

Middle and Late Jurassic radiolarians from the Neotethys suture in the Eastern Alps

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Abstract.—Cherty limestones, marls and radiolarites are widespread in the Hallstatt Mélange of the Northern Calcareous Alps. The mélangé was formed during the Neotethyan orogeny in a series of deep-water basins that progressively developed in front of the advancing nappe front. The low thermal overprint of these rocks favors the good preservation of radiolarians (polycystines) that have been used for dating and reconstructing the Jurassic tectonostratigraphy of the area. This paper describes rich Middle–Late Jurassic radiolarian faunas from four localities in the Hallstatt Mélange near Bad Mitterndorf in Austria. Two different successions, both spanning from the Bathonian to the Oxfordian, are dated. In the first succession, the radiolarites are intercalated between or occur as matrix in mass-flow deposits originating from the accretionary wedge. The second succession is nearly 100 m thick but is devoid of mass-flow deposits and documents a continuous radiolarite deposition in greater distance from the nappe stack. Both successions are ascribed to the Sandlingalm Basin, which evolved on a relatively distal continental margin during early stages of the orogeny.

The highly diverse and well-preserved radiolarian assemblages have been used for a detailed taxonomic study. Two new families are described: *Minocapsidae* n. fam. and *Xitomitridae* n. fam.; six new genera are described *Doliocapsa* n. gen., *Crococapsa* n. gen., *Parvimitrella* n. gen., *Xitomitra* n. gen., *Campanomitra* n. gen., and *Mizukidella* n. gen. In addition, one new replacement name, *Takemuraella* (pro *Triversus*), is introduced, the diagnoses of 6 genera are emended, and two new species are described: *Hemicryptocapsa nonaginta* n. sp. and *Mizukidella mokaensis* n. sp.

Introduction

This paper describes rich Middle and Late Jurassic radiolarian faunas from four localities in the Hallstatt Mélange near Bad Mitterndorf in Austria. Radiolarian assemblages are well preserved, suitable for taxonomic studies, and precise biostratigraphy.

Middle and Late Jurassic low-latitude radiolarians have been relatively well studied in terms of species-level systematics and biochronology (Baumgartner et al., 1995a, b); however, the systematics of genera and families has not been sufficiently elaborated yet. O'Dogherty et al. (2009) presented an illustrated catalogue of type species of Jurassic and Cretaceous genera described so far. All genera were revised, and many were considered as invalid (synonyms, homonyms, *nomina dubia*). Another group of radiolarians that needs taxonomic revision are those Mesozoic species that still bear inappropriate names of Recent genera. The structure of the catalogue, consisting exclusively of illustrations and synonymy, did not allow us to discuss the distinguishing characteristics of the valid genera or to describe new taxa. The primary aim of this paper is to move towards a more natural taxonomy of Jurassic radiolarians. Six new genera are described, a replacement name for a homonym is proposed, the diagnoses of six valid genera are emended, and remarks for several other genera are provided to clarify

their definition. For all new and revised genera, a list of included species is presented. Two new families are erected and two new species are described.

In addition to radiolarian taxonomy, this paper contributes to the biostratigraphic data of the Hallstatt Mélange in the Northern Calcareous Alps. Extensive radiolarian dating over the last 15 years has provided a wealth of age constraints in deep-water sediments of the Tirolic units and the Hallstatt Mélange (Suzuki and Gawlick, 2003, 2009; Missoni and Gawlick, 2011a, b and references therein). These data had important implications for the reconstruction of the Jurassic tectonostratigraphy and distinguished several trench-like basins that formed progressively during the propagation of thrusting (see Missoni and Gawlick, 2011a, b; Gawlick et al., 2012 for the latest reviews). However, the structure of this area, especially that of the Hallstatt Mélange, is extremely complex and the proposed tectonostratigraphic model can still be refined with additional biostratigraphic data.

Geological overview

The study area is located in the central Northern Calcareous Alps around 100 km southeast of Salzburg (Fig. 1.1). The Northern Calcareous Alps represent a far travelled nappe system

in the highest structural position of the Eastern Alps (Tollmann, 1985) and belong palaeogeographically to the Austroalpine domain (Fig. 1.1).

In Middle–Late Triassic times the Austroalpine domain as part of the central and southeastern European shelf show a typical carbonate passive continental margin facies distribution (Fig. 1.2–1.3), whereas in Jurassic times the Austroalpine realm was situated between the Penninic Ocean to the northwest and the Neotethys Ocean in the southeast (Fig. 1.4–1.5).

Contemporaneous with progressive Jurassic extension and opening of the Alpine Atlantic Ocean (and the Penninic realm as part of it; see Missoni and Gawlick, 2011a for details) as an eastward continuation of the Central Atlantic Ocean, closure of parts of the Neotethys Ocean with formation of the Neotethys ophiolite imbricates started in the late Early Jurassic and prevailed until the early Late Jurassic (Karamata, 2006). Obduction of the Neotethys ophiolite imbricates started in the Middle Jurassic and the Austroalpine and its northern and southern equivalents attained a lower plate position (Frisch and Gawlick, 2003, Gawlick et al., 2008, Schmid et al., 2008). Westward to northwestward propagating Middle to early Late Jurassic compression led to the imbrication of the Austroalpine domain and its equivalents along the Neotethys suture and resulted in the Neotethyan orogeny (Missoni and Gawlick, 2011a). A characteristic feature of this orogenesis is the formation of deep-water radiolaritic basins in front of the westward propagating nappe stack. Sediment supply in these basins derived from the nappe fronts.

Gawlick et al. (1999) interpreted this sedimentation pattern as a reflection of nappe movements in the Northern Calcareous Alps in the late Middle to early Late Jurassic and related it to the Kimmeric orogeny according to earlier authors (see ‘Jurassic gravitational tectonics’ in Plöschinger, 1974, 1976; Tollmann, 1981, 1985, 1987; Mandl, 1982). This orogenic event (Lein, 1985, 1987a, b) was related to the closure of the western half of the Neotethys Ocean, today named the Neotethyan orogeny (Missoni and Gawlick, 2011a).

In the southern and therefore highest nappe group (Tirolic units and equivalents, Fig. 1.2–1.3) of the Northern Calcareous Alps the remains of this orogenic event are well preserved with a series of deep-water radiolaritic basins which were formed in sequence in front of the advancing nappe front (e.g., Gawlick et al., 1999, Missoni and Gawlick, 2011b). These southernmost

radiolarite basins contain the Hallstatt Mélange as an erosional product of the Juvavic nappes, which are mainly eroded today. Subsequently the trench-like basins became overthrust and incorporated into the accretionary prism (Missoni and Gawlick, 2011b). This Hallstatt Mélange was therefore formed in the late Early to early Late Jurassic interval as a result of successive shortening of the Triassic to Jurassic distal shelf area (Hallstatt Zone).

Jurassic evolution of the southern Northern Calcareous Alps

In the early Early Jurassic, sedimentation was generally controlled by the topography of the Late Triassic Hauptdolomit/Dachstein carbonate platform (Böhm, 2003, Gawlick and Frisch, 2003; Figs. 1, 2). On top of the Rhaetian shallow-water carbonates, red condensed limestones of the Adnet Group (?late Hettangian/Sinemurian to Toarcian: Böhm, 1992, 2003) were deposited, mostly separated by a gap of sedimentation (mainly early Hettangian, partly also late Hettangian; Fig. 2). On top of the Rhaetian Kössen Formation (e.g., Eiberg Basin, Restental Basin, Fig. 2) cherty and marly bedded limestones (Kendlbach Formation; Scheibelberg Formation: Böhm, 1992, 2003; Krainer and Mostler, 1997; Ebli, 1997) were deposited, while in marginal areas of the basins crinoidal or sponge-spicule rich limestones of the Enzesfeld Formation were laid down (Böhm, 1992). In the late Pliensbachian to early Toarcian a horst-and-graben morphology developed (Bernoulli and Jenkyns, 1974, Krainer et al., 1994) and triggered breccia formation along submarine slopes and escarpments (Böhm et al., 1995). The Toarcian and most of the Middle Jurassic are characterized by starved sedimentation, ferro-manganese crusts, or a hiatus on the horsts, whereas the grabens were filled with deep-water carbonates and breccias, which latter formed near fault scarps. Neptunian dykes are found on the horsts. In the newly formed basinal areas gray bedded limestones of the younger Allgäu Formation were deposited, while condensed red limestones of the Klaus Formation formed on the top of the topographic highs (Krystyn, 1971, 1972; Fig. 2).

This sedimentation pattern changed dramatically in the late Middle Jurassic (Gawlick and Frisch, 2003). Sedimentation resumed with the deposition of radiolarian cherts and radiolaria-rich

Figure 1. Tectonic and paleogeographic maps. (1) Tectonic sketch map of the Eastern Alps and study area (after Tollmann, 1987; Frisch and Gawlick, 2003); GPU Graz Palaeozoic Unit; GU Gurktal Unit; GWZ Greywacke Zone; RFZ Rhenodanubian Flysch Zone. Star indicates study area (Fig. 3). (2) Late Triassic paleogeographic position and facies zones of the Austroalpine domain as part of the northwestern Neotethys passive margin; IAZ = Iberia-Adria Zone transform fault, AAT = future Austroalpine-Adria transform fault, TTT = future Tisza-Tatra transform fault, TMT = future Tisza-Moesia transform fault, AA = Austroalpine, BI = Bihor, BR = Briançonnais, BU = Bükk, C = Csovar, Co = Corsica, DI = Dinarides, DO = Dolomites, DR = Drau Range, HA = Hallstatt Zone, JU = Juvavicum, JL = Julian Alps, ME = Meliaticum, MK = Mecsek, MO = Moma unit, MP = Moesian platform, P = Pilis-Buda, R = Rudabanyaicum, SI = Silicicum, SL = Slovenian trough, SM = Serbo-Macedonian unit, TA = Tatricum, TO = Tornaicum, TR = Transdanubian Range, VA = Vascau unit, WC = central West Carpathians (modified after Haas et al., 1995; Gawlick et al., 1999, 2008). (3) Schematic cross section (for position, see line a-b in 2) showing the typical passive continental margin facies distribution across the Austroalpine domain in Late Triassic time (after Gawlick and Frisch, 2003). (4) Palaeogeographic position of the Northern Calcareous Alps as part of the Austroalpine domain in Late Jurassic time (after Frisch, 1979; Gawlick et al., 2008). In this reconstruction the Northern Calcareous Alps are part of the Jurassic Neotethyan Belt (orogen) striking from the Carpathians to the Hellenides. The Neotethys suture is equivalent to the obducted West-Vardar ophiolite complex (e.g., Dinaric Ophiolite Belt) in the sense of Schmid et al. (2008) = far-travelled ophiolite nappes of the western Neotethys Ocean in the sense of Gawlick et al. (2008) (see Robertson, 2012 for discussion). The eastern part of the Neotethys Ocean remained open = Vardar Ocean (Missoni and Gawlick, 2011a). Toarcian to Early Cretaceous Adria-Apulia carbonate platform and equivalents according to Golonka (2002), Vlahović et al. (2005), and Bernoulli and Jenkyns (2009). (5) Schematic cross section reconstructed for Middle to Late Jurassic times showing the passive continental margin of the Lower Austroalpine domain facing the Penninic Ocean to the northwest (e.g., Tollmann, 1985; Faupl and Wagreich, 2000) and the lower plate position and imbrication of the Austroalpine domain in relation to the obducted Neotethys oceanic crust (after Gawlick et al., 2008; compare with Frisch, 1979). Star indicates position of study area (compare Figure 3).

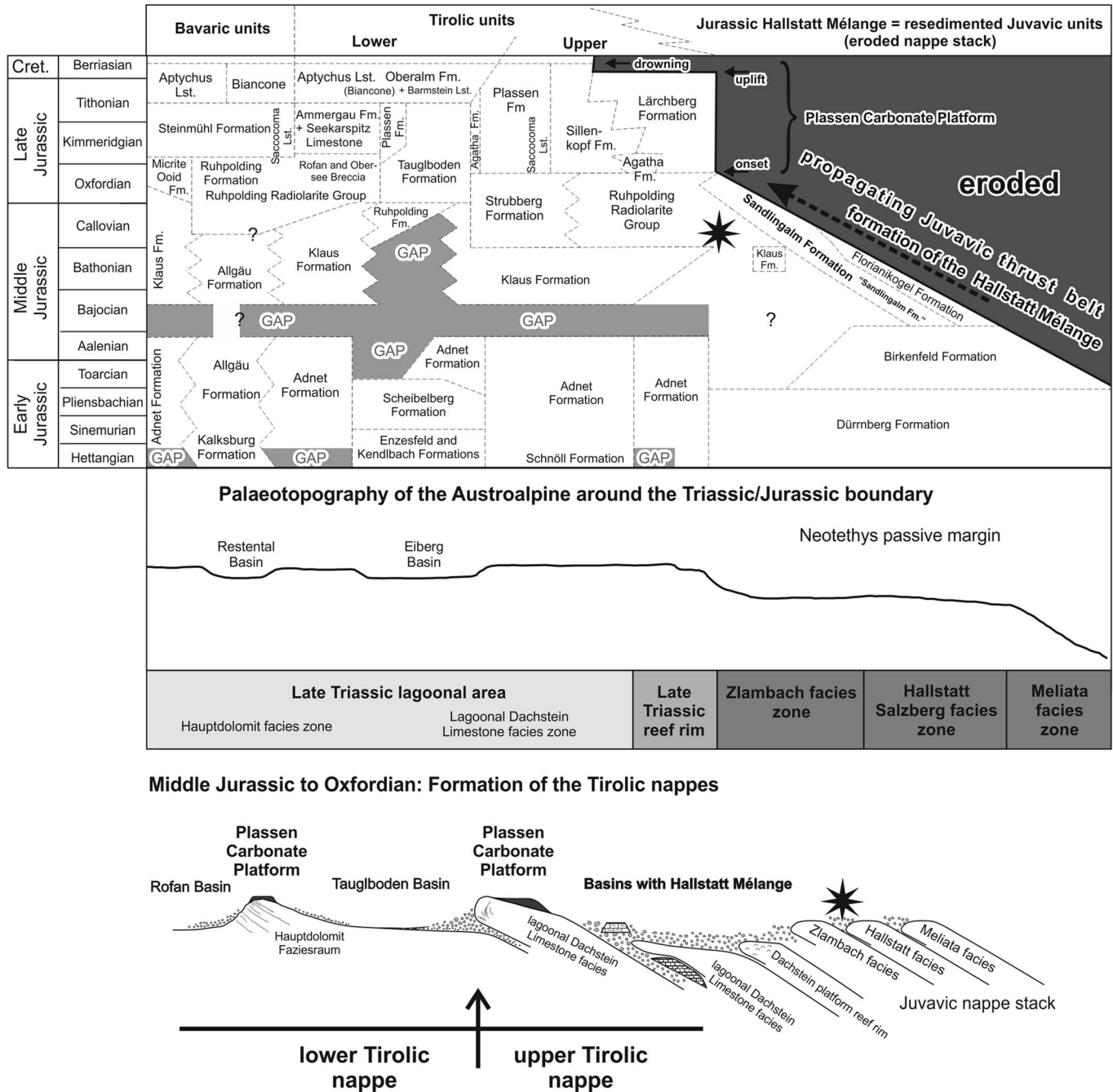


Figure 2. Stratigraphic table with lithostratigraphic names and main tectonic events of the Jurassic in the Austroalpine realm with their variations depending on the palaeogeographic position (after Gawlick et al., 2009); star indicates investigated sequence. Note that this sequence is thrust further northward to its present position during younger shortening events. Bavaric units, Tirolitic units, and the Hallstatt Mélange belong to the Northern Calcareous Alps.

marls, shales, and limestones of the Ruhpolding Radiolarite Group (Diersche, 1980; Gawlick and Frisch, 2003; Fig. 2).

