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Middle and Late Jurassic radiolarians from Nadanhada terrane of eastern Heilongjiang Province, northeastern China

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Abstract. The Nadanhada terrane of northeastern Heilongjiang, northeastern China is composed of Jurassic accretionary complexes (i.e., the Yuejinshan Complex in the west, the Raohe Complex in the east) and succedent cover beds. In this paper we report two radiolarian assemblages recognized from four black claystone samples collected from the Dalingqiao Formation in the Dajiashan area of the Raohe Complex. The *Striatojaponocapsa synconexa*-"*Tricolocapsa*" *tetragona* assemblage of one sample consists of eleven species in eight genera, which indicates a middle Bathonian (Middle Jurassic) age, i.e., correlative with the uppermost *Striatojaponocapsa plicarum* Zone to the lower *Striatojaponocapsa conexa* Zone. The other three samples contain 34 species in 25 genera, which indicate a late Oxfordian–early Tithonian (Late Jurassic) age. The discovery of the Late Jurassic radiolarian assemblage indicates that the Raohe Accretionary Complex was formed during the Late Jurassic. The succedent late Tithonian–early Valanginian *Buchia* fauna-bearing Dong'anzhen Formation may be the earliest cover beds overlying the Raohe Accretionary Complex. Then, during the Early Cretaceous, the Nadanhada terrane received the deposition of the *Aucellina* bivalve fauna-bearing Dajiashan Group. This indicates paleogeographic differentiation between the Nadanhada terrane and the Tamba-Mino-Ashio terrane.

Key words: eastern Heilongjiang, Middle–Late Jurassic, Nadanhada terrane, northeastern China, radiolarian biostratigraphy

Introduction

The early geological study on the Nadanhada terrane of northeastern China began in 1930s by Japanese geologists (Yabe and Ohki, 1957). In 1957 Chinese and Russian scientists conducted joint geological research in the Ussuri River region, and confirmed the occurrence of Late Triassic, Early and Middle Jurassic rocks based on the fossil evidence (Wang, 1959); they came to the conclusion that the Mesozoic mobile belt developed in a geosyncline in the northeastern continental margin of East Asia. Based on fossil records of Late Paleozoic fusulinids the Nadanhada terrane was reinterpreted as a Paleozoic geosyncline that extended from the northeast Sikhote-Alin region (Li *et al*., 1979). But the sporadically and irregularly distributed rocks yield various age fossils, such as Carboniferous and Permian fusulinids in limestone, Triassic conodonts in bedded chert (Wang *et al*., 1986; Buryi, 1996), Triassic, Early and Middle Jurassic radiolarians in bedded chert and siliceous shale (Kojima and Mizutani, 1987; Yang *et al*., 1993) and Late Jurassic to Early Cretaceous *Buchia* bivalves in claystone of the Dong'anzhen Formation (Sun *et al*., 1989; Sha and Fürsich, 1993; Sha *et al*., 1994, 2008, 2009). These research results strongly suggest the melange geological character of the Nadanhada terrane, which together with the Mino and Western Sikhote-Alin terranes formed a single superterrane before the opening of the Japan Sea (Kojima, 1989). This interpretation would be very helpful to understand and decipher the paleo-Pacific-subduction history (Wu *et al*., 2007; Zhou *et al*., 2009, 2014; Kojima *et al*., 2016).

Recent studies demonstrated that the Dajiashan Group, cropping out in the Dajiashan area, southern Nadanhada terrane, yields a middle–late Early Cretaceous *Aucellina* bivalve fauna (Sha, 1990, 2002, 2007). Furthermore, the purported Early Jurassic ammonites of the Dajiashan Group (Li, 1996) are also similar to those of a *Pseudohaploceras* ammonite fauna from the Lower Cretaceous Longzhaogou Group (Futakami *et al*., 1995; Li and Bengtson, 2018). All these facts sparked an interest in restudying the paleontology and biostratigraphy of the Dajiashan Group and its underlying deposits.

Well preserved Middle–Late Jurassic radiolarian faunas are encountered in four samples from the black claystone of the Dalingqiao Formation, which was originally assigned to the Upper Triassic–Lower Jurassic by the Geological Survey of Heilongjiang Province of China (Bureau of Geology and Mineral Resources of Heilongjiang Province, 1993). Detailed taxonomical and biostratigraphical study of the recovered radiolarian faunas of the Dalingqiao Formation would help us to understand the geology of the Nadanhada terrane.

Material and methods

The fieldwork was carried out by the first author in August and September of 2002, and concerned the Dajiashan area, north Hulin. The section P1 was investigated (Figure 1). Some ammonites and bivalves were encountered in the Lower Cretaceous Dajiashan Formation (Figure 2). Although many samples for microfossil analysis were collected, relatively abundant and better-preserved radiolarians were recovered in four samples (P1-08, 09,

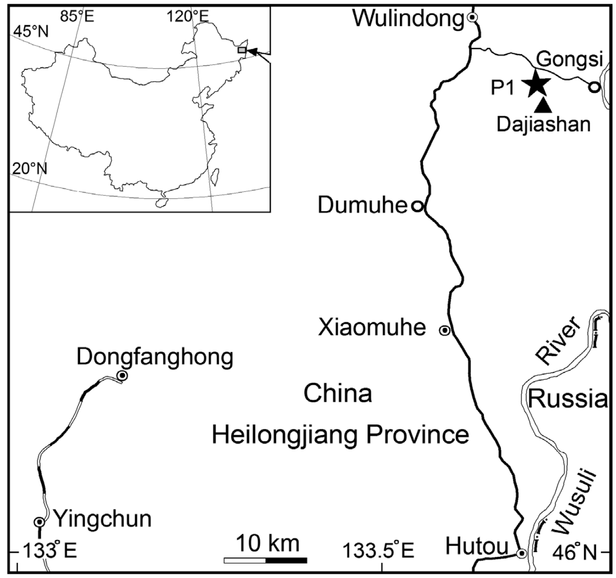

Figure 1. Sketch map showing the sample locality (P1: dark star) in the Nadanhada range area, northeastern China.

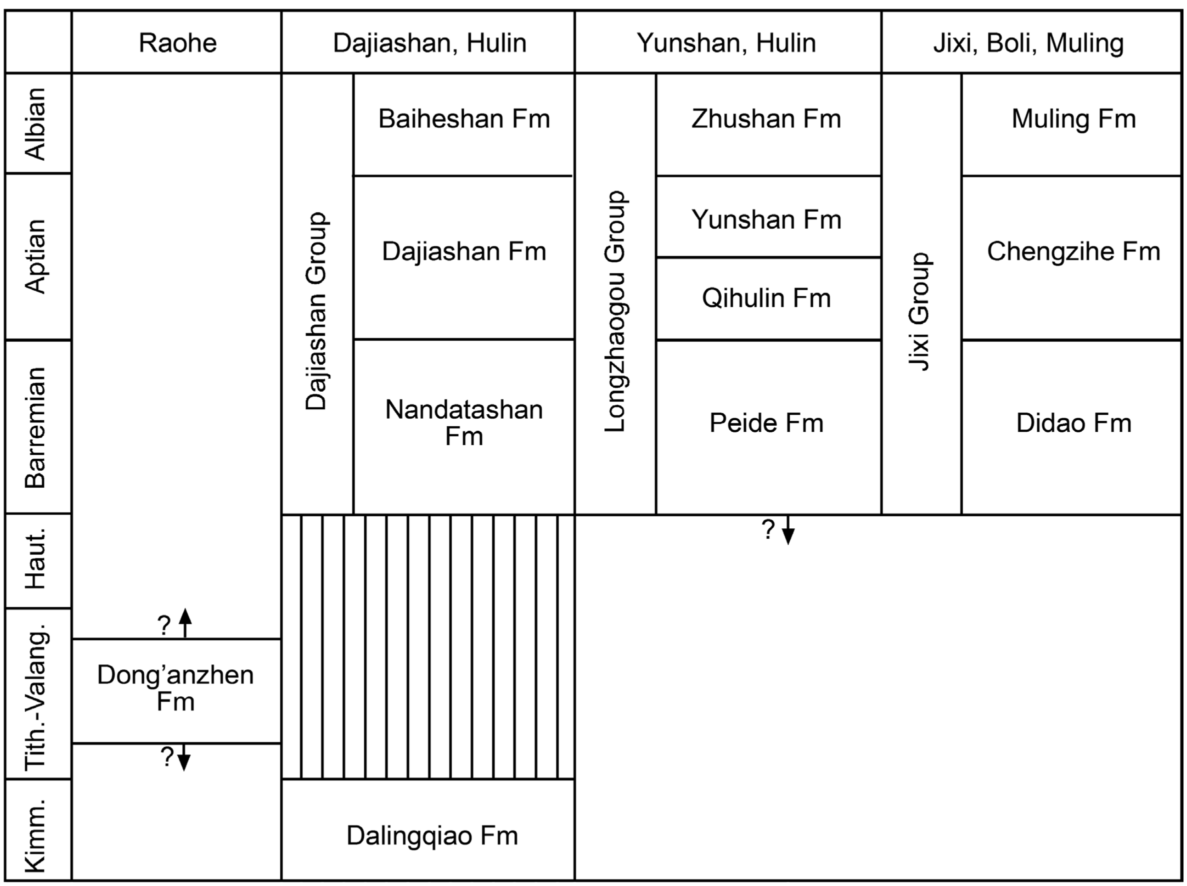

Figure 2. Upper Jurassic and Lower Cretaceous strata in the study area of eastern Heilongjiang, northeastern China (after Sha *et al.*, 2009; Li and Matsuoka, 2015; Li and Bengtson, 2018).

012, 013) (Figure 3) from the Upper Jurassic Dalingqiao Formation, which underlies the Dajiashan Group. Although the four samples were collected in the order of from upper to lower horizons (as is shown in Figure 3), the poor outcrop condition can not clearly show their real relative horizons.

In order to extract the radiolarian tests, the samples were treated after the method initiated by Dumitrica (1970) and described later by Pessagno and Newport (1972). The sample rocks were first crushed into centimeter-sized fragments and treated with 5% hydrofluoric acid (HF) for about 20 hours. The samples were washed in a two-sieved set, the lower one with a mesh diameter of 63 µm, the upper one with a mesh diameter of 315 µm. The fine residues in the lower sieve were dried; the coarser residues in the upper sieve were put back into the plastic beaker, and processed with hydrofluoric acid once more. The radiolarians were then picked from the dry residues with a brush pen bearing two to three hairs under a stereomicroscope and preliminary determined. The better preserved specimens were mounted on stubs and examined and photographed under the Scanning Electron Microscope LEO 1530 VP (the State Key Laboratory of Palaeobiology and Stratigraphy) for more precise determinations.

The section P1 is poorly exposed, and located in the forest in the north of Hulin County, about 12 km southeast of Wulindong, Raohe County. The Dajiashan Group is well developed. The section was measured, by the help of test trenches along the top of the hills, by the Regional Geological Survey of the Bureau of Geology and Mineral Resources of Heilongjiang Province.

In the P1 section the Dajiashan Group is subdivided into three formations, i.e., in ascending order, the Nandatashan, Dajiashan and Baiheshan formations (Figure 2). The Nandatashan Formation is a volcanic-clastic sequence with a thickness of 80 m. The Dajiashan Formation (263 m thick) consists of dark gray claystone, fine-grained sandstone and siltstone, yielding ammonites. The Baiheshan Formation (243 m thick) consists of black claystone intercalating fine-grained sandstone and siltstone, yielding abundant bivalves. The here described Middle and Late Jurassic radiolarians are from the strata classified as the Dalingqiao Formation in the P1 section.

