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Paleozoic and Mesozoic radiolarians from chert pebbles and cobbles of the Lower Cretaceous Choshi Group, Japan

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Abstract The objective of this work is to study the radiolarian-bearing conglomerate in the Barremian–Aptian Choshi Group in Kanto Region, Japan. Radiolarian assemblages extracted from 2 chert gravels within conglomeratic bed show middle Guadalupian (Middle Permian) and late Bathonian to early Callovian (Middle Jurassic), respectively. The provenance of the radiolarian-bearing chert pebbles and cobbles is probably interpreted to be the Late Jurassic accretionary complexes.

Kew words: Choshi Group, Ashikajima Formation, chert, gravel, radiolaria, Jurassic, Permian

Introduction

Gravels in conglomeratic deposits have been thought to be an important indicator for the sediment provenance. In particular, components and ages of fossil assemblages within gravels suggest more information on their paleobiogeographic origins and geotectonic sources.

The Choshi area of the eastern margin of the Kanto Region is located around the boundary area between Southwest Japan and Northeast Japan, and its geotectonic belonging has been still controversial (e.g., Takagi and Takahashi, 2006; Tazawa and Hasegawa, 2007). Judging from Takagi and Takahashi (2006), Paleozoic and Mesozoic basement rocks in the Choshi area have been correlative to be an eastern extension of the Chichibu Composite belt of Southwest Japan (Ando, 2006), while the overlying Neogene strata belong to Northeast Japan (Takahashi, 2006).

Among Paleozoic and Mesozoic systems, the Lower Cretaceous Choshi Group of the shallow-marine siliciclastic successions has been well-studied due to abundant macrofossil occurrences (e.g., Obata *et al.*, 1975; Hayami and Oji, 1980; Kase and Maeda, 1980). However, microfossil occurrences have been limited to foraminifers until recently (e.g., Obata *et al.*, 1975; Matsubara *et al.*, 2005). The authors have attempted to extract radiolarians from the Choshi Group since 2012, and have obtained them from three horizons (Ando *et al.*, 2014; Kashiwagi and Isaji, 2014). Here we show the radiolarian ages of the chert gravels in the basal horizon of the Choshi Group, and discuss their geotectonic provenances based on their ages and faunal compositions.

General Geology

The Choshi area is underlain by the Late Permian Takagami Conglomerate (Kano, 1958; Ozaki, 1959), probably Jurassic Atagoyama Unit (Takahashi, 2008), Lower Cretaceous Choshi Group (Shikama and Suzuki, 1972), and Cenozoic sedimentary and volcanic sequences (Takahashi *et al.*, 2003).

The Choshi Group is distributed along sea cliff in a north-south direction, and subdivided into five formations; the Ashikajima, the Kimigahama, the Inubouzaki, the Toriakeura and the Nagasakihana formations in ascending order (Obata *et al.*, 1975; 1982; Fig. 1). The Ashikajima Formation is distributed in Kurohae, Ashikajima and west to Nagasakihana, and consists of thick-bedded conglomerate in its lower horizon and overlying hummocky cross stratification (HCS) sandstone in its upper horizon (Obata *et al.*, 1975). The Kimigahama Formation is composed of HCS sandstone and mudstone alternations. The sandy

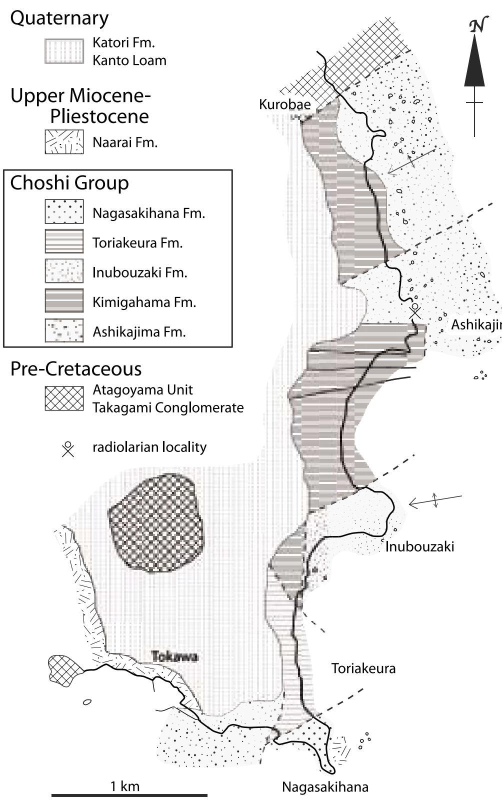

Fig. 1. Geological outline of the Choshi area with sampling locality. Modified from Obata *et al.* (1982).

shell bed occurring in the HCS sandstone bed includes abundant macro- and micro-fossils such as bivalves (Hayami and Oji, 1980), gastropods (Kase and Maeda, 1980; Isaji *et al.*, 2014), otoliths (Miyata *et al.*, 2014), radiolarians (Ando *et al.*, 2014; Kashiwagi and Isaji, 2014), and so on. The Inubouzaki Formation is characterized by thick bedded or amalgamated HCS fine-grained sandstone (Ishigaki and Ito, 2000). The Toriakeura Formation consists of muddy facies with sandstone and mudstone alternations. The Nagasakihana Formation is composed of turbiditic thick-bedded sandstone with convolute lamination.

Ammonoid fossils from the Choshi Group have been studied as an important age-diagnostic taxon in a series of Obata and Matsukawa's researches (e.g., Obata *et al.*, 1975; 1982; Obata and Matsukawa, 2005; 2007; 2009a; 2009b). On the basis of abundant occurrences of ammonoid fossils, the Ashikajima and the Kimigahama formations have been dated to Barremian, and the overlying Inubouzaki and the Toriakeura formations have been assigned to Aptian in age (Obata and Matsukawa, 2007). The age of the Nagasakihana Formation has been tentatively placed to be Albian based on the floating cobble of ammonoid fossil in a distributional area of the Toriakeura Formation (Obata and Matsukawa, 2009a).

Fig. 2. Conglomeratic beds of the Ashikajima Formation west to Ashikajima.

Pre-Cretaceous strata are distributed sporadically in the Choshi area (Fig. 1). At Kurohae, the northern Choshi area, intermittent outcrops of chert have been known along shoreline at least since Yamane (1924). Hanzawa (1950) reported middle Permian *Sphaerulina crassispira* (fusulinoideans) and *Mizzia* (algea) from the gray limestone embedded in the much deformed green chert. During 1980's Mesozoic microfossils had been firstly recovered from the chert at Kurohae; the Middle and Late Triassic radiolarians (Suzuki, 1986) and conodonts (Kunihiro *et al.*, 1984). Due to the occurrences of Triassic radiolarians and conodonts, many researchers have treated the Triassic chert at Kurohae as a part of the Jurassic accretionary complexes (e.g., Katsura *et al.*, 1984; Takahashi, 1990; Tazawa and Hasegawa, 2007; Takahashi, 2008).

