Bulletin of the Geological Survey of Japan, vol. 67 (3), p. 81-100 , 2016

Report

Jurassic radiolarians from the Ichinohe–Kunohe area (Iwate Prefecture) in the North Kitakami Belt, Japan

Satoshi Nakae[1,*]

Satoshi Nakae (2016) Jurassic radiolarians from the Ichinohe–Kunohe area (Iwate Prefecture) in the North Kitakami Belt, Japan. *Bull. Geol. Surv. Japan*, vol. 67 (3), p. 81–100, 4 figs, 2 tables, 3 plates.

Abstract: The North Kitakami Belt in Northeast Japan, occupying a northeastern region of Iwate Prefecture, is chiefly underlain by a sedimentary complex consisting of various rock-types such as basalt, limestone, chert, mudstone and sandstone. These rocks in the studied Ichinohe–Kunohe area in the North Kitakami Belt were explored for their radiolarian content and seven mudstone samples yielded poorly-preserved radiolarian faunas with a dominance of Nassellaria over Spumellaria, as a result. The description and faunal analysis of these radiolarians revealed that the mudstone in this area indicates a long range in age from the Toarcian to the Kimmeridgian.

Keywords: radiolaria, Jurassic, North Kitakami Belt, Ichinohe, Kunohe, Karumai, Iwate Prefecture, Japan

1. Introduction

The North Kitakami Belt in Northeast Japan, subdivided into the Akka–Tanohata and the Kuzumaki–Kamaishi subbelts, is widely underlain by a sedimentary complex. In general, this complex consists of a matrix of middle to late Jurassic terrigenous clastic rock, and fragments of Carboniferous to Permian basalt and limestone of seamount origin and Carboniferous to middle Jurassic pelagic chert (Okami and Ehiro, 1988; Minoura, 1990; Ehiro *et al*., 2008). Due to a spate of reports on Aalenian to Tithonian radiolarian fossils from mudstone (Matsuoka, 1987; Matsuoka and Oji, 1990; Yoshihara *et al*., 2002; Nakae and Kamada, 2003), it has been thought that the complex in the North Kitakami Belt formed along the subduction zone during the middle to late Jurassic Period. These reported fossil localities are distributed widely in this belt, but sparsely. For this reason, more fossil evidence is required to constrain detailed ages of the complex in this belt.

2. Geological setting

The studied Ichinohe–Kunohe area is located at a northeastern region of Iwate Prefecture and includes the boundary fault (Iwaizumi Tectonic Line or Seki–Ôdaita fault) between the two subbelts (Akka–Tanohata and Kuzumaki–Kamaishi) of the NNW–SSE trending North Kitakami Belt (Fig. 1a). According to previous works (Okami and Murata, 1974; Sugimoto, 1974), the sedimentary complex around this area has stratigraphically been divided into the Sawayamagawa, Akka, Takayashiki, Seki, Kassenba, Ôtori and Kuzumaki formations, arranging in ascending order. And it is also intruded by Cretaceous granitic rocks and unconformably overlain by Neogene volcano-sedimentary sequences and Quaternary terrace deposits (Kamada *et al*., 1991). Most recently, Takahashi *et al*. (2016) re-examined and revised the Sugimoto's division on the basis of the genesis relations of lithology such as a basalt-limestone complex of seamount origin (Akka unit), a mélange complex (Takayashiki unit), and oceanic plate stratigraphic successions (Seki and Otori units). In this report, nevertheless, the classic stratigraphic division of the sedimentary complex by Sugimoto (1974) is adopted (Fig. 1b), and three formations of this complex are focused on in terms of the radiolarian age determination.

The Seki and overlying Kassenba formations demonstrate a unique sequence commonly called "Oceanic Plate Stratigraphy" (Isozaki *et al*., 1990), which generally consists of basalt of seamount origin, pelagic chert and clastic sedimentary rock such as mudstone and sandstone with minor amounts of siliceous mudstone and felsic tuff. The major difference between the two formations is a quantity of coarse-grained clastic rock; sandstone is rich in the Kassenba Formation whereas lack in the Seki Formation. On the other hand, the Kuzumaki Formation is characterized by the mixed nature of various lithologies; blocks of basalt, limestone, chert, siliceous mudstone and sandstone are enveloped within foliated or sheared mudstone matrix.

[1] AIST, Geological Survey of Japan, Research Institute of Geology and Geoinformation

*Corresponding author: S.Nakae,Central 7,1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan. Email: nakae-satoshi@aist.go.jp

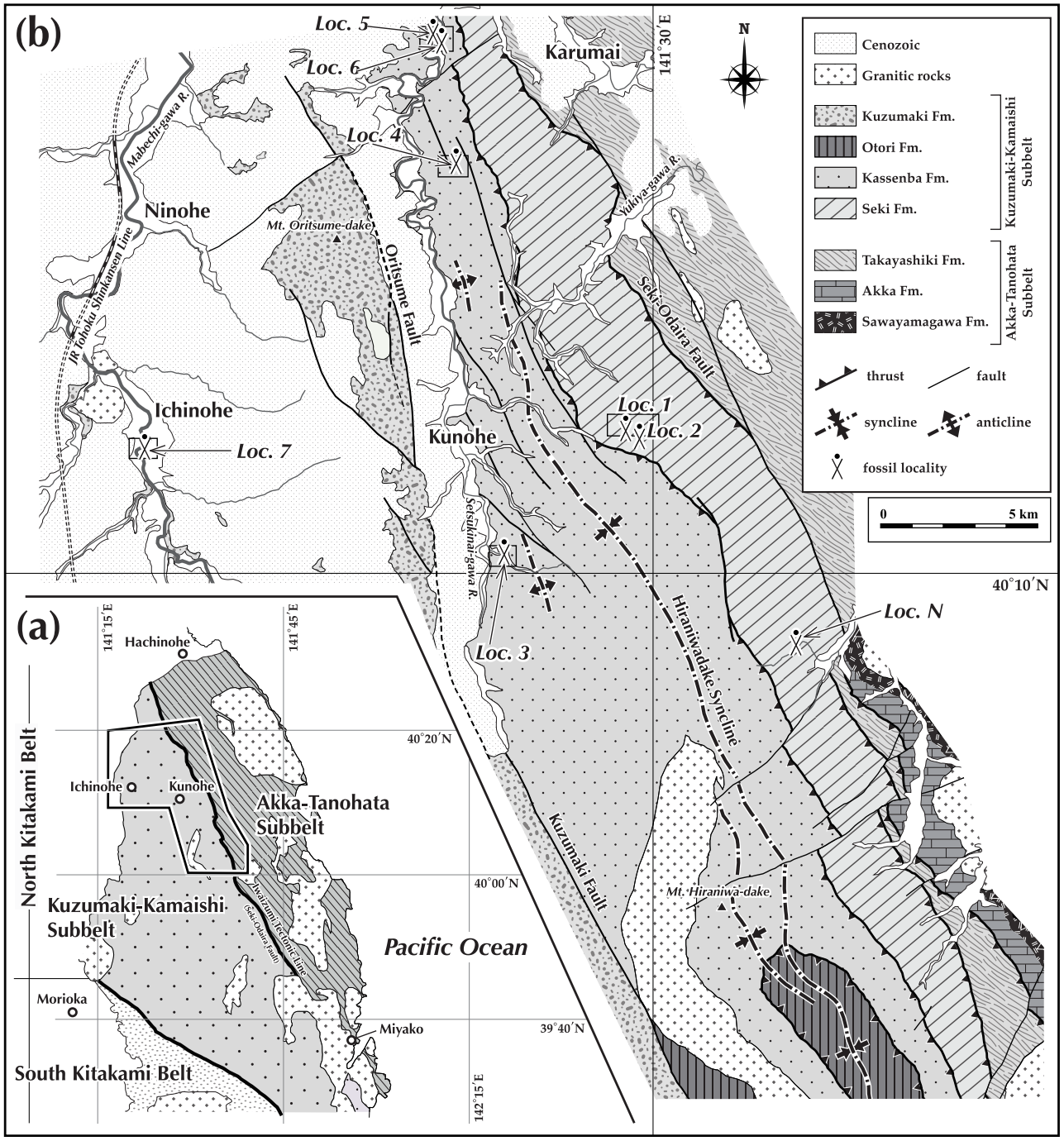

Fig. 1 Geological map of the Ichinohe–Kunohe area in the North Kitakami Belt.
(a) The North Kitakami Belt is located along the Pacific Ocean side of Northeast Japan, and is divided into the Akka–Tanohata and Kuzumaki–Kamaishi subbelts. The Ichinohe–Kunohe area (Iwate Prefecture) is situated in a northern part of the North Kitakami Belt. (b) A simplified geological map of the Ichinohe–Kunohe area. Loc. N is the radiolarian locality reported by Nakae and Kamada (2003). Detailed radiolarian localities with symbols are given in Fig. 2.

3. Materials and method

This study is concerned with an analysis of several radiolarian faunal recovered from rock samples including five siliceous mudstones and two mudstones within the Ichinohe–Kunohe area in the North Kitakami Belt. The samples were undertaken using an usual technique for radiolarian extraction; briefly, the rock samples were individually soaked in dilute hydrofluoric acid (HF) solution (5%) for 10 to 15 hours, before being washed through a 62 μm mesh sieve (235#). As a result, age-diagnostic, but poorly-preserved, radiolarians representative of middle to late Jurassic Period were recovered. The residues of each processed sample were then examined under a stereomicroscope, and radiolarian remains were selected for examination by scanning electronic microscope (SEM).

4. Locality description and samples

Radiolarian localities (Locs. 1–7) are shown in Figs. 1b and 2. Massive and bedded siliceous mudstones of the Seki Formation are respectively exposed at Locs. 1 and 2 (Fig. 2a; Fig. 3a, b), and slightly better preserved radiolarian remains are visible in thin sections (Fig. 4a, b). Locs. 3, 4, 5 and 6 are included in the Kassenba Formation (Fig. 2b, c, d). Bedded siliceous mudstones are exposed at Loc. 3 (Fig. 3c), Loc. 5 (Fig. 3e) and Loc. 6, whereas slaty mudstone is distributed at Loc. 4 (Fig. 3d), and radiolarian remains are also recognized in thin sections (Fig. 4c, d, e). The outcrop at Loc. 7 (Fig. 2e) belonging to the Kuzumaki Formation is composed of mudstone which is partially foliated and intercalated with sandy broken beds (Fig. 3f). Radiolarian remains in this rock sample (Fig. 4f) are not so dominant in comparison with the others.

5. Radiolarian fauna

Identified species detected from the rock samples are listed in Table 1 and given on Plates 1, 2 and 3. Below is a description of a radiolarian fauna of each locality.

(1) Locality 1 (Fig. 2a)
Location: Southeast of Koyukiya, Kunohe Village.
(lat. 40°12′39.0″ N; long. 141°29′19.6″ E)
Sample number: ICH 07-02.
Horizon: Seki Formation.
Lithology: Pale to dark gray, massive, siliceous mudstone.
Fauna: *Striatojaponocapsa plicarum* (Yao), *Striatojaponocapsa* sp. cf. *S. plicarum* (Yao), *Striatojaponocapsa* sp. cf. *S. synconexa* O'Dogherty, Goricăn and Dumitrică, *Theocapsomella* sp. cf. *T. costata* (Chiari, Marcucci and Prela), *Natoba* (?) sp., *Eucyrtidiellum* sp. cf. *E. pustulatum* Baumgartner, *Eucyrtidiellum* sp. cf. *E. unumaense* (Yao), *Guexella* (?) spp., *Transhsuum* sp. cf. *T. maxwelli* gr. (Pessagno), *Archaeodictyomitra* sp., *Spongocapsula krahsteinensis* Suzuki and Gawlick, *Parvicingula cappa* Cortese, *Tethysetta* spp., *Lantus* sp. (Plate 1).
Age: Early–middle Bathonian.