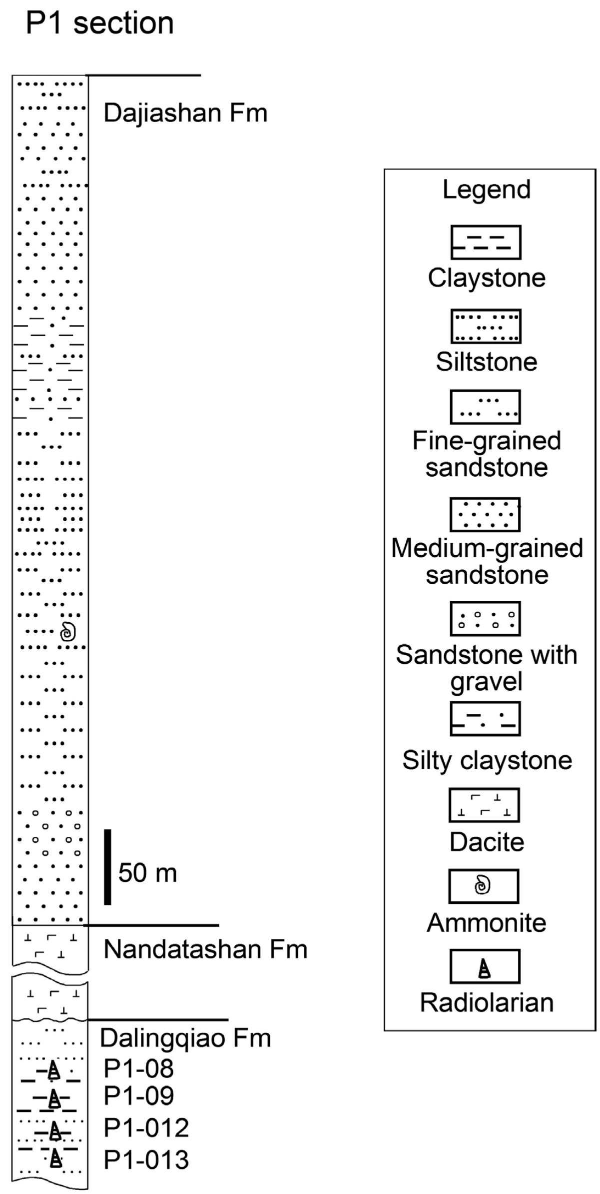

Figure 3. Columnar section of the P1 section with sampling horizons.

Radiolarian assemblages and their age assignments

Well preserved Middle–Late Jurassic radiolarians are encountered in four samples (P1-013, 012, 09, 08) (Table 1) from black claystone in the P1 section of the Dalingqiao Formation, which was originally assigned to the Upper Triassic–Lower Jurassic by the Heilongjiang Geological Survey (Bureau of Geology and Mineral Resources of Heilongjiang Province, 1993). These radiolarians encompass 43 species belonging to 31 genera. Two different-aged radiolarian assemblages have been recognized (Figure 4). The sample P1-09 yields a late Middle Jurassic assemblage, which could be assigned to the uppermost part of the *Striatojaponocapsa plicarum* Zone to the basal part of the *Striatojaponocapsa conexa* Zone (Matsuoka, 1995). The other three samples (P1-08, 012, 013) yield a Late Jurassic assemblage, which could be most probably assigned to the Kimmeridgian *Hsuum*

Table 1. Occurrence of radiolarians in four collected samples (P1-09, 08, 012, 013) from the Dalingqiao Formation in eastern Heilongjiang, northeastern China.

	P1-09	P1-08	P1-012	P1-013
Archaeocenosphaera sp.	X	X		
Caneta? sp. 1	X			
"*Stichocapsa*" *convexa* Yao, 1979	X			
"*Stichocapsa*" *robusta* Matsuoka, 1984	X			
"*Stichocapsa*" sp.	X			
Striatojaponocapsa synconexa O'Dogherty *et al.*, 2005	X			
Tethysetta dhimenaensis (Baumgartner, 1984)	X		X	
Transhsuum? sp.	X			
"*Tricolocapsa*" *tetragona* Matsuoka, 1983	X			
"*Tricolocapsa*" sp.	X			
Unuma gordus Hull, 1997	X			
Arcanicapsa funatoensis (Aita, 1987)		X		
Archaeospongoprunum sp. 1		X		
Archaeospongoprunum sp. 2		X		
Archaeodictyomitra rigida Pessagno, 1977a		X	X	
Archaeodictyomitra sp.		X		
Caneta? sp. 2		X		
Cinguloturris carpatica Dumitrica in Dumitrica and Mello, 1982		X	X	
Cinguloturris fusiformis Hori, 1999		X		
Crococapsa hexagona (Hori, 1999)		X		
Emiluvia praemyogii Baumgartner, 1984		X		
Eucyrtidiellum ptyctum (Riedel and Sanfilippo, 1974)		X		
Eucyrtidiellum unumaense (Yao, 1979)		X		
Gongylothorax favosus Dumitrica, 1970		X		
Loopus sp. 1		X		
Loopus sp. 2		X		
Loopus sp. 3		X		
Olanda? sp.		X		
Paronaella sp. 1		X		
Paronaella sp. 2		X		
Praeconocaryomma? sp.		X		
Protunuma japonicus Matsuoka and Yao, 1985		X		
Theocapsomella himedaruma (Aita, 1987)		X		
Williriedellum marcucciae (Cortese, 1993)		X		
Zhamoidellum sp.		X		
Zhamoidellum ovum Dumitrica, 1970		X	X	
Plegnosphaera? spp.			X	
Pseudoxitus? sp.			X	
Solenotryma ichikawai Matsuoka and Yao, 1985			X	
Triactoma sp.			X	
Orbiculiforma sp.				X
Praeconocaryomma sp.				X
Ristola sp.				X

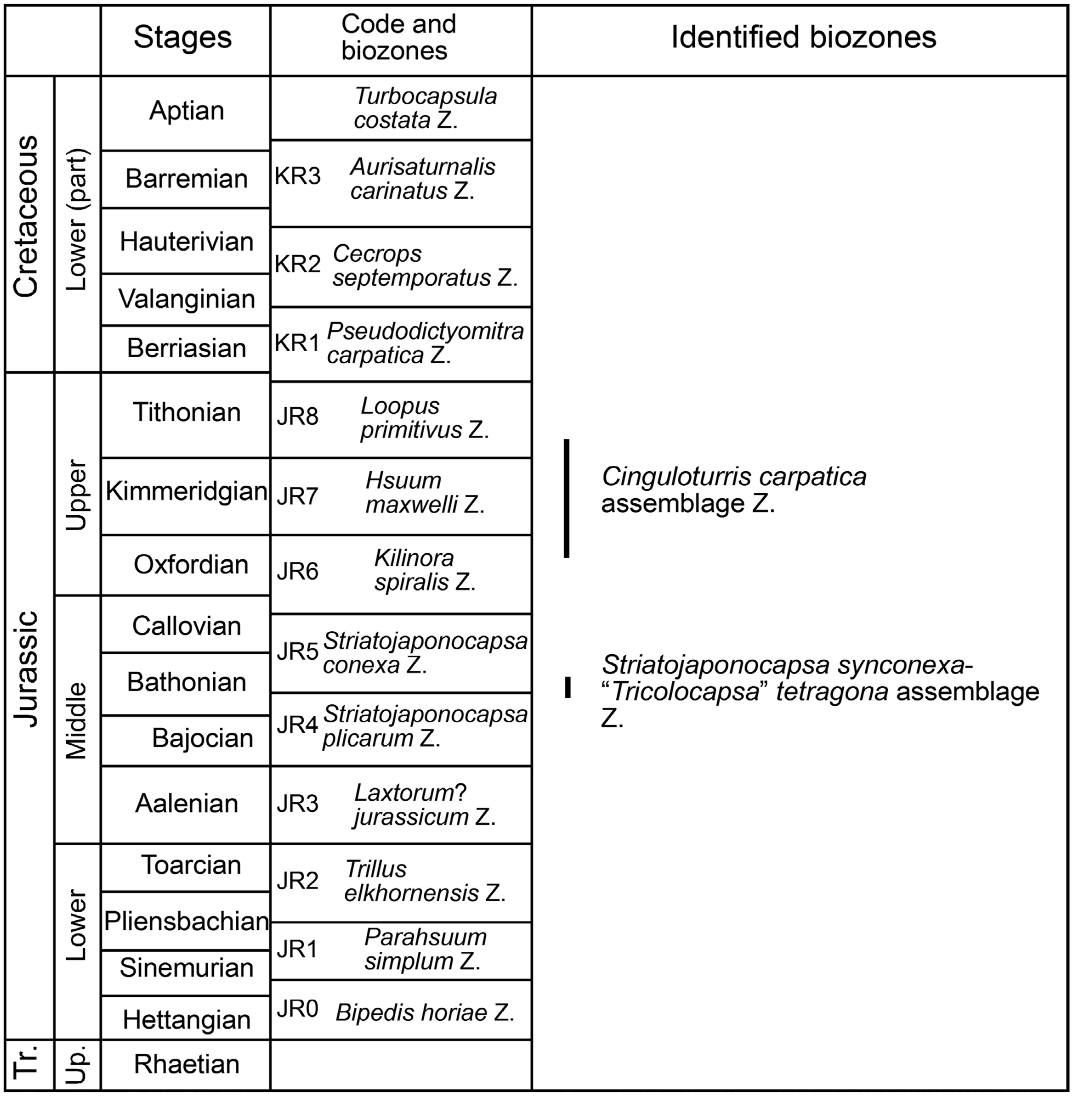

Figure 4. Radiolarian zones (after Matsuoka, 1995, 2006; Matsuoka *et al*., 2002) and the identified biozones for the Nadanhada radiolarian samples.

maxwelli Zone (Matsuoka, 1995).

***Striatojaponocapsa synconexa*-“*Tricolocapsa*” *tetragona* assemblage**

This assemblage consists of eleven species belonging to eight genera; except for cryptothracic Nassellaria, they are: *Archaeocenosphaera* sp., *Caneta*? sp. 1, “*Stichocapsa*” *convexa* Yao, 1979, “*Stichocapsa*” *robusta* Matsuoka, 1984, “*Stichocapsa*” sp., *Striatojaponocapsa synconexa* (O’Dogherty *et al*., 2005), *Tethysetta dhimenaensis* (Baumgartner, 1984), *Transhsuum* sp., *“Tricolocapsa”* sp., *“Tricolocapsa” tetragona* Matsuoka, 1983 and *Unuma gordus* Hull, 1997. Among them some species have geologically long ranges. Such as “*Stichocapsa*” *convexa* has a geological range of early Callovian–late Oxfordian according to Aita (1987), or early Aalenian–early Tithonian according to Baumgartner *et al*. (1995). “*Stichocapsa*” *robusta* ranges from latest Bajocian to early Callovian (Baumgartner *et al.*, 1995), or from early Callovian to late Oxfordian (Aita, 1987). *Tethysetta dhimenaensis* has a geological range of early Bajocian–early Oxfordian. *Striatojaponocapsa synconexa* has a geological range of UAZone 4–5 of Baumgartner *et al*. (1995). “*Tricolocapsa*” *tetragona*, meanwhile, has a restricted geological range, i.e., UAZone 5 of Baumgartner *et al*. (1995) or the uppermost part of the “*Striatojaponocapsa*” *plicarum* Zone to the basal part of the *Striatojaponocapsa conexa* Zone of Matsuoka (1995).

