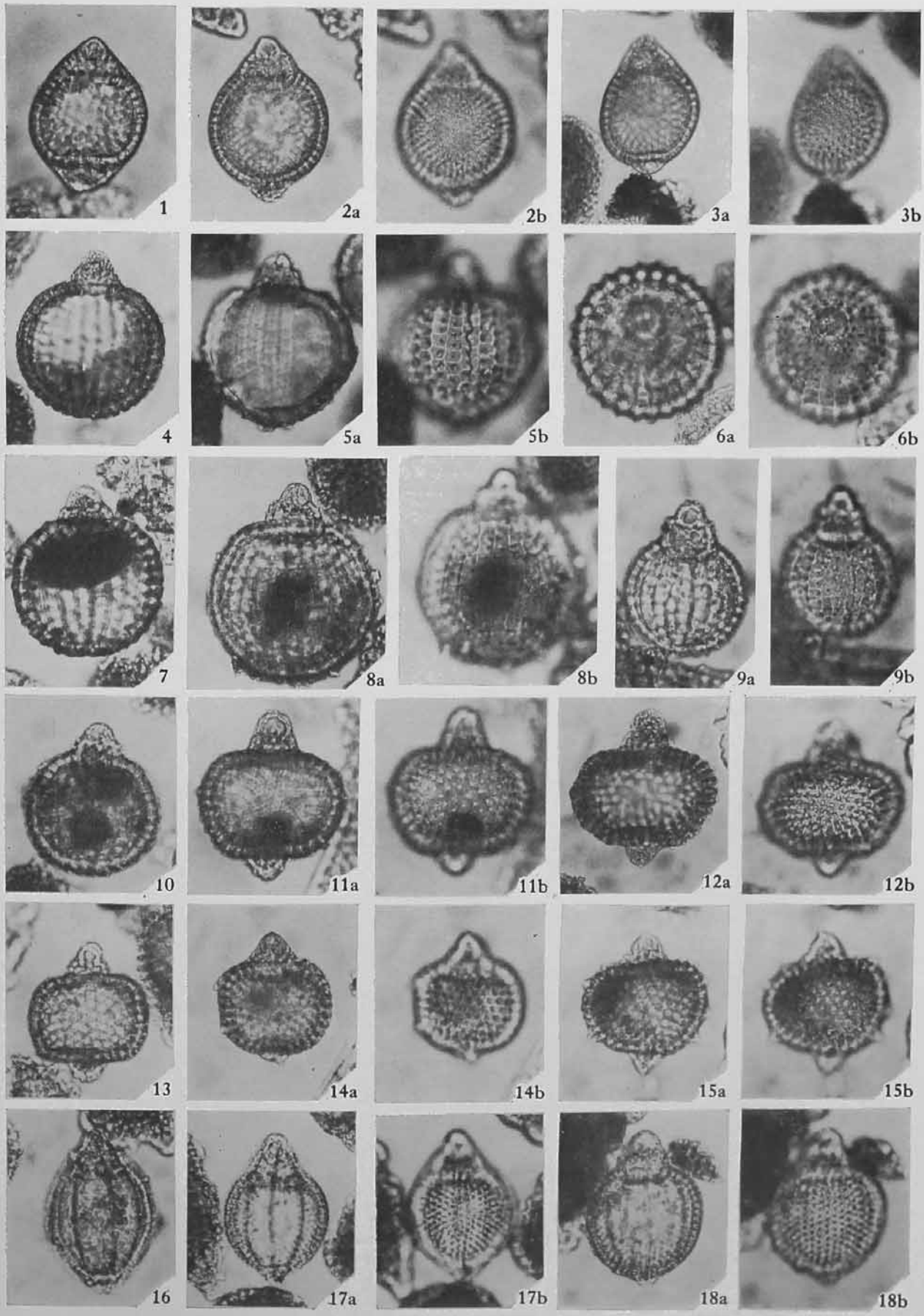
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Plate 9

Explanation of Plate 9

All figures ×200

Figs. 1–2. *Protunuma turbo* Matsuoka, n. sp. ..... Page 24
1. S-02-3, 101.2/31 (61-14, 15) OCU MR 2661
2. S-02-5, 93/54.5 (63-26, 27) OCU MR 2672 Paratype

Figs. 3–7. *Protunuma* (?) *ochiensis* Matsuoka, n. sp. ..... Page 26
3. S-17-4, 89/33.5 (64-27, 28) OCU MR 2686
4. S-17-2, 104.8/42.3 (58-2, 3) OCU MR 2682 Paratype
5. S-17-2, 92.5/30 (59-27, 29) OCU MR 2685
6. S-17-2, 91/37.5 (59-33, 34) OCU MR 2683 Holotype
7. S-17-1, 102.1/45.1 (45-21, 22) OCU MR 2680

