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Stylocapsa (?) *spiralis* Assemblage (Radiolaria) from the Kurisaka Formation of the Torinosu Group in East Shikoku, SW Japan

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Abstract Radiolarian assemblage extracted from the Jurassic Kurisaka Formation of the Torinosu Group is listed, figured and correlated with that of the *Stylocapsa* (?) *spiralis* Zone of Matsuoka and Yao (1986). The age of the Kurisaka Formation is discussed with special respect to the occurrence of the assemblage and the early Kimmeridgian ammonite from the superjacent horizon in the same section.

Key words: Middle-Late Jurassic, biostratigraphy, radiolaria, ammonite, Torinosu Group, Kurosegawa Terrane, Chichibu Superterrane, Shikoku

Introduction

The Torinosu Group, composed mainly of black mudstones, conglomerates and reef limestones, represents Middle to Late Jurassic and Early Cretaceous open-sea and shallow-marine facies in the Outer Zone of the Southwest Japan. In Shikoku, ammonites from the black mudstones in the Group indicate Callovian to Tithonian age (Fig. 1). Some radiolarian assemblages, extracted from the pelitic sediments of the Torinosu Group are assigned to be Middle to Late Jurassic and Early Cretaceous age (Ishida, 1987).

A radiolarian assemblage correlative with the *Stylocapsa* (?) *spiralis* Assemblage of Matsuoka and Yao (1986) are extracted from the type section of the Kurisaka Formation of the Torinosu Group. The author discusses the stratigraphic relation between the *Stylocapsa* (?) *spiralis* Zone and the early Kimmeridgian ammonite-yielding horizon in the Kurisaka section of the Torinosu Group.

Geologic Setting

The Chichibu Superterrane is situated between the Mikabu ophiolites and the Butuzo Tectonic Line. In East Shikoku, the Superterrane is subdivided into the South, Kurosegawa and North Zones by the Junisha Thrust and the Jiganji Fault. The Kurosegawa Zone is further sub-divided into the South and North subzones by the Sakashu Thrust. The Torinosu Group is distributed in the South Zone and the South subzone of the Kurosegawa Zone (Fig. 1). The Group overlies the Jurassic and Pre-Jurassic accretionary complexes and the Triassic molluscan beds. The Kurisaka Formation of the Torinosu Group is distributed in the South subzone of the Kurosegawa Zone. Holotype of *Ataxioceras kurisakense* has been reported from the Kurisaka Formation at Kurisaka, and the age was assigned to early Kimmeridgian (Kobayashi and Fukada, 1947; Sato, 1974). A radiolarian assemblage correlative with that of the *Stylocapsa* (?) *spiralis* Zone of Matsuoka and Yao (1986) is found from the same section (Fig. 2).

The 10 m thick section of the Kurisaka Formation, consisting mainly of mudstones and sandstones with calcareous nodules, shows a thickening and coarsening upward sequence at the type locality, that was formed by one retrogressive event (Fig. 2). Well-preserved specimens of ammonite identified as *Ataxioceras kurisakense* are newly found from the horizon C1 of the calcareous sandy mudstone and muddy sandstone with nodules. Radiolarian fossils are extracted from the calcareous mudstones and laminated mudstone in the horizons A, B, C3 and C2. Among these horizons, radiolarian faunas characteristic of the *Stylocapsa* (?) *spiralis* Zone (Matsuoka & Yao, 1986) commonly occur in the horizons B, C3 and C2.

Paleontological Note

Radiolaria

Stylocapsa (?) *spiralis* Matsuoka, 1982

(Pl. 1, figs. 1-8)

Stylocapsa (?) *spiralis* Matsuoka, 1982: p. 77-78, pl. 3, figs. 1-8; 1992, pl. 5, fig. 1; Aita, 1987, pl. 7, figs. 7a, b.

Stylocapsa (?) *spiralis* Matsuoka s.s.: Matsuoka, 1983, p.