In the Bajocian the sedimentary evolution in the southern (palaeogeographically southeastern, Fig. 1.4–1.5) part of the Tirolitic realm as well as in the Hallstatt realm (Fig. 2) differed from that in the northern part (palaeogeographically in the northwestern, see Fig. 1.4–1.5). Deep-water trench-like basins formed in front of advancing nappes. The first basin group in the southern parts of the Northern Calcareous Alps received mass-flow deposits and large slides up to nappe size, which derived from the Hallstatt Zone (= Hallstatt Mélange;

Gawlick and Frisch, 2003). The thickness of the basin fills may reach 2000 meters (Gawlick, 1996, 1997, Gawlick et al., 2007b). The nappe stack carrying the Hallstatt Mélange is defined as the upper Tirolitic nappe (group) (Frisch and Gawlick, 2003). The second basin group (Fig. 2), the Tauglboden and the Rofan trench-like basins in the north, was subjected to high subsidence and sedimentation rates in the Oxfordian to earliest Kimmeridgian (Schlager and Schlager, 1973, Gawlick and Frisch, 2003). The nappe stack carrying the Tauglboden Mélange is defined as the lower Tirolitic nappe (Frisch and Gawlick, 2003). These two basin groups are different: the huge

mass flows of the Hallstatt Mélange trench-like basins formed earlier from material derived from the outer shelf facing the Neotethys Ocean (Hallstatt Zone, Fig. 1.2–1.5), whereas the Tauglboden Mélange trench-like basin formed later from material derived of the lagoonal part of the Hauptdolomit/Dachstein carbonate platform (Fig. 1.4, 1.5). However, both basins formed syntectonically and suggest a substantial relief between the basin axis and the source area. A third type of radiolarite basin, the Sillenkopf Basin (Missoni et al., 2001), remained in the southern part of the Northern Calcareous Alps as a starved basin in the Kimmeridgian (Fig. 2). This basin contains the earliest ophiolitic detritus from the accreted and obducted Neotethys Ocean floor (Missoni, 2003).

In the Tirolic units of the Northern Calcareous Alps the establishment of the shallow-water Plassen Carbonate Platform started at the frontal parts of the rising and advancing nappes (Gawlick et al., 2002, 2005). From this position, the progradation of several independent platforms took place towards the adjacent radiolarite basins (Gawlick and Frisch, 2003; Gawlick and Schlagintweit, 2006; Gawlick et al., 2005, 2007a, 2012). This resulted in a complex basin-and-rise topography with different types of sediments in shallow-water and deep-water areas (Gawlick and Schlagintweit, 2006). In the Kimmeridgian a huge carbonate platform was formed in the upper Tirolic unit, whereas in the lower Tirolic unit shallow-water carbonates were restricted to its northern part (Gawlick et al., 2007a). The whole Plassen Carbonate Platform cycle lasted from the Kimmeridgian until the late early Berriasian platform drowning (Gawlick and Schlagintweit, 2006).

Description of the studied localities

All studied localities belong to the Hallstatt Mélange around the village of Obersdorf north of Bad Mitterndorf (Fig. 3). For a more detailed description of the geology of the area, the Late Triassic to Late Jurassic sedimentary succession, and radiolarian and conodont dating, see O'Dogherty and Gawlick (2008).

Kumitzberg.—The Late Triassic Hallstatt Limestone block of Mt. Kumitzberg is surrounded by a grassland area without outcropping sedimentary rocks (Fig. 3). Only small pieces of dark-gray to black radiolarites can be found at the western base of Mt. Kumitzberg. During the reconstruction of a small bus station in the excavation hole the contact between the Hallstatt Limestone block and the underlying dark-gray to black radiolarite was visible. The contact between the Hallstatt Limestone block and the radiolarite is erosive. This clearly indicates that the massive limestone block cut deep into the radiolarite succession. Therefore the age of the radiolarites is slightly older than the time of its emplacement. The unlaminated and massive dark-gray radiolarite beds are intercalated by thin layers of cherty shales. Only one sample (EW-158) was collected from this locality.

Steinwand north.—A slightly folded, relative thick radiolarite succession is preserved in a valley between the Steinwand and the Mischenirwiese (Fig. 3), on the southeastern slope of Mount Kampl. This succession occurs on top of the Late Triassic (Rhaetian) lagoonal Dachstein Limestone of the Steinwand (Fig. 4). The overlying Early Jurassic interval is covered by

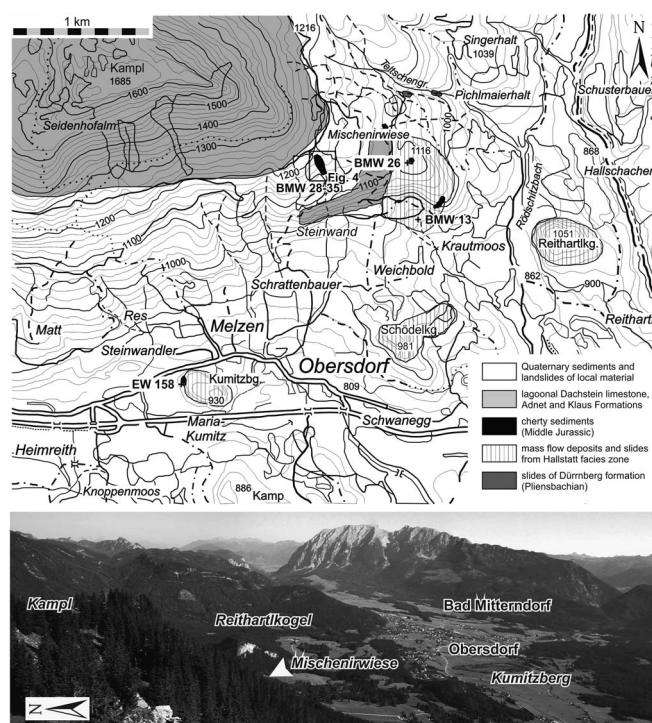


Figure 3. Topography and simplified geology of the study area, showing sample locations (after O'Dogherty and Gawlick, 2008). The plus signs indicate positions of the investigated samples below the Kumitzberg, northwest of Krautmoos, and southeast of the Mischenirwiese and north of the Steinwand. Photo below the map shows the study area as viewed from Mount Kampl to the southwest. The hilly area with dense forest and grassland consists of Jurassic cherty sediments with incorporated mass flows and slides of Hallstatt Limestones. The contact between matrix and blocks or complete sections is visible only in areas with steeper slopes or valleys, or anthropogenic excavations.

Quaternary deposits, but in rare cases some relics of the red nodular limestones of the Adnet Formation occur in the grassland below the dark-gray bedded radiolarite succession. Lower to Middle Jurassic condensed red limestones are well preserved on the southeastern slope of Mount Kampl on top of the Norian/Rhaetian lagoonal Dachstein Limestone. This series represents the northeastern part of the syncline structure between the Steinwand and Mount Kampl.

The lowermost part of the radiolarite succession (sample BMW-28, Fig. 4) outcrops near the entrance of the valley and yielded the oldest assemblage, whereas the youngest part is preserved in the core of the syncline (sample BMW-35, Fig. 4). The thickness of this black radiolarite succession is nearly 100 meters. Intercalated mass-flow deposits are missing in contrast to equivalent successions to the east. Radiolarian dating proves a continuous radiolarite deposition from Bathonian to the Oxfordian. At the end of the valley, near a spring, a small outcrop of gray bioturbated cherty limestones yielded the youngest radiolarians in this area (sample BMW-33). This clearly demonstrates that the radiolarite succession in the valley is separated from the area of the Mischenirwiese by a young fault.

Area between Krautmoos and Mischenirwiese.—The area northwest of Krautmoos (Fig. 3) is characterized by a thick succession of mass-flow deposits with intercalated radiolarite matrix. In a few outcrops, below and between the amalgamated

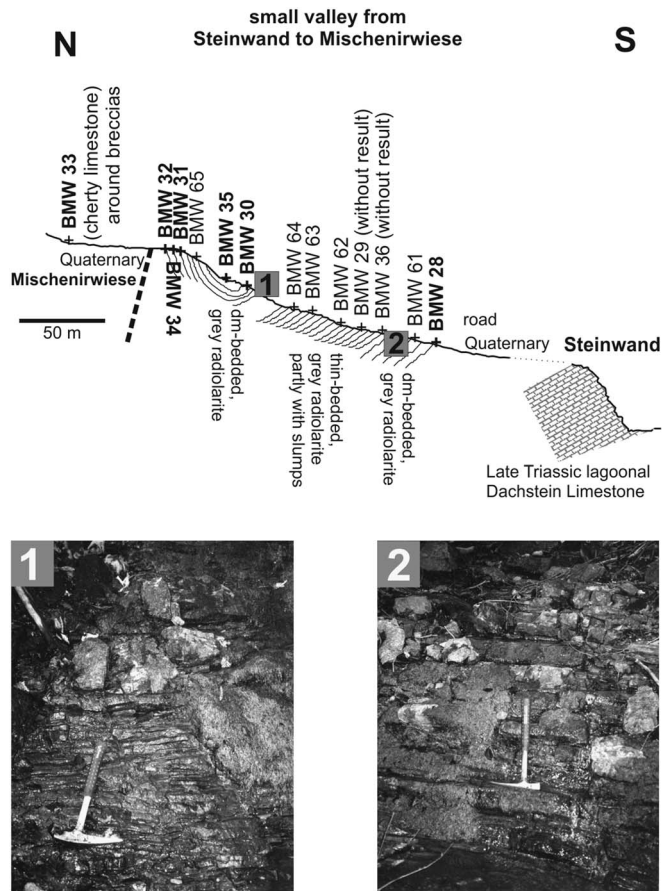


Figure 4. Cross-section in the small valley from Steinwand to Mischenirwiese, with the location of studied samples. Pictures 1 and 2 are details of the radiolaritic facies at lower (uppermost Bajocian–lower Bathonian) and upper (Oxfordian–? Kimmeridgian) part, respectively.

mass-flows matrix, radiolarians are well preserved, mainly in gray massive radiolarites. Two productive samples were taken, one from below the first mass flow (a massive dark-gray radiolarite, BMW-26) and another derived from the higher part of the mass-flow succession (sample BMW-13c).

The components of the different mass-flow deposits consist exclusively of different (gray and red) Hallstatt Limestone components, predominantly of Late Triassic age. Whereas in the lower part of the succession (near the top of the “Krautmoos hill”) the size of the components does not exceed a few decimeters (e.g., near the sample BMW-26), the component size increases upsection. The succession is finally topped by slide blocks of half a kilometer in size, also near Krautmoos. Interestingly in these higher mass-flow deposits radiolarite components occur in addition to the Hallstatt Limestone clasts.

Methods

Samples were selected by examination of thin sections for well-preserved radiolarians. Radiolarite samples were crushed to fragments <2–3 cm in size and placed in 1-liter plastic jars with concentrated hydrochloric acid (32%) until the reaction ceased and all the exposed calcium carbonate was dissolved. Then, the samples were rinsed and processed in the lab with diluted (4%)

hydrofluoric acid for a period of 24 hours to extract radiolarians. The samples were wet-sieved through 200- μ m and 63- μ m sieves and the residues were rinsed and dried in an oven at 40°C. Eleven samples yielded diverse and relatively well-preserved assemblages (see Table 1 for species inventory), in part due to the low thermal overprint of these rocks (estimated by Conodont Color Alteration Index: CAI 1,0, see O’Dogherty and Gawlick, 2008).

Generic and suprageneric systematics used in this work follows De Wever et al. (2001) and O’Dogherty et al. (2009). Radiolarian taxonomy is based on the Middle Jurassic–Early Cretaceous catalogue of the InterRad Jurassic–Cretaceous Working Group (Baumgartner et al., 1995b) for 44 species. Age assignment is based on the Unitary Association Zones (UAZ) established by Baumgartner et al. (1995a), but in order to increase the resolution of this zonation a significant quantity of supplementary species (75 described species and 33 in open nomenclature) are introduced.

Systematic paleontology

Class Radiolaria Müller, 1858
 Subclass Polycystina Ehrenberg, 1838
 Order Nassellaria Ehrenberg, 1876
 Monocyrtids
 Family Poulpidae De Wever, 1981
 Genus *Saitoum* Pessagno, 1977a

Type species.—*Saitoum pagei* Pessagno, 1977a.

Occurrence.—Lower Pliensbachian to upper Barremian.