***Cinguloturris carpatica* assemblage**

This assemblage consists of 34 species belonging to 25 genera; they are *Arcanicapsa funatoensis* (Aita, 1987), *Archaeodictyomitra rigida* Pessagno, 1977a, *Archaeodictyomitra* sp., *Archaeospongoprunum* sp. 1, *Archaeospongoprunum* sp. 2, *Caneta*? sp. 1, *Caneta* sp. 2, *Emiluvia premyogii* Baumgartner, 1984, *Cinguloturris fusiforma* Hori, 1999, *Cinguloturris carpatica* Dumitrica in Dumitrica and Mello, 1982, *Crococapsa hexagona* (Hori, 1999), *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo, 1974), *Eucyrtidiellum unumaense* (Yao, 1979), *Gongylothorax favosus* Dumitrica, 1970, *Loopus* sp. 1, *Loopus* sp. 2, *Loopus*? sp. 3, *Olanda*? sp., *Orbiculiforma* sp., *Paronaella* sp. 1, *Paronaella* sp. 2, *Plegmosphaera*? spp., *Praeconocaryomma*? sp., *Protunuma japonicus* Matsuoka and Yao, 1985, *Pseudoxitus*? sp., *Ristola* sp., *Solenotryma ichikawai* Matsuoka and Yao, 1985, *Tethysetta dhimenaensis* (Baumgartner, 1984), *Theocapsomella himedaruma* (Aita, 1987), *Triactoma* sp., *Unuma gordus* Hull, 1997, *Williriedellum marcucciae* (Cortese, 1993), *Zhamoidellum ovum* Dumitrica, 1970, and *Zhamoidellum* sp.

Among them, *Arcanicapsa funatoensis* ranges from early Callovian to middle Kimmeridgian (Aita, 1987). *Archaeodictyomitra rigida* ranges from middle Oxfordian–early Kimmeridgian to Berriasian or younger (Hull, 1997). *Cinguloturris fusiformis* was reported in the Tithonian of Japan and the Far East of Russia (Hori, 1999). *Cinguloturris carpatica* is very common in the sample P1–08; it ranges from the *Kilinora spiralis* Zone to the *Loopus primitivus* Zone in Japan, in age late Callovian to late Tithonian (Matsuoka and Yao, 1986; Matsuoka, 1995). *Crococapsa hexagona* was described from the Tithonian of Japan (Hori, 1999). *Zhamoidellum ovum* Dumitrica ranges from middle Oxfordian to early Tithonian according to Baumgartner *et al*. (1995). With respect to the cooccurrence of these important species, the radiolarian assemblage is most probably assigned to the *Hsuum maxwelli* Zone (Figure 4), including the upper part of the *Kilinora spiralis* Zone and the lower part of the *Loopus primitivus* Zone (upper Oxfordian–lower Tithonian) (Matsuoka, 1995), although the zonal radiolarian species are not discovered in the three samples.

Discussion on tectonics and paleogeography

The Nadanhada terrane (Mizutani *et al*., 1986; Kojima, 1989; Zhang *et al.*, 1997), located in northeastern Heilongjiang, northeastern China, contains two accretionary complexes related to paleo-Pacific plate subduction and accretion (Kojima and Kametaka, 2000; Wilde and Zhou, 2015; Kojima *et al*., 2016): the Yuejinshan Complex in the west and the Raohe Complex in the east (Zhou *et al*., 2014). The Yuejinshan Complex (consisting of meta-clastic rocks and metamafic-ultramafic rocks) is the first-stage accretionary complex that accreted during the late Early Jurassic and led to the collision of the Jiamusi Massif westwards with the Central Asian Orogenic Belt (Wu *et al*., 2007). The Raohe Complex, the main part of the Nadanhada terrane, is composed of Carboniferous to Permian limestone (Li *et al*., 1979), Middle Triassic–Early Jurassic bedded chert, Middle Jurassic siliceous shale (Mizutani *et al*., 1986; Kojima, 1989; Yang *et al.*, 1993), mafic-ultramafic rocks, which as olistoliths are inbedded in clastic “matrix”. Although there is no fossil evidence, the geological age of the clastic “matrix” was assigned to Late Jurassic or Early Cretaceous by Kojima (1989). Now, we have found four samples (P1-08, 09, 012, 013) yielding two radiolarian assemblages from the Dalingqiao Formation in the P1 section in the Dajiashan area (Figures 3, 4). Three samples (P1-08, 012, 013) contain a Late Jurassic radiolarian assemblage, and one sample (P1-09) yields a Middle Jurassic radiolarian assemblage (Figure 3). As the four radiolarian samples are not in normal stratigraphic order, we interpret the Dalingqiao Formation as the clastic “matrix” of the accretionary melange, while the Late Jurassic radiolarian assemblage would precisely constrain the Late Jurassic accretion of the main part of the Nadanhada terrane. After the accretion event, the succedent late Tithonian–early Valanginian *Buchia* fauna-bearing Dong’anzhen Formation would be the earliest cover beds overlying the Raohe Complex. The Lower Cretaceous Dajiashan Group, containing an *Aucellina* bivalve fauna (Sha, 2007; Sha *et al*., 2009), is contemporaneous with the Longzhaogou Group and the Jixi Group of the Jiamusi Massif (Li and Yang, 2003; Li and Yu, 2004; Li and Matsuoka, 2015; Li and Bengtson, 2018). Although Late Jurassic to Early Cretaceous radiolarian faunas were reported from the Tamba-Mino-Ashio terrane in southwestern Japan, the late Tithonian to early Valanginian *Buchia* fauna is not reported there (Sha *et al*., 1994); moreover, the Early Cretaceous *Aucellina* fauna is not recovered in Japan (Sha *et al*., 1994). These faunal differences may indicate paleogeographic differentiation between the Nadanhada terrane and the Tamba-Mino-Ashio terrane.

Paleontological description

For species, reference to the author, the first illustration, and the currently adopted species concept are given. Genera and species are arranged in alphabetical order within orders Spumellaria and Nassellaria, respectively.

Order Spumellaria Ehrenberg, 1875, emend. De Wever *et al*., 2001

Genus ***Archaeocenosphaera*** Pessagno and Yang, 1989

Type species.—*Archaeocenosphaera ruesti* Pessagno and Yang in Pessagno *et al*., 1989.

Archaeocenosphaera sp.

Figures 5.17, 8.1

Material.—Specimen P1-8-29 is from the sample P1-08; specimen P1-09-25 is from the sample P1-09.

Dimensions (in μm).—Diameter of cortical shell (Max./Min.): 256/241 (P1-8-29), 156/153 (P1-09-25).

Remarks.—Only two specimens are encountered. The cortical test possesses denser pore frames than *Archaeocenosphaera ruesti* Pessagno and Yang in Pessagno *et al*., 1989, and it is easily differentiated from the latter. The Chinese specimens possess massive nodes in the lattices of pore frames, and differ from *A. laseekensis* Pessagno and Yang in Pessagno *et al*., 1989.

Range and occurrence.—Middle and Upper Jurassic. Nadanhada.

Genus ***Archaeospongoprunum*** Pessagno, 1973

Type species.—*Archaeospongoprunum venadoense* Pessagno, 1973.

Archaeospongoprunum sp. 1

Figure 8.3

Material.—Specimen P1-08-24 is from the sample P1-08.

Dimensions (in μm).—Length of spine: 196; length of test: 237; width of test: 193.

Remarks.—Test ellipsoidal, with two triradiate polar spines.

Range and occurrence.—Upper Jurassic. Nadanhada.

Archaeospongoprunum sp. 2

Figure 8.4

Material.—Specimen 108x2-08 is from the sample P1-08.

Dimensions (in μm).—Length of test: 196; width of test: 96.

Remarks.—Test cylindrical, surface ornamented with polygonal pore frames, two polar spines triradiate in axial section.

Range and occurrence.—Upper Jurassic. Nadanhada.

Genus ***Emiluvia*** Foreman, 1973, emend. Pessagno, 1977a

Type species.—*Emiluvia chica* Foreman, 1973.

Emiluvia premyogii Baumgartner, 1984

Figures 8.5, 8.6

Emiluvia premyogii Baumgartner, 1984, p. 762, pl. 3, figs. 6, 8, 9; Hull, 1997, p. 68, pl. 27, figs. 1, 2, 21.

Material.—Specimens 108x2-20, P1-08-28 are from the sample P1-08.

Dimensions (in μm).—Length of long spine, length of short spine, between base of spines, between concave sides: 143, 97, 130, 99 (108x2-20); 262, 209, 184, 134 (P1-08-28).

Remarks.—The small specimens are preserved with broken spines. About 6 pairs of nodes between opposed spines. Center of cross forms a raised polygonal structure often with a center node. Additional lateral meshwork has no significant node.

Occurrence.—UAZones 3–10, early–middle Bajocian to late Oxfordian–early Kimmeridgian. Blake-Bahama Basin, California, Carpathians, Italy, Japan, Nadanhada, Yugoslavia.

Genus ***Orbiculiforma*** Pessagno, 1973

Type species.—*Orbiculiforma quadrata* Pessagno, 1973.

Orbiculiforma sp.

Figure 7.3

Material.—Specimen 13-7 is from the sample P1-013.

Dimensions (in μm).—Test diameter: 240; diameter of central cavity: 120.

Remarks.—Only one specimen encountered. It is similar to *Orbiculiforma lowreyensis* Pessagno, 1977a in having sloping sides and angled periphery. The former differs from the latter in having a smaller test size and relatively larger ratio of central cavity to test diameter.

Range and occurrence.—Middle Jurassic. Nadanhada.

Genus ***Paronaella*** Pessagno, 1971, emend. Baumgartner, 1980

Type species.—*Paronaella solanoensis* Pessagno, 1971.

Paronaella sp. 1

Figure 8.7

Material.—Specimen 108x2-34 is from the sample P1-08.