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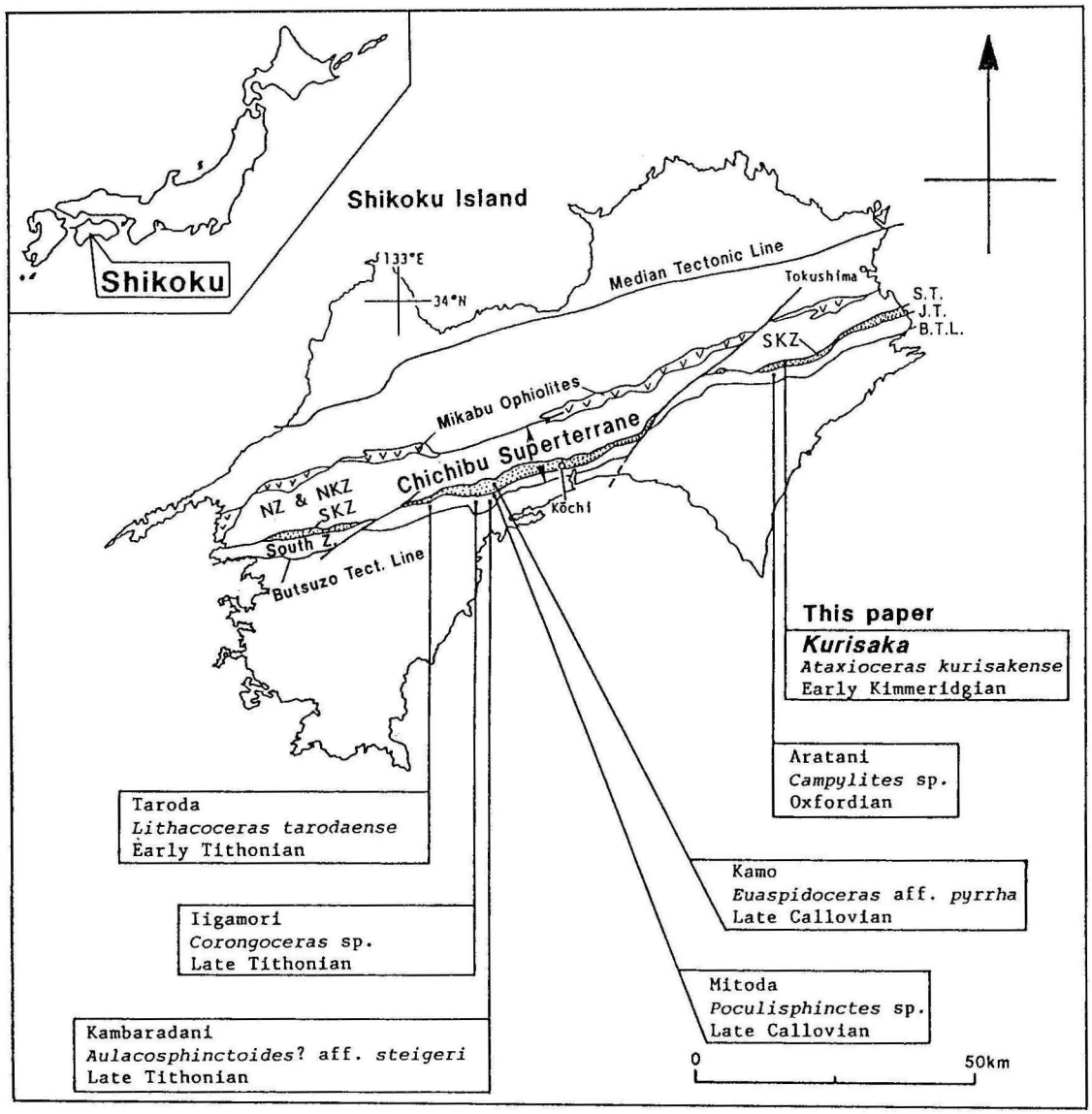

Fig. 1. Geologic outline map showing the localities of ammonites from the Torinosu Group in Shikoku and their ages. Compiled from Kobayashi & Fukada (1947), Kobayashi (1950), Sato (1974), Ishida (1979) and Katto & Matsumoto (1981). NZ & NKZ: North Zone and North subzone of the Kurosegawa Zone. SKZ: South subzone of the Kurosegawa Zone. S.T.: Sakashu Thrust. J.T.: Junisha Thrust. B.T.L.: Butsuzo Tectonic Line.

18, pl. 2, figs. 8, 9; 1986a, pl. 1, figs. 6, 7.

Stylocapsa (?) *spiralis* Matsuoka gr.: Gorican, 1994, p. 89, pl. 11, figs. 1a-c, 2; Baumgartner *et al.*, 1995a, p. 534-535, pl. 3046, figs. 1-5(H).