Saitoum pagei Pessagno, 1977a
 Figure 12.1

- 1977a *Saitoum pagei* Pessagno, p. 98, pl. 12, figs. 11–14.
 2003 *Saitoum pagei*; Dumitrica and Zügel, p. 28, figs. 16A–B.
 2003 *Saitoum pagei*; Suzuki and Gawlick, p. 175, fig. 5.38.
 2006 *Saitoum pagei*; O’Dogherty et al., p. 458, pl. 11, figs. 6–8. [See for complete synonymy]

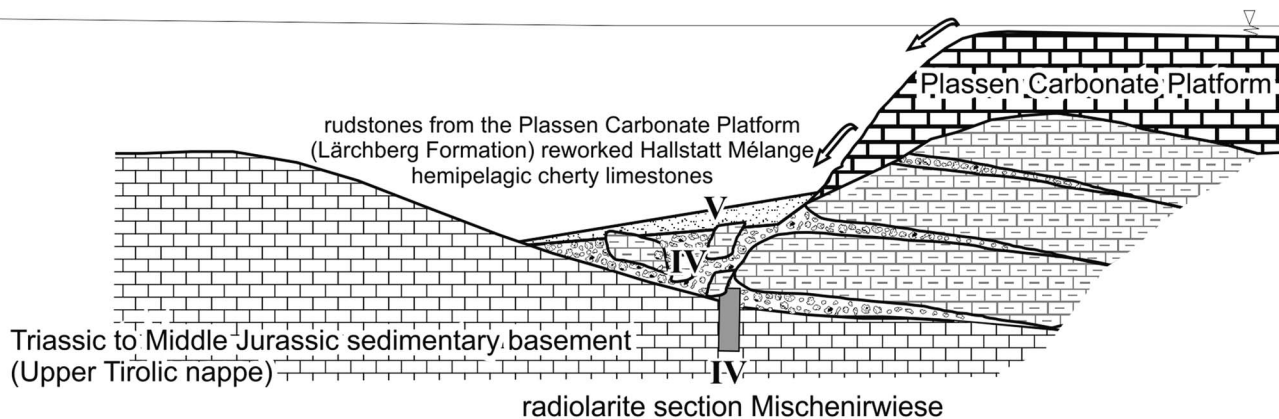
Saitoum trichylum De Wever, 1981
 Figure 12.2–12.3

- 1981 *Saitoum trichylum* De Wever, p. 11, pl. 1, figs. 5–8.
 1995b *Saitoum trichylum*; Baumgartner et al., p. 488, pl. 3021, figs. 1–6. [See for complete synonymy]
 2002 *Saitoum trichylum*; Beccaro et al., pl. 2, fig. 14.
 2003 *Saitoum trichylum*; Suzuki and Gawlick, p. 176, fig. 5.37.

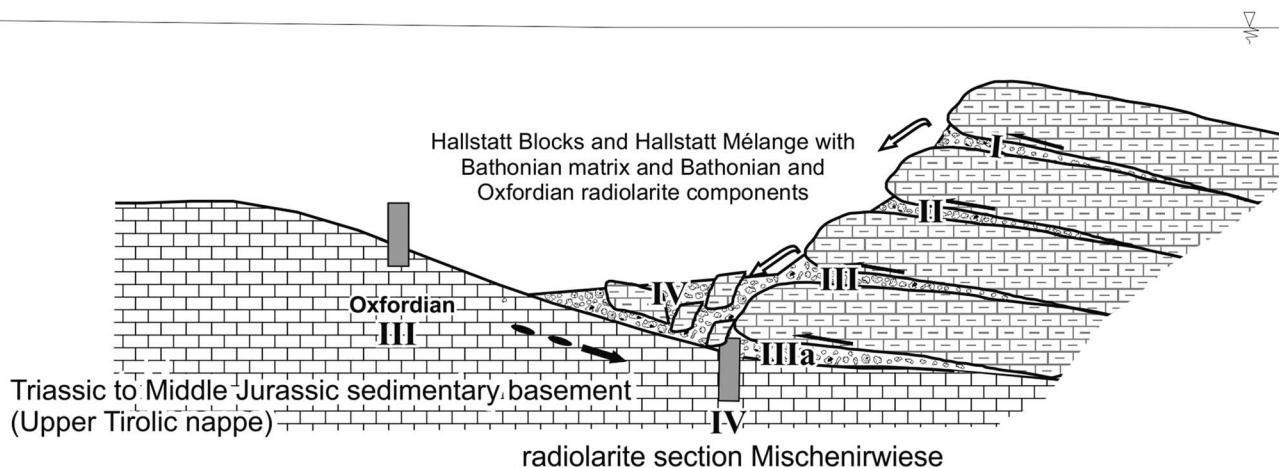
‘Dicyrtids’
 Family Gongylothoracidae Bak, 1999
 Genus *Gongylothorax* Foreman, 1968

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

Kimmeridgian to Tithonian



Oxfordian/Kimmeridgian boundary



Bathonian to Oxfordian

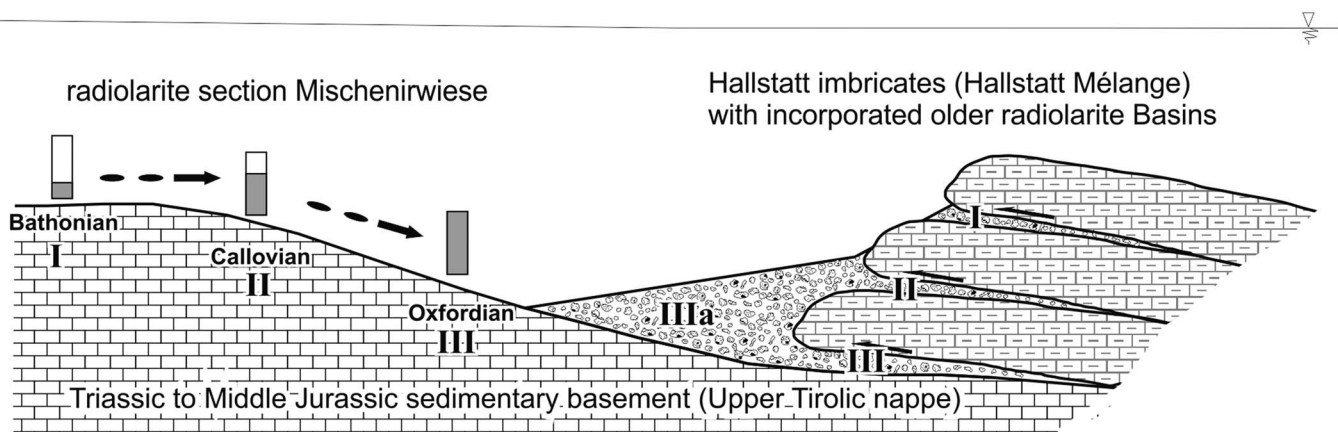


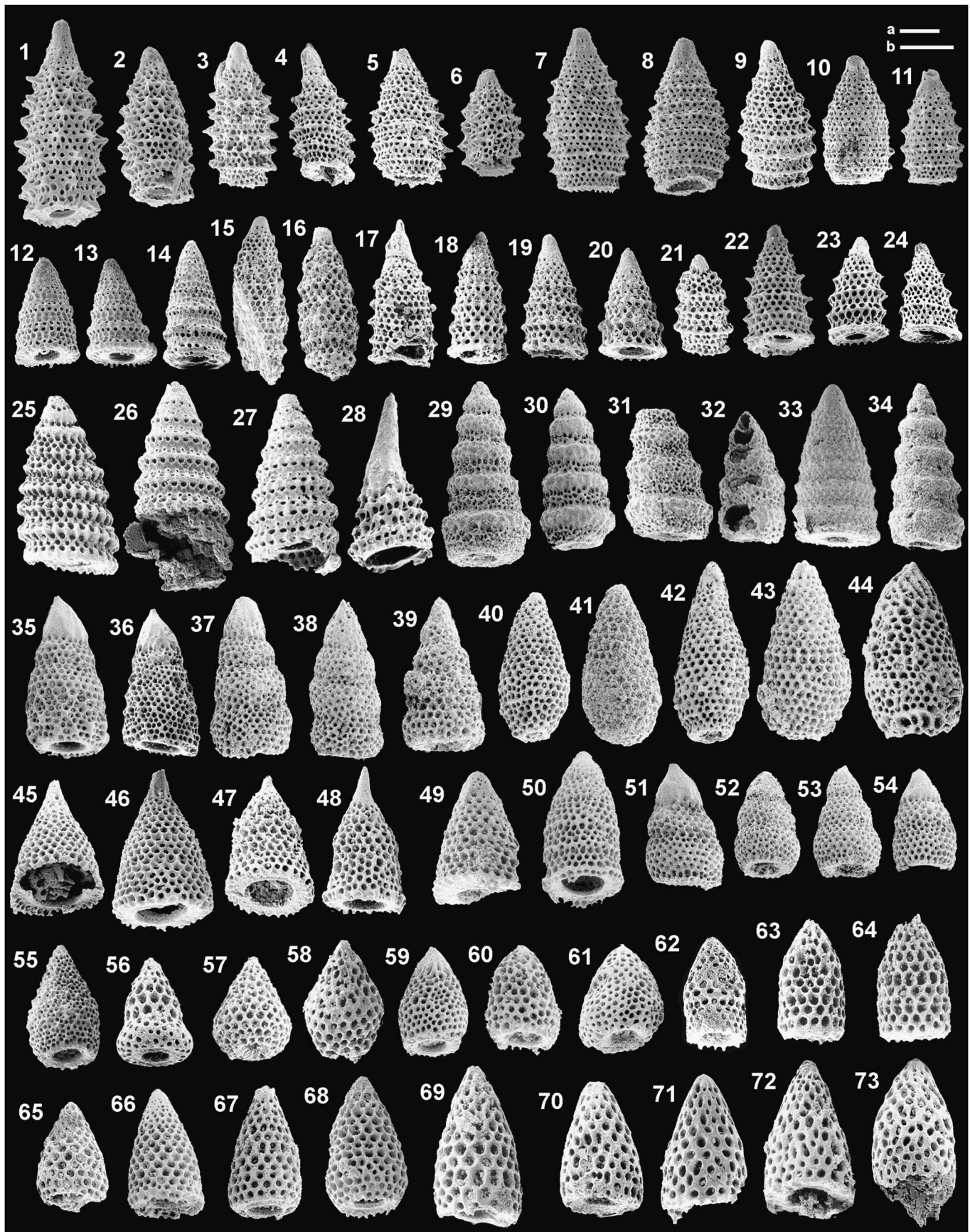
Figure 5. Reconstruction of the geologic evolution from Bathonian to Tithonian times. The radiolarite section Mischenirwiese is a complete radiolarite succession, reworked material from the advancing nappe stack, which consists of different Hallstatt imbricates, is missing. In Oxfordian times the succession was overridden by the Hallstatt mélangé, which formed contemporaneously more to the south as indicated by the different radiolarite matrix ages. In Kimmeridgian–Tithonian times this tectonic nappe stack was sealed by the Plassen Carbonate Platform *sensu lato* (Lärchberg Formation; see Figure 2).

Table 1. Chart showing radiolarian taxa occurrences in studied samples; only absence or presence is noted. Solid circles indicate figured specimens; stars indicate unfigured specimens.