Radiolarian age assignments

The conglomerate beds for study target are occupied to the lower horizon of the Ashikajima Formation of the Choshi Group, and distributed in two localities; Kurohae Fishery Port and west to the Ashikajima. They are characterized by dominant chert gravels with minor gravels of sandstone, shale, limestone and porphyry (Obata *et al.*, 1975). Chert gravels show various colors such as red, pale green, gray, white, black and so on, and some of them contain abundant radiolarian fossils.

Chert gravels were collected for radiolarian analyses west to Ashikajima (Fig. 2). Radiolarians have been

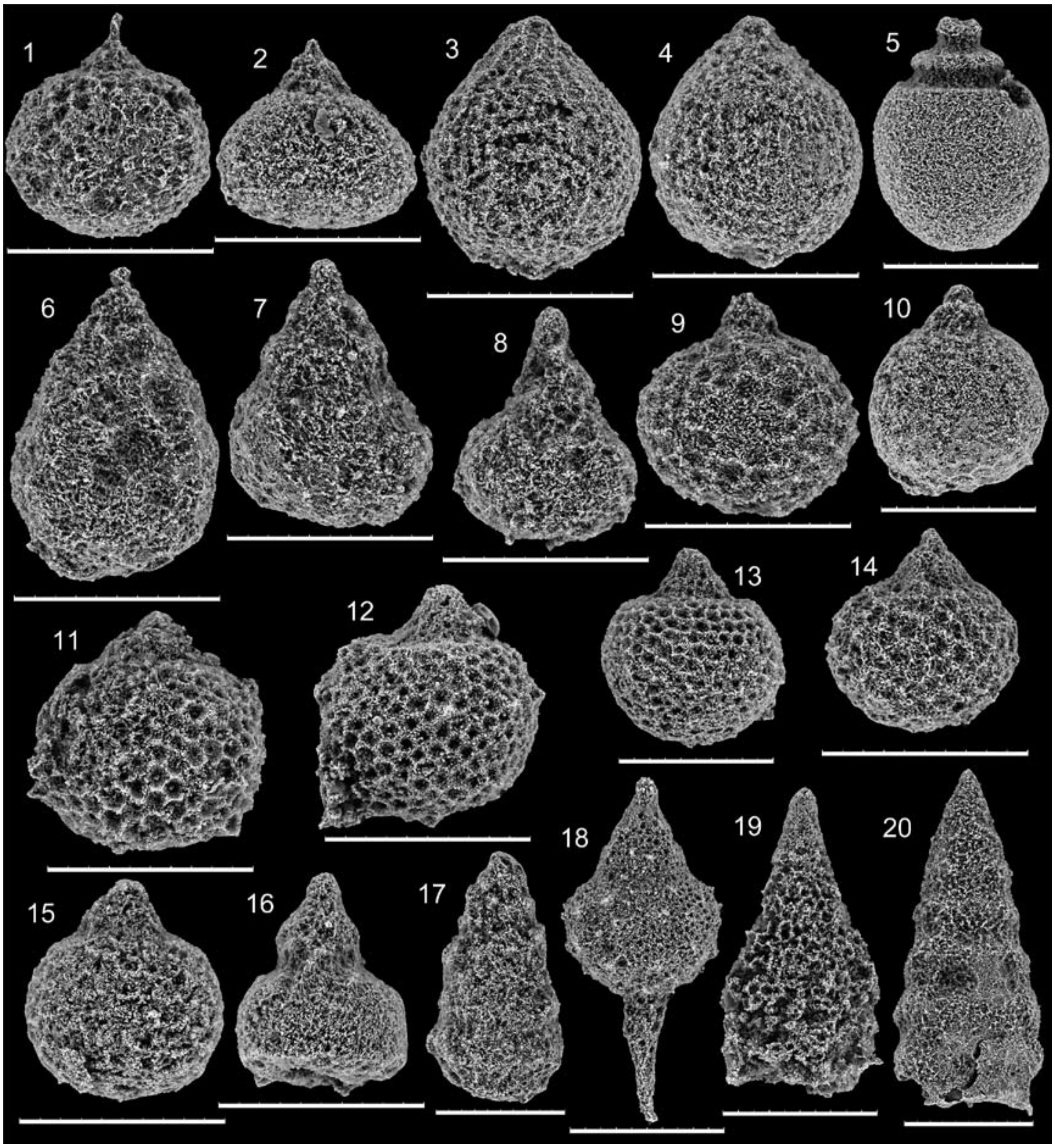

Fig. 3. SEM images of Middle Jurassic radiolarians from the chert gravel collected from the conglomeratic bed of the Ashikajima Formation, Choshi Group. Sample 12072301-03. All scale bars indicate 100 μm. 1, *Sethocapsa* sp., 12072301030051; 2, *Stichocapsa japonica* Yao, 12072301030039; 3–4, *Striatojaponocapsa* sp., 12072301030002, 12072301030036; 5–8. *Stichocapsa* ? or *Tetracapsa* ? spp., 12072301030014, 12072301030024, 12072301030011, 12072301030033; 9–11, Tri-cyrtid nassellaria, 12072301030055, 12072301030041, 12072301030025; 12–13, *Williriedellum* sp. cf. *W. carpathicum* Dumitrica, 12072301030028, 12072301030043; 14–15 *Williriedellum* sp. cf. *W. dierschei* Suzuki and Gawlick, 12072301030062, 12072301030035; 16. *Eucyrtidiellum* sp., 12072301030004; 17, *Amphipyndax* ? sp., 12072301030034; 18, *Syringocapsa* sp., 12072301030005; 19, *Sella* sp. cf. *S. chrafatensis* (El Kadiri), 12072301030061; 20, *Spongocapsula* sp., 12072301030001.

species name \ UAZ, Zones95 scale		1	2	3	4	5	6	7	8	9	10	11	12
Sella chrafatensis (El Kadiri)	2-7												
Williriedellum dierschei Suzuki and Gawlick	3-9												
Stichocapsa japonica Yao	3-8												
Striatojaponocapsa plicarum (Yao)	3-8												
Striatojaponocapsa conexa (Matsuoka)	4-7												
Williriedellum carpathicum (Dumitrica)	7-11												

Fig. 4. Range chart of some age-assignable taxa and radiolarian age of sample 12072301-03.