Remarks: Specimens are characterized by oval shell with spiral plicae on their outer surface. Test elongates axially. The plicae are arranged regularly to form sinistral-spirals. These specimens are closely related to *Stylocapsa* (?) *spiralis* s.s. in Matsuoka (1983, 1986a), which were obtained from both the basal horizon of the *Stylocapsa* (?) *spiralis* Zone (*Gongylothorax sakawaensis-Stichocapsa* sp. C Assemblage) in the Shiraishigawa-1 section (Matsuoka, 1983: pl. 2, figs. 8, 9), and the *Gongylothorax sakawaensis* Subassemblage-Zone in the *Stylocapsa* (?) *spiralis* Assemblage-Zone in the Kawanouchi-1 section (Matsuoka, 1986a: pl. 1, figs. 6, 7) of the South Zone of the Chichibu Superterrane. Occurrence: They are abundantly obtained from the horizons B, C3 and C2.

Tricolocapsa conexa Matsuoka, 1983

(Pl. 1, figs. 9-14)

Tricolocapsa conexa Matsuoka, 1983: p. 20-22, pl. 3, figs. 3-7, pl. 7, figs. 11-14: 1986: pl. 1, figs. 9, 10; Aita, 1987, pl. 7, figs. 9a, b; Baumgartner *et al.*, 1995a, p. 594-595,

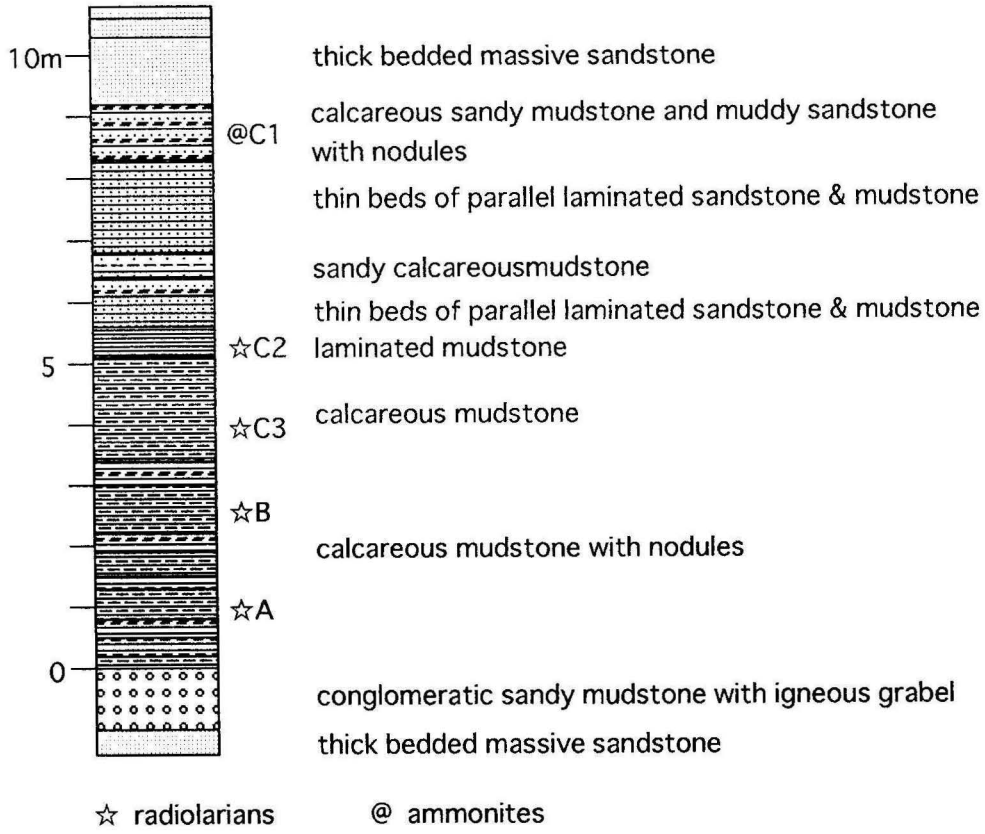

Fig. 2. Stratigraphic column showing the radiolarian and ammonite horizons of the Kurisaka Formation of the Torinosu Group.

pl. 3297, figs. 1-5(H).

Remarks: The outer surface of these tests are characterized by well developed transverse ridges which connect adjacent two longitudinal plicae. Occurrence: HorizonsA, B, C3 and C2.

Tricolocapsa plicarum Yao, 1979
(Pl. 1, figs. 9-14)

Tricolocapsa plicarum Yao, 1979: p. 32-33, pl. 4, figs. 1-11; Matsuoka, 1983, pl. 3, figs. 1,2; Aita, 1987, pl. 7, figs. 10a, b.

Tricolocapsa plicarum ssp. A: Baumgartner *et al.*, 1995a, p. 598-599, pl. 4052, figs. 1-5.