| Locality Sample Number | EW 158 | BMW | | | | | | | | | | UAZ | Figure | |
|--|-----------|-----|----|----|----|----|----|----|----|-----|-----|-----|---------|--------------------|
| | | 28 | 32 | 34 | 31 | 30 | 35 | 33 | 26 | 13b | 13c | | | |
| <i>Arcanica</i> <i>funatoensis</i> | • | | | • | | | | | | • | • | • | (3–11) | 10.5–10.16 |
| <i>Arcanica</i> sp. aff. <i>A. funatoensis</i> | | • | | | | | | | | | | | | 11.27–11.28 |
| <i>Arcanica</i> <i>exquisita</i> | | | • | | | | | | | | | | | 10.3 |
| <i>Arcanica</i> sp. A | | | | | | | | | | | | • | | 10.4 |
| <i>Arcanica</i> <i>undulata</i> | | | • | • | | | | | • | | | | | 10.20–10.22 |
| <i>Archaeodictyomitra</i> sp. aff. <i>A. exigua</i> | | • | | | | | | | | | | • | | 7.18–7.20 |
| <i>Archaeodictyomitra</i> sp. cf. <i>A. annulata</i> | | | | | | • | | | | | | | | 7.21 |
| <i>Archaeodictyomitra</i> <i>minoensis</i> | | | | | | • | • | ? | | | | | (9–12) | 7.40–7.42 |
| <i>Archaeodictyomitra</i> <i>praeapiarium</i> | • | | | | | | | | | • | | | | 7.36–7.37 |
| <i>Archaeodictyomitra</i> <i>prisca</i> | | | | | | | | | | | | • | | 7.43–7.45 |
| <i>Archaeodictyomitra</i> <i>publica</i> | | | | | | | | | | | | • | | 7.17 |
| <i>Archaeodictyomitra</i> <i>rigida</i> | | • | | | | • | • | | | | | | | 7.33–7.35 |
| <i>Archaeodictyomitra</i> <i>spelae</i> | | | | | | | | | | • | | | | 7.48 |
| <i>Archaeodictyomitra</i> <i>tyaughtonensis</i> | | | | | | | • | • | | | | | | 7.38–7.39 |
| <i>Archaeodictyomitra</i> <i>whalenae</i> | | | | | | • | | | | | | • | | 7.46–7.47 |
| <i>Belleza</i> <i>decora</i> | | | | | | | | | | | | • | (4–7) | 8.53 |
| <i>Thanarla</i> <i>patricki</i> gr. | • | | | | | | | • | • | | | • | | 7.22–7.32 |
| <i>Canoptum</i> <i>krahsteine</i> | | | | | | | | | | | | • | | 6.33 |
| <i>Cinguloturris</i> <i>carpatica</i> | | | | | | | | | | | | | (7–11) | 6.29–6.30 |
| <i>Cinguloturris</i> <i>getsensis</i> | | | | | | • | | | | • | | | | 6.31–6.32 |
| <i>Cinguloturris</i> <i>latiannulata</i> | | | | | | | | | | • | | | | 6.34 |
| <i>Theocapsomella</i> <i>cordis</i> | | | | | | | | | | | | • | (5–8) | 11.46 |
| <i>Theocapsomella</i> <i>medvednicensis</i> | | | • | | | | | | | | | | | 11.47 |
| <i>Eucyrtidiellum</i> <i>nodosum</i> | | | | | | | | | | | | • | (3–10) | 8.21–8.23 |
| <i>Eucyrtidiellum</i> <i>ptyctum</i> | | | | | | | | □ | | | | • | (5–11) | 8.20 |
| <i>Eucyrtidiellum</i> <i>pustulatum</i> | | | | | | | | | | • | | • | (5–8) | 8.26–8.27 |
| <i>Eucyrtidiellum</i> <i>pyramis</i> | | | | | | | | | | • | | | (12–13) | 8.19 |
| <i>Eucyrtidiellum</i> <i>unumaense</i> | | • | | | • | | | | | | | | (3–8) | 8.24–8.25 |
| <i>Spinocapsa</i> <i>basilica</i> | | | | | | | | | | | | • | | 8.28 |
| <i>Spinocapsa</i> sp. cf. <i>S. triacantha</i> | | | | | | | | | | | | • | | 8.29 |
| <i>Spinocapsa</i> <i>lata</i> | | | | | | | | | | • | | | | 8.30 |
| <i>Spinocapsa</i> <i>spinosa</i> | | | | | | | | | | | | • | (8–13) | 8.31 |
| <i>Gongylothorax</i> <i>favosus</i> | | | • | • | | • | | | • | | | | (8–10) | 9.39–9.42 |
| <i>Gongylothorax</i> <i>marmoris</i> | | | • | | | | | | | | | | | 11.1–11.3 |
| <i>Gongylothorax</i> sp. A | | | | • | | | | | | | | | | 9.38 |
| <i>Kilinora</i> ? <i>oblongula</i> | | | • | | | | | | | | | | (6–8) | 9.9 |
| <i>Kilinora</i> ? sp. aff. <i>K. oblongula</i> | • | | • | | | | | | | | | | | 10.25–10.26 |
| <i>Hsuum</i> <i>arabicum</i> | | | | | | | | • | | | | | | 7.54 |
| <i>Hsuum</i> <i>obispoense</i> | | | | • | | | | | | | | | | 7.55 |
| <i>Parahsuum</i> sp. aff. <i>P. probosum</i> | | • | | | | | | | | | | | | 7.61 |
| <i>Parahsuum</i> <i>snowshoense</i> | | | | | • | | | | | | | | | 7.50 |
| <i>Parahsuum</i> sp. aff. <i>P. snowshoense</i> | | | | | | | | | | | | • | | 7.51 |
| <i>Parahsuum</i> <i>carpathicum</i> | | | | | | | | | | | | • | | 7.52–7.53 |
| <i>Parahsuum</i> sp. 1 | | | | • | | | | | | | | | | 7.49 |
| <i>Parahsuum</i> sp. 2 | | | | | • | | | | | | | | | 7.56–7.60 |
| <i>Parahsuum</i> sp. 3 | | | | | | | | | | | | • | | 7.62–7.63 |
| <i>Semihsuum</i> <i>amabile</i> | • | | | | | | | | | | | | (4–7) | 7.15–7.16 |
| <i>Transhsuum</i> <i>brevicostatum</i> | | • | | • | | | | | | | | | (3–11) | 8.1–8.3 |
| <i>Transhsuum</i> <i>maxwelli</i> | • | • | | | | | | • | | | | • | | 8.4–8.8, 8.10–8.18 |
| <i>Transhsuum</i> sp. E | | • | | | | | | | | | | | | 8.9 |
| <i>Japonocapsa</i> sp. A | | | | | | | | | | | | • | | 11.4 |
| <i>Striatojaponocapsa</i> <i>conexa</i> | • | | | | | | | | | | | | (4–7) | 11.5–11.7 |
| <i>Striatojaponocapsa</i> <i>riri</i> | | | | • | | | | | | | | | | 11.8–11.9 |
| <i>Striatojaponocapsa</i> <i>synconexa</i> | • | | | | | | | | | | | • | | 11.10–11.13 |
| <i>Striatojaponocapsa</i> spp. | | | | • | • | | | | | | | | | 11.14–11.16 |
| <i>Striatojaponocapsa</i> ? spp. | • | | • | | | | | | | | | • | | 11.17–11.20 |
| <i>Crococapsa</i> <i>tansinhoki</i> | | | | | | | | • | • | | | | | 8.46–8.47 |
| <i>Crococapsa</i> sp. aff. <i>C. tansinhoki</i> | | | | | | | | | | | | • | | 9.17–9.18 |
| <i>Crococapsa</i> sp. aff. <i>C. truncata</i> | | • | | | | | | | | | | | | 8.48 |
| <i>Crococapsa</i> sp. A | | | | | | | | | | | | • | | 8.49–8.52 |
| <i>Crococapsa</i> sp. B | | | | | | | | • | | | | | | 8.45 |
| <i>Crococapsa</i> sp. C | • | | | | | | | | | | | | | 8.43–8.44 |
| <i>Doliocapsa</i> <i>keni</i> | | | | • | | | | | | | | | | 7.4 |
| <i>Doliocapsa</i> <i>matsuokai</i> | | | | | • | | | | | | | • | | 8.33–8.34 |
| <i>Doliocapsa</i> <i>planata</i> | | | | • | | | | | | | | • | | 8.35–8.37 |
| <i>Hiscocapsa</i> <i>kodrai</i> | | | | | | | | | | | | • | | 9.53 |
| <i>Praewilliriedellum</i> <i>convexum</i> | | • | | | | | | | | | | • | (1–11) | 9.27–9.28 |
| <i>Praewilliriedellum</i> <i>robustum</i> | ? | | | • | • | | | | | | | | (5–7) | 10.45? 10.46–10.47 |
| <i>Quarkus</i> <i>japonicus</i> | | | | | • | | | | | | | • | (3–8) | 9.25–9.26 |
| <i>Quarkus</i> <i>madstonensis</i> | | | | | • | | | | | | | | | 9.24 |
| <i>Olanda</i> sp. | | • | | | | | | | | | | | | 7.14 |
| <i>Caneta</i> <i>hsui</i> | | | | | | | | • | | | | | | 6.25 |
| <i>Eoxitus</i> <i>baloghi</i> | | • | | | | | | | • | • | | | | 6.7–6.11 |
| <i>Eoxitus</i> <i>dhimenaensis</i> | | | • | | | | | | | | | • | (3–11) | 6.15–6.16 |
| <i>Eoxitus</i> <i>hungaricus</i> | • | • | | | • | | | | | | | □ | (3–8) | 6.1–6.6 |
| <i>Eoxitus</i> ? <i>brevis</i> | | | | | | | | | | • | | | | 7.9 |
| <i>Eoxitus</i> ? sp. A | | | | | • | | | | | | | | | 6.17 |
| <i>Eoxitus</i> ? sp. B | | | | | • | | | | | | | | | 6.28 |
| <i>Takemuraella</i> <i>japonica</i> | | | | | | | | | | | | • | | 6.49–6.50 |

Table 1. (Continued)

| Locality Sample Number | EW 158 | BMW | | | | | | | | | | | UAZ | Figure |
|---|-----------|-----|----|----|----|----|----|----|----|-----|-----|---|---------|---------------------|
| | | 28 | 32 | 34 | 31 | 30 | 35 | 33 | 26 | 13b | 13c | | | |
| <i>Takemuraella schardti</i> | • | • | | | • | | • | | | | | □ | | 6.18–6.21 |
| <i>Takemuraella</i> sp. cf. <i>T. schardti</i> | | • | | | | | | | | | | | | 7.10–7.11 |
| <i>Takemuraella spinifera</i> | • | • | | | • | | | | | | | | | 6.22–6.24 |
| <i>Pseudodictyomitrella limana</i> | | • | | | | | | | | • | • | | | 6.45–6.48 |
| <i>Pseudodictyomitrella renevieri</i> | • | • | | | | | | | | • | | | | 7.5–7.7 |
| <i>Pseudodictyomitrella</i> sp. cf. <i>P. renevieri</i> | | • | | | | | | | | | | | | 7.8 |
| <i>Saitoum pagei</i> | | • | | | | | | | | | | | (4–11) | 12.1 |
| <i>Saitoum trichylum</i> | | • | | | | | | | | • | | | (7–9) | 12.2–12.3 |
| <i>Loopus</i> sp. aff. <i>L. mexicanus</i> | | | | | | | | | | | • | | | 7.67 |
| <i>Loopus mariae</i> | | | | | • | | | | • | | | | | 7.64–7.66 |
| <i>Loopus mexicanus</i> | | | | | • | | | | | | | | | 7.71 |
| <i>Loopus venustus</i> | | | • | | | | • | | | | • | • | | 7.67–7.70 |
| <i>Mizukidella kamoensis</i> | • | • | | | | | | | | □ | □ | | (3–7) | 6.12–6.14 |
| <i>Mizukidella mokaensis</i> n. sp. | | | | | | | • | • | | | | | | 6.26–6.27 |
| <i>Protunuma europeus</i> | | | | | | | | | | | • | | | 11.42 |
| <i>Protunuma japonicus</i> | | | | | | | | | | | • | | (7–12) | 11.41 |
| <i>Protunuma ochiensis</i> | | • | | | | | | ? | | | | | (5–14) | 11.43 ?–11.44 |
| <i>Protunuma turbo</i> | | | | | | | | | | | • | | (4–7) | 11.39–11.40 |
| <i>Quarticella cicciona</i> | | | | | | | | | | | • | | | 9.56 |
| <i>Quarticella ovalis</i> | | • | | | | | | | | | | | | 9.52 |
| <i>Quarticella</i> sp. A | • | | | | | | | | | | | | | 9.58 |
| <i>Quarticella</i> sp. B | | | | | | | | | | | | | | 9.29–9.30 |
| <i>Quarticella</i> sp. C | | • | | | | | | | | | • | | | 9.54–9.55 |
| <i>Quarticella</i> sp. D | | • | | | | | | | | | | | | 9.57 |
| <i>Unuma gordus</i> | • | • | • | ? | • | | | | • | • | | | (4–6) | 11.29–11.38, 11.45? |
| <i>Unuma laticostatus</i> | • | • | | | | | | | | | • | | (2–5) | 11.21–11.26 |
| <i>Yamatoum</i> sp. A | | • | | | | | | | | | | | | 8.32 |
| <i>Yamatoum spinosum</i> | • | • | | | | | | | | • | • | | | 8.38–8.42 |
| <i>Hemicryptocapsa buekkensis</i> | | • | • | | • | • | | | | • | | | | 9.1–9.6 |
| <i>Hemicryptocapsa carpathica</i> | | • | | | | | | | | | | • | (7–11) | 9.20–9.23 |
| <i>Hemicryptocapsa marcucciae</i> | | • | | | | • | | | | • | • | • | (4–8) | 9.12–9.16 |
| <i>Hemicryptocapsa nonaginta</i> n. sp. | | • | | | | | | | | | • | | (4–5) | 9.19 |
| <i>Hemicryptocapsa yaoi</i> | • | • | • | | | | | | • | • | • | | | 9.31–9.37 |
| <i>Williriedellum</i> sp. cf. <i>W. formosum</i> | | • | | | | | | | | | • | | | 9.45–9.48 |
| <i>Williriedellum crystallinum</i> | | • | | | | • | | | | | | | (7–11) | 9.50–9.51 |
| <i>Williriedellum</i> sp. A | | | | | | | | | | • | • | | | 10.23–10.24 |
| <i>Williriedellum</i> sp. B | | | | | | | | | | | • | | | 9.49 |
| <i>Williriedellum yahazuense</i> | | | | | • | | | | | | | | | 9.43–9.44 |
| <i>Williriedellum?</i> sp. C | | • | | | | | | | | | • | | | 10.1–10.2 |
| <i>Zhamoidellum ovum</i> | | | • | • | | | • | • | | | | • | (9–11) | 10.31–10.40 |
| <i>Zhamoidellum</i> sp. aff. <i>Z. ovum</i> | | | • | | | | • | | | | | | | 9.10–9.11 |
| <i>Zhamoidellum ventricosum</i> | | | | | | | | | | | | | | 10.17–10.19 |
| <i>Zhamoidellum</i> sp. A | | | • | | | | | | • | | | | (8–11) | 9.7–9.8 |
| <i>Zhamoidellum</i> sp. B | | | • | | | | • | | | | | • | | 10.27–10.30 |
| <i>Zhamoidellum</i> sp. C | • | | | | | | • | | | • | | | | 10.41–10.44 |
| <i>Campanomitra</i> sp. aff. <i>C. buekkensis</i> | | | | | | | • | | | | | | | 6.44 |
| <i>Campanomitra tuscanica</i> | | • | | | | | | | • | | | • | | 6.65–6.69 |
| <i>Campanomitra</i> sp. aff. <i>C. tuscanica</i> | | | • | | | | • | | | • | | | | 6.62–6.64 |
| <i>Campanomitra</i> sp. aff. <i>C. ulivii</i> | | | • | • | | | | | | | | | | 6.70–6.73 |
| <i>Campanomitra?</i> sp. A | | | | | | | | | | | | | | 6.40–6.43 |
| <i>Campanomitra?</i> spp. | • | | | | | | • | | | • | • | | | 6.56–6.61 |
| <i>Parvimitrella wallacheri</i> | | | | | | | | | | | | • | | 6.39 |
| <i>Xitomitra annibill</i> | | | | | | | | | | | • | | | 6.51–6.54 |
| <i>Xitomitra tairai</i> | | | | | | | | | • | • | • | • | | 6.35–6.38 |
| <i>Xitomitra?</i> sp. A | | | | | | | • | | | | | | | 6.55 |
| <i>Xitus skenderbegi</i> | • | | | | | | | | | • | | | | 7.1–7.3 |
| <i>Xitus</i> sp. A | | | | • | | | | | | | | | | 7.12–7.13 |
| <i>Crucella theokafensis</i> | | | | | | | | | | | | • | (7–11) | 12.37 |
| <i>Emiluvia salensis</i> | • | | | | | | | | | • | | | (4–13) | 12.39–12.40 |
| <i>Emiluvia sedecimporata</i> | | | • | | | | | □ | | | | | (3–11) | 12.38 |
| <i>Emiluvia?</i> sp. | | • | | | | | | | | | | | | 12.41 |
| <i>Homoeoparonaella elegans</i> | | • | | | | | | | | | | | (4–10) | 12.32 |
| <i>Homoeoparonaella</i> spp. | | | | | • | | | | | | | | | 12.35–12.36 |
| <i>Paronaella kotura</i> | • | | | • | | | | | | | | | (3–10) | 12.33–12.34 |
| <i>Paronaella pristidentata</i> | • | | | | | | | | | | | | (10–11) | 12.31 |
| <i>Angulobracchia</i> spp. | | • | | | | | | | | • | | | | 12.28–12.30 |
| <i>Alievium?</i> sp. aff. <i>A. crassum</i> | | | | | | | | | | • | | | | 12.9 |
| <i>Alievium?</i> longispineum | □ | • | | | | | | | | | □ | | | 12.7–12.8 |
| <i>Tritrabs ewingi</i> | | • | • | | | | | | | | | | (4–22) | 12.24–12.27 |
| <i>Gorgansium silviesense</i> | | • | | | | | | | | | • | | | 12.5–12.6 |
| <i>Pantanellium riedeli</i> | • | • | | | • | | | | | | | | (7–12) | 12.13–12.15 |
| <i>Archaeospongoprimum elegans</i> | • | • | | • | | | | | | | | | | 12.10–12.12 |
| <i>Bernoullius cristatus</i> | • | | | | | | | | | | | | (5–8) | 12.4 |
| <i>Hexasaturnalis minor</i> | | | | | | | □ | | | | | • | | 12.23 |
| <i>Hexasaturnalis nakasekoi</i> | • | • | | | | | □ | | | | | | | 12.19–12.20 |
| <i>Hexasaturnalis suboblongus</i> | • | • | | | | | | | | | □ | | | 12.21–12.22 |
| <i>Hexasaturnalis tetraspinus</i> | • | | | | | | | | | | □ | | (1–6) | 12.16–12.18 |



Occurrence.—Upper Bajocian to upper Maastrichtian.