(2) Locality 2 (Fig. 2a)
Location: Southeast of Koyukiya, Kunohe Village.
(lat. 40°12′36.3″ N; long. 141°29′33.3″ E)
Sample number: ICH 07-03.
Horizon: Seki Formation.
Lithology: Pale gray, weakly bedded, siliceous mudstone.
Fauna: *Williriedellum* sp., *Zhamoidellum* spp., *Hiscocapsa* spp., *Theocapsomella* (?) sp., *Eucyrtidiellum* sp. cf. *E. pustulatum* Baumgartner, *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo), *Eucyrtidiellum nodosum* Wakita, *Eucyrtidiellum* spp., *Stichomitra* (?) sp., *Transhsuum brevicostatum* gr. (Ožvoldová), *Transhsuum* sp. cf. *T. brevicostatum* gr. (Ožvoldová), *Transhsuum maxwelli* gr. (Pessagno), *Archaeodictyomitra prisca* Kozur and Mostler, *Archaeodictyomitra whalenae* Kozur and Mostler, *Archaeodictyomitra* sp. cf. *A. apiarium* (Rüst), *Archaeodictyomitra* spp., *Cinguloturris* (?) spp., *Tethysetta* sp. cf. *T. mashitaensis* (Mizutani), *Triversus* (?) sp. (Plate 2).
Age: Middle Bathonian–late Kimmeridgian, probably early Kimmeridgian.

(3) Locality 3 (Fig. 2b)
Location: Shimo-sawanai, Kunohe Village.
(lat. 40°10′32.0″ N; long. 141°26′19.3″ E)
Sample number: ICH 01-05.
Horizon: Kassenba Formation.
Lithology: Light gray, bedded, siliceous mudstone.
Fauna: *Guexella* (?) sp., Nassellaria gen. et sp. indet. (Plate 3)
Age: Probably late Bajocian–early Oxfordian.

(4) Locality 4 (Fig. 2c)
Location: East of Araida, Karumai Town.
(lat. 40°17′35.9″ N; long. 141°25′13.7″ E)
Sample number: ICH 21-03.
Horizon: Kassenba Formation.
Lithology: Gray, slaty mudstone.
Fauna: *Williriedellum* (?) sp., *Zhamoidellum* (?) sp., *Eucyrtidiellum* spp., *Transhsuum* (?) sp., Nassellaria gen. et sp. indet. (Plate 3).
Age: Probably late Aalenian–late Kimmeridgian.

(5) Locality 5 (Fig. 2d)
Location: Hayato, Karumai Town.
(lat. 40°19′35.4″ N; long. 141°24′50.0″ E)
Sample number: ICH 23-03.
Horizon: Kassenba Formation.
Lithology: Light gray, bedded, siliceous mudstone.
Fauna: Nassellaria gen. et sp. indet. (Plate 3).
Age: Unknown.

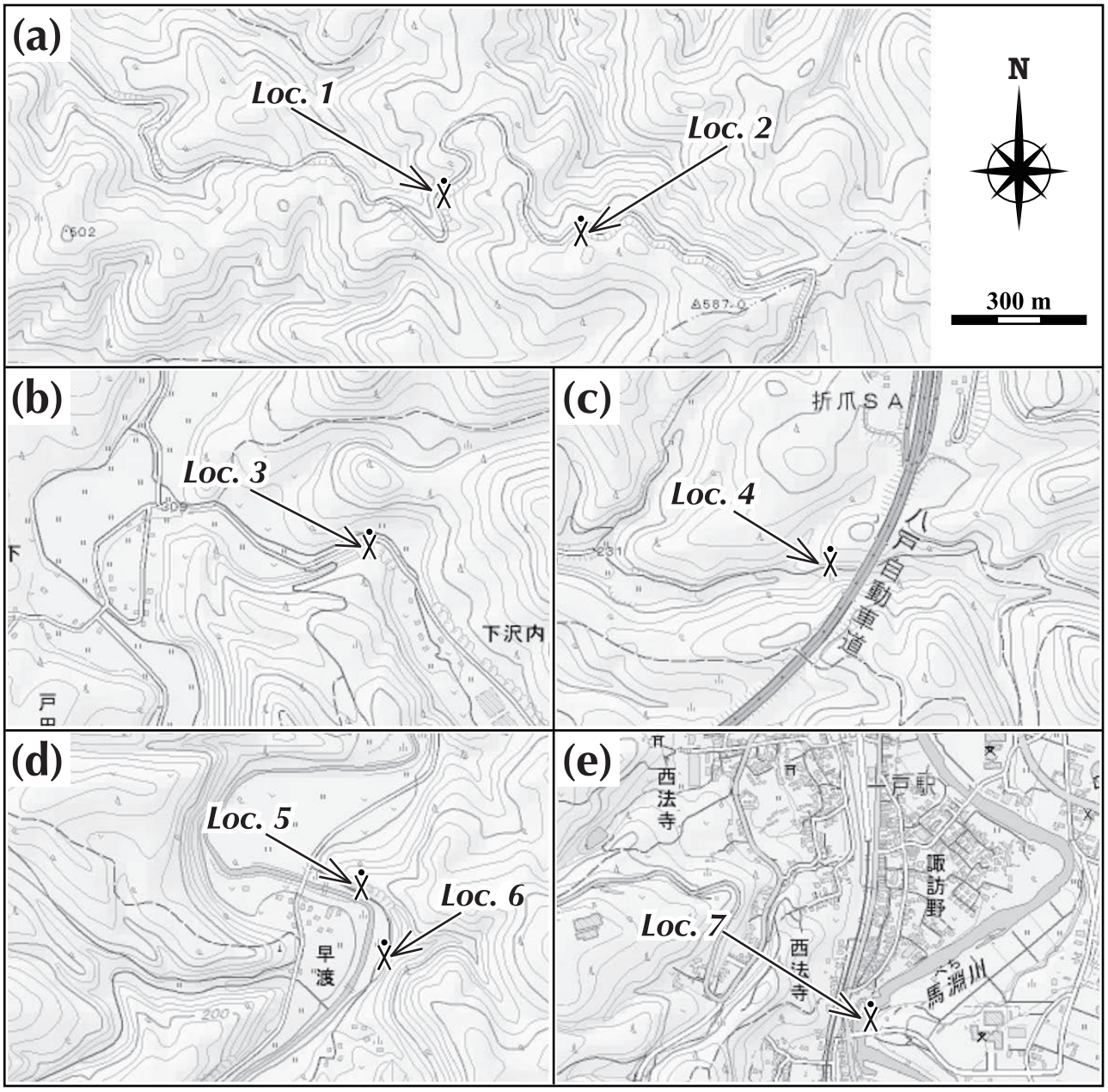

Fig. 2 Localities of mudstone samples yielding Jurassic radiolarians.
Topographic maps are downloaded from the website of Geospatial Information Authority of Japan. URL of each map is as follows; (a) http://maps.gsi.go.jp/#16/40.209835/141.494669/& base=std&ls=std&disp=1&vs=c1j0l0u0f0, (b) http://maps.gsi.go.jp/#16/40.175414/141.438514/&base=std&ls=std&disp=1&vs=c1j0l0u0f0, (c) http://maps.gsi.go.jp/#16/40.293578/141.418236/&base=std&ls=std&disp=1&vs=c1j0l0u0f0, (d) http://maps.gsi.go.jp/#16/40.325952/ 141.413087/&base=std&ls=std&disp=1&vs=c1j0l0u0f0, and (e) http://maps.gsi.go.jp/#16/40.207500/141.297623/&base=std&ls=std&disp=1&vs=c1j0l0u0f0

(6) Locality 6 (Fig. 2d)
Location: Hayato, Karumai Town.
(lat. 40°19′31.3″ N; long. 141°24′50.6″ E)
Sample number: ICH 23-04.
Horizon: Kassenba Formation.
Lithology: Light gray, bedded, siliceous mudstone.
Fauna: Angulobracchiidae gen. et sp. indet. (Plate 3).
Age: Unknown.

(7) Locality 7 (Fig. 2e)
Location: Suwano, Ichinohe Town.
(lat. 40°12′18.5″ N; long. 141°17′51.1″ E)
Sample number: ICH 56-01.
Horizon: Kuzumaki Formation.
Lithology: Dark gray, mudstone.
Fauna: *Eucyrtidiellum* (?) sp., *Unuma* (?) sp., Nassellaria gen. et sp. indet. (Plate 3).

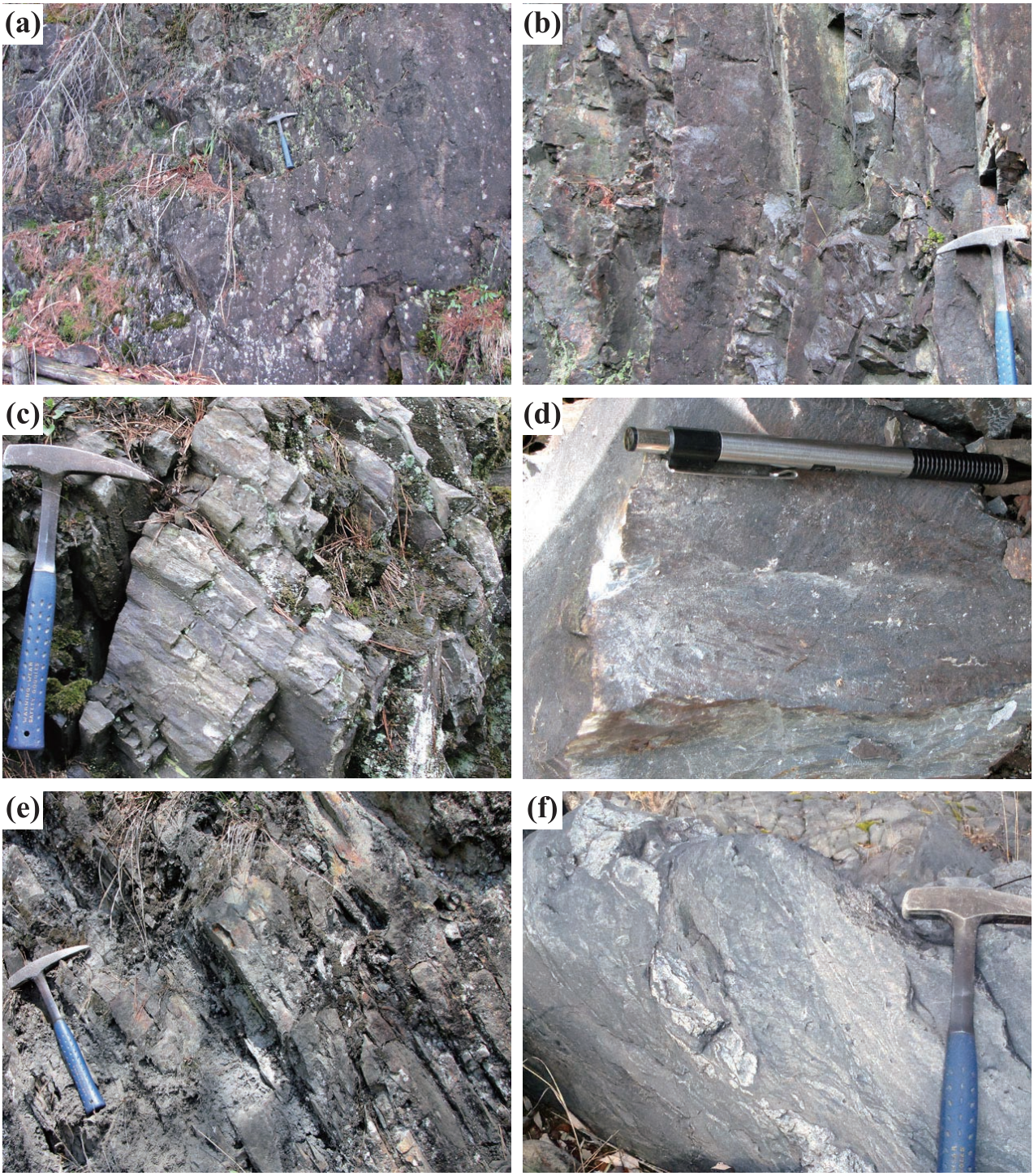

Fig. 3 Mudstone outcrops at radiolarian localities.
(a)–(b) Siliceous mudstone of the Seki Formation, southeast of Koyukiya (a: Locality 1, b: Locality 2). (c) Siliceous mudstone of the Kassenba Formation, at Shimo-sawanai (Locality 3). (d) Mudstone of the Kassenba Formation, east of Araida (Locality 4). (e) Siliceous mudstone of the Kassenba Formation at Hayato (Locality 5). (f) Mudstone of the Kuzumaki Formation at Suwano (Locality 7).