Remarks: Compared with *Tricolocapsa conexa,* the outer surface of these specimens are ornamented only by longitudinal plicae without transverse ridges. Occurrence: Horizons B and C2.

Tricolocapsa tetragona Matsuoka, 1983
(Pl. 1, fig. 24)

Tricolocapsa tetragona Matsuoka, 1983: p. 22-23, pl. 3, figs. 8-12, pl. 8, figs. 4-10; Aita, 1987, pl. 7, figs. 11a, b; Baumgartner et al., 1995a, p. 600-601, pl. 4054, figs. 1-3(H).

Remarks: Outer surface of test is ornamented by tetragonal frames which are formed by the connection of longitudinal plicae and transverse ridges. Occurrence: Only one specimen was extracted from the horizon C3 of the Kurisaka section together with *Tricolocapsa conexa.*

Tricolocapsa yaoi Matsuoka, 1986a
(Pl. 1, fig. 22)

Tricolocapsa yaoi Matsuoka, 1986a: p. 106-107, pl. 2, figs. 1-4, pl. 3, figs. 1-8.

Remarks: Based on existence of weakly protruded rim around the basal aperture, only one specimen was identified with this species that co-occurred with *Tricolocapsa conexa.* Occurrence: Horizon C3. According to Matsuoka (1986a), *T. yaoi* occurred together with *T. conexa* in the Kawanouchi-1 section (11-096) of the Sakawa area.

Tricolocapsa (?) sp. aff. *T.* (?) *fusiformis* Yao, 1979
(Pl. 2, figs. 1-3)

Tricolocapsa (?) sp. aff. *T.* (?) *fusiformis* Yao: Matsuoka,

1983, p.19-20, pl. 2, figs. 12, 13, pl. 8, figs. 2, 3.

Tricolocapsa (?) sp. aff. *T.* (?) *fusiformis* Yao sensu Matsuoka: Baumgartner *et al.*, 1995a, p. 596-597, pl. 4050, fig. 1.

Remarks: Specimens from Kurisaka are closely similar to those from the *Tricolocapsa conexa* Zone and the *Stylocapsa* (?) *spiralis* Zone in Shiraishi-gawa 1 section by Matsuoka (1983). Compared with the original species by Yao (1979), each specimen from Kurisaka and Shiraishi-gawa 1 section has a smaller dish like basal appendage and has more smooth shell surface with a few small pores. Matsuoka (1983) assigned the specimens with the ratio (MW/AW) of more than 2.0 to *T.* (?) sp. aff. *T.* (?) *fusiformis*. Every specimen from the Kurisaka section meets the criterion. Measurement (three specimens): The maximum width of shell (MW, in μm) / the maximum width of basal appendage (AW, in μm): the ratio (MW/AW), 80/24: 3.3, 77/24: 3.2 and 85/29: 2.9. Occurrence: Horizon C2.

Eucyrtidiellum nodosum Wakita, 1988
(Pl. 1, fig. 23)

Eucyrtidiellum sp. aff. *E. unumaense* (Yao): Matsuoka, 1986a, pl. 2, fig. 9.

Eucyrtidiellum sp. d: Nagai, 1986, pl. 2, fig. 9.

Eucyrtidiellum nodosum Wakita, 1988: p. 408, pl. 4, fig. 29; pl. 5, fig. 16; Matsuoka, 1992, pl. 4, fig. 10; Baumgartner *et al.*, 1995a, p. 213, pl. 3014, figs. 1-3(H).

Remarks: Whole external surface of thorax and abdomen is ornamented by numerous obliquely intersecting tubercles. As their abdomens are not regularly perforated by larger pores, this specimen is closely related to the one from the *Tricolocapsa yaoi* Assemblage-Zone in the Kawanouchi-1 section described by Matsuoka (1986a). Occurrence: Horizon C2.

Gongylothorax favosus Dumitrica, 1970 group
(Pl. 2, figs. 4-9)

Gongylothorax favosus Dumitrica, 1970: p. 2-13, pl. 1, figs. 1a-c, 2; Matsuoka, 1986a, pl. 2, fig. 5; Baumgartner *et al.*, 1995a, p. 230-232, pl. 6131, figs. 1-7(H).

Gongylothorax sp. aff. *G. favosus* Dumitrica: Baumgartner et al., 1995a, p. 232-233, pl. 3279, figs. 1-7.