Gongylothorax favosus Dumitrica, 1970
Figure 9.39–9.42

- 1970 *Gongylothorax favosus* Dumitrica, p. 56, pl. 1, figs. 1a–c, 2.
1995b *Gongylothorax favosus*; Baumgartner et al., p. 230, pl. 6131, figs. 1–7.
2003 *Gongylothorax favosus*; Suzuki and Gawlick, p. 205, fig. 6.96. [See for complete synonymy]
2009 *Gongylothorax favosus favosus*; Suzuki and Gawlick, p. 180, fig. 5.31A–C, 32A–B; fig. 6.21A–B. [See for complete synonymy]

Gongylothorax marmoris Kiessling in Kiessling and Zeiss, 1992
Figure 11.1–11.3

- 1992 *Gongylothorax* (?) *marmoris* Kiessling in Kiessling and Zeiss, p. 190, pl. 2, figs. 8–10.
2003 *Gongylothorax* cf. *marmoris*; Suzuki and Gawlick, fig. 5.47.

Remarks.—Originally this species was questionably attributed to *Gongylothorax* because the internal structure of the cephalis was not observed, but otherwise all characteristics match with the diagnosis of the genus.

Gongylothorax sp. A
Figure 9.38

Remarks.—The ridges around the hexagonal areas are more elevated in relief than the pores commonly observed in *Gongylothorax* (see *Gongylothorax* sp. aff. *G. favosus* in Baumgartner et al., 1995b, p. 232 = *Gongylothorax favosus oviformis* Suzuki and Gawlick 2009, p. 180, fig. 5.33A–34C; fig. 6.22A–26B).

Genus *Kilinora* Hull, 1997

Type species.—*Stylocapsa? spiralis* Matsuoka, 1982.

Occurrence.—Lower Bathonian to middle Callovian.

Kilinora? oblongula (Kocher in Baumgartner et al., 1980)
Figure 9.9

- 1980 *Stylocapsa oblongula* Kocher in Baumgartner et al., p. 62, pl. 6, fig. 1.
2006 *Kilinora* (?) *oblongula*; O'Dogherty et al., p. 443, pl. 8, figs. 25–29. [See for complete synonymy]
2007b *Stylocapsa oblongula*; Gawlick et al., fig. 17.25.
2013 *Kilinora* (?) *oblongula*; Chiari et al., fig. 13c.

Remarks.—According to O'Dogherty et al., 2006, the genus is queried because this species does not exhibit a linear arrangement of pores, and clearly lacks costae. It may belong to a new genus.

Kilinora? sp. aff. *K. oblongula* (Kocher in Baumgartner et al., 1980)
Figure 10.25–10.26

Remarks.—This form strongly resembles *Kilinora* (?) *oblongula* as illustrated by O'Dogherty et al., 2006 on pl. 8, figures 25–26, but possesses a somewhat pointed basal appendage.

'Multicytrids'

Family Diacanthocapsidae O'Dogherty, 1994

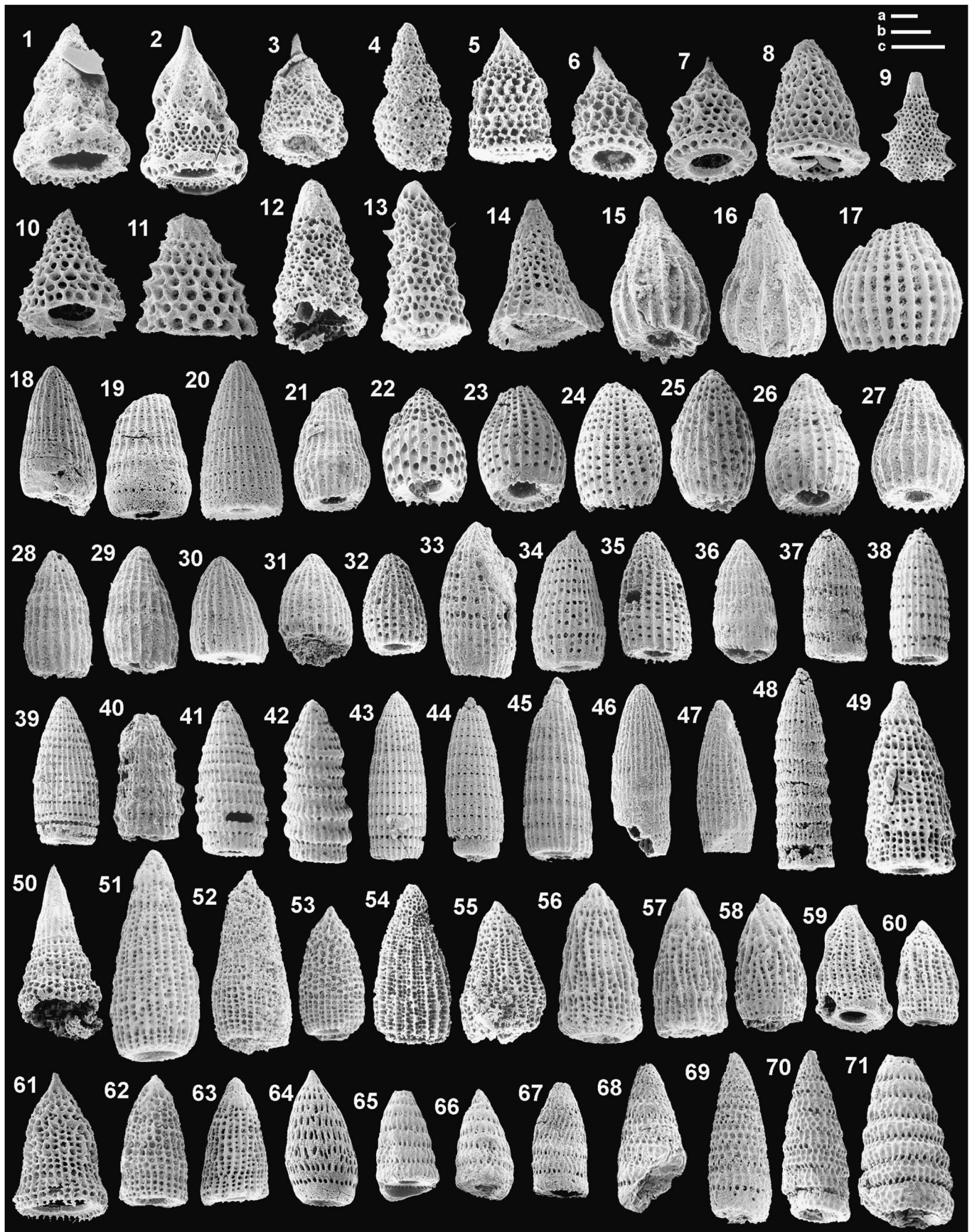
Genus *Theocapsomella* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006.

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

Remarks.—This genus was misspelled as *Theocapsommella* in all descriptions of the species originally included under this genus (O'Dogherty et al., 2006). According to ICZN Art. 24.2.3, the selection of the correct original spelling should be *Theocapsomella*. This was the original name followed by the expression n. gen. (O'Dogherty et al., 2006, p. 454) and was also fixed as the correct original spelling by the first reviser (O'Dogherty et al., 2009).

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Figure 6. Scale bars (a, b) measure 50 µm; each radiolarian scanning micrograph is designated by sample and specimen number, followed by the corresponding scale. (1–6) *Eoxitus hungaricus* Kozur, sample BMW-28 (1, 073/a; 2, 072/a; 6, 043/a); sample EW-158 (3, 005/a; 5, 017/a); sample BMW-31 (4, 008/a). (7–11) *Eoxitus baloghi* Kozur, sample BMW-28 (7, 045/a; 8, 070/a; 11, 061/a); sample BMW-26 (9, 011/a); sample BMW-13b (10, 017/a). (12–14) *Mizukidella kamoensis* (Mizutani and Kido), sample BMW-28 (12, 064/a); sample EW-158 (13, 009/a; 14, 015/a). (15–16) *Eoxitus dhimenaensis* (Baumgartner), sample BMW-32 (15, 077/a); sample BMW-13c (16, 052/a). (17) *Eoxitus?* sp. A, sample BMW-31 (17, 011/a). (18–21) *Takemuraella schardti* (O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al.) sample BMW-35 (18, 006/a); sample BMW-26 (19, 008/a; 20, 016/a; 21, 055/a). (22–24) *Takemuraella spinifera* (Takemura), sample BMW-28 (22, 060/a); sample BMW-31 (23, 018/a); sample EW-158 (24, 060/a). (25) *Caneta hsui* (Pessagno), sample BMW-35 (25, 015/a). (26–27) *Mizukidella mokaensis* n. sp., sample BMW-33 (26, 004/b, paratype); sample BMW-35 (27, 001/a, holotype). (28) *Eoxitus?* sp. B, sample BMW-31 (28, 028/b). (29–30) *Cinguloturris carpatica* in Dumitrica and Mello, sample BMW-13c (29, 026/a; 30, 018/a). (31–32) *Cinguloturris getsensis* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., sample BMW-26 (31, 025/a); sample BMW-30 (32, 001/b). (33) *Canoptum krahsteinense* (Suzuki and Gawlick in Gawlick et al.), sample BMW-13b (33, 19/b). (34) *Cinguloturris latiannulata* (Grill and Kozur), sample BMW-26 (34, 010/b). (35–38) *Xitomitra tairai* (Aita), sample BMW-13c (35, 055/a; 37, 043/a; 38, 070/a); sample BMW-33 (36, 001/a). (39) *Parvimitrella wallacheri* (Grill and Kozur), sample BMW-13c (39, 036/b). (40–43) *Campanomitra?* sp. A, sample BMW-13c (40, 021/a; 41, 054/a; 42, 010/a; 43, 030/a). (44) *Campanomitra* sp. aff. *C. bueckensis* (Grill and Kozur), sample BMW-35 (44, 012/a). (45–48) *Pseudodictyomitrella limana* (Cortese), sample BMW-13b (45, 032/b); sample BMW-28 (46, 014/b); sample BMW-26 (47, 048/b; 48, 039/b). (49–50) *Takemuraella japonica* (Takemura), sample BMW-13b (49, 013/b); sample BMW-13c (50, 034/a). (51–54) *Xitomitra annibill* (Kocher), sample BMW-13c (51, 088/a; 52, 028/a; 53, 044/a; 54, 042/a). (55) *Xitomitra?* sp. A, sample BMW-35 (55, 020/a). (56–61) *Campanomitra?* spp., sample BMW-26 (56, 054/b); sample EW-158 (57, 026/b); sample BMW-35 (58, 026/a); sample BMW-13c (59, 045/a; 60, 092/b); sample BMW-13b (61, 050/b). (62–64) *Campanomitra* sp. aff. *C. tuscanica* (Chiari, Cortese, and Marcucci in Chiari et al.), sample BMW-32 (62, 041/b); sample BMW-35 (63, 023/b); sample BMW-13b (64, 012/b). (65–69) *Campanomitra tuscanica* (Chiari, Cortese, and Marcucci in Chiari et al.), sample BMW-32 (65, 030/a); sample BMW-13c (66, 126/a; 67, 077/b); sample BMW-28 (68, 001/a); sample BMW-33 (69, 008/b). (70–73) *Campanomitra* sp. aff. *C. ulivii* (Chiari, Cortese, and Marcucci in Chiari et al.), sample BMW-34 (70, 014/b; 71, 012/b; 72, 034/b); sample BMW-32 (73, 102/b).



In the original description (O'Dogherty et al., 2006), *Theocapsomella* included also some four-segmented nassellarians (e.g., *Stichocapsa himedaruma* Aita). On the other hand, a phylogenetic relationship of *Stichocapsa himedaruma* Aita and *Stichocapsa convexa* Yao was also assumed (see O'Dogherty et al., 2006, p. 441). New findings are in favor of the latter opinion (see Šegvić et al., 2014, pl. 1, figs. 21, 22).

Occurrence.—Lower Bathonian to lower Berriasian.

Theocapsomella cordis (Kocher in Baumgartner et al., 1980)
Figure 11.46

- 1980 *Stylocapsa cordis* Kocher in Baumgartner et al., p. 62, pl. 6, fig. 1.
2006 *Theocapsomella cordis*; O'Dogherty et al., p. 443, pl. 8, figs. 25–29. [See for complete synonymy]
2009 *Theocapsomma cordis*; Suzuki and Gawlick, p. 181, figs. 5.37A–B, 6.28A–B.
2013 *Theocapsomella cordis*; Chiari et al., fig. 14e.

Theocapsomella medvednicensis (Goričan in Halamić et al., 1999)
Figure 11.47

- 1999 *Theocapsomma medvednicensis* Goričan in Halamić et al., p. 37, pl. 1, figs. 12–16.
2003 *Theocapsomma medvednicensis*; Suzuki and Gawlick, p. 206, fig. 6.87.
2006 *Theocapsomella medvednicensis* (Goričan); O'Dogherty et al., p. 456, pl. 8, figs. 30, 33–37. [See for complete synonymy]
2008 *Theocapsomma* sp. aff. *T. medvednicensis*; Baumgartner et al., pl. 4, fig. 10.
2009 *Theocapsomma medvednicensis*; Suzuki and Gawlick, p. 181, figs. 5.38A–B.

Family Minocapsidae new family

Type genus.—*Minocapsa* Matsuoka, 1991a.

Other genera.—*Crococapsa* new genus; *Doliocapsa* new genus; *Hemicryptocephalis* Li, 1988; *Hiscocapsa* O'Dogherty, 1994; *Praewilliriedellum* Kozur, 1984 (syn. *Hemicryptocephalis*); and *Quarkus* Pessagno, Blome, and Hull in Pessagno et al., 1993.

Diagnosis.—Pyriform to ovoidal shell consisting in usually four segments. Last segment with or without an aperture. Lattice shell composed of small rounded to large polygonal pore frames.

Etymology.—After type genus.

Occurrence.—Early Pliensbachian to Middle Albian.