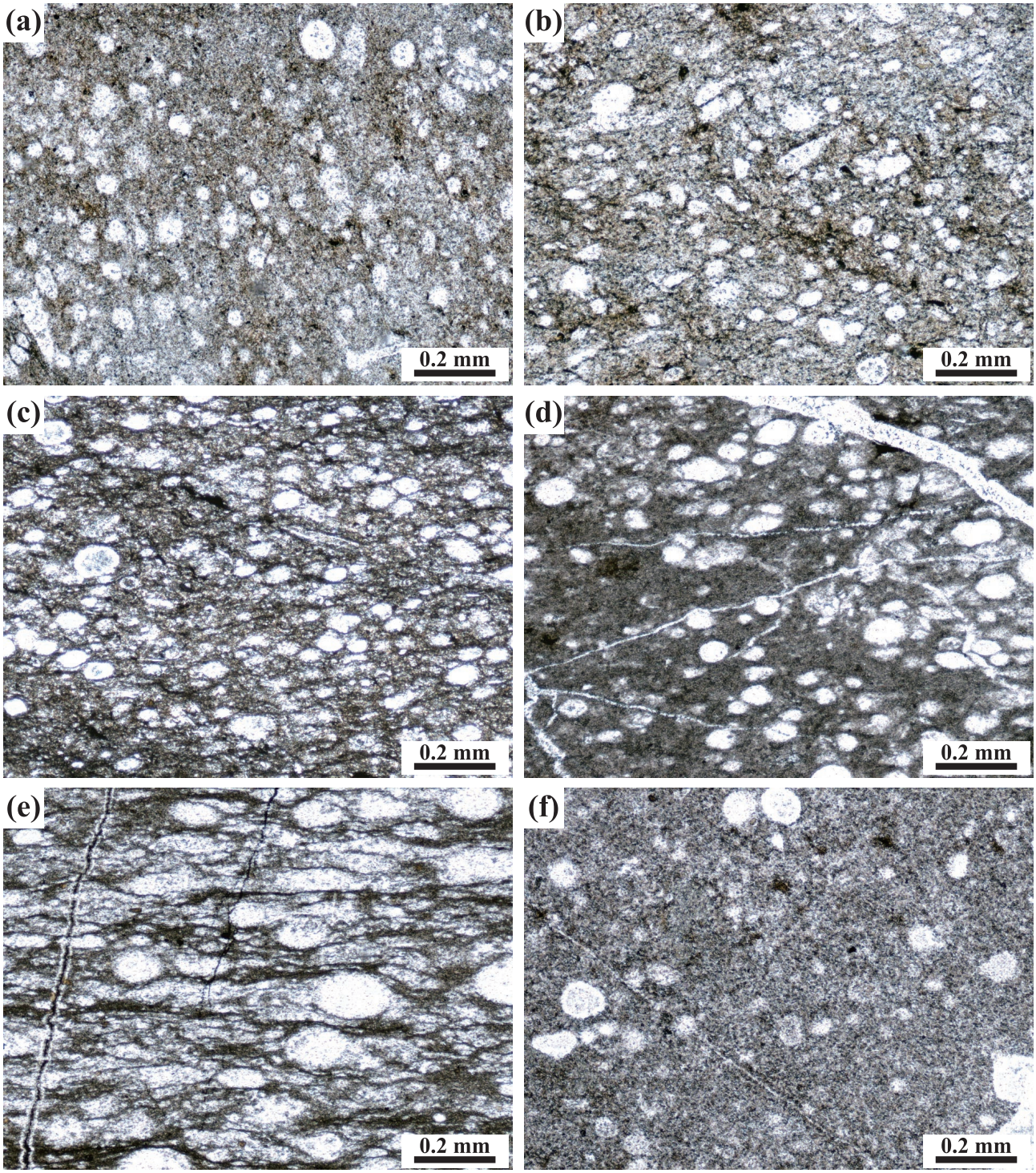

Fig. 4 Microphotographs of the thin sections.
(a)–(b) Siliceous mudstone of the Seki Formation (a: Locality 1, b: Locality 2). (c) Mudstone of the Kassenba Formation (c: Locality 4). (d)–(e) Siliceous mudstone of the Kassenba Formation (d: Locality 5, e: Locality 6). (f) Mudstone of the Kuzumaki Formation (Locality 7). Under the microscope, all these mudstones are dotted with radiolarian remains which are white in color and oval or triangular in shape.

Table 1 List of radiolarian species detected from the Ichinohe–Kunohe area in the North Kitakami Belt.

Locality Number (Loc.)	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Sample Number	**ICH 07–02**	**ICH 07-03**	**ICH 01-05**	**ICH 21-03**	**ICH 23-03**	**ICH 23-04**	**ICH 56-01**
Horizon (Formation)	**Seki**		**Kassenba**				**Kz**
Williriedellum sp.		+					
Williriedellum (?) sp.				+			
Zhamoidellum spp.		+					
Zhamoidellum (?) sp.				+			
Hiscocapsa spp.		+					
Striatojaponocapsa plicarum (Yao)	+						
Striatojaponocapsa sp. cf. *S. plicarum* (Yao)	+						
Striatojaponocapsa sp. cf. *S. synconexa* O'Dogherty, Goričan and Dumitrică	+						
Theocapsomella sp. cf. *T. costata* (Chiari, Marcucci and Prela)	+						
Theocapsomella (?) sp.		+					
Natoba (?) sp.	+						
Eucyrtidiellum sp. cf. *E. pustulatum* Baumgartner	+	+					
Eucyrtidiellum sp. cf. *E. unumaense* (Yao)	+						
Eucyrtidiellum ptyctum (Riedel and Sanfilippo)		+					
Eucyrtidiellum nodosum Wakita		+					
Eucyrtidiellum spp.		+		+			
Eucyrtidiellum (?) sp.							+
Guexella (?) spp.	+		+				
Stichomitra (?) sp.		+					
Transhsuum brevicostatum gr. (Ožvoldová)		+					
Transhsuum sp. cf. *T. brevicostatum* gr. (Ožvoldová)		+					
Transhsuum maxwelli gr. (Pessagno)		+					
Transhsuum sp. cf. *T. maxwelli* gr. (Pessagno)	+						
Transhsuum (?) sp.				+			
Archaeodictyomitra prisca Kozur and Mostler		+					
Archaeodictyomitra whalenae Kozur and Mostler		+					
Archaeodictyomitra sp. cf. *A. apiarium* (Rüst)		+					
Archaeodictyomitra spp.	+	+					
Unuma (?) sp.							+
Spongocapsula krahsteinensis Suzuki and Gawlick	+						
Cinguloturris (?) spp.		+					
Parvicingula cappa Cortese	+						
Tethysetta sp. cf. *T. mashitaensis* (Mizutani)		+					
Tethysetta spp.	+						
Triversus (?) sp.		+					
Lantus sp.	+						
Angulobracchiidae gen. et sp. indet.						+	
Nassellaria gen. et sp. indet.			+	+	+		+

Kz: Kuzumaki

Age: Probably early Toarcian–late Bathonian.

6. Age assignment discussion

In order to determine the age of the radiolarian faunas extracted from the mudstone samples in the Ichinohe–Kunohe area, the zonation schemes proposed by Baumgartner *et al*. (1995) and Matsuoka (1995a) for the middle to late Jurassic Period are primarily applicable; Unitary Association Zone (UAZone) assignments of Baumgartner *et al*. (1995) are adopted for the biostratigraphic ranges of the extracted radiolarian species, and further the ranges of radiolarian genera that were recently extensively analyzed by O'Dogherty *et al*. (2009) are used in this study (Table 2).

The above two zonations can be compared to each other (e.g., the base of UAZone 4 of Baumgartner *et al*. (1995) and JR4 (*Striatojaponocapsa plicarum* Zone) of Matsuoka (1995a) are defined by the first appearance biohorizone of the same species), but it is well known that a certain amount of difference in age has emerged between these zones. Therefore in this report, the ages of UAZones are recalculated on the basis of the dataset of Matsuoka (1995a).

(1) ICH07-02 (Loc. 1)

This siliceous mudstone sample of the Seki Formation yielded a radiolarian fauna (Plate 1), whose preservation is slightly better than the others. Among Nassellaria, *Striatojaponocapsa* and *Eucyrtidiellum* are the most abundant genera, and minor amounts of *Transhsuum*, *Archaeodictyomitra*, *Spongocapsula*, *Tethysetta* and others are also included. Most of these genera have a wide biostratigraphic range from Pliensbachian to Tithonian or to much younger stage (Table 2; O'Dogherty *et al*., 2009).

According to Baumgartner *et al*. (1995), the occurrence of *Striatojaponocapsa plicarum* in this sample allows its assignment to UAZones 4–5, which corresponds to JR4–JR5 (*Striatojaponocapsa plicarum* Zone and *Striatojaponocapsa* conexa Zone: lower Bajocian to lower Callovian) of Matsuoka (1995a). On the other hand, Matsuoka and Yao (1986) defined the base of JR4 (*Tricolocapsa plicarum* Zone) of Matsuoka (1983) by the first appearance biohorizon (FAB) of *Striatojaponocapsa plicarum*. Later Matsuoka (1995b) also mentioned that this FAB should be set between UAZone 3 and UAZone 4, being correlated to the Aalenian/Bajocian boundary.

Several specimens being quite similar to *Striatojaponocapsa synconexa* were detected from this sample. O'Dogherty *et al*. (2005) discussed on the range of *Striatojaponocapsa synconexa* based on the recalculation by Savary and Guex (1999), and summarized that its FAB is situated just above the last appearance biohorizon (LAB) of *Striatojaponocapsa plicarum* and slightly below the FAB of *Striatojaponocapsa conex*a. This biohorizon (FAB of *Striatojaponocapsa synconexa*) therefore is settled within lower Bathonian. Furthermore, Hatakeda *et al*. (2007) revealed that the morphological change from *Striatojaponocapsa plicarum* to *Striatojaponocapsa conexa* through *Striatojaponocapsa synconexa* was continueously and gradually occurred during a relatively short range (lower–middle Bathonian) across the boundary between the *Striatojaponocapsa plicarum* and *Striatojaponocapsa conexa* Zones. On the basis of the co-existence of these two species, it is reasonable that this samples is assigned to lower to middle Bathonian.

Eucyrtidiellum sp. cf. *E. pustulatum*, *Eucyrtidiellum* sp. cf. *E. unumaense* and *Transhsuum* sp. cf. *T. maxwelli* gr. were also found in this sample. Although these species existed in a long range from UAZone 3 to UAZone 10, their co-occurrence can be restricted to UAZones 5–8 (middle Bathonian to lower Kimmeridgian). This age assignment is concordant to those determined by the co-occurrence of *Striatojaponocapsa plicarum* and *Striatojaponocapsa* sp. cf. *S. synconexa*.

(2) ICH07-03 (Loc. 2)

This sample of siliceous mudstone collected from the Seki Formation contains a relatively poorly-preserved radiolarian fauna whose diversity is slightly higher than the others (Plate 2). Within the fauna, *Eucyrtidiellum*, *Transhsuum* and *Archaeodictyomitra* are the most abundant genera, and minor amounts of *Williriedellum*, *Zhamoidellum*, *Hiscocapsa* and *Tethysetta* are also recognized. According to O'Dogherty *et al*. (2009), these genera existed together within a range from upper Bathonian to upper Kimmeridgian whereas each genus has a much wider range from Pliensbachian to middle Cretaceous (Table 2).