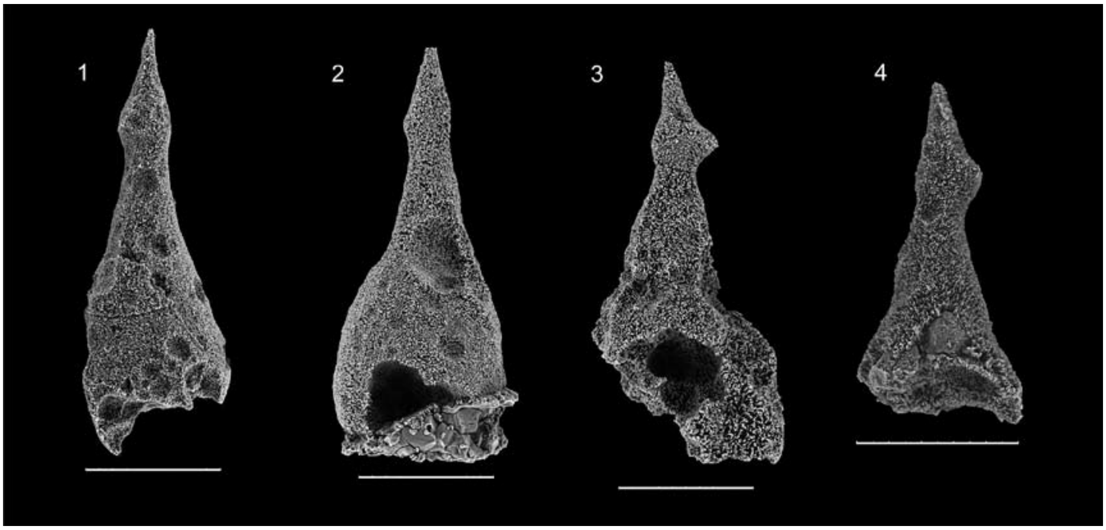

Fig. 5. Middle Permian radiolarians from the chert gravel collected from the conglomeratic bed of the Ashikajima Formation, Choshi Group. Sample 12072301-06. All scale bars indicate 100 µm. 1–4, *Pseudoalbaillella* sp. cf. *P. monacantha* (Ishiga and Imoto).

extracted from chert gravels by using diluted hydrofluoric acid, according to the method proposed by Dumitrica (1970) and Pessagno and Newport (1972). In this paper, we adopt the radiolarian zonation based on the Unitary Association Zone (UAZ, Zones95 scale) proposed by Baumgartner et al. (1995).

Sample 12072301-03 contains poorly- to moderately-preserved radiolarian assemblage; *Amphipyndax* ? sp., *Eucyrtidiellum* sp., *Sella* sp. cf. *S. chrafatensis* (El Kadiri), *Sethocapsa* ? sp., *Spongocapsula* ? sp., *Stichocapsa japonica* Yao, *Stichocapsa* ? or *Tetracapsa* ? spp., *Striatojaponocapsa* sp., *Syringocapsa* sp., *Williriedellum* sp. cf. *W. carpathicum* Dumitrica, *Williriedellum* sp. cf. *W. dierschei* Suzuki and Gawlick, and Tri-cyrtid nassellaria (Fig. 3). Two specimens of *Striatojaponocapsa* sp. can be identified as *Striatojaponocapsa conexa* (Matsuoka), *Striatojaponocapsa plicarum* (Yao) and/or *Striatojaponocapsa synconexa* O'Dogherty, Gorican and Dumitrica due to a few morphological features (See remarks of *Striatojaponocapsa* sp.). Its possible occurrence range of *Striatojaponocapsa* sp. is the UAZ. 3–8 according to Baumgartner *et al.* (1995). The co-occurrence of *Sella chrafatensis*, *Stichocapsa japonica*, *Striatojaponocapsa* sp., *Williriedellum carpathicum*, and *Williriedellum dierschei* indicates the UAZ. 7 which is corresponded to late Bathonian to early Callovian (Middle Jurassic) in age (Fig. 4).

Sample 12072301-06 yields poorly-preserved Follicucullidae radiolarians. *Pseudoalbaillella* sp. cf. *P. monacantha* (Ishiga and Imoto) is only identified in specific level (Fig. 5), and occurrence range of *Pseudoalbaillella monacantha* has been restricted to the *Pseudoalbaillella monacantha* Zone (=*Follicucullus monacanthus* Range zone of Ishiga (1986, 1990)) according to Late Paleozoic radiolarian zonations proposed by Ishiga (1986, 1990). *Pseudoalbaillella monacantha* Zone defined by the first and last occurrences of *Pseudoalbaillella monacantha* indicates a middle Guadalupian age (middle Middle Permian) (Zhang *et al.*, 2014).

Discussion

The conglomerate beds in the Ashikajima Formation include abundant chert gravels, although there has been no examination on radiolarians until our research. Furthermore it has been suggested that the origin of chert gravels in the Ashikajima Formation was the Jurassic accretionary complexes only due to lithological similarities of cherts (e.g., Matsubara *et al.*, 2005). Here we discuss the provenances of chert gravels based on newly-extracted radiolarians which show the Middle Permian (middle Guadalupian) and the Middle Jurassic (late Bathonian to early Callovian) respectively.

Chert gravels in the Ashikajima Formation must be derived from the accretionary complexes based on the common lithological features. The accretionary complexes are individually characterized by each reconstructed oceanic plate stratigraphy, which is generally composed of basaltic volcanic rocks, reefal limestone, bedded chert, siliceous mudstone, and terrigenous coarse-grained clastic rocks (mudstone, sandstone-mudstone alternations and sandstone) in ascending order (e.g., Matsuoka, 1984; Matsuoka and Yao, 1990; Matsuda and Isozaki, 1991), and their stratigraphies in Japan have been summarized by some researchers (e.g., Ichikawa *et al.* eds., 1990; Matsuoka *et al.*, 1998; Nakae, 2000). Also the formational age of each accretionary complex corresponds to the arrival time of the accretion-related oceanic crust in general.

The Middle Jurassic chert comprise a part of the Late Jurassic to middle Early Cretaceous accretionary complexes in the Southern Chichibu belt (Matsuoka et al., 1998) and the Late Jurassic to earliest Cretaceous accretionary complexes in the Tamba, Mino, and Ashio belts (Nakae, 2000). The Ashikajima Formation including the Middle Jurassic chert gravel has been dated to Barremian (middle Early Cretaceous) for its depositional age due to ammonoid stratigraphic researches (Obata and Matsukawa, 2007; 2009a). To sum up, the Late Jurassic accretionary complex is the most proper candidate for the Middle Jurassic chert provenance.