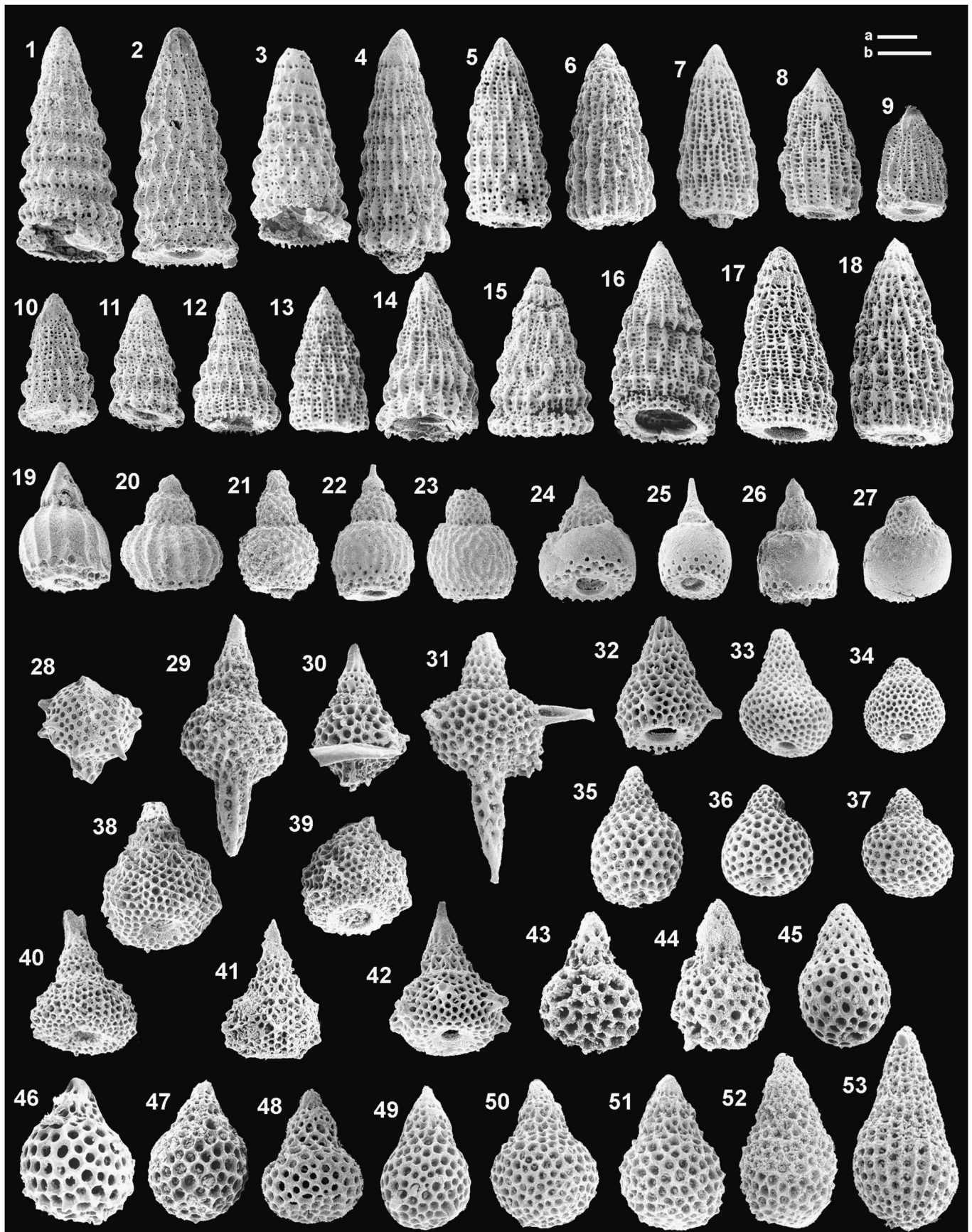
Remarks.—This family is erected for genera included in the unnamed family *pro* Stichocapsidae used by O'Dogherty et al., 2009. The genus *Aitaum* Pessagno and Hull, 2002 is an exception because it has a multisegmented test composed of three to four post-abdominal segments. *Aitaum* has more affinity with the genus *Lantus* Yeh, 1987a and other eucyrtidiid-type nassellarians.

Genus *Crococapsa* new genus

Type species.—*Sethocapsa hexagona* Hori, 1999.

Other species.—*Cyrtocapsa asseni* Tan, 1927; *Minocapsa aitai* Hull, 1997; *Minocapsa truncata* Wu, 2000; *Minocapsa? tansinhoki* Hull, 1997; *Sethocapsa accincta* Steiger, 1992; *Sethocapsa horokanaiensis* Kawabata, 1988; *Sethocapsa kitoi* Jud, 1994; *Sethocapsa lagenaria* Wu and Li, 1982; *Sethocapsa pseudouterculus* Aita in Aita and Okada, 1986; *Sethocapsa? subcrassitestata* Aita in Aita and Okada, 1986; *Sethocapsa? zweilii* Jud, 1994; *Sethocapsa hashimotoi* Tumanda, 1989; *Theocapsa simplex* Tan, 1927; and *Theocapsa uterculus* Parona, 1890.

Figure 7. Scale bars (a, b, c) measure 50 µm; each radiolarian scanning micrograph is designated by sample and specimen number, followed by the corresponding scale. (1–3) *Xitus skenderbegi* (Chiari, Marcucci, and Prella), sample BMW-26 (1, 009/c; 3, 066/c); sample EW-158 (2, 014/c). (4) *Doliocapsa keni* (Kocher), sample BMW-34 (4, 035/c). (5–7) *Pseudodictyomitrella renevieri* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., sample EW-158 (5, 055/c); sample BMW-26 (6, 036/c); sample BMW-28 (7, 003/c). (8) *Pseudodictyomitrella* sp. cf. *P. renevieri* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., sample BMW-28 (8, 046/c). (9) *Eoxitus? brevis* Kozur, sample BMW-26 (9, 038/b). (10–11) *Takemuraella* sp. cf. *T. schardtii* (O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al.), sample BMW-28 (10, 063/c; 11, 053/c). (12–13) *Xitus* sp. A, sample BMW-34 (12, 008/c; 13, 005/c). (14) *Olanda* sp., sample BMW-28 (14, 067/c). (15–16) *Semihsuum amabile* (Aita), sample BMW-26 (15, 070/c); sample EW-158 (16, 007/c). (17) *Archaeodictyomittra publica* (Hull), sample BMW-13c (17, 099/c). (18–20) *Archaeodictyomittra* sp. aff. *A. exigua* Blome, sample BMW-13b (18, 013/c; 19, 028/c); sample BMW-28 (20, 062/c). (21) *Archaeodictyomittra* sp. cf. *A. annulata* Kozur and Mostler in Grill and Kozur, sample BMW-30 (21, 59/c). (22–32) *Thanarla patricki* gr. (Kocher), sample BMW-33 (22, 022/c); sample BMW-35 (23, 028/c; 24, 024/c; 25, 037/c; 26, 030/c; 29, 007/c; 32, 025/c); sample EW-158 (27, 063/c); sample BMW-13c (28, 129/c); sample BMW-13b (30, 004/c; 31, 022/c). (33–35) *Archaeodictyomittra rigida* Pessagno, sample BMW-30 (33, 039/c); sample BMW-28 (34, 042/c); sample BMW-35 (35, 021/c). (36–37) *Archaeodictyomittra praeaparium* Cordey, sample BMW-26 (36, 024/b); sample EW-158 (37, 059/b). (38–39) *Archaeodictyomittra tyaughtonensis* Cordey, sample BMW-35 (38, 005/b; sample BMW-33 (39, 005/b). (40–42) *Archaeodictyomittra minoensis* (Mizutani), sample BMW-30 (40, 057/b); sample BMW-35 (41, 017/b; 42, 010/b). (43–45) *Archaeodictyomittra prisca* Kozur and Mostler in Grill and Kozur, sample BMW-13c (43, 075/b; 44, 051/b; 45, 017/b). (46–47) *Archaeodictyomittra whalenae* Kozur and Mostler in Grill and Kozur, BMW-31 (46, 026/b); sample BMW-13c (47, 049/b). (48) *Archaeodictyomittra spelae* Chiari, Cortese and Marcucci in Chiari et al., sample BMW-26 (48, 043/b). (49) *Parahsuum* sp. 1 sensu O'Dogherty et al., sample BMW-34 (49, 006/c). (50) *Parahsuum snowshoense* (Pessagno and Whalen), sample BMW-31 (50, 021/b). (51) *Parahsuum* sp. aff. *P. snowshoense* (Pessagno and Whalen), sample BMW-13c (51, 031/b). (52–53) *Parahsuum carpathicum* Widz and De Wever, sample BMW-13c (52, 050/b; 53, 076/b). (54) *Hsuuum arabicum* Dumitrica in Dumitrica et al., sample BMW-35 (54, 009/a). (55) *Hsuuum obispoense* Pessagno, sample BMW-34 (55, 7/b). (56–60) *Parahsuum* sp. 2 sensu O'Dogherty et al., sample BMW-13c (56, 020/b; 57, 025/b; 58, 033/b); sample BMW-31 (59, 016/b; 60, 070/b). (61) *Parahsuum* sp. aff. *P. probosum* (Pessagno and Whalen), sample BMW-28 (61, 054/c). (62–63) *Parahsuum* sp. 3 sensu O'Dogherty et al., sample BMW-13c (62, 035/b; 63, 080/b). (64–66) *Loopus mariae* Beccaro, sample BMW-34 (64, 003/b; 65, 009/b); sample BMW-33 (66, 007/b). (67–70) *Loopus venustus* (Chiari, Cortese, and Marcucci in Chiari et al.), sample BMW-13b (67, 001/b); sample BMW-32 (68, 009/c); sample BMW-13c (69, 082/c); sample BMW-35 (70, 011/c). (71) *Loopus mexicanus* (Hull), sample BMW-34 (71, 020/c).



Diagnosis.—Tetracyrtid nassellarian having a globose postabdominal segment. Lattice meshwork with polygonal pore frames lacking nodes or tubercles on its surface. Closed antapically or having a discrete number of small pores grouped into a depression (see *Sethocapsa uterculus* in Baumgartner et al., 1995b, p. 505, pl. 5462, fig. 2). Collar and lumbar strictures slightly recognizable or indistinct externally. Large and globose postabdominal segment is well distinguished from the abdomen by a marked stricture.

Etymology.—From the latin *croco* (saffron) and *capsa* (box); feminine gender.

Occurrence.—Bathonian to middle Albian.

Remarks.—O'Dogherty (1994) erected the genus *Hiscocapsa* for a heterogeneous group of tetracyrtid nassellarians displaying a wide variety of pore frame arrangement. However, many species assigned originally to *Hiscocapsa* are clearly separated by lacking a distal aperture and bearing no tubercles on the surface.

Crococapsa n. gen. differs from *Minocapsa* Matsuoka, 1991a, by its distinct fourth segment, which is globose and well differentiated from the abdomen by a marked stricture. *Crococapsa* n. gen. also differs from *Lantus* Yeh, 1987a by having only one postabdominal chamber.

Crococapsa tansinhoki (Hull, 1997)

Figure 8.46–8.47

1997 *Minocapsa*(?) *tansinhoki* Hull, p. 148, pl. 38, figs. 4, 6.

2006 *Minocapsa*(?) *tansinhoki*; O'Dogherty et al., 2006, p. 444, pl. 6, figs. 16, 17. [See for complete synonymy]

Remarks.—O'Dogherty et al. (2006, p. 444) first questioned the placement of this species to *Minocapsa* because the basal aperture was absent and the phylogenetic relationship with early Jurassic representatives was not demonstrated. This species fits well in the general description of the new genus *Crococapsa*.

Crococapsa sp. aff. *C. tansinhoki* (Hull, 1997)

Figure 9.17–9.18

Remarks.—These forms differ from Hull's material by having smaller and more numerous pores on the abdomen.

Crococapsa sp. aff. *C. truncata* (Wu, 2000)

Figure 8.48

aff. 2000 *Minocapsa truncata* Wu, p. 304, pl. 2, figs. 1, 5–6.

Remarks.—This specimen differs from the Tibetan specimens by displaying a proportionally larger last segment.

Crococapsa sp. A

Figure 8.49–8.52

Remarks.—These specimens resemble *Crococapsa* sp. aff. *C. truncata* (Wu, 2000), but the proximal part of the shell is relatively longer and elongated.

Crococapsa sp. B

Figure 8.45

Remarks.—This specimen is closely related to other congeneric forms included in this paper, but differs by the well-marked polygonal pore frames on almost all the shell surface.

Crococapsa sp. C

Figure 8.43–8.44

Remarks.—These specimens are very close to *Crococapsa tansinhoki* but they display more cylindrical and smoother thorax.

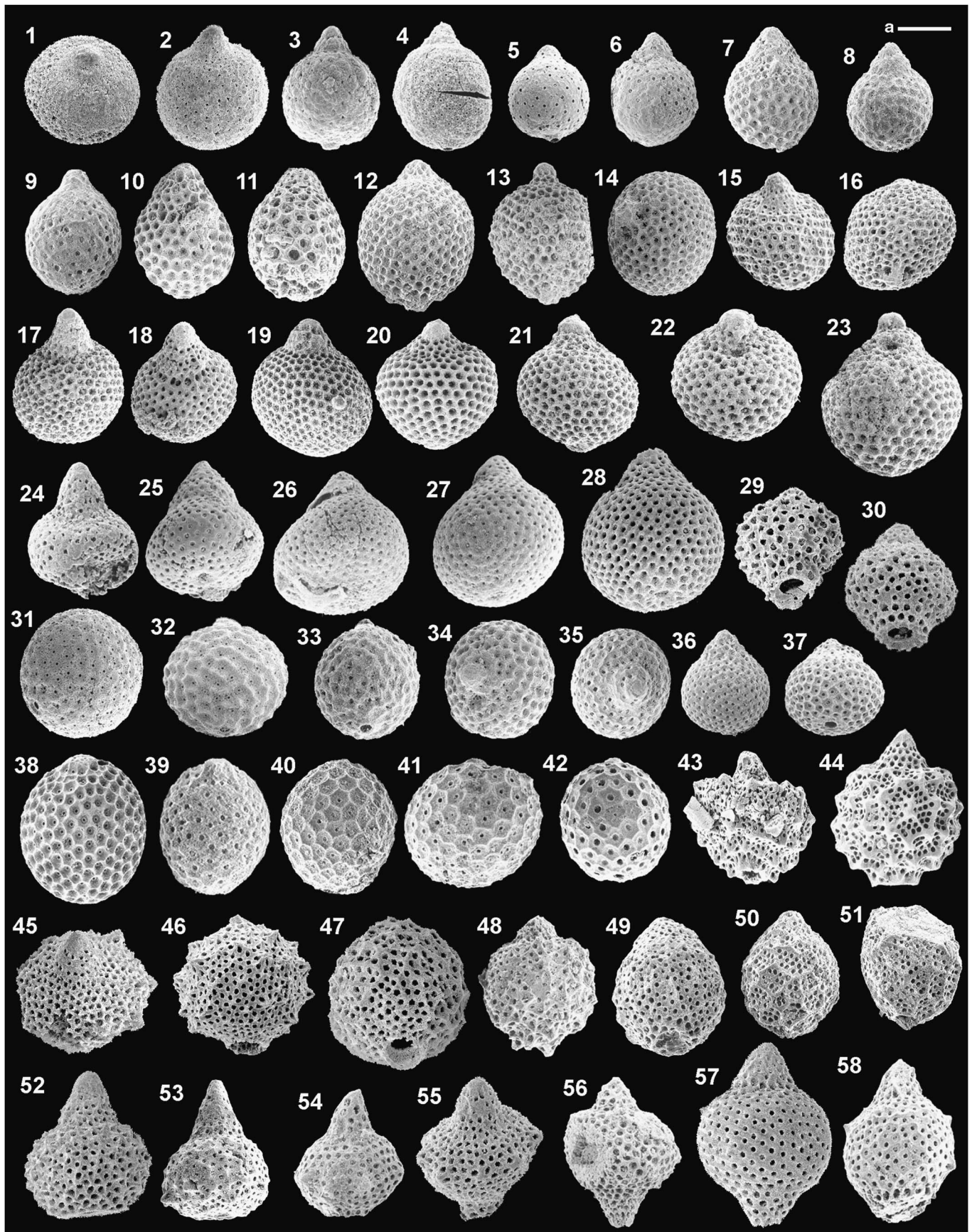
Genus *Doliocapsa* new genus

Type species.—*Stichomitra* (?) *stecki* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006.