Among the obtained specimens, *Eucyrtidiellum ptyctum*, *Eucyrtidiellum nodosum*, *Transhsuum brevicostatum* gr., *Transhsuum maxwelli* gr., *Archaeodictyomitra prisca*, and *Archaeodictyomitra whalenae* are identified at a species level, and some of them are stated to display following biostratigraphic ranges (Baumgartner *et al*., 1995); *Eucyrtidiellum ptyctum* (UAZones 5–11), *Eucyrtidiellum nodosum* (UAZones 3–10), *Transhsuum brevicostatum* gr. (UAZones 3–11), and *Transhsuum maxwelli* gr. (UAZones 3–10), respectively. Based on this, the range of their co-occurrence is assigned to UAZones 5–10 (middle Bathonian–upper Kimmeridgian).

In addition to the above, *Eucyrtidiellum pustulatum* (UAZones 5–8), *Archaeodictyomitra apiarium* (UAZones 8–22) and *Tethysetta mashitaensis* (UAZones 8–15) were found in this sample, although there remains slightly doubtful whether these species can be definitely identified. This evidence provides a possible biostratigraphic range (UAZone 8: lower Kimmeridgian) to the co-occurrence of these species.

Consequently, a reasonable range of this fauna is probably restricted to lower Kimmeridgian, or at least middle Bathonian–upper Kimmeridgian.

Table 2 List of radiolarian genera and their biostratigraphic ranges from O'Dogherty *et al.* (2009).

Genus	Range
Williriedellum	upper Aalenian — lower Aptian
Zhamoidellum	lower Pliensbachian — upper Barremian
Hischocapsa	upper Bathonian — middle Albian
Striatojaponocapsa	lower Bajocian — upper Callovian
Theocapsomella	lower Bathonian — lower Berriasian
Natoba	lower Pliensbachian — lower Toarcian
Eucyrtidiellum	lower Pliensbachian — upper Tithonian
Guexella	upper Bajocian — lower Oxfordian
Transhsuum	lower Pliensbachian — upper Kimmeridgian
Archaeodictyomitra	lower Pliensbachian — upper Campanian
Unuma	lower Toarcian — upper Bathonian
Spongocapsula	upper Bajocian — lower Campanian
Cinguloturris	upper Bathonian — lower Valanginian
Parvicingula	upper Bathonian — upper Hauterivian
Tethysetta	lower Bajocian — lower Aptian
Triversus	upper Pliensbachian — upper Bathonian
Lantus	lower Pliensbachian — lower Kimmeridgian

(3) ICH01-05 (Loc. 3)

Only two radiolarian remains, which are poorly-preserved, were found in the sample of siliceous mudstone from the Kassenba Formation; one is *Guexella* (?) sp. and the other is an unidentified species of Nassellaria (Plate 3). Because of the rare radiolarian occurrence, it is quite difficult to determine the age of this fauna. The range of genus *Guexella* is stated as upper Bajocian–lower Oxfordian (Table 2); therefore this fauna is probably assigned to the similar age.

(4) ICH21-03 (Loc. 4)

Poorly-preserved radiolarians such as *Williriedellum* (?) sp., *Zhamoidellum* (?) sp., *Eucyrtidiellum* spp. and *Transhsuum* (?) sp. were yielded from slaty mudstone of the Kassenba Formation (Plate 3). It is quite difficult to constrain the age of this poorly-preserved fauna, but the fauna probably ranges from upper Aalenian to upper Kimmeridgian (Table 2).

(5) ICH23-03 (Loc. 5) and ICH23-04 (Loc. 6)

No age-diagnostic species has been found in two siliceous mudstone samples of the Kassenba Formation (Plate 3). Hence, the age of each sample is unknown.

(6) ICH56-01 (Loc. 7)

It is the only sample which was derived from mudstone of the Kuzumaki Formation and yielded highly damaged radiolarian remains. Among them, it seems that *Eucyrtidiellum* (?) sp. and *Unuma* (?) sp. may be identifiable at a genus level (Plate 3). If this identification is reasonable, the sample can probably be correlated to lower Toarcian to upper Bathonian. As the above, this age assignment is controversial.

7. Conclusion

The main conclusions of this study concern the age assignment of seven rock samples in the Ichinohe–Kunohe area, the North Kitakami Belt. Two siliceous mudstone samples of the Seki Formation are relatively accurately assigned as early–middle Bathonian and early Kimmeridgian in age, respectively. On the Kassenba Formation, three siliceous mudstone and one slaty mudstone samples were collected, but their ages can not be restricted precisely; providing late Bajocian–early Oxfordian to the siliceous mudstone and late Aalenian–late Kimmeridgian to the slaty mudstone. On the other hand, the Kuzumaki Formation is probably assigned to early Toarcian–late Bathonian in age.

8. Systematic Paleontology

Descriptions of the radiolarian species examined in this study mainly employed the taxonomic classification of De Wever *et al*. (2001) and O'Dogherty *et al*. (2009).

Subclass **RADIOLARIA** Müller 1858
Order **NASSELLARIA** Ehrenberg 1875

Family **WILLIRIEDELLIDAE** Dumitrică 1970

Genus ***Williriedellum*** Dumitrică 1970

***Williriedellum* sp**.
(Plate 2, fig. 1)
Remarks: This specimen is identical with genus *Williriedellum* based on the outline of its shell and having three segments; cephalis is small, thorax is slightly depressed into abdomen, and abdomen is large and globose. An apertural tube, which is not clearly found, is recognized at the end of the abdomen. But, cylindrical pores on the abdominal surface are obscure.

***Williriedellum* (?) sp.**
(Plate 3, fig. 3)

Genus ***Zhamoidellum*** Dumitrică 1970

***Zhamoidellum* spp.**
(Plate 2, figs. 2–3)
Remarks: The obtained specimens are composed of three segments. Cephalis is small. Thorax is partly encased in large and globose abdomen. Hexagonal pore frames are visible on the abdominal surface.

***Zhamoidellum* (?) sp.**
(Plate 3, fig. 4)

Genus ***Hiscocapsa*** O'Dogherty 1994

***Hiscocapsa* spp.**

(Plate 2, figs. 4–5)
Remarks: Test of the obtained specimens is composed of four segments. Small cephalis, thorax and abdomen form together a narrow conical portion. Fourth segment is large and inflated in shape, possessing a constricted aperture. Ornamentation (pores or spines) on the test surface is not clearly recognized due to poorly-preservation.

Genus ***Striatojaponocapsa*** Kozur 1984

O'Dogherty *et al*. (2005) restricted the generic name *Striatojaponocapsa* to the phylogenetic lineage *S. tegiminis* (Matsuoka) – *S. plicarum* (Yao) – *S. synconexa* O'Dogherty *et al*. – *S. conexa* (Matsuoka) – *S. lacrimalis* (Matsuoka). Some species belonging to this lineage are differentiated by ornamentation on surface of their tests; *S. synconexa* O'Dogherty *et al*. differs from *S. plicarum* (Yao) by the presence of a porous depression, and from *S. conexa* (Matsuoka) by lack of transversal ridges between plicae.

Striatojaponocapsa plicarum (Yao) 1979
(Plate 1, fig. 1)
1979 *Tricolocapsa plicarum* n. sp. – Yao, p. 32–33, plate 4, figs. 1–11.
1982 *Tricolocapsa plicarum* Yao – Sashida *et al*., plate 2, fig. 1.
1982 *Tricolocapsa plicarum* Yao – Kido *et al*., plate 5, fig. 1.
1983 *Tricolocapsa plicarum* Yao – Matsuoka, p. 20, plate 3, fig. 1.
1984 *Tricolocapsa plicarum* Yao – Baumgartner, p. 790, plate 10, fig. 6.
1984 *Striatojaponocapsa plicarum* (Yao) – Kozur, plate 7, fig. 3.
1995 *Tricolocapsa plicarum plicarum* Yao – Baumgartner *et al*., p. 598–599, plate 4053, figs. 1–3.
1997 *Striatojaponocapsa plicarum plicarum* (Yao) – Hull, p. 168. plate 37, figs. 6, 9.
Remarks: Although this specimen is not well-preserved, it is identical with *Striatojaponocapsa plicarum* (Yao) by possessing a dish-like basal appendage and longitudinal plicae on its surface.
Range: UAZones 4–5 (Baumgartner *et al*., 1995; Savary and Guex, 1999), corresponding to lower Bajocian–lower Callovian (Matsuoka, 1995b).

Striatojaponocapsa* sp. cf. *S. plicarum (Yao) 1979
(Plate 1, fig. 2)
Remarks: This specimen is incomplete and questionably assigned to *Striatojaponocapsa plicarum* (Yao), because its longitudinal plicae on the surface are faintly recognized.

Striatojaponocapsa* sp. cf. *S. synconexa O'Dogherty, Goričan and Dumitrică in O'Dogherty, Markus, Goričan, Dumitrică and Masson 2005
(Plate 1, figs. 3–7)
Remarks: *Striatojaponocapsa synconexa* O'Dogherty *et al*. is synonymous with *Tricolocapsa plicarum* ssp. A which has been defined by Baumgartner *et al*. (1995). This species is quite similar to *Striatojaponocapsa conexa* (Matsuoka) by presence of longitudinal plicae and a circular depression at its basal part, but slightly different from *Striatojaponocapsa conexa* (Matsuoka) by lacking transversal ridges between plicae. Poorly-preserved specimens were found in the present material and are characterized by a circular depression. However, presence of the transversal ridges between plicae is obscure.

Family **DIACANTHOCAPSIDAE** O'Dogherty 1994

Genus ***Theocapsomella*** O'Dogherty, Goričan and Dumitrică in O'Dogherty, Markus, Goričan, Dumitrică and Masson 2005

According to the original definition by O'Dogherty *et al*. (2005), the test of *Theocapsomella* is composed of three segments; cephalis small, thorax much larger and inflated, abdomen subglobular and usually somewhat larger than thorax, and lumbar stricture between thorax and abdomen is well pronounced.

Theocapsomella* sp. cf. *T. costata (Chiari, Marcucci and Prela) 2002
(Plate 1, fig. 8)
Remarks: The obtained specimen is composed of three segments. Cephalis is small and hemispherical. Much larger thorax and abdomen, which are separated by a lumbar stricture, possess wide raised longitudinal ridges on their surface. Based on these characteristic features, this specimen resembles to *Theocapsomella costata* (Chiari, Marcucci and Prela), although rounded pores on the test surface are invisible due to poor-preservation.

***Theocapsomella* (?) sp.**
(Plate 2, fig. 6)

Family **EUCYRTIDIELLIDAE** Takemura 1986

Genus ***Natoba*** Pessagno and Poisson 1981

***Natoba* (?) sp.**
(Plate 1, fig. 9)

Genus ***Eucyrtidiellum*** Baumgartner 1984

Eucyrtidiellum* sp. cf. *E. pustulatum Baumgartner 1984
(Plate 1, fig. 11; Plate 2, fig. 7)
Remarks: The obtained specimens are poorly-preserved and composed of four segments. Large pores are recognized at the joint between the abdomen and fourth segment. It is similar to *Eucyrtidiellum pustulatum* Baumgartner or *Eucyrtidiellum dentatum* Baumgartner in outer shape.

However, *Eucyrtidiellum pustulatum* is more suitable for the obtained specimens than the latter by possessing an irregularly nodose abdomen. Each specimen lacks in a flat terrace and a sharp edge at the top of abdomen, which is a characteristic feature of *Eucyrtidiellum dentatum*.

Eucyrtidiellum* sp. cf. *E. unumaense (Yao) 1979
(Plate 1, figs. 12–14)
Remarks: *Eucyrtidiellum unumaense* (Yao) is composed of four segments. Its large and inflated hemispherical abdomen has smooth surface without pores. On the obtained specimens, any pronounced ornamentation (pores, plicae or pore frames) is invisible on the abdominal surface.