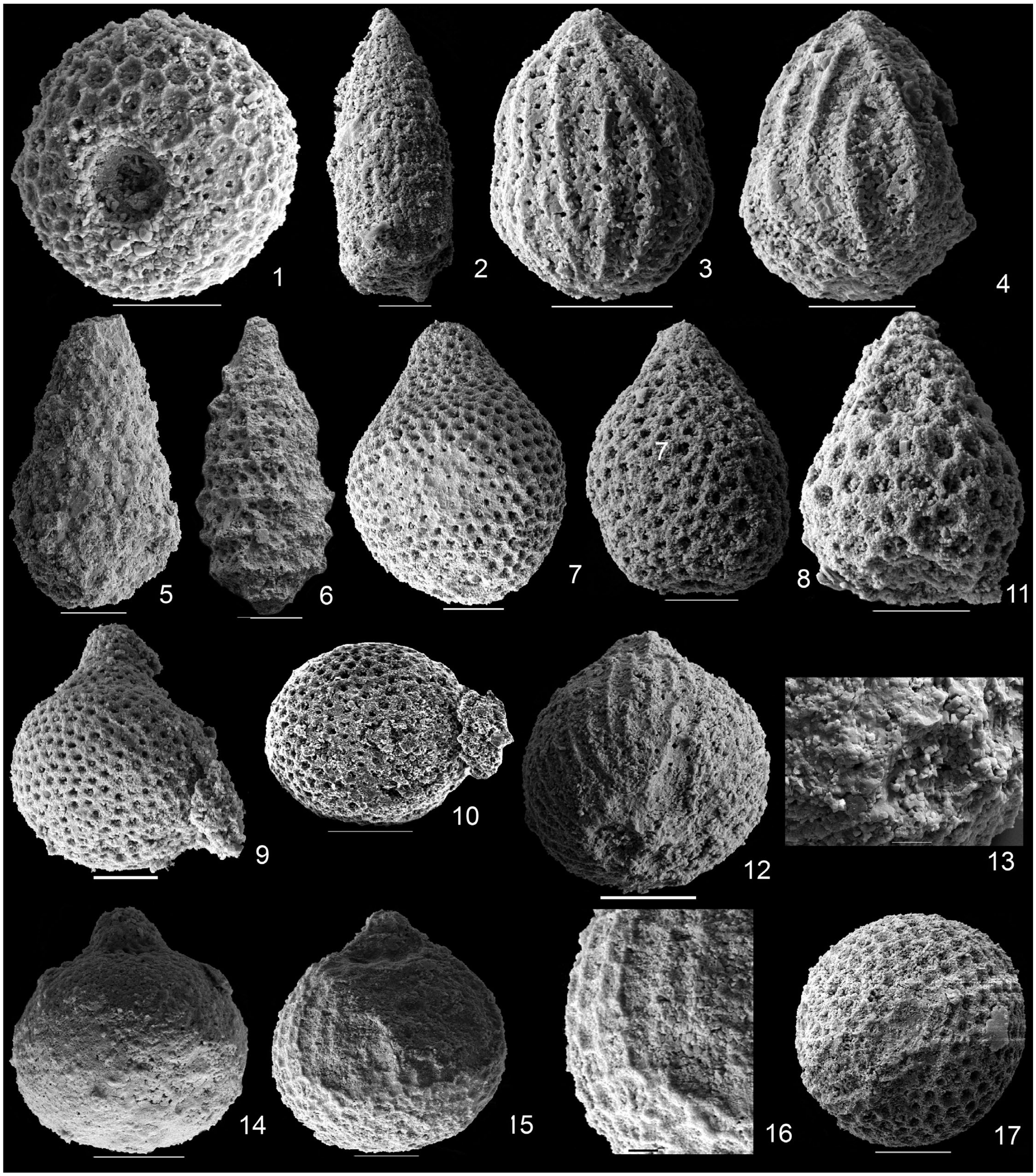

Figure 5. All specimens are from sample P1-09 in the Dajiashan area of Hulin County, eastern Heilongjiang Province, northeastern China. All scale bars are 50 μm except for further indication. **1**, Cryptothoracic Nassellaria, specimen P1-09-4; **2**, *Transhsuum*? sp., specimen P1-9-3; **3, 4,** *Unuma gordus* Hull, 1997; 3, specimen P1-9-4; 4, specimen P1-9-7; **5,** *Caneta*? sp. 1, specimen P1-09-22; **6,** *Tethysetta dhimenaensis* (Baumgartner, 1984), specimen P1-12-9; **7, 8,** "*Stichocapsa*" *robusta* Matsuoka, 1984; 7, specimen P1-09-24; 8, specimen P1-9-5; **9, 10,** "*Stichocapsa*" *convexa* Yao, 1979, specimen P1-09-10-3; 9, side view; 10, aperture view; **11,** "*Stichocapsa*" sp., specimen P1-9-8; **12, 13,** *Striatojaponocapsa synconexa* O'Dogherty, Gorican and Dumitrica in O'Dogherty *et al*., 2005, specimen P1-9-28; 12, side view; 13, apertural view, shows the circular depression near the aperture, scale bar 10 μm; **14,** *"Tricolocapsa"* sp., specimen P1-9-20; **15, 16,** *"Tricolocapsa" tetragona* Matsuoka, 1983, specimen P1-9-6; 15, side view; 16, enlargement of the left part of the specimen of 15, showing the tetragonal pore frames consisting of the longitudinal plicae and the interposed transverse bars, scale bar 10 μm; **17,** *Archaeocenosphaera* sp., specimen P1-09-25.

Dimensions (in μm).—Length of rays: AX (A axis), 200; BX (B axis), 219; CX (C axis), 238; narrowest width of rays: AX, 86; BX, 86; CX, 76; width of ray tips: AX, 133; BX, 133; CX, 124.

Remarks.—The present specimen is preserved with faint polygonal pore frames in the surface of rays and the central part, the spines at the ray tips are broken. With respect to the test outline and the dimensions, it is closely related to *Paronaella mulleri* Pessagno, 1977a, but the lack of information about the inner structure makes further comparison difficult.

Range and occurrence.—Upper Jurassic. Nadanhada.

Paronaella sp. 2

Figure 8.8

Material.—Specimen P1-08-26 is from the sample P1-08.

Dimensions (in μm).—Length of rays: AX (A axis), ?; BX (B axis), 216; CX (C axis), 168; width of base of rays: AX, 112; BX, 112; CX, 104; length of ray spines: AX, ?; BX, ?; CX, 24.

Remarks.—The specimen is closely related to *Paronaella pygmaea* Baumgartner, 1980 except for the large size of the present specimen. The poor preservation and the lack of information on the inner structure make further identification difficult.

Range and occurrence.—Upper Jurassic. Nadanhada.

Genus ***Plegmosphaera*** Haeckel, 1881

Type species.—*Plegmosphaera maxima* Haeckel, 1887.

Plegmosphaera? spp.

Figures 6.1, 6.2

Material.—Specimen P1-8-16 is from the sample P1-08; specimen P1-9-10 is from the sample P1-09; specimens P1-12-1, 6, 7, 29, 31, 32, 33 are from the sample P1-012; specimen P1-13-2 is from the sample P1-013.

Dimensions (in μm).—Diameter of cortical shell (Max./Min.): 144/135 (P1-8-16), 235/209 (P1-9-10), 291/257 (P1-12-1), 224/223 (P1-12-6), 219/206 (P1-12-7), 230/222 (P1-12-29), 249/238 (P1-12-31), 145/132 (P1-12-32), 148/128 (P1-12-33), 173/168 (P1-13-2).

Remarks.—The Chinese specimens are spherical or ellipsoidal spongy spumellarians. They should be differentiated into different species, but since the inner structure of the present specimens is not preserved, they are only preliminarily included in the genus.

Range and occurrence.—Late Callovian to Berriasian. Antarctica, Italy, Nadanhada, Oman.

Genus ***Praeconocaryomma*** Pessagno, 1976

Type species.—*Praeconocaryomma universa* Pessagno, 1976.

Praeconocaryomma? sp.

Figures 7.1, 7.2, 8.2

Material.—Specimen P1-08-17 is from the sample P1-08; Specimens P1-13-5, 12, 14 are from the sample P1-013.

Description.—Cortical test spherical, having numerous mammae in lower relief, and having triangular meshwork in the area between mammae.

Dimension (in μm).—Diameter of cortical test 208 (P1-08-17), 260/247 (P1-13-5), 253/207 (P1-13-12), 256/249 (P1-13-14).

Remarks.—The Chinese specimen is similar to *Praeconocaryomma mamillaria* (Rüst) by sharing triangular meshwork in the area between small mammae in lower relief, but the present specimen is poorly preserved, and this hampers further comparison.

Range and occurrence.—Upper Jurassic. Nadanhada.

Genus ***Triactoma*** Rüst, 1885

Type species.—*Triactoma tithonianum* Rüst, 1885, subsequent designation by Campbell, 1954.

Triactoma sp.

Figures 6.3, 6.4

Material.—Specimens P1-12-4, P1-12-8 are from the sample P1-012.

Description.—Cortical shell large, spherical, composed of very massive hexagonal or pentagonal pore frames; about twelve pore frames visible on test surface along axis of each spine. Three spines broken, two of them closely spaced, the third one widely separated from the other two.

Dimension (in μm).—Diameter of cortical shell: 228.

Remarks.—The specimens preserved with broken spines, two of them closely spaced, cortical shell large, spherical with the hexagonal and pentagonal pore frames.

Range and occurrence.—Upper Jurassic. Nadanhada.

Order Nassellaria Ehrenberg, 1875
Genus ***Arcanicapsa*** Takemura, 1986

Type species.—*Arcanicapsa sphaerica* Takemura, 1986.

Arcanicapsa funatoensis (Aita, 1987)

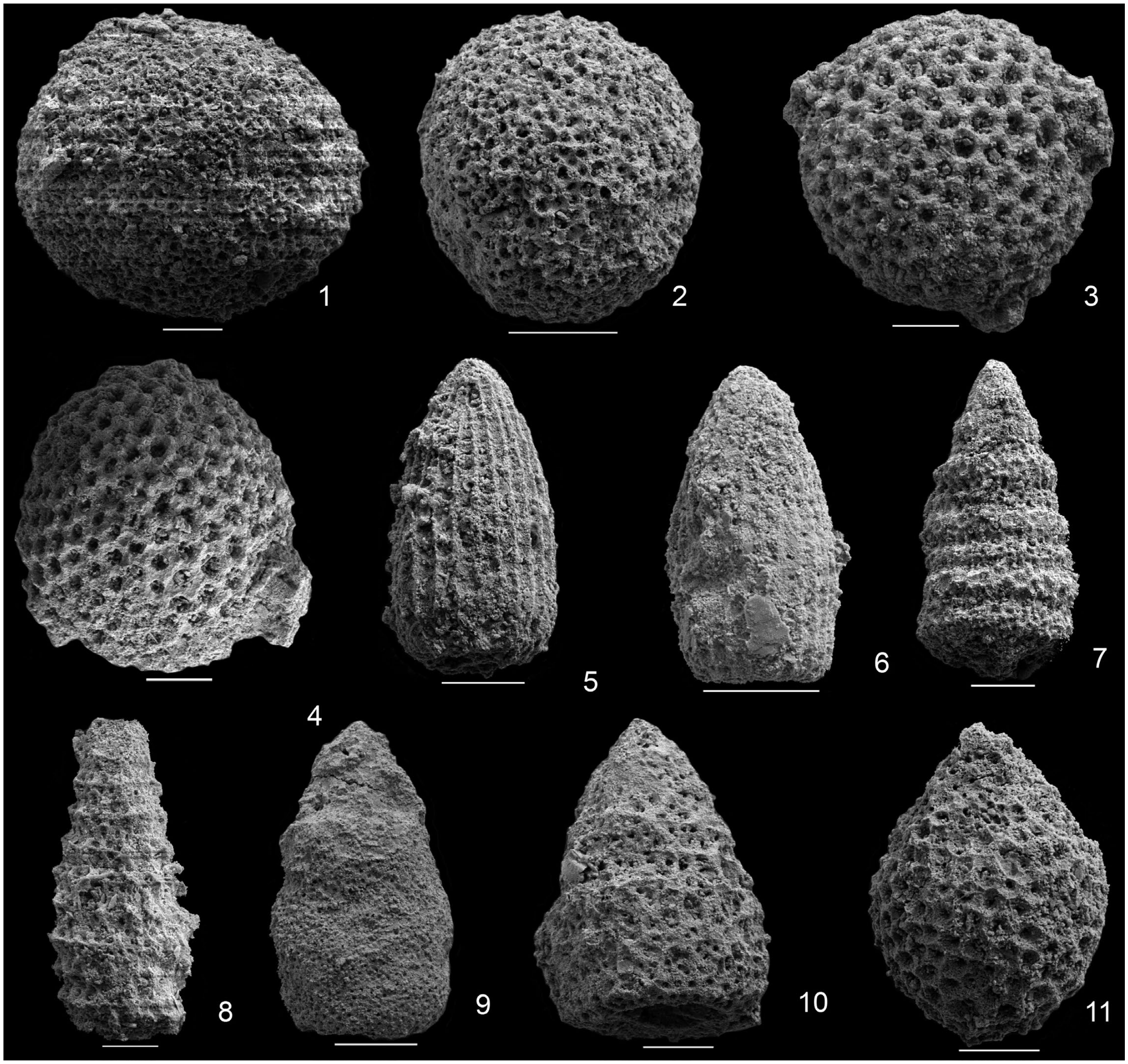

Figure 6. All specimens are from sample P1-012 in the Dajiashan area of Hulin County, eastern Heilongjiang Province, northeastern China. All scale bars are 50 µm. **1, 2,** *Plegmosphaera*? spp.; 1, specimen P1-12-1; 2, specimen P1-12-32; **3, 4,** *Triactoma* sp.; 3, specimen P1-12-4; 4, specimen P1-12-8; **5, 6,** *Archaeodictyomitra rigida* Pessagno, 1977a; 5, specimen P1-12-26; 6, specimen P1-12-43; **7,** *Cinguloturris carpatica* Dumitrica in Dumitrica and Mello, 1982, specimen P1-12-11; **8,** *Tethysetta dhimenaensis* (Baumgartner, 1984), specimen P1-12-27; **9,** *Solenotryma ichikawai* Matsuoka and Yao, 1985, specimen P1-12-41; **10,** *Pseudoxitus*? sp., specimen P1-12-19; **11,** *Zhamoidellum ovum* Dumitrica, 1970, specimen P1-12-30.