Other species.—*Hiscocapsa acuta* Hull, 1997; *Hiscocapsa minuta* Yeh, 2011; *Hiscocapsa planata* Wu, 2000 (syn. *Stichocapsa magnipora*); *Sethocapsa lugeoni* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006; *Sethocapsa taukhaensis* Kemkin and Tacketani, 2004; *Solenotryma kenii* Kocher, 1981; *Stichocapsa magnipora* Chiari, Marcucci, and Prela, 2002; *Stichomitra doliolum* Aita in Aita and Okada, 1986; and ?*Quarticella hunzikeri* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006.

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Figure 8. Scale bars (a, b) measure 50µm; each radiolarian scanning micrograph is designated by sample and specimen number, followed by the corresponding scale. (1–3) *Transhuum brevicostatum* (Ožvoldová), sample BMW-26 (1, 013/b); sample BMW-28 (2, 068/a); sample BMW-34 (3, 002/a). (4–8, 10–18) *Transhuum maxwelli* (Pessagno), BMW-13c (4, 083/a; 6, 021/a; 7, 048/a; 18, 024/a); sample BMW-35 (5, 003/a; 13, 027/a; 15, 004/a; 16, 002/a); sample BMW-26 (8, 015/a; 11, 060/a); sample BMW-28 (10, 071/a); sample EW-158 (12, 062/a; 14, 012/a; 17, 061/a). (9) *Transhuum* sp. E sensu (Yao), sample BMW-28 (9, 066/a). (19) *Eucyrtidiellum pyramis* (Aita in Aita and Okada), sample BMW-33 (19, 019/b). (20) *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo), BMW-13c (20, 139/b). (21–23) *Eucyrtidiellum nodosum* Wakita, sample BMW-13c (21, 074/b; 22, 005/b; 23, 134/b). (24–25) *Eucyrtidiellum unumaense* (Yao), sample BMW-28 (24, 017/b); sample BMW-31 (25, 045/b). (26–27) *Eucyrtidiellum pustulatum* Baumgartner, sample BMW-33 (26, 028/b); sample BMW-13b (27, 060/b). (28) *Spinocapsa basilica* (Hull), sample BMW-13c (28, 064/a). (29) *Spinocapsa* sp. cf. *S. triacantha* (Fischli), sample BMW-13c (29, 046/a). (30) *Spinocapsa lata* (Yang), sample BMW-33 (30, 018/a). (31) *Spinocapsa spinosa* (Ožvoldová), sample BMW-13c (31, 057/a). (32) *Yamatoum* sp. A, sample BMW-28 (32, 047/b). (33–34) *Doliocapsa matsuokai* (Yeh), sample BMW-13b (33, 049/b); sample BMW-31 (34, 048/b). (35–37) *Doliocapsa planata* (Wu), sample BMW-13c (35, 131/a; 37, 089/a); sample BMW-34 (36, 029/a). (38–42) *Yamatoum spinosum* (Takemura), sample EW-158 (38, 022/b); sample BMW-13b (39, 054/b); sample BMW-26 (40, 073/b; 41, 049/b); sample BMW-28 (42, 051/b). (43–44) *Crococapsa* sp. C, sample EW-158 (43, 067/b; 44, 070/b). (45) *Crococapsa* sp. B, sample BMW-35 (45, 032/b). (46–47) *Crococapsa tansinhoki* (Hull), sample BMW-33 (46, 023/b); sample BMW-35 (47, 022/b). (48) *Crococapsa* sp. aff. *C. truncata* (Wu), sample BMW-28 (48, 057/b). (49–52) *Crococapsa* sp. A, sample BMW-13c (49, 009/b; 50, 073/b; 51, 007/b; 52, 004/b). (53) *Belleza decora* (Rüst), sample BMW-13c (53, 012/b).



Diagnosis.—Shell with four segments (rarely more), generally thick-walled. Cephalis small, spherical, poreless, without apical horn. Other segments latticed with polygonal pore frames and lacking tubercles or nodes. Last segment somewhat inflated and having an aperture.

Etymology.—From *dolium* (barrel) and *capsa* (box); feminine gender.

Occurrence.—Lower Toarcian to Tithonian.

Remarks.—This new genus is differentiated from *Praewilliriedellum* Kozur, 1984, by having very distinct strictures and well-differentiated segments.

Doliocapsa matsukai (Yeh, 2009)
Figure 8.33–8.34

- 1998 *Stichocapsa* sp. F Arakawa, p. 63, pl. 6, fig. 274.
2005 *Stichocapsa* sp. Šmuc and Goričan, pl. 3, figs. 22a–b.
2009 *Hiscocapsa matsukai* Yeh, p. 67, pl. 21, figs. 1, 8, 20, 22.
2011 *Hiscocapsa matsukai*; Yeh, p. 16, pl. 7, figs. 10–13.
2011 *Hiscocapsa* cf. *matsukai*; Yeh, p. 16, pl. 5–7.

Remarks.—The proximal part in our specimens is slightly longer than in the type material. This species differs from all others representatives herein illustrated by having smaller and more numerous polygonal pores, less marked strictures at joints, and longer proximal conical part.

Doliocapsa keni (Kocher, 1981)
Figure 7.4

- 1981 *Solenotryma keni* Kocher, p. 91, pl. 16, figs. 11–12.
2006 *Stichomitra* (?) *keni* (Kocher); O'Dogherty et al., p. 442, pl. 5, fig. 6.

Doliocapsa planata (Wu, 2000)
Figure 8.35–8.37

- 2000 *Hiscocapsa planata* Wu, p. 303, pl. 1, figs 7–8.

- 2002 *Stichocapsa magnipora* Chiari, Marcucci and Prela, p. 76, pl. 3, figs. 13–17.

Genus *Hiscocapsa* O'Dogherty, 1994

Type species.—*Cyrtocapsa grutterinki* Tan, 1927.

Other species.—*Sethocapsa aitai* Chiari, Marcucci, and Prela, 2002; *Sethocapsa kodrai* Chiari, Marcucci, and Prela, 2002; *Stichocapsa pseudornata* Tan, 1927; and *Stichocapsa ruteni* Tan, 1927.

Emended diagnosis.—*Hiscocapsa* is emended in order to include only tetracyrtid nassellarians having a globose post-abdominal segment with tubercles. A large distal aperture is also presented and sometimes, when preserved, an appendage. We note that terminally closed species with tubercles (e.g., *Sethocapsa kaminogoensis* Aita in Aita and Okada, 1986; *Sethocapsa* spp., pl. 5, fig. 15 in Aita and Okada, 1986; *Sethocapsa* sp. 8, pl. 2, fig. 32 in Matsuoka, 1998) should belong to a new genus, which is not described herein.

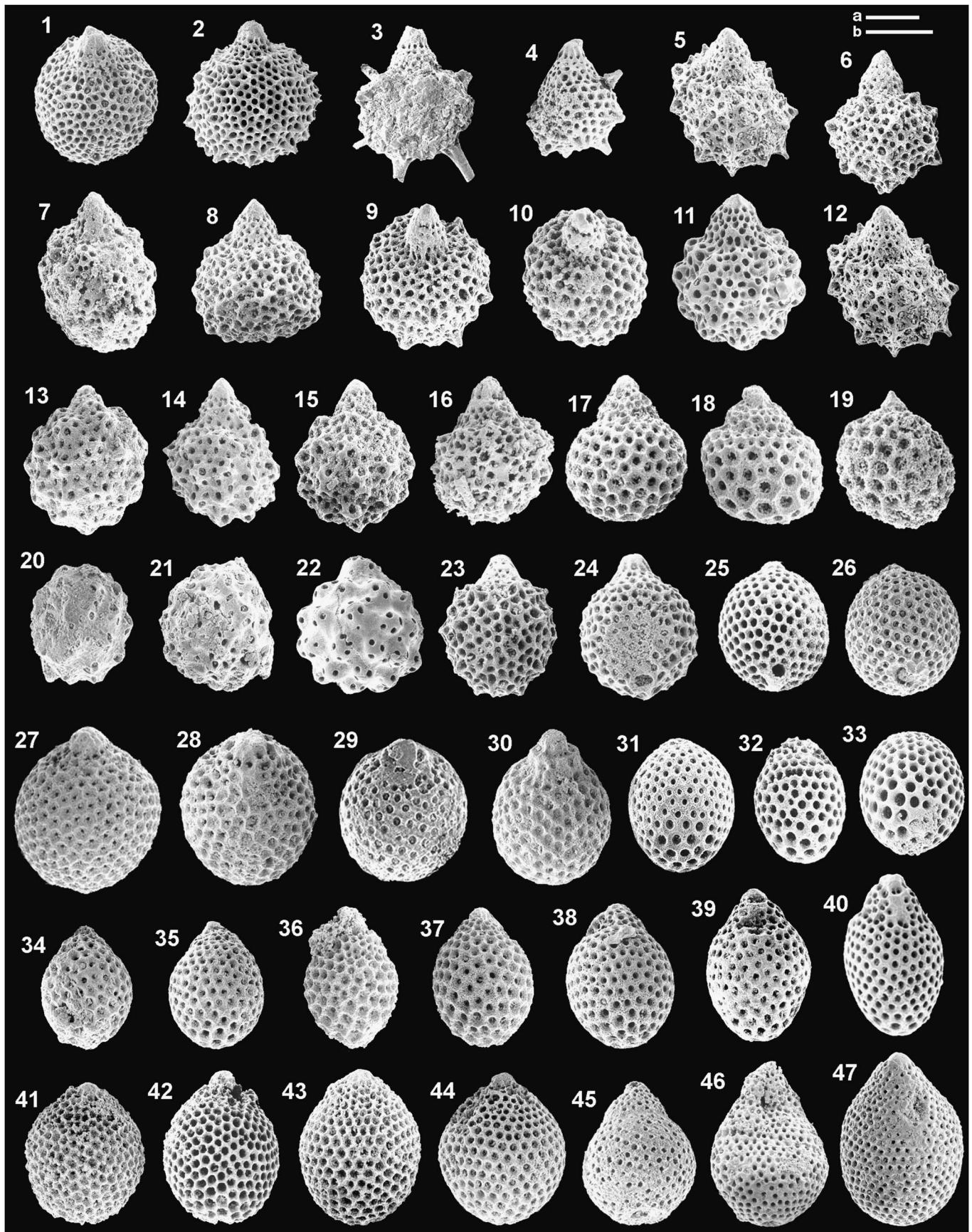
Occurrence.—Upper Bathonian to upper Aptian.

Hiscocapsa kodrai (Chiari, Marcucci, and Prela, 2002)
Figure 9.53

- 2002 *Sethocapsa kodrai* Chiari, Marcucci and Prela, p. 74, pl. 3, figs. 1–7.
2003 *Quarticella ovalis* Takemura; Suzuki and Gawlick, p. 199, fig. 5.40.
2005 non *Sethocapsa kodrai*; Nakae and Komuro, fig. 4.47.
2012 *Hiscocapsa kodrai*; Djeric et al., pl. 1, fig. 23.

Remarks.—This species is very similar to *Quarticella ovalis* Takemura, but its aperture is much narrower. The larger postabdominal segment also displays well-differentiated tubercles instead of the typical spiny surface of *Quarticella ovalis*. *Hiscocapsa kodrai* might belong to *Quarticella*, but study of the internal structure is required before this new generic assignation is proposed. In the type material, a flattened base with a constricted aperture is clearly distinct (see Chiari et al., 2002, pl. 3, fig. 3). This flattened base is never present in representatives of *Quarticella*.

Figure 9. Scale bar measures 50 µm; each radiolarian scanning micrograph is designated by sample and specimen number. (1–6) *Hemicryptocapsa bueckensis* (Kozur), sample BMW-28 (1, 029; 2, 028); sample BMW-26 (3, 033); sample BMW-31 (4, 032); sample BMW-32 (5, 018); sample BMW-30 (6, 010). (7–8) *Zhamoidellum* sp. A, sample BMW-32 (7, 051); sample BMW-33 (8, 031). (9) *Kilinora? oblongula* (Kocher in Baumgartner et al.), sample BMW-32 (9, 005). (10–11) *Zhamoidellum* sp. aff. *Z. ovum* Dumitrica, sample BMW-30 (10, 015); sample BMW-32 (11, 086). (12–16) *Hemicryptocapsa marcucciae* (Cortese), sample BMW-32 (12, 087); sample BMW-26 (13, 074); sample BMW-13c (14, 141); sample BMW-13b (15, 065); sample BMW-30 (16, 043). (17–18) *Crococapsa* sp. aff. *C. tansinhoki* (Hull), sample BMW-13c (17, 140; 18, 011). (19) *Hemicryptocapsa nonaginta* n. sp., BMW-13b (19, 039, paratype). (20–23) *Hemicryptocapsa carpathica* (Dumitrica), sample BMW-13c (20, 100; 21, 123; 22, 119; 23, 091). (24) *Quarkus madstonensis* Pessagno, Blome, and Hull in Pessagno et al., sample BMW-31 (24, 029). (25–26) *Quarkus japonicus* (Yao), sample BMW-13b (25, 026); sample BMW-31 (26, 067). (27–28) *Praewilliriedellum convexum* (Yao), sample BMW-13b (27, 027); sample BMW-28 (28, 038). (29–30) *Quarticella* sp. B, sample BMW-28 (29, 056; 30, 010). (31–37) *Hemicryptocapsa yaoi* (Kozur), sample BMW-13c (31, 116; 32, 112; 34, 118); sample EW-158 (33, 028); sample BMW-33 (35, 011); sample BMW-13b (36, 073); sample BMW-32 (37, 061). (38) *Gongylothorax* sp. A, sample BMW-34 (38, 019). (39–42) *Gongylothorax favosus* Dumitrica, sample BMW-32 (39, 058); sample BMW-30 (40, 045); sample BMW-34 (41, 025); sample BMW-33 (42, 036). (43–44) *Williriedellum yahazuense* (Aita), sample BMW-34 (43, 032); sample BMW-33 (44, 009). (45–48) *Williriedellum* sp. cf. *W. formosum* (Chiari, Marcucci, and Prela), sample BMW-28 (45, 049; 46, 033; 47, 058); sample BMW-13b (48, 067). (49) *Williriedellum* sp. B, sample BMW-13b (49, 053). (50–51) *Williriedellum crystallinum* Dumitrica, sample BMW-32 (50, 032); sample BMW-30 (51, 007). (52) *Quarticella ovalis* Takemura, sample BMW-28 (52, 034). (53) *Hiscocapsa kodrai* (Chiari, Marcucci, and Prela), sample BMW-13b (53, 030). (54–55) *Quarticella* sp. C, sample BMW-13b (54, 041); sample BMW-28 (55, 050). (56) *Quarticella cicciona* (Chiari, Marcucci, and Prela), sample BMW-13b (56, 033). (57) *Quarticella* sp. D, sample BMW-28 (57, 041). (58) *Quarticella* sp. A, sample EW-158 (58, 065).