Permian chert is also one of the lithological compositions for Permian and Jurassic-middle Early Cretaceous accretionary complexes (Ichikawa *et al.* eds., 1990). *Pseudoalbaillella monacantha*, the only identified species herein, has been well-known radiolarian species from the Middle Permian bedded chert of the Jurassic accretionary complexes; the Southern Chichibu belt (e.g., Yoshida and Murata, 1985; Nishizono *et al.*, 1996; Takami *et al.*, 1999), the Northern Chichibu belt (e.g., Kurimoto, 1986; Kuwahara *et al.*, 2006), and the Tamba-Mino-Ashio belt (e.g., Ishiga *et al.*, 1982; Sano *et al.*, 2010). While *P. monacantha* in the Akiyoshi belt of the Permian accretionary complex has been reported only from acidic tuff beds (Sano *et al.*, 1987; Yamashita and Ishiga, 1990) and mudstones (Naka and Ishiga, 1985; Ishiga and Suzuki, 1988), not from the bedded chert. Thus the middle Middle Permian chert gravel is also originated from the Jurassic-middle Early Cretaceous accretionary complexes.

We conclude that chert gravels in the Ashikajima Formation have been probably derived from the Late Jurassic accretionary complex.

Systematic Paleontology

Class Actinopoda
Subclass Radiolaria Müller, 1858
Order Polycystida Ehrenberg, 1838; emend. Riedel, 1967
Suborder Nassellariina Ehrenberg, 1876

Family Arcanicapsidae Takemura, 1986
Genus *Sethocapsa* Haeckel, 1882
***Sethocapsa* ? sp.**
(Fig. 3.1 and Table 1)

Remarks: The material possesses two- to four-segments with thin apical horn, and is characterized by a large globose last segment. Some morphoforms similar in outline of test to our material were described as the genus *Sethocapsa* Haeckel (*Sethocapsa cetia*, *Sethocapsa leiostraca*, *Sethocapsa trachyostraca*) by Foreman (1973). Here, we tentatively assign this material to the genus *Sethocapsa*.

Table 1. Measurements of *Sethocapsa* ? sp.

Specimen	TH	MW	Fig.
12072301030051	110	100	3.1

TH, Total Height; MW, Maximum width

Genus *Stichocapsa* Haeckel, 1882

Stichocapsa japonica Yao

(Fig. 3.2 and Table 2)

Stichocapsa japonica Yao – Yao, 1979, pl. 6, figs. 8–12, pl. 7, figs. 1–15

Remarks: Although the illustration of our specimen is slightly slanting lateral view, a flat surface of anti-apical portion is easily distinguishable. Also its surface ornamentation is lacking due to bad preservation. Overall outline of the test and its size allow a critical identification to *Stichocapsa japonica* Yao.

Table 2. Measurements of *Stichocapsa japonica* Yao.

Specimen	TH	MW	Fig.
12072301030039	93	98	3.2

TH, Total Height; MW, Maximum width

Genus *Striatojaponocapsa* Kozur, 1984, emend. Hull, 1997

***Striatojaponocapsa* sp.**

(Figs. 3.3–3.4 and Table 3)

Remarks: The illustrated specimens resemble *Striatojaponocapsa plicarum* (Yao), *Striatojaponocapsa conexa* (Matsuoka), and/or *Striatojaponocapsa synconexa* O'Dogherty, Gorican and Dumitrica in drop-like outline of test with longitudinal costae through their overall tests. However more morphological characteristics are necessary for specific identification; whether transverse ridges between longitudinal costae exist or not, development degree of basal appendage, and whether peripheral convex ridge exist or not around circular depression on the distal portion (Yao, 1979; Matsuoka, 1983; O'Dogherty *et al.*, 2006; Hatakeda *et al.*, 2007). Due to poor preservation, we find it difficult to observe above-mentioned morphological features.

Table 3. Measurements of *Striatojaponocapsa* sp.

Specimen	TH	MW	Fig.
12072301030002	128	108	3.3
12072301030036	123	104	3.4

TH, Total Height; MW, Maximum width

Genus *Tetracapsa* Haeckel, 1882

***Stichocapsa* ? or *Tetracapsa* ? spp.**

(Figs. 3.5–3.8 and Table 4)

Remarks: These specimens illustrated herein are internal mold. Lacking of surface ornamentation doesn't allow precise generic or specific identification. They probably have four segments, although developmental degrees of outer strictures between the segments and latticed test on the surface are unknown due to their internal mold. Here they are tentatively assigned to the genus *Stichocapsa* Haeckel or *Tetracapsa* Haeckel based on the generic criteria based on Suzuki and Gawlick (2009).

Table 4. Measurements of *Stichocapsa* ? or *Tetracapsa* ? spp.

Specimen	TH	MW	Fig.
12072301030014	152	115	3.5
12072301030024	153	101	3.6
12072301030011	131	100	3.7
12072301030033	119	90	3.8

TH, Total Height; MW, Maximum width

Tri-cyrtid nassellaria

(Figs. 3.9–3.11 and Table 5)

Remarks: These morphospecies are characterized by pentagonal to hexagonal pore frames on their abdominal surfaces. A small pore is perforated in the center of each pore frame. It could not be observed whether thorax sinks into abdomen or not from SEM images. These specimens are distinguishable from *Williriedellum* sp. cf. *W. dierschei* Suzuki and Gawlick in having slightly more pore frames and larger test.

Table 5. Measurements of Tri-cyrtid nassellaria.

Specimen	TH	MW	Fig.
12072301030055	109	109	3.9
12072301030041	137	117	3.10
12072301030025	118	116	3.11

TH, Total Height; MW, Maximum width

Family Williriedellidae Dumitrica, 1970

Genus *Williriedellum* Dumitrica, 1970

Williriedellum* sp. cf. *W. carpathicum Dumitrica

(Figs. 3.12–3.13 and Table 6)

Williriedellum carpathicum Dumitrica – Dumitrica, 1970, pl. 9, figs. 56a, 56b, 57–59, pl. 10, fig. 61

Remarks: Moderately-preserved two materials show similar outline of test to *Williriedellum carpathicum* Dumitrica. Although our specimens seem not to possess an apertural tube, one of a diagnosis for identification of *Williriedellum carpathicum*, it is probably due to poor preservation.

Table 6. Measurements of *Williriedellum* sp. cf. *W. carpathicum* Dumitrica.

Specimen	TH	MW	Fig.
12072301030028	118	110	3.12
12072301030043	130	119	3.13

TH, Total Height; MW, Maximum width

***Williriedellum* sp. cf. *W. dierschei* Suzuki and Gawlick**
(Figs. 3.14–3.15 and Table 7)

Williriedellum dierschei Suzuki and Gawlick – Gawlick *et al.*, 2004, figs. 4.1–4.6

Remarks: Although whether a thorax sinks into an abdomen or not is unknown, the illustrated two specimens are similar to *Williriedellum dierschei* Suzuki and Gawlick in having pentagonal to hexagonal pore frames with a small pore in their central parts on the abdominal surface and faintly possessing the tube-like structure around the basal aperture. Also our specimens are not inconsistent in test size to those of *Williriedellum dierschei* (Gawlick *et al.*, 2004; total height=100–112 µm and maximum width of test=91–105 µm).