Figures 9.16, 9.17

Sethocapsa funataoensis Aita, 1987, p. 73, pl. 2, figs. 6a–7b; pl. 9, figs. 14, 15; Baumgartner *et al*., 1995, p. 494, pl. 3070, figs. 1–4, 5.

Zhamoidellum funatoensis (Aita). Hull, 1997, p. 132, pl. 38, figs. 13, 15.

Arcanicapsa funatoensis (Aita, 1987). Nishihara and Yao, 2005, fig. 5.1; O'Dogherty *et al*., 2017, p. 45, figs. 10.5–10.16.

Material.—Specimens P1-8-49, 59 are from the sample P1-08.

Dimensions (in µm).—Height/maximal width: 174/143 (P1-8-49), 153/158 (P1-8-59).

Remarks.—The Chinese specimens are slightly different from the Japanese type specimen by having a roughened thorax with a lesser number of pores.

Range and occurrence.—UAZones 3–11, early–

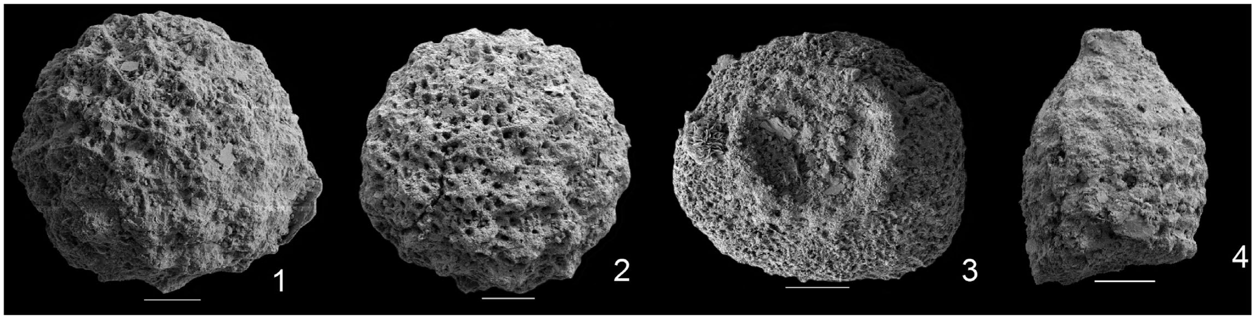

Figure 7. All specimens are from sample P1-013 in the Dajiashan area of Hulin County, eastern Heilongjiang Province, northeastern China. All scale bars are 50 μm. **1, 2,** *Praeconocaryomma* sp.; 1, specimen P1-13-5; 2, specimen P1-13-14; **3,** *Orbiculiforma* sp., specimen P1-13-7; **4,** *Ristola* sp., specimen P1-13-11.

middle Bajocian to late Kimmeridgian–early Tithonian (Baumgartner *et al*., 1995). California, Austria, Japan, Nadanhada.

Genus ***Archaeodictyomitra*** Pessagno, 1976, emend. Pessagno, 1977b, Yang, 1993

Type species.—Archaeodictyomitra squinaboli Pessagno, 1976.

Archaeodictyomitra rigida Pessagno, 1977a

Figures 6.5, 6.6, 8.12, 8.13

Archaeodictyomitra rigida Pessagno, 1977a, p. 81, pl. 7, figs. 10, 11; Wu, 1993, p. 123, pl. 2, fig. 18; Hull, 1997, p. 79, pl. 32, fig. 6.

Material.—Specimens P1-8-38, P1-8-39 are from the sample P1-08; specimens P1-12-26, P1-12-43 are from the sample P1-012.

Dimensions (in μm).—Height/Width: 152/84 (P1-8-38), 160/93 (P1-8-39), 182/99 (P1-12-26), 134/71 (P1-12-43).

Remarks.—The Chinese specimens have a lesser number of chambers than the holotype of the species, but the other characters agree well with the type specimen.

Range and occurrence.—Middle Oxfordian–lower Kimmeridgian to Berriasian or younger. California; Nadanhada, Tibet, China.

Archaeodictyomitra sp.

Figure 8.14

Material.—Specimen P1-08-20 is from the sample P1-08.

Dimensions (in μm).—Length/Width: 167/101 (P1-08-20)

Remarks.—The specimens have similar outlines and the same number of widely spaced longitudinal costae as one of the two figured specimens of *Archaeodictyomitra pseudomulticostata* of Dumitrica *et al*. (1997, pl. 7, fig. 5), but differs in that the latter species has an inflated final chamber.

Range and occurrence.—Upper Jurassic. Nadanhada.

Genus ***Caneta*** Pessagno, Blome and Hull in Pessagno *et al*., 1993

Type species.—*Parvicingula hsui* Pessagno, 1977a.

Caneta? sp. 1

Figure 5.5

Material.—Specimen P1-09-22 is broken and from the sample P1-09.

Dimension (in μm).—Height/Maximum width: 217/125.

Remarks.—The Chinese specimen is preserved with a broken cephalis. It has a smaller and broader test than the type species *Caneta hsui*.

Range and occurrence.—Middle Jurassic. Nadanhada.

Caneta sp. 2

Figure 9.1

Material.—Specimen P108-1 is from the sample P1-08.

Dimension (in μm).—Height/Width (maximum): 308/131.

Remarks.—The Chinese specimen is similar to *Svinitzium pseudopuga* Dumitrica *et al.*, 1997, but differs by having a slender test outline and stronger H-linked costae in the circumferential ridges.

Range and occurrence.—Upper Jurassic. Nadanhada.

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

Type species.—Cinguluturris carpatica Dumitrica in

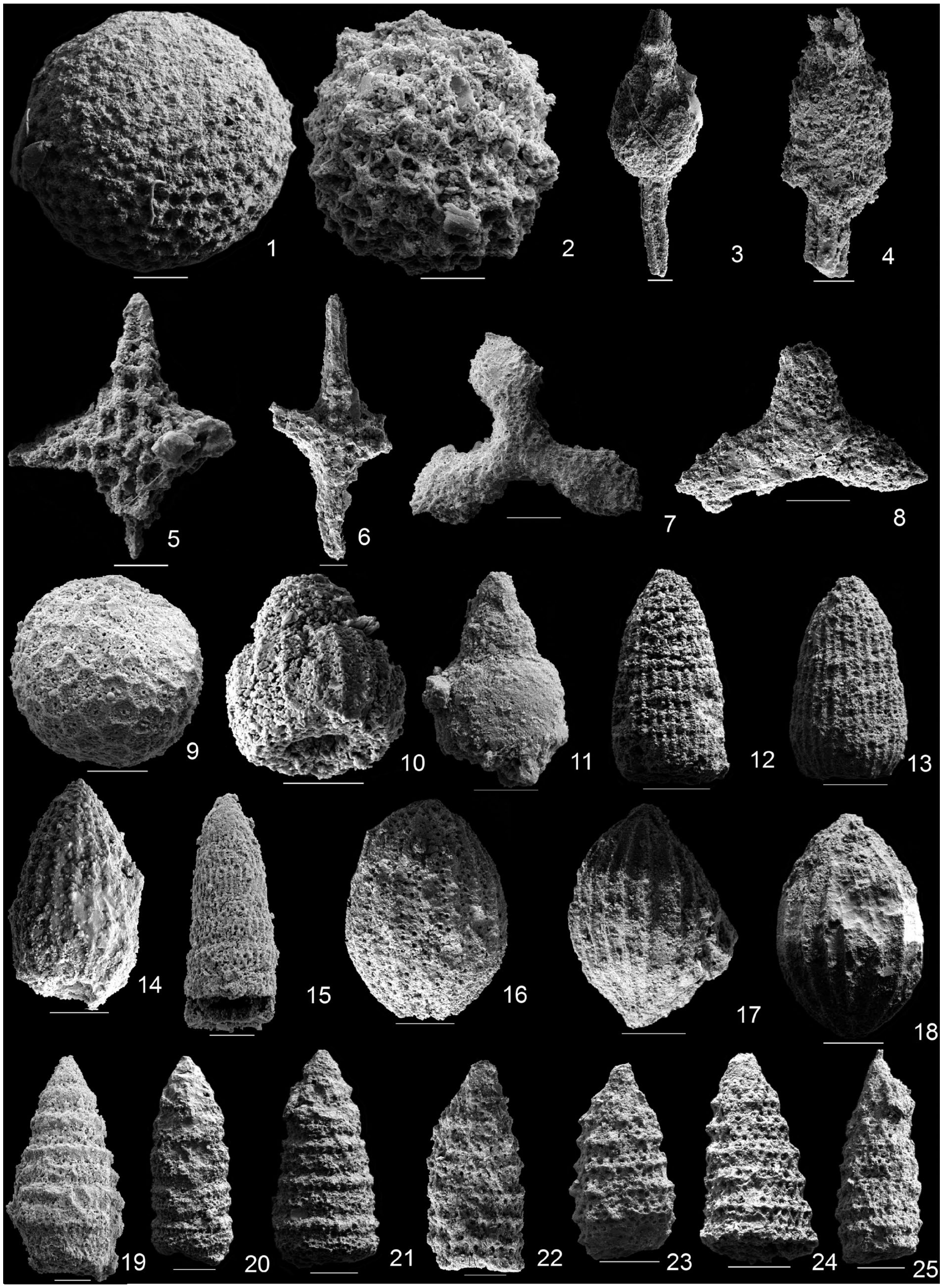

Figure 8. All specimens are from sample P1-08 in the Dajiashan area of Hulin County, eastern Heilongjiang Province, northeastern China. All scale bars are 50 µm. **1,** *Archaeocenosphaera* sp., specimen P1-8-29; **2,** *Praeconocaryomma*? sp., specimen P1-08-17; **3,** *Archaeospongoprunum* sp. 1, specimen P1-08-24; **4,** *Archaeospongoprunum* sp. 2, specimen 108x2-08; **5,6,** *Emiluvia praemyogii* Baumgartner, 1984; 5, specimen 108x2-20; 6, specimen P1-08-28; **7,** *Paronaella* sp. 1, specimen 108x2-34, scale bar 100 µm; **8,** *Paronaella* sp. 2, specimen P1-08-26, scale bar 100 µm; **9,** *Gongylothorax favosus* Dumitrica, 1970, specimen P1-08-11; **10,** *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo, 1974), specimen 108x2-24; **11,** *Eucyrtidiellum unumaense* (Yao, 1979), specimen P1-8-64; **12, 13,** *Archaeodictyomitra rigida* Pessagno, 1977a; 12, specimen P1-8-38; 13, specimen P1-8-39; **14,** *Archaeodictyomitra* sp., specimen P1-08-20; **15,** *Loopus*? sp. 1, specimen P1-08-2; **16,** *Unuma gordus* Hull, 1997, specimen P1-8-69; **17, 18,** *Protunuma japonicus* Matsuoka and Yao, 1985; 17, specimen P1-8-1; 18, specimen P1-8-25; **19,** *Cinguloturris fusiformis* Hori, 1999, specimen P1-08-4; **20, 21,** *Cinguloturris carpatica* Dumitrica in Dumitrica and Mello, 1982; 20, specimen P1-8-9; 21, specimen P1-8-46; **22–25,** *Tethysetta dhimenaensis* (Baumgartner, 1984); 22, specimen 108x2-28; 23, specimen P1-8-27; 24, specimen P1-8-37; 25, specimen P1-8-42.