Eucyrtidiellum ptyctum (Riedel and Sanfilippo) 1974
(Plate 2, fig. 8)
1974 *Eucyrtidium ptyctum* n. sp. – Riedel and Sanfilippo, p. 778, plate 5, fig. 7; plate 12, fig. 14.
1977 *Eucyrtidium* (?) ptyctum Riedel and Sanfilippo – Pessagno, p. 94, plate 12, fig. 7.
1984 *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo) – Baumgartner, p. 764, plate 4, figs. 1–3.
1986 *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo) – Matsuoka, plate 2, fig. 10.
1987 *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo) – Aita, p. 65, plate 4, figs. 12a–b; plate 10, fig. 14; plate 14, fig. 3.
1990 *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo) – Nagai and Mizutani, p. 595, plate 3, figs. 5a–b.
Remarks: Plicae are faintly visible and arranged longitudinally on the inflated abdomen. These characters are recognized in *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo) and *Eucyrtidiellum pyramis* (Aita), but number of the plicae is different; 9 to 11 plicae in lateral view of *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo) and 5 to 6 plicae in lateral view of *Eucyrtidiellum pyramis* (Aita). 11 plicae are recognized in the examined specimen.
Range: UAZones 5–11 (Baumgartner *et al*., 1995), corresponding to middle Bathonian–late Tithonian (Matsuoka, 1995b).

Eucyrtidiellum nodosum Wakita 1988
(Plate 2, fig. 9)
1985 *Eucyrtidium* sp. – Baumgartner, fig. 38.m.
1986 *Eucyrtidium* sp. aff. *E. unumaense* (Yao) – Matsuoka, plate 2, fig. 9; plate 3, fig. 10.
1988 *Eucyrtidiellum nodosum* n. sp. – Wakita, p. 408, plate 4, fig. 29; plate 5, fig. 16.
1988 *Eucyrtidiellum nodosum* Wakita – Nagai, plate 1, fig. 5; plate 2, fig. 6.
Remarks: This examined specimen is poorly-preserved, but ornamentation consisting of small noses is remained on abdominal surface.
Range: UAZones 3–10 (Baumgartner *et al*., 1995), corresponding to late Aalenian–late Kimmeridgian (Matsuoka, 1995b).

***Eucyrtidiellum* spp.**
(Plate 2, figs. 10–11; Plate 3, figs. 5–6)

***Eucyrtidiellum* (?) sp.**
(Plate 3, fig. 20)

Family **EUCYRTIDIIDAE** Ehrenberg 1847

Genus ***Guexella*** Baumgartner 1984

***Guexella* (?) spp.**
(Plate 1, figs. 15–17; Plate 3, fig. 2)

Genus ***Stichomitra*** Cayeux 1897

***Stichomitra* (?) sp.**
(Plate 2, fig. 27)

Family **HSUIDAE** Pessagno and Whalen 1982

Genus ***Transhsuum*** Takemura 1986

***Transhsuum brevicostatum* gr.** (Ožvoldová) 1975
(Plate 2, figs. 12–13)
1975 *Lithostrobus brevicostatus* – Ožvoldová, p. 617, fig. 12j.
1981 *Hsuum brevicostatum* (Ožvoldová) – Kocher, p. 73, plate 14, fig. 3.
1984 *Hsuum brevicostatum* (Ožvoldová) – Baumgartner, p. 769, plate 5, figs. 1–2.
1993 *Hsuum brevicostatum* (Ožvoldová) – Pessagno *et al*., p. 136, plate 6, figs. 3, 4, 21, 23.
Remarks: Tests of the obtained specimens are composed of 11 segments, regularly broadening distally. Each segment after fourth one is characterized by discontinuous longitudinal costae. Two rows of pore are faintly recognized between adjacent costae.
Range: UAZones 3–11 (Baumgartner *et al*., 1995), corresponding to late Aalenian–late Tithonian (Matsuoka, 1995b).

***Transhsuum* sp. cf. *T. brevicostatum* gr.** (Ožvoldová) 1975
(Plate 2, fig. 14)
Remarks: General shape of the obtained specimen is similar to *Transhsuum brevicostatum*, but its detailed ornamentation is not clear.

***Transhsuum maxwelli* gr**. (Pessagno) 1977
(Plate 2, fig. 15)
1977 *Hsuum maxwelli* – Pessagno, p. 81, plate 7, figs. 14–16.
1981 *Hsuum maxwelli* Pessagno – Kocher, p. 73, plate 14, fig. 14.
1984 *Hsuum maxwelli* Pessagno – Pessagno *et al*., p. 25, plate 1, fig. 6.
1984 *Hsuum maxwelli* Pessagno gr. – Baumgartner, p.

769, plate 5, figs. 3–4.
1988 *Hsuum maxwelli* Pessagno gr. – Ožvoldová, plate 3, fig. 3 ; plate 6, fig. 10.

Remarks: The obtained specimen is composed of more than 10 segments, with distally diverging discontinuous costae. Two rows of pore frames are recognized between costae on at least upper segments.
Range: UAZones 3–10 (Baumgartner *et al*., 1995), corresponding to late Aalenian–late Kimmeridgian (Matsuoka, 1995b).

***Transhsuum* sp. cf. *T. maxwelli* gr.** (Pessagno) 1977
(Plate 1, fig. 18)
Remarks: The obtained specimen is a broken form of *Transhsuum*, and probably composed of more than 10 segments. This specimen is similar to *Transhsuum maxwelli* gr. in having the same feature of discontinuous costae.

***Transhsuum* (?) sp.**
(Plate 3, fig. 10)

Family **ARCHAEODICTYOMITRIDAE** Pessagno 1976

Genus ***Archaeodictyomitra*** Pessagno 1976

Archaeodictyomitra prisca Kozur and Mostler in Grill and Kozur 1986
(Plate 2, fig. 18)
1982 *Archaeodictyomitra* sp. A – Sashida *et al*., plate 2, fig. 9.
1986 *Archaeodictyomitra prisca* n. sp. – Kozur and Mostler in Grill and Kozur, p. 258–259, plate 8, figs. 3–6.
1998 *Archaeodictyomitra whalenae* Kozur and Mostler – Ožvoldová, plate IV, fig. 11.
2005 *Archaeodictyomitra prisca* Kozur and Mostler – O'Dogherty *et al*., p. 430, plate 1, figs. 4–5.

Remarks: The obtained specimen is identical with *Archaeodictyomitra prisca* Kozur and Mostler, which is characterized by slender test with indistinct stricture and by closely spaced longitudinal costae.

Archaeodictyomitra whalenae Kozur and Mostler in Grill and Kozur 1986
(Plate 2, fig. 19)
1982 *Archaeodictyomitra* sp. A – Pessagno and Whalen, p. 117, plate 8, fig. 10.
1982 *Archaeodictyomitra* sp. J – Kishida and Sugano, plate 12, fig. 11.
1986 *Archaeodictyomitra whalenae* n. sp. – Kozur and Mostler in Grill and Kozur, p. 260, plate 9, figs. 2–5.
1998 *Archaeodictyomitra whalenae* Kozur and Mostler – Ožvoldová, plate IV, fig. 10.
2005 *Archaeodictyomitra whalenae* Kozur and Mostler – O'Dogherty *et al*., p. 430–431, plate 1, figs. 8–9.

Remarks: The test is conical and the width of segments increases rapidly at upper portion, but slightly decreases lower portion. Strictures are shallow and weakly developed. Small pores in some strictures are visible, but always closed in the case of the obtained specimen, due to poorly-preservation.

Archaeodictyomitra* sp. cf. *A. apiarium (Rüst) 1885
(Plate 2, figs. 16–17)
Remarks: These specimens are similar to *Archaeodictyomitra apiarium* (Rüst) in having low circumferential ridges and continuous longitudinal costae, but slightly different from the latter in their long and slender form.

***Archaeodictyomitra* spp.**
(Plate 1, fig. 19; Plate 2, figs. 20–22)
Remarks: The obtained specimens are multi-segmented and elongated conical in outer shape, and are covered by linearly arranged continuous costae.

Family **UNUMIDAE** Pessagno
in Pessagno, Finch and Abbott 1979

Genus ***Unuma*** Ichikawa and Yao 1976

***Unuma* (?) sp.**
(Plate 3, fig. 25)

Family **SPONGOCAPSULIDAE** Pessagno 1977

Genus ***Spongocapsula*** Pessagno 1977

Spongocapsula krahsteinensis Suzuki and Gawlick in Gawlick, Schlagintwei, Ebli and Suzuki 2004
(Plate 1, figs. 20–21)
1982 *Canoptum* sp. – Kido *et al*., plate 2, fig. 6.
1985 *Canoptum* sp. – Yamamoto *et al*., p. 34, plate 3, fig. 10.
1992 *Spongocapsula palmerae* Pessagno – Ožvoldová, plate 4, fig. 9.
1996 *Spongocapsula* (?) sp. – Nishizono, plate 27, fig. 11.
1998 *Canoptum* sp. A sensu Yao – Arakawa, plate 9, fig. 399.
2001 *Spongocapsula palmerae* Pessagno – Hori, plate 4, fig. 14.
2004 *Spongocapsula krahsteinensis* n. sp. – Suzuki and Gawlick in Gawlick, Schlagintwei, Ebli and Suzuki, pl. 313–315, plate 4, fig. 7–10.

Remarks: Entire shell of *Spongocapsula krahsteinensis* is composed of a spongy meshwork, which is covered with a thin layer of fine-grained gravel. Cephalis is conical without apical horn. Post-cephalic segments are truncated cone-shaped, and their width gradually increases in the distal direction. Circumferential ridges are striking between the post-abdominal chambers. The examined specimens are longer than the holotype described by

Suzuki and Gawlick.
Range: Late Bajocian–Callovian (Gawlick *et al*., 2004).

Genus ***Cinguloturris*** Dumitrica
in Dumitrica and Mello 1982

***Cinguloturris* (?) spp.**
(Plate 2, figs. 23–24)

Family **PARVICINGULIDAE** Pessagno 1977

Genus ***Parvicingula*** Pessagno 1977

Parvicingula cappa Cortese 1993
(Plate 1, fig. 10)
1985 *Parvicingula* (?) sp. – Yamamoto *et al*., p. 37, plate 6, figs. 4–5.
1993 *Parvicingula cappa* n. sp. – Cortese, pl. 176, plate 4, figs. 1–4.
1994 *Parvicingula cappa* Cortese – Matsuoka *et al*., plate 11, fig. 15.
1998 *Parvicingula* (?) sp. J0 – Arakawa, plate 10, fig. 462.
1998 *Parvicingula* (?) sp. J1 – Arakawa, plate 10, fig. 463.
2002 *Parvicingula* (?) sp. – Nakae, fig. 5, h–i.
2003 *Parvicingula cappa* Cortese – Suzuki and Gawlick, pl. 187–188, fig. 6, 83–84.
Remarks: The obtained specimen is multi-segmented and conical in outer shape. Hexagonally arranged pores are faintly found on the test surface but no circumferential ridges are developed.
Range: latest Bathonian–early Callovian (Suzuki and Gawlick, 2003).

Genus ***Tethysetta*** Dumitrica in Dumitrica *et al*. 1997

Tethysetta* sp. cf. *T. mashitaensis (Mizutani) 1981
(Plate 2, fig. 25)
Remarks: The obtained specimen is multi-segmented and spindle-shaped. Distal part seems to be closed with a narrow tube. One row of pore is found on the edge of circumferential ridges, although three rows of pore are arranged in well-preserved specimens.

***Tethysetta* spp.**
(Plate 1, figs. 22–23)
Remarks: Test of each specimen detected is multi-segmented and spindle-shaped, and its distal part (last few segments) become narrower. A narrow tube is lacking due to poor preservation. Circumferential ridges at joints between segments are somewhat nodose.

Genus ***Triversus*** Takemura 1986

***Triversus* (?) sp.**
(Plate 2, fig. 26)

NASSELLARIA Incertae sedis

Genus ***Lantus*** Yeh 1987

***Lantus* sp.**
(Plate 1, fig. 24)
Remarks: The examined specimen belongs to genus *Lantus* by similar overall form and by having a final post-abdominal segment which is closed with an ellipsoidal cap.