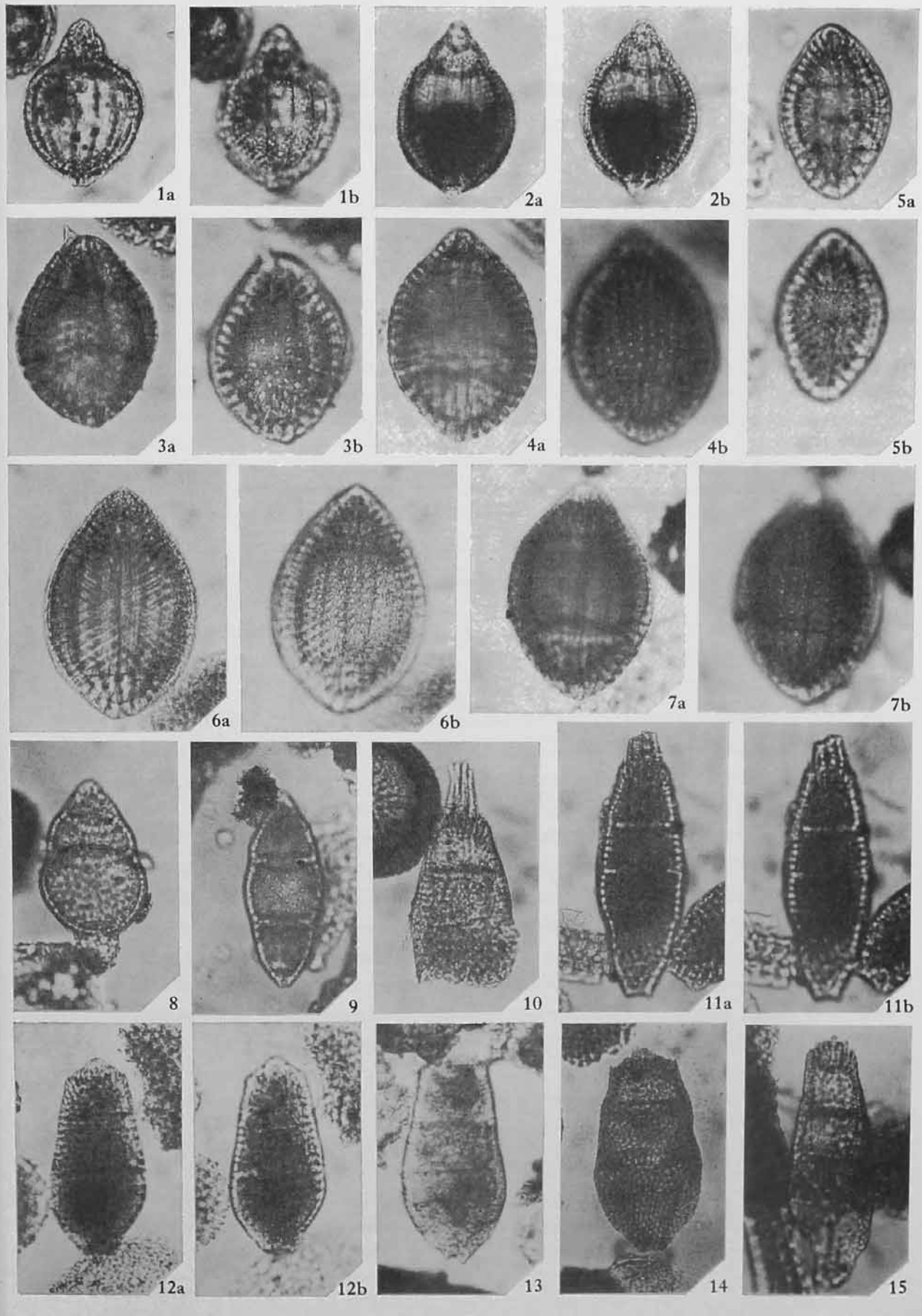
Fig. 8. *Cyrtocapsa mastoidea* Yao ..... Page 24
F-22-2, 103.8/34.5 (7-33)

Fig. 9. *Cyrtocapsa* (?) *kisoensis* Yao ..... Page 24
F-21-3, 92.6/50.2 (4-23)

Figs. 10–11. *Cyrtocapsa* sp. D ..... Page 24
10. S-17-3, 99/42 (60-23)
11. S-17-3, 96/27.8 (60-31, 32)

Figs. 12–14. *Lithocampe* (?) *nudata* Kocher ..... Page 27
12. S-02-4, 103/35 (62-1, 2)
13. M-64-1, 90/41.5 (56-1)
14. S-15-3, 86/41.2 (65-29)

Fig. 15. *Lithocampe* (?) sp. aff. *L.* (?) *nudata* Kocher ..... Page 27
S-17-3, 100.2/35.5 (60-21)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