Table 7. Measurements of *Williriedellum* sp. cf. *W. dierschei* Suzuki and Gawlick.

Specimen	TH	MW	Fig.
12072301030062	99	95	3.14
12072301030035	109	97	3.15

TH, Total Height; MW, Maximum width

Family Eucyrtidiellidae Takemura, 1986
Genus *Eucyrtidiellum* Baumgartner, 1984
***Eucyrtidiellum* sp.**
(Fig. 3.16 and Table 8)

Remarks: The depicted specimen can be assigned to the genus *Eucyrtidiellum* described by Baumgartner (1984) in generic level based on its diagnostic outline of test except for the fourth segment.

Table 8. Measurements of *Eucyrtidiellem* sp.

Specimen	TH	MW	Fig.
12072301030004	109	84	3.16

TH, Total Height; MW, Maximum width

Family Amphipyndacidae Riedel, 1967
Genus *Amphipyndax* Foreman, 1966
***Amphipyndax* ? sp.**
(Fig. 3.17 and Table 9)

Remarks: Our material is similar in overall outline and size of test to *Amphipyndax durisaeptum* Aita and *Amphipyndax tsunoensis* Aita newly described by Aita (1987), although surface ornamentation can't be observed clearly due to bad preservation. This specimen is questionably assigned to the genus *Amphipyndax*.

Table 9. Measurements of *Amphipyndax* ? sp.

Specimen	TH	MW	Fig.
12072301030034	196	108	3.17

TH, Total Height; MW, Maximum width

Genus *Syringocapsa* Neviani, 1900
***Syringocapsa* sp.**
(Fig. 3.18 and Table 10)

Remarks: For the genus *Syringocapsa*, we follow the generic criteria revised by Hori (1988); the genus *Syringocapsa* differs from the genus *Podobursa* by lacking radial spines on the inflated segment. The present material possesses three segments (cephalis, thorax and abdomen) divided by external constrictions, and a terminal tube attached distally. The surface of inflated abdomen is covered by fine, circular pore frames with some nodes or tiny spines. The illustrated specimen has finer pores on its abdominal surface than those of many forms of the genus *Syringocapsa*.

Table 10. Measurements of *Syringocapsa* sp.

Specimen	TH	MW	Fig.
12072301030005	225	105	3.18

TH, Total Height; MW, Maximum width

Family Archaeodictyomitridae Pessagno, 1976
Genus *Sella* (El Kadiri, 2007)
Sella* sp. cf. *S. chrafatensis (El Kadiri)
(Fig. 3.19 and Table 11)

Linaresia chrafatensis El Kadiri – El Kadiri, 1992, pl. 1, figs. 6–8

Linaresia chrafatensis El Kadiri – Chiari *et al.*, 2008, pl. 1, fig. 19

Remarks: Due to homonym preoccupied by copepod crustaceans, El Kadiri (2007) modified its generic name from *Linaresia* newly-proposed by El Kadiri (1992) to *Sella* (O'Dogherty *et al.*, 2009). The illustrated specimen resembles proximal one-half portion of *Sella chrafatensis* (El Kadiriin) in possessing a massive apical horn and pore arrangement on the post-cephalic segments.

Table 11. Measurements of *Sella* sp. cf. *S. chrafatensis* (El Kadiri).

Specimen	TH	MW	Fig.
12072301030061	201	106	3.19

TH, Total Height; MW, Maximum width

Family Theoperidae
Genus *Spongocapsula* Pessagno, 1977
***Spongocapsula* ? sp.**
(Fig. 3.20 and Table 12)

Remarks: The present material is an internal mold. Two successive segments are constricted by conspicuous strictures. Surface of test is probably covered by spongy meshwork. This specimen can be questionably assigned to the genus *Spongocapsula* Pessagno.

Table 12. Measurements of *Spongocapsula* ? sp.

Specimen	TH	MW	Fig.
12072301030001	269	118	3.20

TH, Total Height; MW, Maximum width

Suborder Albaillellaria Deflandre, 1953
Family Follicucullidae Ormiston and babcock, 1979
Genus *Pseudoalbaillella* Holdsworth and Jones, 1980
Pseudoalbaillella* sp. cf. *P. monacantha (Ishiga and Imoto)
(Figs. 5.1–5.4)

Follicucullus monacanthus Ishiga and Imoto – Ishiga *et al.*, 1982, pl. 4, figs. 15–17, 21–23; Zhang *et al.*, 2014, pl. 1, figs. 8–11

Pseudoalbaillella monacantha (Ishiga and Imoto) – Wang *et al.*, 2012, pl. 17, figs. 12–14, 27–34; Ito *et al.*, in press, figs. 3.19–3.22

short form of *Pseudoalbaillella monacantha* (Ishiga and Imoto) – Ito *et al.*, in press, figs. 3.23–3.30

Remarks: Our specimens illustrated herein are characterized by ventral flap attached on pseudothorax and remarkably inflated pseudoabdomen.

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References

Aita, Y. 1987. Middle Jurassic to Lower Cretaceous radiolarian biostratigraphy of Shikoku with reference to selected sections in Lombardy Basin and Sicily. Sci. Rep. Tohoku Univ. Ser. II 58: 1–91.

Ando, H. 2006. Geologic setting of the Choshi and Nakaminato Groups and Oarai Formation exposed along the Pacific coast in the eastern end of Kanto Plain. Jour. Geol. Soc. Japan 112 (1): 84–97. (In Japanese with English abstract)

Ando, H., K. Kashiwagi, R. Hirayama and S. Toshimitsu. 2014. Cretaceous forearc basin siliciclastic successions along the Pacific coast, central Japan: Choshi, Nakaminato and Futaba groups. *In* Organizing and Scientific Committee of the IGCP 608 (ed.), Field Excursion Guide, The Second International Symposium of International Geoscience Programme (IGCP) Project 608 "Cretaceous ecosystems and their responses to paleoenvironmental changes in Asia and the western Pacific", Ibaraki: 1–42.

Baumgartner, P. O. 1984. A Middle Jurassic-Early Cretaceous low-latitude radiolarian zonation based on Unitary Associations and age of Tethyan radiolarites. Eclogae geol. Helv. 77 (3): 729–837.