Acknowledgements
This report is based on results of the study "Geology of the Ichinohe district" which has been conducted by the Geological Survey of Japan, AIST. Thanks are extended to Dr. T. Uchino (GSJ) for his helpful comments regarding the manuscript. Prof. Hisashi Suzuki (Otani University, Kyoto) is gratefully acknowledged for thorough review of the manuscript.

References

Aita, Y. (1987) Middle Jurassic to Lower Cretaceous radiolarian biostratigraphy of Shikoku with reference to selected sections in Lombardy basin and Sicily. *Science Reports of Tohoku Univ*., *Series 2*, *Geology*, **58**, 1–9.

Arakawa, Y. (1998) Middle Jurassic radiolarian assemblages from manganese dioxide nodule, Kuzuu area of the Ashio Terrane, central Japan. *Bulletin of Tochigi Prefectural Museum*, **15**, 51–76. (in Japanese with English abstract)

Baumgartner, P. O. (1984) A Middle Jurassic–Early Cretaceous low-latitude radiolarian zonation based on Unitary Associations and age of Tethyan radiolarites. *Eclogae Geologicae Helvetiae*, **77**, 729–841.

Baumgartner, P. O. (1985) Jurassic sedimentary evolution and nappe emplacement in the Argolis Peninsula (Peloponnesus, Greece). *Mémoires de la Société Helvétique des Sciences Naturelles*, **99**, 1–111.

Baumgartner, P. O., O'Dogherty, L., Gorican, S., Dumitrica-Jud, R., Dumitrica, P., Pillevuit, A., Urquhart, E., Matsuoka, A., Danelian, T., Bartolini, A., Carter, E. S., De Wever, P., Kito, N., Marcucci, M. and Steiger, T. (1995) Radiolarian catalogue and systematics of Middle Jurassic to Early Cretaceous Tethyan genera and species. *In* Baumgartner, P. O., O'Dogherty, L., Gorican, S., Urquhart, E., Pillevuit, A. and De Wever, P. eds., *Middle Jurassic to Early Cretaceous Radiolaria of Tethys: occurrence, systematics*, *biochronology*. *Mémoires de Géologie (Lausanne)*, no. 23, Lausanne, Switzerland, 37–685.

Cayeux, L. (1897) Contribution à l'étude micrographique des terrains sédimentaires. 1. Étude de quelques depots siliceux secondaires et terriaires du Bassin de Paris et de la Belgique. 2. Craie de Bassin de Paris. *Mémoires de la Société Géologique de Nord*, *Lille*,

4, 1–591.

Chiari, M., Marcucci, M. and Prela, M. (2002) New species of Jurassic radiolarians in the sedimentary cover of ophiolites in the Mirdita area, Albania. *Micropaleontology*, **48**, Supplement 1, 61–87.

Cortese, G. (1993) Radiolarian biostratigraphy of the Tuscan Cherts (Tuscan successions) from Val di Lima, Tuscany, Northern Apennines. *Paleopelagos*, **3**, 169–189.

De Wever, P., Dumitrica, P., Caulet, J. P., Nigrini, C. and Caridroit, M. (2001) *Radiolarians in the sedimentary record*. Gordon and Breach Science Publishers, 533 p.

Dumitrică, P. (1970) Cyrtocephalic and cyrtothracic Nassellaria in some Mesozoic deposits of Romania. *Revue Roumaine de Géologie*, *Géophysique et Géographie (série de Géolgie)*, **14**, 45–124.

Dumitrica, P. and Mello, J. (1982) On the age of the Meliata roup and the Silica Nappe radiolarites (localities Drzkovce and Bohunovo, Slovak Karst, CSSR). *Geologické práce, Zpravy*, **77**, 17–28.

Dumitrica, P., Immenhauser, A. and Dumitrica-Jud, R. (1997) Mesozoic radiolarian biostratigraphy from Masirah Ophiolite, Sultanate of Oman. Part I: Middle Triassic, Uppermost Jurassic and Lower Cretaceous Spumellarians and multisegmented Nassellarians. *Bulletin of National Museum of Natural Science*, *Taiwan*, no. 9, 1–106.

Ehiro, M., Yamakita, S. Takahashi, S. and Suzuki, N. (2008). Jurassic accretionary complexes of the North Kitakami belt in the Akka-Kuji area, Northeast Japan. *Journal of Geological Society of Japan*, **144**, supplement, 317–139. (in Japanese, with English abstract)

Ehrenberg, C. G. (1847) Über die mikroskopischen kieselschaligen Polycystinen als mächtige Gebirgsmasse von Barbados und über das Verhaltniss der aus mehr als 300 neuen Arten bestehenden ganz eigenthumlichen Formengruppe jener Felsmasse zu den jetzt lebenden Thieren und zur Kreidebildung Eine neue Anregung zur Erforschung des Erdlebens. *Bericht der königlichen preussischen Akademie der Wissenschaften zu Berlin*, Abhandlungen, Jahre 1847, 40–60.

Ehrenberg, C. G. (1875) Fortsetzung der mikrogeologischen Studien als Gesammt-Ubersichtder mikroskopischen Palaontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rucksicht auf den Polycystinen-Mergel von Barbados. *Bericht der königlichen preussischen Akademie der Wissenschaften zu Berlin*, Abhandlungen, Jahre 1875, 1–225.

Gawlick, H.-J., Schlagintwei, F., Ebli, O. and Suzuki, H. (2004) Die Plassen-Formation (Kimmeridgium) des Krahstein (Steirisches Salzkammergut, Österreich) und ihre Unterlagerung: neue Daten zur Fazies, Biostratigraphie und Sedimentologie. *Zentralblatt für Geologie und Paläontologie*, *Teil 1*, **2003**, 295–334.

Grill, J. and Kozur, H. (1986) The first evidence of the *Unuma echinatus* radiolarian zone in the Rudabanya Mts. (northern Hungary). *Geologisch Paläontologische Mitteilungen Innsbruck*, **13**, 239–275.

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

Hori, N. (2001) Triassic and Jurassic radiolarians from the chert–clastic sequence of the Takatori Unit in the Torinoko block, Yamizo mountains. *News of Osaka Micropaleontologists*, *Special Volume*, no. 12, 159–180. (in Japanese with English abstract)

Hull, D. M. (1997) Upper Jurassic Tethyan and southern Boreal radiolarians from western North America. *Micropaleontology*, **43**, supplement 2, 202 p.

Ichikawa, K. and Yao, A. (1976) Two new genera of Mesozoic cyrtoid radiolarians from Japan. *In* Takayanagi, Y. and Saito, T. eds., *Progress in Micropaleontology*. Special publication. Micropaleontology Press, American Museum of Natural History, New York, 110–117.

Isozaki, Y., Maruyama, S. and Furuoka, F. (1990) Accreted oceanic materials in Japan. *Tectonophysics* **181**, 179–205.

Kamada, K., Hata, M., Kubo, K. and Sakamoto, T. (1991) *Geological Map of Japan 1:200,000, Hachinohe*. Geological Survey of Japan.

Kido, S., Kawaguchi, I., Adachi, M. and Mizutani, S. (1982) On the *Dictyomitrella* (?) *kamoensis* – *Pantanellium foveatum* assemblage in the Mino area, central Japan. *News of Osaka Micropaleontologists*, *Special Volume*, no. 5, 195–210. (in Japanese with English abstract)

Kishida, Y. and Sugano, K. (1982) Radiolarian zonation of Triassic and Jurassic in outer side of Southwest Japan. *News of Osaka Micropaleontologists*, *Special Volume*, no. 5, 271–300. (in Japanese with English abstract)

Kocher, R. N. (1981) Biochronostratigraphische Untersuchungen oberjurassischer radiolarien führender Gesteine, insbesondere der Südalpen. *Mitteilungen aus dem Geologischen Institut der Eidgenössischen Technischen Hochschule und der Universitat Zurich*, *Neue Folge*, **234**, 1–184.

Kozur, H. (1984) New radiolarian taxa from the Triassic and Jurassic. *Geologisch Paläontologische Mitteilungen Innsbruck*, **15**, 49–88.

Matsuoka, A. (1983) Middle and Late Jurassic radiolarian biostratigraphy in the Sakawa and adjacent areas, Shikoku, Southwest Japan. *Journal of Geosciences*, *Osaka City Univ*., **26**, 1–48.

Matsuoka, A. (1986) Faunal change of radiolarians around the Jurassic–Cretaceous boundary – with special reference to some multi-segmented nassellarians. *Fossils*, **40**, 1–15. (in Japanese with English abstract)

Matsuoka, A. (1987) Radiolarian age of the Shiriyazaki

Group in Aomori Prefecture, northeast Japan. *Fossils* **42**, 7–13. (in Japanese with English abstract)

Matsuoka, A. (1995a) Jurassic and Lower Cretaceous radiolarian zonation in Japan and in the western Pacific. *Island Arc*, **4**, 140–153.

Matsuoka, A. (1995b) Middle Jurassic–Lower Cretaceous radiolarian zonation in Japan and the western Pacific, and age assignments based on the Unitary Associations method. *In* Baumgartner, P. O., O'Dogherty, L., Gorican, S., Urquhart, E., Pillevuit, A. and De Wever, P. eds., *Middle Jurassic to Early Cretaceous Radiolaria of Tethys: occurrence, systematics, biochronology. Mémoires de Géologie (Lausanne)*, no. 23, Lausanne, Switzerland, 1049–1057.

Matsuoka, A. and Oji, T. (1990) Middle Jurassic radiolarian fossils from the Magisawa Formation in the Taro belt, North Kitakami Mountains. *Journal of Geological Society of Japan*, **96**, 239–241. (in Japanese with English abstract)

Matsuoka, A. and Yao, A. (1986) A newly proposed radiolarian zonation for the Jurassic of Japan. *Marine Micropaleontology*, **11**, 91–105.

Matsuoka, A., Hori, R., Kuwahara, K., Hiraishi, M., Yao, A. and Ezaki, Y. (1994) Triassic–Jurassic radiolarian-bearing sequences in the Mino Terrane, central Japan. *Guide book for Interrad VII field excursion*, 19–61, Organizing Committee of Interrad VII, Osaka.

Minoura, K. (1990) The pre-Cretaceous geology and tectonics of northern Kitakami region. *In* Ichikawa, K., Mizutani, S., Hara, I., Hada, S., Yao, A. eds., *Pre-Cretaceous terranes of Japan* (Publication of IGCP project No. 224: Pre-Jurassic evolution of eastern Asia). Osaka, 267–279.

Mizutani, S. (1981) A Jurassic formation in the Hida-Kanayama area, central Japan. *Bulletin of Mizunami Fossil Museum*, **8**, 147–190.

Müller, J. (1858) Uber die Thalassicollen, Polycystinen und Acanthometren des Mittelmeeres. *Konigliche Preussische Akademie der Wissenschaften zu Berlin*, Abhandlungen, Jahre 1858, 1–62.

Nagai, H. (1988) Early Jurassic *Eucyrtidiellum* (Radiolaria) from Kamiaso, Gifu Prefecture, central Japan. the Mino terrane. *Bulletin of Nagoya Univ*., *Furukawa Museum*, **4**, 1–9.

Nagai, H. and Mizutani, S. (1990) Jurassic *Eucyrtidiellum* (Radiolaria) in the Mino terrane. *Transactions and Proceedings of Palaeontological Society of Japan*, *N.S*., **159**, 587–602.

Nakae, S. (2002) Triassic and Jurassic radiolarians from the Tamba Terrane in the Nishizu district, Fukui, Southwest Japan. *Bulletin of Geological Survey of Japan*, **53**, 51–59.