Remarks: There is some diversity of pore frame and shell-size. Some of these specimens have more or less small shells, and the form of pore frame changes partially from complete hexagon to irregular one or pentagon. Occurrence: Horizons A, C3 and C2.

Ristola dhimenaensis (Baumgartner), 1984
(Pl. 2, figs. 10-11)

Parvicingula dhimenaensis Baumgartner, 1984: p. 778-779, pl. 7, figs. 2, 3, ?4; Matsuoka,1986a, pl. 2, fig. 12; Aita, 1987, pl. 2, figs. 3a-b, 5a-b, pl. 9, figs. 12, 13;

Parvicingula dhimenaensis dhimenaensis Baumgartner: Baumgartner *et al.*, 1995a, p. 406-407, pl. 4072, figs. 1(H)-3.

Parvicingula dhimenaensis ssp. A: Baumgartner *et al.*, 1995a, p. 406-407, pl. 4071, figs. 1-2. ?3, ?4.

Remarks: Specimens from Kurisaka correspond to the holotype in having regularly spaced nodes on the circumferential ridges. Diagonal bars connect nodes together Cephalis seems round. Occurrence: Horizon C2.

Cinguloturris carpatica Dumitrica, 1982 group
(Pl. 2, figs. 12-14)

Cinguloturris carpatica Dumitrica, 1982: Dumitrica and Mello, 1982, p. 22, pl. 4, figs. 7-11; Matsuoka and Yao, 1985, pl. 2, fig. 13; Matsuoka, 1986a, pl. 2, fig. 16;Aita, 1987, pl. 10, fig. 12, Baumgartner *et al.*, 1995a, p.142-143, pl. 3193, figs. 1-6(H).

Remarks: In spite of some diversity in outline and pore frame, every postabdominal chamber of these specimens has maximum width near the proximal side where the pore frames form characteristic plastery-pattern. Occurrence: Horizons C3 and C2.

Pseudodictyomitra (?) sp. D of Matsuoka, 1986a
(Pl. 2, figs. 15,16, 20-22)

Pseudodictyomitra (?) sp. D: Matsuoka, 1986a, pl. 2, fig. 11; 1986b, pl. 4, figs. 1-4.

Remarks: Specimenss from Kurisaka show a wide variety of their ornaments. They are broadly comparative with those by Matsuoka (1986b: pl. 4, figs. 1-4), and with the specimen from the *Tricolocapsa yaoi* Assemblage-Zone by Matsuoka (1986a). However, no specimens with the same ornament as ones figured by Matsuoka and Yao (1985: pl. 2, figs. 6, 7) and Matsuoka (1986b: pl. 4, fig. 5) from the Uppermost Jurassic Torinosu Group, were not found from Kurisaka. They are characterized by a transverse row of round dimples on the middle of each segment, and by a small pore in the center of each dimple. Occur-

Table 1. Radiolarians from the Kurisaka section.

Specific Name / Horizon	A	B	C3	C2
Stylocapsa (?) *spiralis* Matsuoka		*	*	***
Tricolocapsa conexa Matsuoka	*	*	*	***
Tricolocapsa plicarum Yao		*		***
Tricolocapsa tetragona Matsuoka			*	
Tricolocapsa yaoi Matsuoka				*
Tricolocapsa (?) sp. aff. *T* . (?) *fusiformis* Yao				***
Eucyrtidiellum nodosum Wakita				*
Gongylothorax favosus Dumitrica group	*		***	***
Ristola dhimenaensis (Baumgartner)				***
Cinguloturris carpatica Dumitrica group			*	***
Pseudodictyomitra (?) sp. D of Matsuoka			**	***
Archaeodictyomitra suzukii Aita		*	**	
Archaeodictyomitra sp. aff. *A. pseudoscalaris* (Tan Sin Hok)		***		

* rare ** common ***abundant

rence: Horizons C3 and C2.

Archaeodictyomitra sp. aff. *A. pseudoscalaris* (Tan Sin Hok), 1927

(Pl. 2, figs. 23, 24)

Archaeodictyomitra sp. aff. *A. pseudoscalaris* (Tan Sin Hok): Matsuoka, 1986b, pl. 3, figs. 12, 16, 19.

Remarks: Each post-abdominal chamber has a weak constriction near its middle part, and then expands at the septal joint to form crenulation in distal test. This feature resembles with the original species described by Tan (1927), but differs from it by having dense and fine costae, rounded outline of the proximal test and cylindrical outline of distal test in lateral view of the former species. Occurrence: Horizon B.