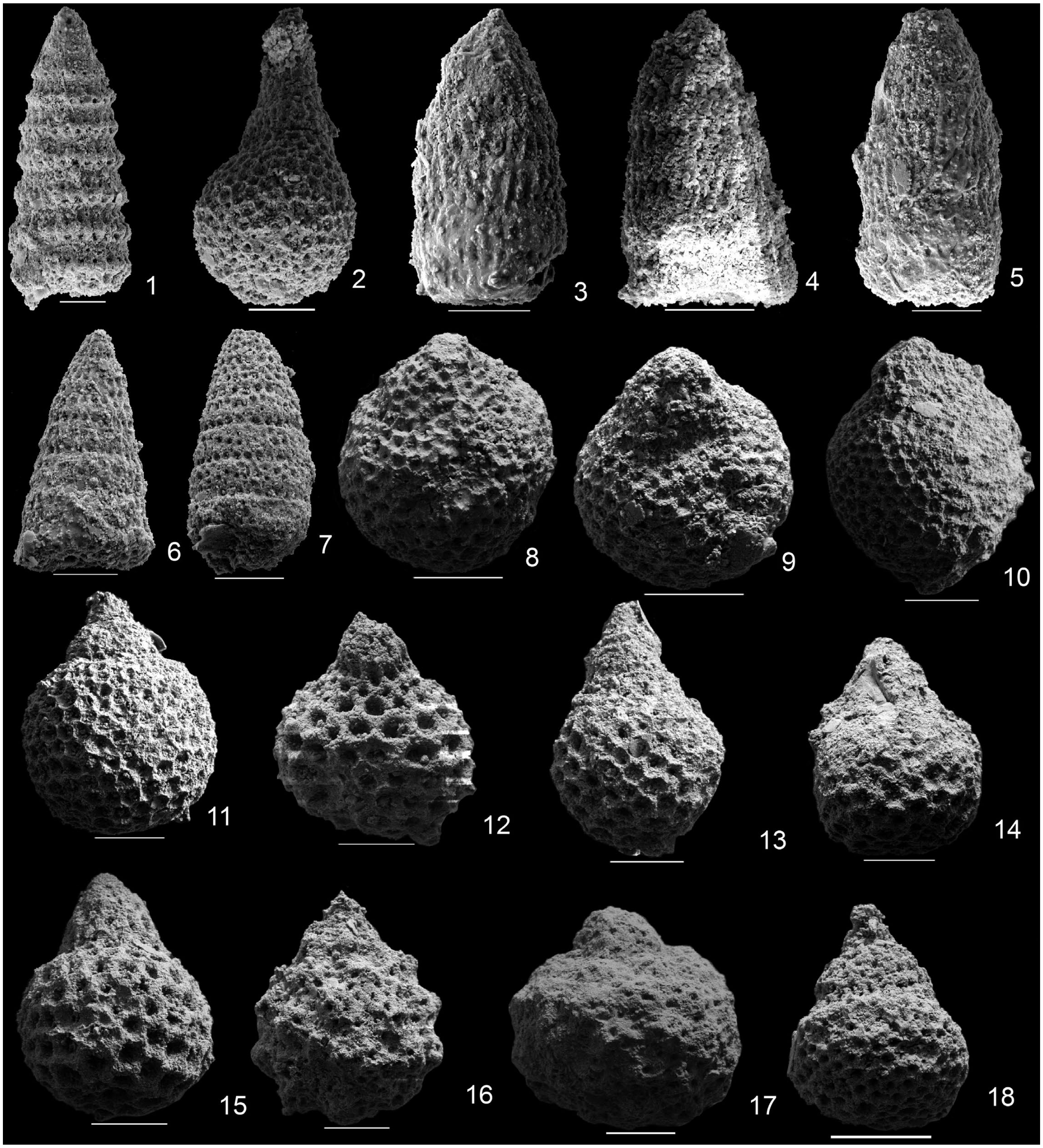

Figure 9. All specimens are from sample P1-08 in the Dajiashan area of Hulin County, eastern Heilongjiang Province, northeastern China. All scale bars are 50 µm. **1,** *Caneta* sp. 2, specimen P108-1; **2,** *Olanda*? sp., specimen 108x2-25; **3–5,** *Loopus* sp. 2; 3, specimen P1-08-30; 4, specimen 108x2-11; 5, specimen 108x2-12; **6, 7,** *Loopus*? sp. 3; 6, specimen P1-08-6; 7, specimen P1-08-25; **8, 9,** *Zhamoidellum ovum* Dumitrica, 1970; 8, specimen P1-8-32; 9, specimen P1-8-50; **10,** *Williriedellum marcucciae* (Cortese, 1993), specimen P1-8-40; **11,** *Zhamoidellum* sp. specimen P1-8-44; **12–15,** *Crococapsa hexagona* (Hori, 1999); 12, specimen P1-8-19; 13, specimen P1-8-10; 14, specimen P1-8-15; 15, specimen P1-8-60; **16, 17,** *Arcanicapsa funatoensis* (Aita, 1987); 16, specimen P1-8-49; 17, specimen P1-8-59; **18,** *Theocapsomella himedaruma* (Aita, 1987), specimen P1-8-54.

Dumitrica and Mello, 1982.

Cinguloturris fusiforma Hori, 1999

Figure 8.19

Cinguloturris fusiforma Hori, 1999, p. 93, fig. 9(3–6); fig. 11(6).

Material.—Specimen P1-08-4 is from the sample P1-08.

Dimensions (in μm).—Height/Maximum width: 302/163.

Remarks.—The species differs from *Cinguloturris carpatica* by having a spindle- shaped outline.

Range and occurrence.—Tithonian (Upper Jurassic). Russia, Japan, Nadanhada.

Cinguloturris carpatica Dumitrica in Dumitrica and Mello, 1982

Figures 6.7, 8.20, 8.21

Cinguloturris carpatica Dumitrica. Dumitrica and Mello, 1982, p. 23, pl. 4, figs. 7–14; Matsuoka and Yao, 1986, pl. 2, fig. 14; Matsuoka, 1986a, pl. 2, fig. 16; pl. 3, fig. 11a, b; Baumgartner *et al*., 1995, p. 142, pl. 3193, figs. 1–6; Yang and Matsuoka, 1997, pl. 3, fig. 9; Hori, 1999, p. 91, fig. 9(1); Matsuoka *et al*., 2002, fig. 5(16).

Material.—Specimens P1-8-4, P1-8-9, P1-8-43, P1-8-46 are from the sample P1-08; specimen P1-12-11 is from the sample P1-012.

Dimensions (in μm).—Height/Maximum width: 189/108 (P1-8-4), 252/102 (P1-8-9).

Remarks.—Diameter of segment increasing rapidly up to the third segment, and slower in the following ones, so that the postabdominal chambers become cylindrical. The spongy network between adjacent segments is well developed beginning with the third or fourth constriction.

Range and occurrence.—The species ranges within UAZones 7–11, upper Bathonian–lower Callovian to upper Kimmeridgian–lower Tithonian (Baumgartner *et al*., 1995); Callovian to Tithonian (Hori, 1999). Caucasus, Japan, Nadanhada, northern Apennines, Russian Far East, Tibet, western Carpathians, western Pacific Ocean (ODP Leg 129, Site 801), Yugoslavia.

Genus ***Crococapsa***

Type species.—*Tetracapsa pilula* Rüst, 1885.

Crococapsa hexagona (Hori, 1999)

Figures 9.12–9.15

Sethocapsa hexagona Hori, 1999, p. 74, fig. 6(12–16); fig. 11(1a, b).

Material.—Specimens P1-8-10, 15, 19, 60, and P108-27 are from the sample P1-08.

Description.—Test consists of four segments. Cephalis subspherical, imperforate, without an apical horn, and slightly encased in the thorax. Thorax and abdomen trapezoidal and perforate. First three segments are almost the same height and gradually increase in width. Strictures are weakly developed. The final segment is very large and spherical, and possesses strong hexagonal pore frames with rounded pores.

Dimensions (in μm).—Height/Maximal Width: 162/118 (P1-8-10), 149/115 (P1-8-15), 143/126 (P1-8-19), 142/124 (P1-8-60), ?/177 (P108-27).

Remarks.—The present specimens differ from the Japanese specimens of *T. hexagona* Hori by having a smaller test and by possessing a spherical final chamber, but with respect to the strong hexagonal pore frames, they can be assigned to the Japanese species. The present specimens are similar to *Hiscocapsa asseni* (Tan) (O'Dogherty, 1994) but differ from the latter by possessing larger and fewer pore frames in the shell of the final chamber, and by lacking a terminal aperture.

Range and occurrence.—Upper Jurassic. Japan, Nadanhada.

Genus ***Eucyrtidiellum*** Baumgartner, 1984

Type species.—*Eucyrtidium* (?) *unumaensis* Yao, 1979.

Eucyrtidiellum ptyctum (Riedel and Sanfilippo, 1974)

Figure 8.10

Eucyrtidium ptyctum Riedel and Sanfilippo, 1974, p. 778, pl. 5, fig. 7; pl. 12, fig. 14, not fig. 15; Matsuoka and Yao, 1985, pl. 2, fig. 8.

Eucyrtidiellum ptyctum (Riedel and Sanfilippo). Matsuoka, 1986a, pl. 2, fig. 10; Baumgartner *et al*., 1995, p. 214, pl. 3017, figs. 1–8.

Material.—Specimen 108x2-24 is from the sample P1-08.

Dimensions (in μm).—Height/Maximum width: 95/87.

Remarks.—The present species differs from other species of the genus by having a thorax with numerous small nodes and a wholly costated abdomen.

Range and occurrence.—UAZones 5–11, latest Bajocian–early Bathonian to late Kimmeridgian-early Tithonian (Baumgartner *et al.*, 1995). Callovian to Tithonian (Hori, 1999). Argolis Peninsula, Blake-Bahama Basin (DSDP Site 534), California Coast Ranges, western Pacific Ocean (ODP Leg 129, Site 801), Yugoslavia.

Eucyrtidiellum unumaense (Yao, 1979)

Figure 8.11

Eucyrtidium ptyctum Riedel and Sanfilippo, 1974, p. 778, pl. 12, fig. 15 only.

Eucyrtidium (?) *unumaensis* Yao, 1979, p. 39, pl. 9, figs. 1–11.

Eucyrtidium (?) *unumaense* Yao. Matsuoka, 1982, pl. 1, fig. 15; Matsuoka, 1985, pl. 1, fig. 9; Kojima, 1989, pl. 2, fig. 5a, b; Matsuoka, 1992, pl. 1, fig. 8; pl. 2, fig. 7.
Eucyrtidiellum unumaense unumaense (Yao). Baumgartner *et al*., 1995, p. 222, pl. 3012, figs. 1, 2.

Material.—Specimen P1-8-64 is from the sample P1-08.

Dimension (in μm).—Height/Maximum width: 168/101.

Remarks.—The Chinese specimen is poorly preserved, and with a relatively long thorax, but there may be intraspecific variation.

Range and occurrence.—UAZones 3–8, early middle Bajocian to middle Callovian–early Oxfordian (Baumgartner *et al*., 1995). Far East Russia, Japan, Yugoslavia, Nadanhada.

Genus ***Gongylothorax*** Foreman, 1968, emend. Dumitrica, 1970

Type species.—*Dicolocapsa verbeeki* Tan Sin Hok, 1927.