Baumgartner, P. O., L. O'Dogherty, Š. Goričan, R. Dumitrica-Jud, P. Dumitrica, A. Pillevuit, E. Urquhart, A. Matsuoka, T. Danelian, A. Bartolini, E. S. Carter, P. De Wever, N. Kito, M. Marcucci and T. Steiger. 1995. Radiolarian catalogue and systematics of Middle Jurassic to Early Cretaceous Tethyan genera and species. *In* Baumgartner, P. O., L. O'Dogherty, Š. Goričan, E. Urquhart, A. Pillevuit and P. De Wever. (eds.), Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology, Mém. Géol. (Lausanne) 23: 37–685.

Chiari, M., P. Di Stefano and G. Parisi. 2008. New stratigraphical data on the Middle-Late Jurassic biosiliceous sediments from the Sicanian basin, western Sicily (Italy). Swiss Jour. Geosci. 101 (2): 415–429.

Deflandre, G. 1953. Radiolaries fossiles. *In* Grasse, P.P. (ed.), Traité de Zoologie 1: 390–435.

Dumitrica, P. 1970. Cryptocephalic and cryptothoracic Nassellaria in some Mesozoic deposits of Romania. Rev. Roum. Géol., Géophys., Géogr., Sér. Géol. 14 (1): 45–124.

Ehrenberg, C. G. 1839. Über die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen. Abh. Konigl. Akad. Wiss. Berlin Jahre 1838: 59–147.

Ehrenberg, C. G. 1876. Fortsetzung der mikrogeologischen Studien als Gesammt-Übersicht der mikroskopischen Paläontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rücksicht auf den Polycystinen-Mergel von Barbados. Abh. Königl. Preuß. Akad. Wiss. Berlin 1875: 1–225.

El Kadiri, K. 1992. Description de nouvelles espèces de radiolaires jurassiques de la Dorsale calcaire externe (Rif, Maroc). Rev. Esp. Paleont. 7, Extra 3: 37–48.

El Kadiri, K. 2007. *Sella*, a new name for the genus Linaseria El Kadiri 1992 (Nassellaria, Radiolaria) preoccupied by copepod crustaceans (Lamippidae, Maxillopoda). Rev. Esp. Paleont. 22 (1): 88.

Foreman, H. P. 1966. Two Cretaceous radiolarian genera. Micropaleontology 12 (3): 355–359.

Foreman, H. P. 1973. Radiolaria from DSDP Leg 20. *In* Heezen, B. C., I. D. MacGregor, et al. (eds.) Init. Repts. DSDP 20: pp. 249–305.

Gawlick, H. J., F. Schlagintweit, O. Ebli and H. Suzuki. 2004. Die Plassen-Formation (Kimmeridgium) des Krahstein (Steirisches Salzkammergut, Österreich) und ihre Unterlagerung: neue Daten zur Fazies, Biostratigraphie und Sedimentologie. Zbl. Geol. Paläont. Teil I: 295–334. (In German with English abstract)

Haeckel, E. 1882. Entwurf eines Radiolarien-Systems auf Grund von Studien der Challenger-Radiolarien. Jena. Zeit. Naturwiss. Med. -Naturwiss. Gesell. Jena 15: 418–472.

Hanzawa, S. 1950. On the occurrences of the foraminiferal genera, Eoverbeekina, Nankinella, and Sphaerulina from Japan. IGPS Tohoku Univ. (2): 1–12.

Hatakeda, K., N. Suzuki and A. Matsuoka. 2007. Quantitative morphological analyses and evolutionary history of the Middle Jurassic polycystine radiolarian genus *Striatojaponocapsa* Kozur. Marine Micropaleontology 63 (1–2): 39–56.

Hayami, I. and T. Oji. 1980. Early Cretaceous bivalvia from the Choshi District, Chiba Prefecture, Japan. Trans. Proc. Palaeont. Soc. Japan, N. S. (120): 419–448.

Holdsworth, B. K. and D. L. Jones. 1980. Preliminary radiolarian zonation for Late Devonian through Permian time. Geology 8 (6): 281–285.

Hori, R. 1988. Some characteristic radiolarians from Lower Jurassic bedded cherts of the Inuyama area, Southwest Japan. Trans. Proc. Palaeont. Soc. Japan, N. S. (151): 543–563.

Hull, D.M. 1997. Upper Jurassic Tethyan and southern Boreal radiolarians from western North America. Micropaleontology 43 (Supple. 2): 1–202.

Ichikawa, K., S. Mizutani, I. Hara, S. Hada and A. Yao. (eds.) 1990. Pre-Cretaceous terranes of Japan. IGCP Project No. 224: Pre-Jurassic Evolution of Eastern Asia, 413 pp., Nippon Insatsu Shuppan Co. Ltd., Osaka.

Isaji, S., T. Haga and K. Kashiwagi. 2014. A planispiral 'lower heterobranch' gastropod from the Lower Cretaceous Choshi Group, Chiba Prefecture, Japan. Ann. Meet. Palaeont. Soc. Japan, Abstr. 2014: 46. (In Japanese)

Ishiga, H. 1986. Late Carboniferous and Permian radiolarian biostratigraphy of Southwest Japan. Jour. Geosci., Osaka City Univ. 29: 89-100.

Ishiga, H. 1990. Paleozoic radiolarians. *In* Ichikawa, K., S. Mizutani, I. Hara, S. Hada and A. Yao (eds.), Pre-Cretaceous terranes of Japan, pp. 285–295, Nippon Insatsu Shuppan Co. Ltd., Osaka.

Ishiga, H., T. Kito and N. Imoto. 1982. Middle Permian radiolarian assemblages in the Tamba District and an adjacent area, Southwest Japan. Earth Sci. (Chikyu Kagaku) 36 (5): 272–281.

Ishiga, H. and S. Suzuki. 1988. Late Paleozoic radiolarian assemblages from the Shimomidani Formation in Akiyoshi Terrane, Southwest Japan. Jour. Geol. Soc. Japan 94 (7): 493–499.