Archaeodictyomitra suzukii Aita, 1987

(Pl. 2, figs. 17-19)

Archaeodictyomitra suzukii Aita, 1987: p. 71, pl. 2, figs. 1a-2b, pl. 9, fig. 9.

Remarks: Outline of test is more slender than *Archaeodictyomitra rigida*, and the costal number is countable approximately 12 in lateral view. Based on the correspondence of costal number and the test-outline, these specimens are identified as *A. suzukii*. Occurrence: Horizons B and C3.

Remarks on the *Stylocapsa* (?) *spiralis* Assemblage

A specific list of the radiolarian assemblage from the Kurisaka section is shown in Table 1. According to the works by Matsuoka (1986a, b), Aita (1987), Yao (1990), Gorican (1994), Baumgartner *et al.* (1995b) and others, the vertical distribution of related radiolarian species in the Upper Jurassic section is compiled as Table 2. Radiolarian assemblage from Kurisaka characterized by common or abundant occurrence of *Stylocapsa* (?) *spiralis*, *Tricolocapsa conexa*, *Tricolocapsa plicarum*, *Ristola dhimenaensis*, *Archaeodictyomitra* sp. aff. *A. pseudoscalaris*, *Pseudodictyomitra* (?) sp. D of Matsuoka, *Gongylothorax favosus* group, *Cinguloturris carpatica* group and *Tricolocapsa* (?) sp. aff. *T.* (?) *fusiformis*. This assemblage is also accompanied with *Archaeodictyomitra suzukii*, *Eucyrtidiellum nodosum*, *Tricolocapsa yaoi* and *Tricolocapsa tetragona*. This specific association with an exception of *T. tetragona* is identical to that of the *Stylocapsa* (?) *spiralis* Zone of Matsuoka and Yao (1986). Among these species, *S.* (?) *spiralis* and *T. conexa* co-occur in the horizons B, C3 and C2.

After the works by Matsuoka and Yao (1986), the *Stylocapsa* (?) *spiralis* Zone is also defined from the first appearance (FEAB) of *S.* (?) *spiralis* to the last occurrence (LOB) of *T. conexa* (Yao: 1990; Matsuoka: 1992, 1995). Therefore, at least the beds from B to C2 in the Kurisaka section belong to their *S.* (?) *spiralis* Zone. Yao (1990)

Table 2. Vertical distribution of selected radiolarian species. Modified after Matsuoka (1983, 1986a, b, 1992), Matsuoka & Yao (1985, 1986), Yao (1990), Gorican (1994) and INTERRAD Jurassic-Cretaceous Working Group (1995). Massive line: correlative in Tethys region; break line: correlative in Japan.

Specific Name / UA Zones 95	1	2	3	4	5	6	7	8	9	10	11	12
Stylocapsa (?) *spiralis* Matsuoka												
Tricolocapsa conexa Matsuoka												
Tricolocapsa plicarum Yao												
Tricolocapsa tetragona Matsuoka												
Tricolocapsa yaoi Matsuoka												
Tricolocapsa (?) sp. aff. *T* . (?) *fusiformis* Yao												
Eucyrtidiellum nodosum Wakita												
Gongylothorax favosus Dumitrica group												
Ristola dhimenaensis (Baumgartner)												
Cinguloturris carpatica Dumitrica group												
Pseudodictyomitra (?) sp. D of Matsuoka												
Archaeodictyomitra suzukii Aita												
Archaeodictyomitra sp. aff. *A. pseudoscalaris* (Tan Sin Hok)												

considered the age to be Oxfordian. Aita (1987) studied radiolarian biostratigraphy in Shikoku with reference to selected sections in Tethys region, and established 12 radiolarian zones. Among them, he correlated *Stylocapsa* (?) *spiralis* Interval-zone, *Gongylothorax sakawaensis* Zone and *Foremanella hipposidericus* Zone in ascending order with the lower, middle, and probably the upper part of the *Stylocapsa* (?) *spiralis* Zone of Matsuoka and Yao (1986) respectively, based on the first appearance data of *S.* (?) *spiralis*, *Gongylothorax sakawaensis* and *Foremanella hipposidericus*. *S.* (?) *spiralis* occurs in whole of the three zones. The top of the *F. hipposidericus* Zone is not recognized in Shikoku. According to the assignment by Aita (1987), the age of his *S.* (?) *spiralis* Interval-Zone falls within a middle to late Callovian - early Oxfordian age range together with subjacent *Amphipyndax tsunoensis* Interval-Zone, and the *F. hipposidericus* Zone will be placed within the upper Oxfordian.