Nakae, S.and Kamada, K. (2003) Late Jurassic radiolarians from the Rikuchu-Seki district in the North Kitakami belt, Northeast Japan. *Journal of Geological Society of Japan*, **109**, 722–725. (in Japanese with English abstract)

Nishizono, Y. (1996) Mesozoic convergent process of the Southern Chichibu Terrane in West Kyushu, Japan, on the basis of Triassic to Early Cretaceous radiolarian biostratigraphy. *Kumamoto Journal of Science (Earth Science)*, **14**, 45–226. (in Japanese with English abstract)

O'Dogherty, L. (1994) Biochronology and paleontology of Mid-Cretaceous radiolarians from northern Apennines (Italy) and Betic Cordillera (Spain). *Mémoires de Géologie (Lausanne)*, no. 21, Lausanne, Switzerland, 1–415.

O'Dogherty, L., Markus, B, Goričan, Š., Dumitrică, P. and Masson, H. (2005) Bathonian radiolarians from an ophiolitic mélange of the Alpine Tethys (Gets Nappe, Swess-French Alps). *Micropaleontology*, **51**, 425–485.

O'Dogherty, L., Carter, E. S., Dumitrica, P., Goričan, Š. and De Wever, P. (2009) An illustrated and revised catalogue of Mesozoic radiolarian genera – objectives, concepts and guide for users. *Geodiversitas*, **31**, 191–356.

Okami, K. and Ehiro, M. (1988) Review and recent progress of studies on the pre-Miyakoan sedimentary rocks of the northern Kitakami massif, Northeast Japan. *Earth Science (Chikyu Kagaku)*, **42**, 187–201. (in Japanese with English abstract)

Okami, K. and Murata, M. (1974) Geologic study along the Hiranuka river, western margin of the northern part of the Kitakami massif, Northwest Japan. *Technology Reports of Iwate University*, **27**, 21–25.(in Japanese with English abstract)

Ožvoldová, L. (1975) Upper Jurassic radiolarians from the Kysuca Series in the Klippen belt. *Západné Karpaty*, *Séria Paleontológia*, **1**, 73–86.

Ožvoldová, L. (1988) Radiolarian associations from radiolarites of the Kysuca succession of the Klippen belt in the vicinity of Myjava – Turá Lúka (West Carpathians). *Geologicky Sborník (Bratislava)*, **39**, 369–392.

Ožvoldová, L. (1992) The discovery of a Callovian radiolarian association in the Upper Posidonia beds of the Pieniny succession of the Klippen belt (Western Carpathians). *Geologica Carpathica*, **43**, 111–122.

Ožvoldová, L. (1998) Middle Jurassic radiolarian assemblages from radiolarites of the Silica Nappe (lovak Karst, western Carpathians). *Geologica Carpathica*, **49**, 289–296.

Pessagno, E. A., Jr. (1976) Radiolarian zonation and stratigraphy of the California Coast Ranges. *Micropaleontology Special Publication*, **2**, 1–95.

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

Pessagno, E. A., Jr. and Poisson, A. (1981) Lower Jurassic radiolaria from the Gümüşlü allochton of southwestern Turkey (Taurides Occidentales). *Bulletin of Mineral Research and Exploration Institute of Turkey*. no. 92,

47–69.
Pessagno, E. A., Jr. and Whalen, P. A. (1982) Lower and Middle Jurassic Radiolaria (multicyrtid Nassellariina) from California, east-central Oregon and the Queen Charlotte Islands, B.C. *Micropaleontology*, **28**, 111–169.
Pessagno, E. A., Jr., Finch, W. and Abbott, P. L. (1979) Upper Triassic Radiolaria from the San Hipólito Formation, Baja California. *Micropaleontology*, **25**, 160–197.
Pessagno, E. A., Jr., Blome, C. D. and Longoria, J. F. (1984) A revised radiolarian zonation for the Upper Jurassic of western North America. *Bulletin of American Paleontology*, **87**, 1–51.
Pessagno, E. A., Jr., Blome, C. D., Hull, D. M. and Six, W. M. (1993) Jurassic radiolaria from the Josephine ophiolite and overlying strata, Smith River subterrane (Klamath Mountains), northwestern California and southwestern Oregon. *Micropaleontology*, **39**, 93–166.
Riedel, W. R. and Sanfilippo, A. (1974) Radiolaria from the southern Indian Ocean, DSDP Leg 26. *Initial Reports of Deep Sea Drilling Project*, U.S. Government Printing Office, Washington, D.C., **26**, 771–814.
Rüst, D. (1885) Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Jura. *Palaeontographica*, **31**, 269–321.
Sashida, K., Igo, H., Igo, H., Takizawa, S., Hisada, K., Shibata, T., Tsukada, K. and Nishimura, H. (1982) On the Jurassic radiolarian assemblages in the Kanto district. *News of Osaka Micropaleontologists*, *Special Volum*e, no. 5, 9–23. (in Japanese)
Savary, J. and Guex, J. (1999) Discrete biochronological scales and Unitary Associations: Description of the BioGraph computer program. *Mémoires de Géologie (Lausanne)*, no. 34, Lausanne, Switzerland, 1–281.
Sugimoto, M. (1974) Stratigraphical study in the outer belt of the Kitakami massif, Northeast Japan. *Contributions. Institute*. *Geology and Paleontology*, *Tohoku Univ*., no. 74, 1–48.
Suzuki, H. and Gawlick, H.-J. (2003) Biostratigraphie und taxonomie der Radiolarien aus den Kieselsedimenten der Blaa Alm und nördlich des Loser (Nördliche Kalkalpen, Callovium– Oxfordium). *Mitteilungen Gesellschaft Geologie Bergbaustud*. *Österreich*, **46**, 137–228.
Takahashi, S., Ehiro, M., Suzuki, N. and Yamakita, S. (2016) Subdivisional scheme of the North Kitakami belt, Northeast Japan and its tectonostratigraphic correlation to the Oshima and South Chichibu belts: and examination of the Jurassic accretionary complex in the west Akka area. *Journal of Geological Society of Japan*, **122**, 1–22. (in Japanese with English abstract)
Takemura, A. (1986) Classification of Jurassic nassellarians (Radiolaria). *Palaeontographica. Abteilung A: Palaeozoologie-Stratigraphie*, **195**, 29–74.
Wakita, K. (1988) Early Cretaceous mélange in the Hida-Kanayama area, central Japan. *Bulletin of Geological Survey of Japan*, **39**, 367–421.
Yamamoto, H., Mizutani, S. and Kagami, H. (1985) Middle Jurassic radiolarians from Blake Bahama Basin, West Atlantic Ocean. *Bulletin of Nagoya Univ. Museum*, **1**, 25–49.
Yao, A. (1979) Radiolarian fauna from the Mino belt in the northern part of the Inuyama area, central Japan, Part II: Nasselaria I. *Journal of Geosciences*, *Osaka City Univ*., **15**, 21–72.
Yeh, K.-Y. (1987) Taxonomic studies of Lower Jurassic Radiolaria from east–central Oregon. *Special Publication*, *National Museum of Natural Science*, *Taiwan*, no. 2, 169 p.
Yoshihara, K., Suzuki, N. and Ehiro, M. (2002) Middle Jurassic radiolarian-bearing manganese nodules from the Kuzumaki-Kamaishi belt in the northern Kitakami massif and its significance. *Journal of Geological Society of Japan*, **108**, 536–539. (in Japanese with English abstract)

Recieved March 18, 2016
Accepted July 5, 2016

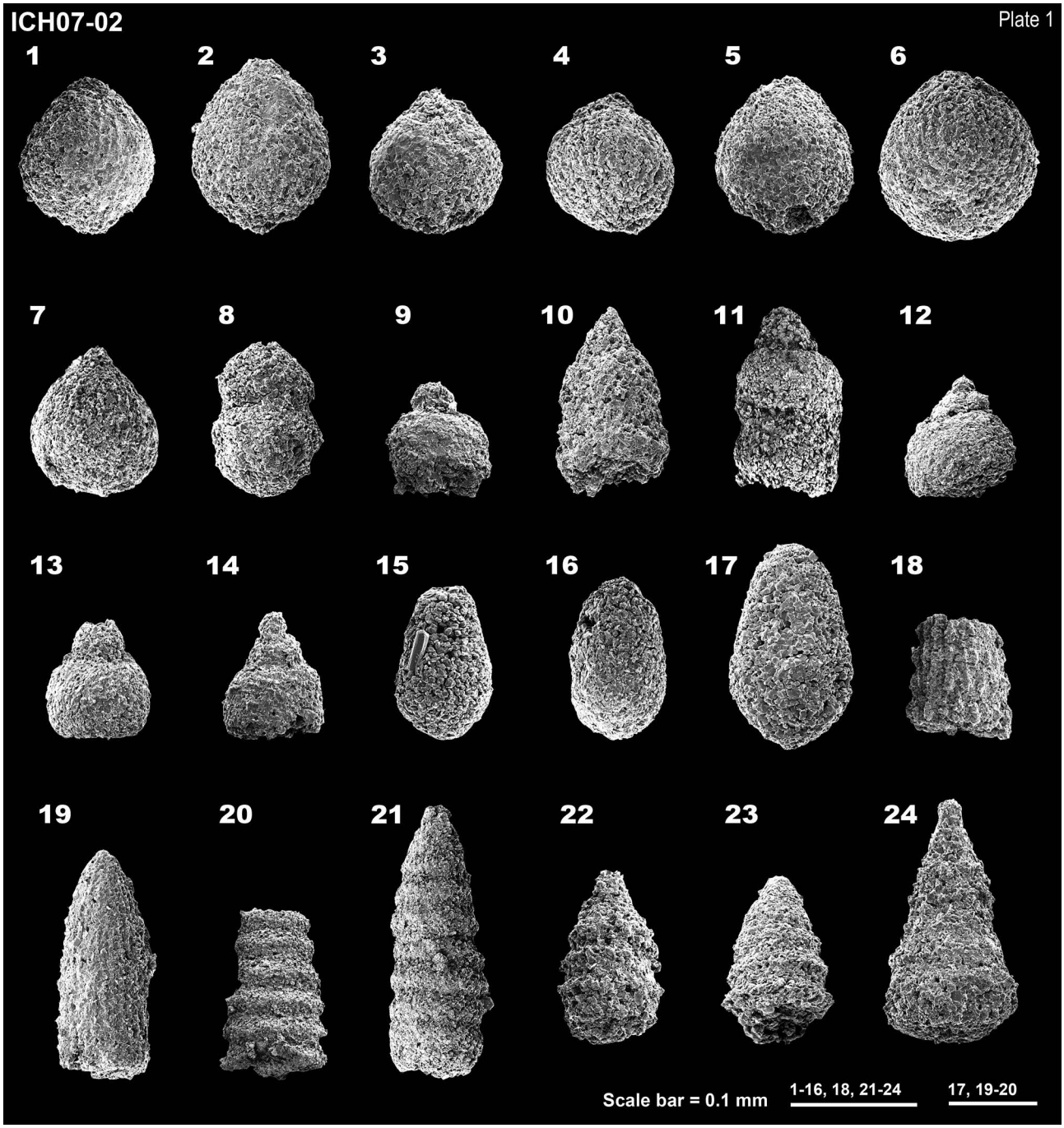

Plate 1 SEM images of Jurassic radiolarians from the Seki Formation in the Ichinohe–Kunohe area.
ICH07-02 (Locality 1: Seki Formation), **1:** *Striatojaponocapsa plicarum* (Yao), **2:** *Striatojaponocapsa* sp. cf. *S. plicarum* (Yao), **3–7:** *Striatojaponocapsa* sp. cf. *S. synconexa* O'Dogherty, Goričan and Dumitrică, **8:** *Theocapsomella* sp. cf. *T. costata* (Chiari, Marcucci and Prela), **9:** *Natoba* (?) sp., **10:** *Parvicingula cappa* Cortese, **11:** *Eucyrtidiellum* sp. cf. *E. pustulatum* Baumgartner, **12–14:** *Eucyrtidiellum* sp. cf. *E. unumaense* (Yao), **15–17:** *Guexella* (?) spp., **18:** *Transhsuum* sp. cf. *T. maxwelli* gr. (Pessagno), **19:** *Archaeodictyomitra* sp., **20–21:** *Spongocapsula krahsteinensis* Suzuki and Gawlick, **22–23:** *Tethysetta* spp., **24:** *Lantus* sp. All scale bars are equal to 0.1 mm.