Ishigaki, A. and M. Ito. 2000. Size population of hummocky bedforms: an example from the Lower Cretaceous Choshi Group, northeastern Boso Peninsula, Japan. Jour. Geol. Soc. Japan 106 (7): 472–481. (In Japanese with English abstract)

Ito, T., Q. Feng and A. Matsuoka. in press. Taxonomic significance of short forms of middle Permian *Pseudoalbaillella* Holdsworth and Jones, 1980

(Follicucullidae, Radiolaria). Rev. Micropaleont.
Kano, H. 1958. On a granite–bearing conglomerate from the Choshi Peninsula, Chiba Prefecture, Japan –Studies on the granite–bearing conglomerates in Japan, No. 5–. Jour. Geol. Soc. Japan 64 (757): 551–556. (In Japanese with English abstract)
Kase, T. and H. Maeda. 1980. Early Cretaceous gastropoda from the Choshi District, Chiba Prefecture, central Japan. Trans. Proc. Palaeont. Soc. Japan, N. S. (118): 291–324.
Kashiwagi, K. and S. Isaji. 2014. Radiolarians from the Lower Cretaceous Choshi Group, Chiba Prefecture, Japan. Ann. Meet. Palaeont. Soc. Japan, Abstr. 2014: 51. (In Japanese)
Katsura, Y., F. Masuda and I. Obata. 1984. Storm-dominated shelf sea from the Lower Cretaceous Choshi Group, Japan. Ann. Rep., Inst. Geosci., Univ. Tsukuba (10): 92–95.
Kozur, H. 1984. New radiolarian taxa from the Triassic and Jurassic. Geol. Palaontol. Mitt. Innsbruck 13 (2): 49–88.
Kunihiro, S., H. Saito and S. Sakagami. 1984. Discovery of Triassic conodonts from the "Kurohae chert" in the Choshi Peninsula. Jour. Geogr. 93 (5): 57–59. (In Japanese)
Kurimoto, C. 1986. Northern subbelt of the Chichibu Belt in the Shimizu-Misato area, Wakayama prefecture, Southwest Japan. Jour. Geol. Soc. Japan 92 (10): 737–748. (In Japanese with English abstract)
Kuwahara, K., K. Fujinaga and Y. Kato. 2006. Radiolarian Age of Manganese Ore and Red Chert from the Ananai Stratiform Manganese Deposit in the Northern Chichibu Belt, Central Shikoku, Japan. Resour. Geol. 56 (4): 415–421.
Matsubara, Y., K. Hisada, I. Motoyama and H. Nishi. 2005. Stratigraphy and geologic structure of the Cretaceous Choshi Group in the Inubosaki Point, Central Japan. Bull. Saitama Mus. Nat. Hist. (22): 1–14. (In Japanese with English abstract)
Matsuda, T. and Y. Isozaki. 1991. Well-documented travel history of Mesozoic pelagic chert in Japan: from remote ocean to subduction zone. Tectonics 10 (2): 475–499.
Matsuoka, A. 1983. Middle and Late Jurassic radiolarian biostratigraphy in the Sakawa and adjacent area, Shikoku, Southwest Japan. Jour. Geosci. Osaka City Univ. 26: 1–48.
Matsuoka, A. 1984. Togano Group of the Southern Chichibu Terrane in the western part of Kochi Prefecture, southwest Japan. Jour. Geol. Soc. Japan 90 (7): 455–477. (In Japanese with English abstract)
Matsuoka, A. and A. Yao. 1990, Southern Chichibu Terrane. *In* Ichikawa, K., S. Mizutani, I. Hara, S. Hada and A. Yao (eds.), Pre-Cretaceous terranes of Japan, pp. 203–216, Nippon Insatsu Shuppan Co. Ltd., Osaka.
Matsuoka, A., S. Yamakita, M. Skakibara and K. Hisada. 1998. Unit division of the Chichibu Composite Belt from a view point of accretionary tectonics and geology of western Shikoku, Japan. Jour. Geol. Soc. Japan 104 (9): 634–653. (In Japanese with English abstract)
Miyata, S., S. Isaji and K. Kashiwagi. 2014. The first record of otoliths from the Kimigahama Formation (Lower Cretaceous) of the Choshi Group, Chiba Prefecture, Japan. Ann. Meet. Palaeont. Soc. Japan, Abstr. 2014: 45. (In Japanese)
Müller, J. 1858, Über die Thalassicollen, Polycystinen und Acanthometren des Mittelmeeres. Abhandl. d. Kgl. Akad. d. Wiss. Berlin, 1–62. (In German)
Naka, T. and H. Ishiga. 1985. Discovery of Permian radiolarians from the Nishiki Group in western part of Sangun-Chugoku Belt, Southwest Japan. Earth Sci. (Chikyu Kagaku) 39 (3): 229–233. (In Japanese)
Nakae, S. 2000. Regional correlation of the Jurassic accretionary complex in the Inner Zone of Southwest Japan. Mem. Geol. Soc. Japan (55): 73–98. (In Japanese with English abstract)
Neviani, A. 1900. Supplemento alla fauna a radiolari delle rocce mesozoiche del Bolognese. Boll. Soc. Geol. Ital. 19: 645–671.
Nishizono, Y., H. Yoshida and M. Murata. 1996. The siliceous rock facies near the Permo-Triassic (P/T) boundary in the Southern Chichibu Terrane, Kyushu. Jour. Geol. Soc. Japan 102 (7): 591–608. (In Japanese with English abstract)
Obata, I., S. Hagiwara and S. Kamiko. 1975. Geological age of the Cretaceous Choshi Group. Bull. Nat. Sci. Mus. Tokyo, Ser. C 1 (1): 17–36. (In Japanese with English summary)
Obata, I., S. Maiya, Y. Inoue and M. Matsukawa. 1982. Integrated mega- and micro-fossil biostratigraphy of the Lower Cretaceous Choshi Group, Japan. Bull. Nat. Sci. Mus. Tokyo, Ser. C 8 (4): 145–179.
Obata, I. and M. Matsukawa. 2005. Some Jurassic ammonites as derived fossils from the Miocene Naarai Formation, Japan. Ann. Rep., Fukada Geol. Inst. (6): 113–124.
Obata, I. and M. Matsukawa. 2007. Barremian–Aptian (Early Cretaceous) ammonoids from the Choshi Group, Honshu (Japan). Cret. Res. 28 (3): 363–391.
Obata, I. and M. Matsukawa. 2009a. Supplementary

description of the ammonoids from the Barremian to the Albian of the Choshi Peninsula, Japan. Cret. Res. 30 (1): 253–269.

Obata, I. and M. Matsukawa. 2009b. Some ammonoids from the Barremian and probable Albian of the Choshi Peninsula, Japan. Bull. Tokyo Gakugei Univ., Nat. Sci. 61: 97–103.

O'Dogherty, L., M. Bill, Š. Goričan, P. Dumitrica and H. Masson. 2006. Bathonian radiolarians from an ophiolitic mélange of the Alpine Tethys (Gets Nappe, Swiss-French Alps). Micropaleontology 51 (6): 425–485.

O'Dogherty, L., E. S. Carter, P. Dumitrica, Š. Goričan, P. De Wever, A. N. Bandini, P. O. Baumgartner and A. Matsuoka. 2009. Catalogue of Mesozoic radiolarian genera. Part 2: Jurassic-Cretaceous. Geodiversitas 31 (2): 271–356.

Ormiston, A. and L. Babcock. 1979. *Follicucullus*, new radiolarian genus from the Guadalupian (Permian) Lamar Limestone of the Delaware Basin. Jour. Paleontol. 53 (2): 328–334.