Matsuoka (1992) correlated the *S.* (?) *spiralis* Zone with the Zone A2 of Baumgartner (1984), and assigned the age as late Callovian-Early Oxfordian. Matsuoka (1995) also regarded the age as late Callovian to Oxfordian. Because the *S.* (?) *spiralis* group is recognized in the Core 117 of the DSDP in Blake Bahama Basin, and it was dated late Callovian - early Oxfordian by calcareous nannofossils (Roth *et al.*, 1983) or Oxfordian by dinoflagellates (Habib & Drugg, 1983). According to the UA Zones 95, co-occurrence of the characteristic species of the *Stylocapsa* (?) *spiralis* Assemblage from the Kurisaka Section is correlative widely with the UA Zones 5-7, especially with UA Zones 6-7 that are assigned as middle Bathonian to early Callovian (Baumgartner *et al.*, 1995b). The calibration of UA Zone 7 is based on the co-occurrence with late Bathonian ammonites at Cerro de la Martina (INTERRAD J-CWG, 1995).

Notes on the age of the Kurisaka Formation

The radiolarian assemblage from the Kurisaka Formation belongs presumably to the assemblage of the upper part of *S.* (?) *spiralis* Zone by Matsuoka and Yao (1986) and Matsuoka (1992, 1995). It is correlative with the assemblages of the upper part of above-mentioned three zones by Aita (1987), and also of the UA Zones 6-7 of Baumgartner *et al.* (1995b). Thus the occurrence of the radiolarian assemblage is totally in concordant with the occurrence of the ammonite from superjacent horizon of C1 that was assigned to be early Kimmeridgian.

There are three main possibilities for the age of the formation. The one is that the radiolarian assemblage indicates an age far older than the superjacent horizon of Kimmeridgian ammonite. In this case just as the calibration by Baumgartner *et al.* (1995b), a hiatus between Bathonian and Kimmeridgian should be considered. The second is that the age of the assemblage is very close to the age of the Kimmeridgian ammonite. The third is that the assemblage belongs also nearly the same age as the ammo-

nite horizon, but the ammonite age is older than Kimmeridgian.

From the sedimentologic view, lithologic difference effects the occurrence of radiolarians in the Kurisaka section. Numerous and various species of radiolarians occur in the laminated mudstone of the horizon C2 as compared with those in the calcareous mudstone with nodules of the horizons A, B and C3 (Table 1), and the ammonite-bearing sandy mudstone and muddy sandstone of the horizon C1 scarcely occurs well-preserved radiolarians. Furthermore, all the horizons from A to C1 in the Kurisaka section are included in 10 m thickness of beds composed mainly of detrital materials. They seems to be formed during a short retrogressive period, as the beds form a part of one thickening and coarsening upward sequence.

Therefore, the author considers that the beds of the *S.* (?) *spiralis* assemblage belongs to the upper part of the *S.* (?) *spiralis* Zone and the age is very close to the age of *Ataxioceras kurisakense*, and that the beds of the Kurisaka Formation are presumably the upper Callovian-Oxfordian and lower Kimmeridgian.