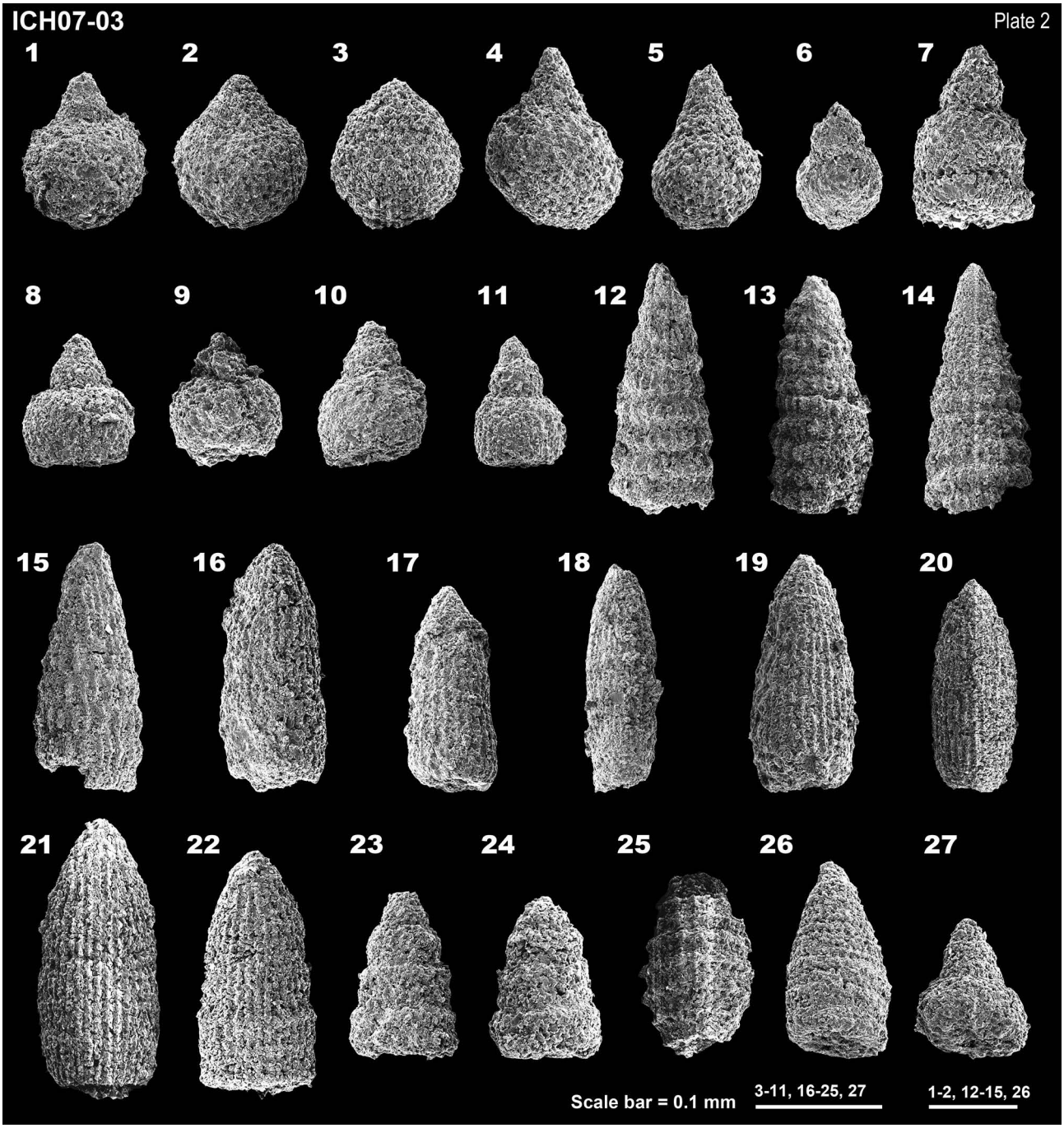

Plate 2 SEM images of Jurassic radiolarians from the Seki Formation in the Ichinohe–Kunohe area.
ICH07-03 (Locality 2: Seki Formation), **1:** *Williriedellum* sp., **2–3:** *Zhamoidellum* spp., **4–5:** *Hiscocapsa* spp., **6:** *Theocapsomella* (?) sp., **7:** *Eucyrtidiellum* sp. cf. *E. pustulatum* Baumgartner, **8:** *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo), **9:** *Eucyrtidiellum nodosum* Wakita, **10–11:** *Eucyrtidiellum* spp., **12–13:** *Transhsuum brevicostatum* gr. (Ožvoldová), **14:** *Transhsuum* sp. cf. *T. brevicostatum* gr. (Ožvoldová), **15:** *Transhsuum maxwelli* gr. (Pessagno), **16–17:** *Archaeodictyomitra* sp. cf. *A. apiarium* (Rüst), **18:** *Archaeodictyomitra prisca* Kozur and Mostler, **19:** *Archaeodictyomitra whalenae* Kozur and Mostler, **20–22:** *Archaeodictyomitra* spp., **23–24:** *Cinguloturris* (?) spp., **25:** *Tethysetta* sp. cf. *T. mashitaensis* (Mizutani), **26:** *Triversus* (?) sp., **27:** *Stichomitra* (?) sp. All scale bars are equal to 0.1 mm.

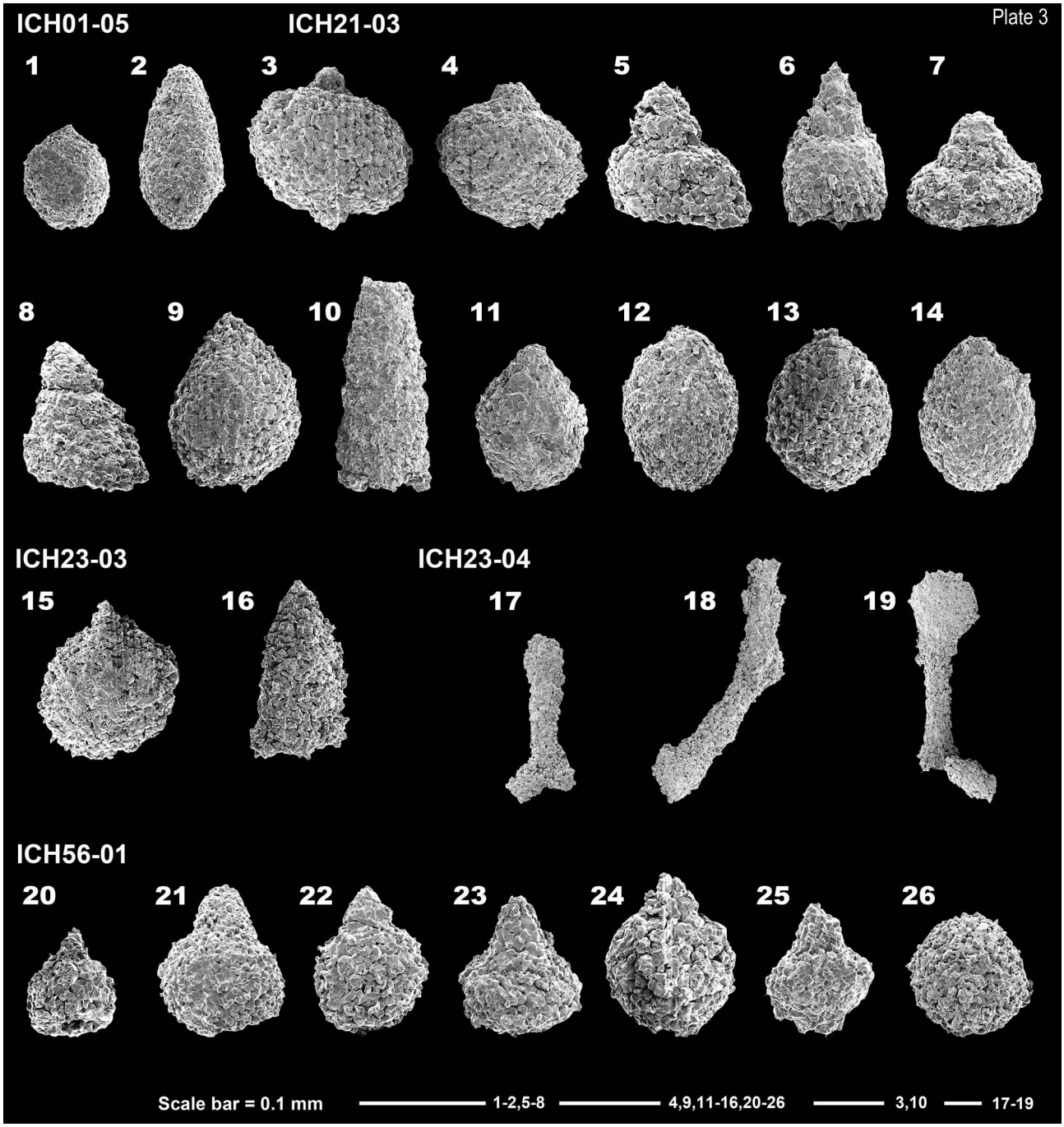

Plate 3 SEM images of Jurassic radiolarians from the Kassenba and Kuzumaki formations in the Ichinohe–Kunohe area. **ICH01-05** (Locality 3: Kassenba Formation). **1:** Nassellaria gen. et sp. indet., **2:** *Guexella* (?) sp. **ICH21-03** (Locality 4: Kassenba Formation), **3:** *Williriedellum* (?) sp., **4:** *Zhamoidellum* (?) sp., **5–6:** *Eucyrtidiellum* spp., **7–9, 11–14:** Nassellaria gen. et sp. indet. **10:** *Transhsuum* (?) sp. **ICH23-03** (Locality 5: Kassenba Formation), **15–16:** Nassellaria gen. et sp. indet. **ICH23-04** (Locality 6: Kassenba Formation), **17–19:** Angulobracchiidae gen. et sp. indet. **ICH56-01** (Locality 7: Kuzumaki Formation), **20:** *Eucyrtidiellum* (?) sp., **21–24:** Nassellaria gen. et sp. indet., **25:** *Unuma* (?) sp., **26:** Spherical radiolaria. All scale bars are equal to 0.1 mm.

北部北上帯一戸－九戸地域（岩手県）から産出したジュラ紀放散虫

中江　訓

要　旨

東北日本の北部北上帯には，玄武岩・石灰岩・チャート・泥岩・砂岩などの多様な岩石から構成される堆積岩複合体が分布する．岩手県北部の一戸－九戸地域におけるこれらの岩石のうち5地点の珪質泥岩ならびに2地点の泥岩から，Nassellaria目が卓越する放散虫群集を得た．本報告ではこれらの放散虫化石群集を記載するとともにその種構成に基づき，一戸－九戸地域に分布する珪質泥岩ならびに泥岩の地質時代が前期ジュラ紀（Toarcian）から後期ジュラ紀（Kimmeridgian）に至ると結論した．

難読･重要地名

Akka：安家，Araida：新井田，Hachinohe：八戸，Hayato：早渡，Hiraniwadake：平庭岳，Ichinohe：一戸，Iwate：岩手，Kamaishi：釜石，　Karumai：軽米，Kassenba：合戦場，Koyukiya：小雪屋，Kunohe：九戸，Kuzumaki：葛巻，Mabechi-gawa：馬淵川，Ninohe：二戸，North　Kitakami　belt：北部北上帯，Ôdaira：大平，Ôtori：大鳥，Oritsume-dake：折爪岳，Sawayamagawa：沢山川，Seki：関，Setsukinai-gawa：瀬月内川，Shimo-sawanai：下沢内，Suwano：諏訪野，Takayashiki：高屋敷，Tanohata：田野畑，Yukiya-gawa：雪谷川.