Gongylothorax favosus Dumitrica, 1970

Figure 8.9

Gongylothorax favosus Dumitrica, 1970, p. 56, pl. 1, fig. 1a–c, 2; Baumgartner *et al*., 1995, p. 230, pl. 6131, figs. 1–6, 7; Hori, 1999, p. 74, fig. 6(10).

Material.—Specimen P1-08-11 is from the sample P1-08.

Dimensions (in μm).—Width of thorax: 153.

Remarks.—The Chinese specimen has a spherical thorax whose surface is ornamented with regularly arranged hexagonal pore frames, bearing a small pore in the center. All these features agree well with *Gongylothorax favosus*.

Range and occurrence.—UAZones 8–10, middle Callovian–early Oxfordian to late Oxfordian–early Kimmeridgian (Baumgartner *et al*., 1995). Bathonian to Tithonian (Hori, 1999). California, Eastern Alps, Japan, Nadanhada, Romania, western Pacific Ocean (ODP Leg 129, Site 801), Yugoslavia.

Genus ***Loopus*** Yang, 1993

Type species.—*Pseudodictyomitra primitiva* Matsuoka and Yao, 1985.

Loopus sp. 1

Figure 8.15

Material.—Specimen P1-08-2 is from the sample P1-08.

Dimensions (in μm).—Length/Width: 265/103.

Remarks.—The present specimen is attributed to *Loopus* because most segments bear longitudinal and discontinuous costae.

Range and occurrence.—Upper Jurassic. Nadanhada.

Loopus sp. 2

Figures 9.3–9.5

Material.—Specimens P1-08-30, 108x2-11, 108x2-12 are from sample P1-08.

Dimension (in μm).—Height/Maximal width: 181/97 (P1-08-30), 164/99 (108x2-11), 209/108 (108x2-12).

Remarks.—The Chinese specimens are similar to *Loopus nudus* (Schaaf, 1981) (Dumitrica *et al*., 1997, pl. 5, figs. 6, 23) in having the same test outline and the same number of chambers, but they differ from the latter by having weakly developed strictures between chambers, and by having more distinct fine costae on the chamber surfaces.

Range and occurrence.—Upper Jurassic. Nadanhada.

Loopus? sp. 3

Figures 9.6, 9.7

Material.—Specimens P1-08-6, 25 are from the sample P1-08.

Dimensions (in μm).—Height/Maximal width: 169/107 (P1-08-6), 163/94 (P1-08-25).

Remarks.—The Chinese specimens possess one row of large primary pores in strictures between segments, but the postcephalic chambers possess three rows of primary and relict pores instead of fine costae. They differ from the typical taxa of *Loopus*, thus they are tentatively assigned to the genus *Loopus*. The Chinese specimens are closely similar to *Pseudodictyomitra*? sp. D from the Upper Jurassic to Lower Cretaceous Torinosu Group and Yura Formation (Matsuoka and Yao, 1985, pl. 2, figs. 6, 7), and from the Upper Jurassic of Togano Group (Matsuoka, 1986a, pl. 2, fig. 11) of Japan, but the former differs from the latter in having three rows of primary and relict pores in each postcephalic segment instead of two rows in the latter taxon.

Range and occurrence.—Upper Jurassic. Nadanhada.

Genus ***Olanda*** Hull, 1997

Type species.—*Olanda olorina* Hull, 1997.

Olanda? sp.

Figure 9.2

Material.—One broken specimen 108x2-25 is from the sample P1-08.

Dimension (in µm).—Height/Maximal width: 229/127.

Remarks.—The present broken specimen is composed of an apical slender conical part and a large final postabdominal bulbous chamber. But the apical conical part does not have longitudinal costae, which are well developed in the type species *Olanda olorina*. The Chinese specimen is similar to *Sethocapsa dorysphaeroides* Neviani (Baumgartner *et al*., 1995, p. 494, pl. 5544), but differs from the latter by having constricted aperture.

Range and occurrence.—Upper Jurassic. Nadanhada.

Genus ***Protunuma*** Ichikawa and Yao, 1976

Type species.—Protunuma fusiformis Ichikawa and Yao, 1976.

Protunuma japonicus Matsuoka and Yao, 1985

Figures 8.17, 8.18

Protunuma fusiformis Ichikawa and Yao. Mizutani, 1981, p. 181, pl. 63, figs. 1, 8; pl. 64, fig. 3.
Protunuma japonicus Matsuoka and Yao, 1985, p. 130, pl. 1, figs. 11–15; pl 3, figs. 6–9; Matsuoka, 1986a; pl. 2, fig. 7; Baumgartner *et al*., 1995, p. 434, pl. 3292, figs. 1–8; Hull, 1997, p. 156, pl. 43, figs. 8, 14, 15; Zügel, 1997, p. 204, fig. 5(8); Hori, 1999, p. 85, fig. 7(20); Kiessling, 1999, p. 28, pl. 13, fig. 19; Matsuoka *et al*., 2005, figs. 4(11), 5(11).

Material.—Specimens P1-8-1, P1-8-25 are from the sample P1-08.

Dimension (in µm).—Height/Width: 174/115 (P1-8-1), 183/120 (P1-8-25).

Remarks.—This species is similar to *Protunuma fusiformis* Ichikawa and Yao and *P. turbo* Matsuoka in outer shape, but differs in that the latter two forms have externally recognizable lumbar stricture, because the abdomen expands more strongly than the thorax in the latter two species.

Range and occurrence.—UAZones 7–12, late Bathonian–early Callovian to early–early late Tithonian (Baumgartner *et al.*, 1995); Oxfordian–Tithonian (Hori, 1999). Blake-Bahama Basin (DSDP Site 534), California Coast Ranges, Eastern Alps, Eastern Atlantic Ocean (DSDP Leg 41, Site 367), Japan, Nadanhada, Northern Apennines, Northern Calcareous Alps, Russian Far East, Solnhofen (Southern Germany), Southern Alps, Southern Tibet, Western Carpathians, western Pacific Ocean (ODP Leg 129, Site 801), Yugoslavia.

Genus ***Pseudoxitus*** Wu and Pessagno in Wu, 1993; emend. Dumitrica in Dumitrica *et al.*, 1997

Type species.—*Pseudoxitus inflatus* Wu, 1993.

Pseudoxitus? sp.

Figure 6.10

Material.—Specimen P1-12-19 is from the sample P1-012.

Dimension (in µm).—Height/Maximal width: 207/160.

Remarks.—The present form is tentatively attributed to *Pseudoxitus* because of lacking well developed tubercles. The outer layer structure mainly consists of irregular bars. The specimen differs from the known taxa of the genus by the cylindrically inflated final chamber.

Range and occurrence.—Middle Jurassic. Nadanhada.

Genus ***Ristola*** Pessagno and Whalen, 1982, emend. Baumgartner, 1984

Type species.—*Parvicingula* (?) *procera* Pessagno, 1977a.

Ristola sp.

Figure 7.4

Material.—Specimen P1-13-11 is from the sample P1-013.

Description.—Test preserved with the apical part. Cephalis with a massive horn. Apical part covered by a outer layer of broad bars, the inner layer of test invisible.

Dimensions (in µm).—Height/Maximal width: 180/155.

Remarks.—Only one broken specimen is encountered. The conical, apical portion is covered by an outer layer, which indicates that the specimen could be assigned to *Ristola*.

Range and occurrence.—Upper Jurassic, Nadanhada.

Genus ***Solenotryma*** Foreman, 1968

Type species.—*Solenotryma dacryodes* Foreman, 1968.

Solenotryma ichikawai Matsuoka and Yao, 1985

Figure 6.9

Solenotryma? *ichikawai* Matsuoka and Yao, 1985, p. 133, pl. 3, fig. 21.
Solenotryma ichikawai Matsuoka and Yao. Baumgartner *et al*., 1995, p. 508, pl. 4037, figs. 1–5; Hori, 1999, p. 87, fig. 8.12; Matsuoka *et al*., 2005, fig. 5(12).

Material.—Specimen P1-12-41 is from the sample P1-012.

Dimensions (in µm).—Height/Maximal width: 193/112.

Remarks.—The Chinese specimen differs from the species *Solenotryma palmerae* Pessagno in that the latter possesses more chambers and has a slenderer test outline. The present specimen differs from *S. perampla* (Rüst) in that the latter is a much larger form with a more broad conical test outline.

Range and occurrence.—UAZones 7–21, late Bathonian–early Callovian to early Barremian (Baumgartner *et al*., 1995); Torinosu Group, southwestern Japan; Nadanhada.

Genus ***Stichocapsa*** Haeckel, 1881

Type species.—*Stichocapsa jaspidea* Rüst, 1885.

"*Stichocapsa*" *robusta* Matsuoka, 1984

Figures 5.7, 5.8

Stichocapsa robusta Matsuoka, 1984, p. 146, pl. 1, figs. 6–13; pl. 2, figs. 7–12; Matsuoka, 1986b, pl. 1, fig. 12; Matsuoka, 1988, pl. 1, fig. 8; Matsuoka, 1992, pl. 5, fig. 3; Baumgartner *et al*., 1995, p. 524, pl. 3298, figs. 1–7; Matsuoka *et al*., 2002, fig. 5(4).

Material.—Specimens P1-09-24 and 9-5 are from the sample P1–09.

Dimensions (in μm).—Height/Maximal width: 165/126 (P1-9-5); 232/181 (P1-09-24).

Remarks.—The lumbar sutural pore is not visible. The species is similar to "*Stichocapsa*" *convexa* Yao, 1979, but differs from the latter in its thick wall, internally tapering pores and wider apical conical part.

Range and occurrence.—Middle to lower Upper Jurassic. Nadanhada and Tibet, China; Japan; southern California Coast Ranges.

"*Stichocapsa*" *convexa* Yao, 1979

Figures 5.9, 5.10

Stichocapsa convexa Yao, 1979, p. 35, pl. 5, figs. 14–16; pl. 6, figs. 1–7; Matsuoka, 1985, pl. 1, fig. 8; Baumgartner *et al*., 1995, p. 518, pl. 3055, figs. 1–4.

Material.—Specimen P1-09-10 is from the sample P1-09.

Dimensions (in μm).—Height/Maximal width: 225/170.

Remarks.—Shell of four segments, cephalis poreless, thorax and abdomen truncated-cornical. The fourth segment truncated-spherical with a small aperture.

Range and occurrence.—Middle and Upper Jurassic. Nadanhada; Japan.

"*Stichocapsa*" sp.

Figure 5.11

Material.—Specimen P1-9-8 is from the sample P1-09.

Dimensions (in μm).—Height/Maximal width: 131/110.

Remarks.—The Chinese specimen differs from the species *Stichocapsa praepulchella* Hori, 1999 by having fewer rows of transverse pores, fewer segments and a smaller test.

Range and occurrence.—Upper Jurassic. Nadanhada.

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

Type species.—*Tricolocapsa plicarum* Yao, 1979.

Striatojaponocapsa synconexa O'Dogherty, Gorican and Dumitrica in O'Dogherty *et al*., 2005

Figures 5.12, 5.13

Tricolocapsa plicarum Yao. Matsuoka, 1983, p. 20, pl. 3, fig. 2.
Tricolocapsa plicarum ssp. A. Baumgartner *et al*., 1995, p. 598, pl. 4052, figs. 1–5.
Striatojaponocapsa synconexa O'Dogherty, Gorican and Dumitrica in O'Dogherty *et al*., 2005, p. 447, pl. 10, figs. 9–17.

Material.—Specimen P1-9-28 is from the sample P1-09.

Dimensions (in μm).—Height/Maximal width: 140/132.

Remarks.—Outer surface of shell ornamented with continuous longitudinal plicae, without transverse ridges between adjacent plicae.

Range and occurrence.—UAZones 4–5, late Bajocian–early Bathonian (Baumgartner *et al*., 1995), Japan, Greece, eastern Alps, western Carpathians, Nadanhada; Middle to Upper Jurassic of the United States.