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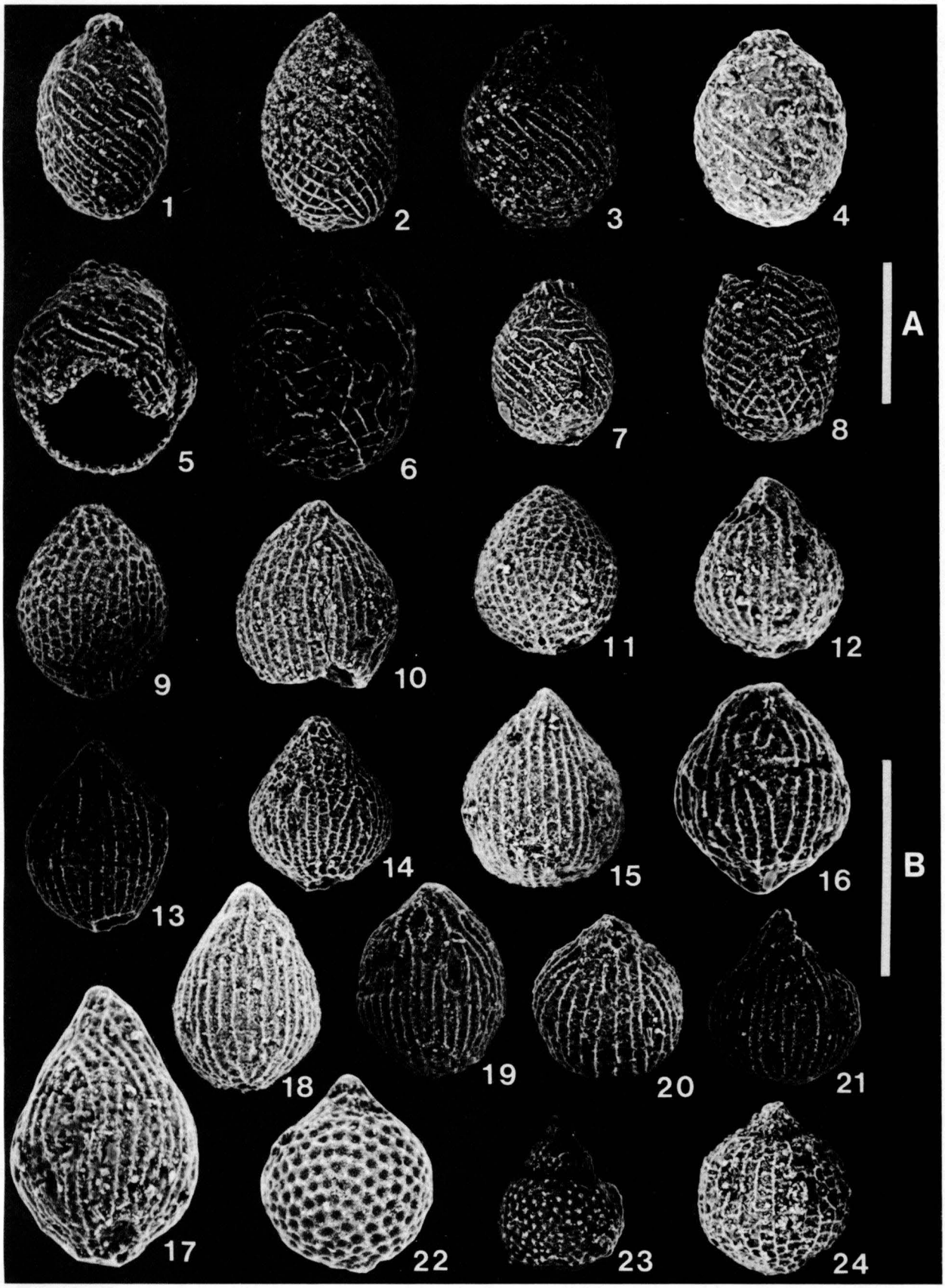
Explanation of Plate 1

SEM photographs of the radiolarians. All the specimens belong to the *Stylocapsa* (?) *spiralis* Assemblage and occur in the Kurisaka Formation of the Torinosu Group. All scale bars indicate 100 μm. Bar A: 1-5, 7-15, 18-24; bar B: 6, 16,17.

1-8. *Stylocapsa* (?) *spiralis* Matsuoka. 1-6: C2; 7: C3; 8: B
9-14. *Tricolocapsa conexa* Matsuoka. 9,10: C2; 11, 12: C3, 13: B, 14: A.
15-21. *Tricolocapsa plicarum* Yao. 15-20: C2; 21: B.
22. *Tricolocapsa yaoi* Matsuoka. C2
23. *Eucyrtidiellum nodosum* Wakita. C2
24. *Tricolocapsa tetragona* Matsuoka. C3

Plate 1



Explanation of Plate 2

SEM photographs of the radiolarians. All the specimens belong to the *Stylocapsa* (?) *spiralis* Assemblage and occur in the Kurisaka Formation of the Torinosu Group. All scale bars indicate 100 μm. Bar A: 6-11, 13, 15-19, 23, 24; bar B: 1-5, 12, 14, 20-22.

1-3. *Tricolocapsa* (?) sp. aff. *T.* (?) *fusiformis* Yao. C2.
4-9. *Gongylothorax favosus* Dumitrica. 4, 5: C2; 6-8: C3; 9: A.
10, 11. *Ristola dhimenaensis* (Baumgartner). C2.
12-14. *Cinguloturris carpatica* Dumitrica. 12,13: C2; 14: C3.
15, 16, 20-22. *Pseudodictyomitra* (?) sp. D of Matsuoka, 1986a. 15, 20, 21: C2; 16, 22: C3.
17-19. *Archaeodictyomitra suzukii* Aita. 17, 18: C3; 19: B.
23, 24. *Archaeodictyomitra* sp. aff. *A. pseudoscalaris* (Tan Sin Hok). B.

Plate 2