Ozaki, H. 1959. Stratigraphical studies on the Paleozoic conglomerate in the Tyosi Peninsula, Tiba Prefecture, Japan. Bull. Nat. Sci. Mus. 4 (2): 188–201. (In Japanese with English abstract)

Pessagno, E. A. Jr. 1976. Radiolarian zonation and stratigraphy of the Upper Cretaceous portion of the Great Valley Sequence, California Coast Ranges. Micropaleontology, Spec. Publ. (2): 1–96.

Pessagno, E. A. Jr. 1977. Upper Jurassic radiolaria and radiolarian biostratigraphy of the California Coast Ranges. Micropaleontology 23 (1): 56–113.

Pessagno, E. A. Jr. and R. L. Newport. 1972. A technique for extracting radiolaria from radiolarian cherts. Micropaleontology 18 (2): 231–234.

Riedel, W. R. 1967. Some new families of radiolaria. Proc. Geol. Soc. London 1640, 148–149.

Rüst, D., 1885, Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Jura. Palaeontographica, 31 (5–6), 273–321.

Sano, H., Y. Iijima and H. Hattori. 1987. Stratigraphy of the Paleozoic rocks in the Akiyoshi Terrane of the central Chugoku Massif. Jour. Geol. Soc. Japan 93 (12): 865–880. (In Japanese with English abstract)

Sano, H., K. Kuwahara, A. Yao and S. Agematsu. 2010. Panthalassan seamount-associated Permian-Triassic boundary siliceous rocks, Mino terrane, central Japan. Paleontol. Res. 14 (4): 293–314.

Shikama, T. and S. Suzuki. 1972. Stratigraphy and Tectonic development mainly of Cretaceous formations of Choshi Peninsula, Chiba Prefecture. Sci. Rep. Yokohama Nat. Univ. Sec. II (19): 133–157. (In Japanese with English abstract)

Suzuki, H. and Gawlick, H. J., 2009, Jurassic radiolarians from cherty limestones below the Hallstatt salt mine (Northern Calcareous Alps, Austria). N. Jb. Geol. Paläont. Abh. 251 (2): 155–197.

Suzuki, R. 1986. Radiolarians from "the Kurohae Formation" in the Choshi area, Chiba Prefecture, Japan. 93th Ann. Meet. Geol. Soc. Japan, Abstr. 1986: 208. (English translation from the original written in Japanese)

Takagi, H. and M. Takahashi. (eds.) 2006. Geotectonic boundary between Northeast and Southwest Japan concealed beneath the Kanto Plain - integrated approach of surface and subsurface geology-. Jour. Geol. Soc. Japan 112 (1): Special Issue: 1–103. (In Japanese with English abstract)

Takahashi, M. 2006. Tectonic boundary between Northeast and Southwest Japan Arcs during Japan Sea opening. Jour. Geol. Soc. Japan 112 (1): 14–32. (In Japanese with English abstract)

Takahashi, M. 2008. Choshi area. *In* Geol. Soc. Japan, ed., Regional Geology 3, Kanto Region, pp. 193–196. Asakura Shoten, Tokyo. (English translation from the original written in Japanese)

Takahashi, M., I. Sudo, J. Ohki and Y. Yanagisawa. 2003. Chronostratigraphy of the Miocene Series in the Choshi area, Chiba Prefecture, central Japan. Jour. Geol. Soc. Japan 109 (6): 345–360. (In Japanese with English abstract)

Takahashi, N. 1990. Geology of the Pre-Cretaceous Atagoyama Group in the Choshi Peninsula, Chiba Prefecture, Japan–Description of the lithofacies and discussion of sedimentary and tectonic processes–. Jour. Natu. Hist. Mus. Inst. Chiba (1): 1–13. (In Japanese with English abstract)

Takami, M., R. Takemura, Y. Nishimura and T. Kojima. 1999. Reconstruction of oceanic plate stratigraphies and unit division of Jurassic-Early Cretaceous accretionary complexes in the Okinawa Islands, central Ryukyu Island Arc. Jour. Geol. Soc. Japan 105 (12): 866–880. (In Japanese with English abstract)

Takemura, A. 1986. Classification of Jurassic nassellarians (Radiolaria). Palaeontographica 195 (1-3): 29–74.

Tazawa, J. and Y. Hasegawa. 2007. Permian fusulinoideans from the Atagoyama Formation of Choshi, Chiba Prefecture, central Japan, and their tectonic significance. Jour. Geol. Soc. Japan 113 (8): 406–416. (In Japanese with English abstract)

Wang, Y. J., H. Luo and Q. Yang. (eds) 2012. Late

Paleozoic Radiolarians in the Qinfang area, Southeast Guangxi. China University Science Technical Press, Hefei, 127pp. (In Chinese with English taxonomic descriptions)
Yamane, S. 1924. Explanatory text of the Geologic map of Japan, Choshi, Zone 24, Col. III, Sheet 110, Scale 1:75,000. Geol. Surv. Japan 43+4 p. (In Japanese with English abstract)
Yamashita, M. and H. Ishiga. 1990. Correlation between the radiolarian and the fusulinacean biostratigraphy of the upper Middle Permian in Atetsu Plateau, Okayama Prefecture, Southwest Japan. Jour. Geol. Soc. Japan 96 (8): 687–689. (In Japanese with English abstract)
Yao, A. 1979. Radiolarian fauna from the Mino Belt in the Northern part of the Inuyama area, central Japan Part II: Nassellaria 1. Jour. Geosci, Osaka City Univ. 22: 21–72.
Yoshida, H. and M. Murata. 1985. Permian radiolarian biostratigraphy from the north-eastern part of Saiki City, Oita Prefecture, Japan. Jour. Geol. Soc. Japan 91 (8): 525–533. (In Japanese with English abstract)
Zhang, L., T. Ito, Q. Feng, M. Caridroit and T. Danelian. 2014. Phylogenetic model of *Follicucullus* lineages (Albaillellaria, Radiolaria) based on high-resolution biostratigraphy of the Permian Bancheng Formation, Guangxi, South China. Jour. Micropaleont. 33 (2): 179–192.

下部白亜系銚子層群のチャート礫から産出した中古生代放散虫化石

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本研究の目的は，関東地方の下部白亜系（Barremian-Aptian）の銚子層群中に挟在される，含放散虫の礫岩の研究である．礫岩層中の2試料のチャート礫から得られた放散虫化石群集は，それぞれペルム紀中世Guadalupianとジュラ紀中世Bathonian後期～ Callovian前期を示す．放散虫化石を含むチャート礫の起源は，恐らくはジュラ紀新世付加体と判断できる．