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

Type species.—*Tethysetta pygmaea* Dumitrica in Dumitrica *et al*., 1997.

Tethysetta dhimenaensis (Baumgartner, 1984)

Figures 6.8, 8.22–8.25

Parvicingula dhimenaensis Baumgartner, 1984, p. 778, pl. 7, figs. 2, 3; Matsuoka, 1986a, pl. 2, fig. 12; Dumitrica *et al*., 1997, p. 49, pl. 11, figs.
Parvicingula dhimenaensis dhimenaensis Baumgartner. Baumgartner *et al*., 1995, p. 406, pl. 4072, figs. 1–3; Chiari *et al*., 1997, pl. 3, fig. 3; Zügel, 1997, p. 206, fig. 5(13); Hori, 1999, p. 96, fig. 9(16).
Tethysetta dhimenaensis (Baumgartner). Ishida, 2011, p. 108, fig. 6.19.

Material.—Specimens 108x2–22, 28, P1-8-24, 27, 37, 58, 68 are from the sample P1-08; specimens P1-12-9, 15, 24, 27 are from the sample P1-012.

Dimensions (in μm).—Height/Maximum width: 240/113 (108x2-28), 163/89 (P1-8-27), 161/95 (P1-8-37), 212/91 (P1-8-42), 195/96 (P1-8-58), 228/113 (P1-8-68), 225/105 (P1-12-9), 296/131 (P1-12-15), 231/110 (P1-12-24).

Remarks.—Baumgartner (1984) described from Greece the species *Parvicingula dhimenaensis*, which included at least two morphotypes. According to the character of the proximal portion of the tests, Baumgartner *et al*. (1995) separated these two morphotypes into two subspecies, i.e., *P. dhimenaensis dhimenaensis* and *P. dhimenaensis* ssp. A. The former has a shorter cephalo-thorax portion, while the latter has a long and externally smooth proximal portion which is composed of cephalis, thorax, abdomen and possibly the first postabdominal chamber. As noted by Baumgartner (1984) the species *P. dhimenaensis* differs from other *Parvicingula* in having circumferential ridges with regularly spaced nodes and diagonal bars connecting between nodes. Thus Dumitrica *et al*. (1997) attributed this species to *Tethysetta*. The Chinese specimens agree very well with the subspecies *Tethysetta dhimenaensis*.

Range and Occurrence.—UAZones 3–11 early-middle Bajocian to early Tithonian) (Baumgartner *et al*., 1995), or Callovian to Tithonian (Hori, 1999), up to Berriasian (Kiessling, 1995; Dumitrica *et al*., 1997). Nadanhada, east-central Mexico, Japan, Northern Apennines, Solnhofen (southern Germany), Southern Alps, Western Carpathians, Western Himalaya, Yugoslavia.

Genus ***Theocapsomella*** O'Dogherty, Gorican and Dumitrica in O'Dogherty *et al*., 2005

Type species.—*Theocapsomma cordis* Kocher, 1981.

Theocapsomella himedaruma (Aita, 1987)

Figure 9.18

Stichocapsa himedaruma Aita, 1987, p. 74, pl. 3, figs. 1a–3; pl. 10, figs. 1, 2; O'Dogherty *et al*., 2005, p. 452.

Material.—Specimen P1-8-54 is from the sample P1-08.

Dimensions (in μm).— Height/Maximal width: 102/91.

Remarks.—The Chinese specimen possesses a similar test outline to the Japanese species *Theocapsomella himedaruma*, but differs by having a relatively smaller abdomen and a larger final segment. This difference may be intraspecific variation.

Range and occurrence.—Late Middle–early Late Jurassic. Japan, Nadanhada.

Genus ***Transhsuum*** Takemura, 1986

Type species.—*Transhsuum medium* Takemura, 1986.

Transhsuum? sp.

Figure 5.2

Material.—Specimen P1-9-3 is from the sample P1-09.

Dimensions (in μm).—Length/Width: 264/108.

Remarks.—The present specimen is questionably attributed to *Transhsuum* because it is a multisegmented Nassellaria, but its discontinuous longitudinal costae are poorly preserved.

Range and occurrence.—Middle Jurassic. Nadanhada.

Genus *Tricolocapsa* Haeckel, 1881

Type species.—*Tricolocapsa theophrasti* Haeckel, 1887.

"Tricolocapsa" sp.

Figure 5.14

Material.—Specimen P1-9-20 is from the sample P1-09.

Dimensions (in μm).—Height/Maximal width: 129/120.

Remarks.—Test with three segments. Shell surface ornamentation not preserved.

Range and occurrence.—Middle Jurassic. Nadanhada.

"Tricolocapsa" tetragona Matsuoka, 1983

Figures 5.15–5.16

Tricolocapsa tetragona Matsuoka, 1983, p. 22, pl. 3, figs. 8–12; pl. 8, figs. 4–10; Matsuoka and Yao, 1986, pl. 1, fig. 18; Baumgartner *et al*., 1995, p. 600, pl. 4054, figs. 1–3.

Material.—Specimens P1-9-6 is from the sample P1-09.

Description.—Test with three segments. Cephalis small, rounded, poreless. Thorax cylindrical with small pores. Abdomen spherical with longitudinal plicae and transverse ridges connecting adjacent two longitudinal plicae.

Dimensions (in μm).—Height/Maximal width: 175/170.

Remarks.—The present specimen is poorly preserved with several longitudinal plicae and transverse ridges between plicae on the abdomen. It is possible to assign it to *Tricolocapsa tetragona*.

Range and occurrence.—UAZone 5 (latest Bajocian–early Bathonian) (Baumgartner *et al*., 1995). Japan, Nadanhada.

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

Type species.—*Unuma typicus* Ichikawa and Yao, 1976.

Unuma gordus Hull, 1997

Figures 5.3, 5.4, 8.16

Unuma sp. A. Baumgartner *et al*., 1995, p. 624, pl. 3309, figs. 1–4.
Unuma gorda Hull, 1997, p. 172, pl. 43, figs. 9, 11, 12; Chiari *et al*., 2003, pl. 2, fig. 19; Chiari *et al*., 2004, pl. 3, fig. 15.

Unuma gordus Hull. Suzuki and Gawlick, 2009, p. 177, fig. 6(2A, B); Djerić *et al*., 2012, p. 362, pl. 1, fig. 24.

Material.—Specimen P1-8-69 is from the sample P1–08; Specimens P1-9-4, P1-9-7 are from sample P1-09.

Dimensions (in μm).—Height/Width: 191/139 (P1-8-69), 120/92 (P1-9-4), 137/107 (P1-9-7).

Remarks.—The genus *Unuma* was established as of masculine gender (Ichikawa and Yao, 1976), so that the species name was changed to *gordus* by Suzuki and Gawlick (2009). Test broadly spindle-shaped, with four segments. The present specimens are closely related to *Unuma* sp. A (Baumgartner *et al*., 1995, p. 624, pl. 3309, figs. 1–4), which is considered a synonym of *Unuma gordus*.

Range and occurrence.—UAZones 4–6, late Bajocian–middle Bathonian (Baumgartner *et al*., 1995), United States, Japan, southern Alps, Nadanhada.

Genus ***Williriedellum*** Dumitrica, 1970

Type species.—*Williriedellum crystallinum* Dumitrica, 1970.

Williriedellum marcucciae (Cortese, 1993)

Figures 9.10, 9.11

Williriedellum sp. A gr. Matsuoka, 1983, p. 23, pl. 4, figs. 1–3; pl. 8, figs. 11–15.

Williriedellum marcuccii Cortese, 1993, p. 180, pl. 7, figs. 6, 7.

Williriedellum marcucciae (Cortese, 1993). Suzuki and Gawlick, 2009, p. 179, fig. 5(25), fig. 6(49A, B).

Material.—Specimen P1-8-40 is from the sample P1-08.

Dimensions (in μm).—Height/Maximal width: 169/131.

Remarks.—The species name has been revised from *marcuccii* to *marcucciae* because the species was named after Prof. Marta Marcucci (Suzuki and Gawlick, 2009).

Range and occurrence.—UAZones 4–8, late Bajocian–early Oxfordian (Baumgartner *et al.*, 1995). Austria, Japan, Nadanhada.

Genus ***Zhamoidellum*** Dumitrica, 1970

Type species.—*Zhamoidellum ventricosum* Dumitrica, 1970.

Zhamoidellum ovum Dumitrica, 1970

Figures 6.11, 9.8, 9.9

Zhamoidellum ovum Dumitrica, 1970, p. 79, pl. 9, figs. 52a, b, 53, 54; Baumgartner *et al*., 1995, p. 656, pl. 4079, figs. 2, 4, 6; O'Dogherty *et al*., 2017, p. 50, figs. 10.31–10.40.

Material.—Specimens P1-8-18, 32, 50, 55 are from the sample P1-08; specimen P1-12-5, 30 are from the sample P1-012.

Dimensions (in μm).—Height/Maximal width: 145/142 (P1-8-18), 128/116 (P1-8-32), 128/97 (P1-8-47), 119/108 (P1-8-50), 109/93 (P1-8-55), ?/173 (P1-12-5), 194/146 (P1-12-30).

Remarks.—Baumgartner *et al*. (1995) figured six specimens for the species *Zhamoidellum ovum*, their specimen (pl. 4079, fig. 1) is closely related to *Z. mikamense* Aita, 1987 because of the well developed lumbar stricture; the specimens (pl. 4079, figs. 3 and 5) show dimple-shaped pits in the lumbar stricture, within the pits there are smaller pore frames than the surrounding ones. These pits look like sutural pores, but Dumitrica did not mention this structure in the original description of the species, and thus these two specimens should be assigned to the genus *Complexapora* Kiessling in Kiessling and Zeiss, 1992.

The Chinese specimens are closely related to *Z. ovum*, not only in test outline, but also in possessing the same porous structure in the thick-walled thorax and abdomen.

Range and occurrence.—UAZones 9–11, mid–late Oxfordian to early Tithonian (Baumgartner *et al.*, 1995). Romania, Japan, Nadanhada.

Zhamoidellum sp.

Figure 9.11

Material.—Specimens P1-8-44 is from the sample P1-08.

Dimensions (in μm).—Height/Maximal width: 164/133.

Remarks.—The thorax is porous with its lower part constricted and depressed into the abdominal cavity, showing a clear lumbar stricture.

Range and occurrence.—Upper Jurassic, Nadanhada.

Conclusion

Four black claystone samples (P1-08, 09, 012, 013) from the Upper Jurassic Dalingqiao Formation of the Nadanhada terrane contain well preserved radiolarian faunas. The sample P1-09 yields a *Striatojaponocapsa synconexa*-"*Tricolocapsa*" *tetragona* assemblage, which indicates a Middle Jurassic Bathonian age. The other three samples contain a Late Jurassic *Cinguloturris carpatica* assemblage, which may be of a late Oxfordian–early Tithonian age. The discovery of new Late Jurassic radiolarians indicates that the Raohe Complex was accreted during the Late Jurassic paleo-Pacific subduction. Then, the succedent late Tithonian–early Valanginian *Buchia* fauna-bearing Dong'anzhen Formation may be the earliest cover beds overlying the Raohe Complex.

The development of the Lower Cretaceous *Aucellina* bivalve fauna-bearing Dajiashan Group indicates a paleogeographic differentiation between the Nadanhada terrane and the Tamba-Mino-Ashio terrane.

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Author contributions

G Li has carried out the field work, conducted laboratory analysis, fossil SEM imaging and manuscript writing. A Matsuoka revised the taxonomic part. Q Yang make taxonomic revision. JG Sha has planned this research and discussed with G Li to revise the figures.