Genus *Praewilliriedellum* Kozur, 1984

Type species.—*Praewilliriedellum cephalospinosum* Kozur, 1984.

Other species.—*Stichocapsa? pseudoconvexa* Kemkin and Taketani, 2004; *Stichocapsa convexa* Yao, 1979; *Stichocapsa robusta* Matsuoka, 1984; and *Theocorys renzae* SchAAF, 1981.

Emended diagnosis.—*Praewilliriedellum* is emended in order to allocate clear tetracyrtid forms (e.g., *Stichocapsa robusta* Matsuoka). Many representatives of this genus have an abdomen partially encased in the postabdominal segment, making it hard to differentiate externally. The degree of encasement is nevertheless much lower than in *Williriedellum* and other genera assigned to Williriedellidae.

Occurrence.—Upper Aalenian to upper Barremian.

Praewilliriedellum convexum (Yao, 1979)
Figure 9.27–9.28

- 1979 *Stichocapsa convexa* Yao, p. 35, pl. 5, figs. 14–16; pl. 6, figs. 1–7.
2003 *Stichocapsa convexa*; Suzuki and Gawlick, p. 212, fig. 6.51.
2006 *Stichocapsa convexa*; O'Dogherty et al., p. 441, pl. 6, fig. 35. [See for complete synonymy]
2007b *Stichocapsa convexa*; Gawlick et al., figs. 7.15, 8.32, 17.23, 18.10.
2008 *Praewilliriedellum convexum*; Beccaro et al., pl. 2, fig. 26.
2009 *Stichocapsa convexa*; Suzuki and Gawlick, p. 186, figs. 5.54A–B.
2013 *Praewilliriedellum convexum*; Chiari et al., fig. 13n.

Praewilliriedellum robustum (Matsuoka, 1984)
Figure 10.45?, 10.46–10.47

- 1984 *Stichocapsa robusta* Matsuoka, p. 146, pl. 1, figs. 6–13; pl. 2, figs. 7–12.
2003 *Stichocapsa robusta*; Suzuki and Gawlick, p. 213, fig. 5.44.
2006 *Stichocapsa robusta*; O'Dogherty et al., p. 441, pl. 6, figs. 31–34. [See for complete synonymy]
2007b *Stichocapsa robusta*; Gawlick et al., fig. 8.34.
2008 *Praewilliriedellum robustum*; Beccaro et al., pl. 2, fig. 27.
2013 *Praewilliriedellum robustum*; Chiari et al., fig. 13p.

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

Type species.—*Quarkus madstonensis* Pessagno, Blome, and Hull in Pessagno et al., 1993.

Other species.—*Stichocapsa japonica* Yao, 1979.

Occurrence.—Lower Bajocian to upper Callovian. A very similar specimen, but questionable to this genus, was found in upper Berriasian material of the Mariana Trench (*Stichocapsa* sp. 8 Matsuoka, 1998, pl. 2, fig. 24). We do not assign this species to *Quarkus* because continuous record from the Callovian to the Berriasian has not been demonstrated yet.

Quarkus japonicus (Yao, 1979)
Figure 9.25–9.26

- 1979 *Stichocapsa japonica* Yao, p. 36, pl. 6, figs. 8–12; pl. 7, figs. 1–15.
2006 *Stichocapsa japonica*; O'Dogherty et al., p. 441, pl. 6, fig. 6. [See for complete synonymy]
2009 *Stichocapsa japonica*; Suzuki and Gawlick, p. 186, figs. 5.53.
2012 *Praewilliriedellum japonicum*; Goričan et al., pl. 1, fig. 20.
2013 *Praewilliriedellum japonicum*; Chiari et al., fig. 13o.

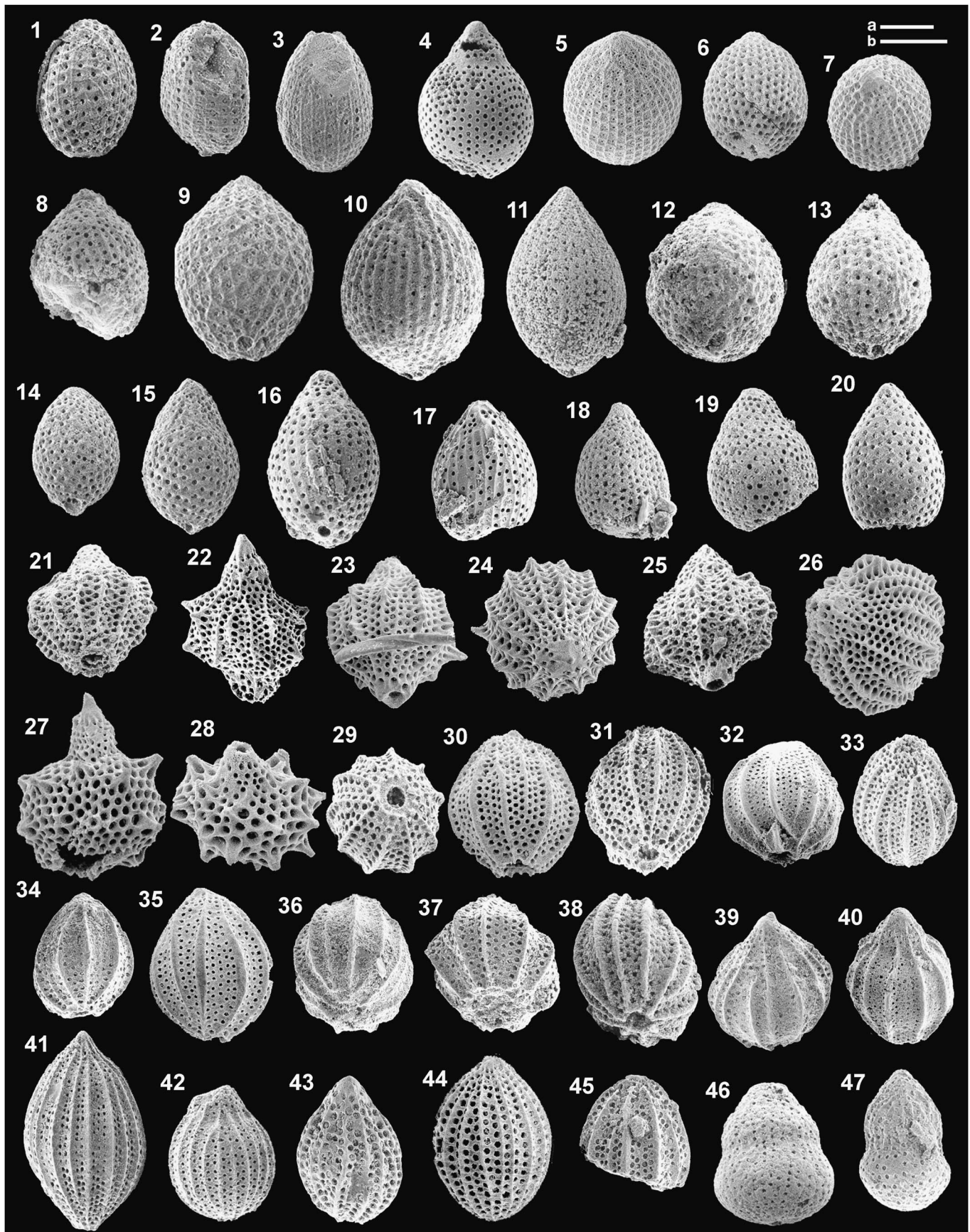
Remarks.—This species has always been assigned to the genus *Stichocapsa* (considered as a nomen dubium by O'Dogherty et al., 2009, p. 330), however we note that this commonly illustrated species is very close to *Quarkus madstonensis*, the only difference being the less-expanded fourth segment. Judging from the stratigraphic distribution, *Quarkus japonicus* may be the ancestor of *Quarkus madstonensis*. An intermediate form (*Stichocapsa* sp. aff. *S. japonica* Yao) was illustrated by Chiari et al., 2002 (pl. 3, figs. 18–22) from the upper Bajocian–lower Bathonian of Albania.

Quarkus madstonensis Pessagno, Blome, and Hull in Pessagno et al., 1993
Figure 9.24

- 1993 *Quarkus madstonensis* Pessagno, Blome, and Hull in Pessagno et al., p. 159, pl. 8, figs. 9, 13–15, 24.
2006 *Williriedellum madstonense*; O'Dogherty et al., p. 446, pl. 6, figs. 9–10.
2008 *Williriedellum madstonense*; Danelian et al., pl. 1, fig. 11.

←

Figure 10. Scale bars (a, b) measure 50 μm; each radiolarian scanning micrograph is designated by sample and specimen number, followed by the corresponding scale. (1–2) *Williriedellum?* sp. C, sample BMW-13b (1, 066/a); sample BMW-28 (2, 007/a). (3) *Arcanicapsa exquisita* (Hull), sample BMW-32 (3, 013/a). (4) *Arcanicapsa* sp. A, sample BMW-13b (4, 029/a). (5–16) *Arcanicapsa funatoensis* (Aita), sample BMW-26 (5, 035/a; 6, 031/a; 10, 037/a; 13, 035/a; 15, 032/a); sample EW-158 (7, 021/a; 8, 029/a; 9, 019/a); sample BMW-34 (11, 011/a); sample BMW-13b (12, 103/a); sample BMW-13c (14, 106/a; 16, 132/a). (17–19) *Zhamoidellum ventricosum* Dumitrica, sample BMW-13c (17, 121/a; 18, 114/a; 19, 136/a). (20–22) *Arcanicapsa undulata* (Heitzer), sample BMW-32 (20, 024/a); sample BMW-33 (21, 032/a); sample BMW-34 (22, 016/a). (23–24) *Williriedellum* sp. A, sample BMW-26 (23, 059/a); sample BMW-13b (24, 074/b). (25–26) *Kilinora* sp. aff. *K. oblongula* (Kocher in Baumgartner et al.), sample EW-158 (25, 027/b); sample BMW-32 (26, 047/b). (27–30) *Zhamoidellum* sp. B, sample BMW-13c (27, 093/b); sample BMW-35 (28, 033/b); sample BMW-32 (29, 084/b); sample BMW-30 (30, 013/b). (31–40) *Zhamoidellum ovum* Dumitrica, sample BMW-33 (31, 021/a; 32, 012/a; 33, 016/a; 35, 017/a; 39, 034/a); sample BMW-32 (34, 046/a); sample BMW-13c (36, 130/a; 37, 101/a); sample BMW-35 (38, 034/a); sample BMW-34 (40, 018/a). (41–44) *Zhamoidellum* sp. C, sample BMW-26 (41, 005/a; 44, 063/a); sample BMW-35 (42, 035/a); sample EW-158 (43, 004/a). (45–47) *Praewilliriedellum robustum* (Matsuoka), sample EW-158 (45, 025/b); sample BMW-31 (46, 071/a); sample BMW-34 (47, 017/a).



Family Arcanicapsidae Takemura, 1986
Subfamily Arcanicapsinae Takemura, 1986

Included genera.—*Arcanicapsa* Takemura, 1986; *Fultacapsa* Ožvoldová in Ožvoldová and Frantová, 1997; *Religa* Whalen and Carter, 2002; *Squinabollum* Dumitrica, 1970; *Trisyrringium* Vinassa de Regny, 1901; and the group of species assigned to *Dorypyle* Squinabol, 1904. *Dorypyle* should be regarded as a nomen dubium that requires a new genus for taxonomic stability.

The genera *Arcanicapsa* Takemura, 1986 and *Yamatoum* Takemura, 1986 were questionably placed under this family in the recent revision by O'Dogherty et al., 2009, but, as stated by Takemura 1986, the cephalic structure has more affinities with the genus *Unuma* Ichikawa and Yao, 1976. In this paper we follow the same opinion. In the same revision by O'Dogherty et al., 2009, the genus *Solidea* Whalen and Carter in Carter et al., 1998 was erroneously placed in this subfamily, but its correct placement should be in Favosyringiinae.

Genus *Arcanicapsa* Takemura, 1986

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

Other species.—*Sethocapsa aculeata* Cortese, 1993; *Sethocapsa congduensis* Li and Wu, 1985; *Sethocapsa echinata* Li and Wu, 1985; *Sethocapsa leiostraca* Foreman, 1973b; *Sethocapsa trachyostraca* Foreman, 1973b; *Sethocapsa funatoensis* Aita, 1987; and *Zhamoidellum? exquisita* Hull, 1997.

Occurrence.—Lower Toarcian to lower Aptian.

Remarks.—*Arcanicapsa* as originally described has a stout apical horn (Takemura 1986, p. 54). In this paper we broaden the definition to include morphologically closely similar species without apical horn. Such tricyrtids, having a closed abdomen ornamented with spines or nodes, have been traditionally ascribed to *Sethocapsa* (e.g., *Sethocapsa funatoensis* Aita), which is considered nomen dubium (O'Dogherty et al., 2009). Some species were questionably assigned to *Zhamoidellum* (e.g., *Zhamoidellum? exquisita* Hull). Here we assign to *Zhamoidellum* only species without tubercles (see discussion under *Zhamoidellum*). Species with a clear distinction between upward-directed spines proximally and downward-directed spines distally belong to *Trisyrringium* Vinassa de Regny (see O'Dogherty, 1994, p. 208; O'Dogherty et al., 2009).

Arcanicapsa exquisita (Hull, 1997)
Figure 10.3

- 1997 *Zhamoidellum (?) exquisita* Hull, p. 132, pl. 38, figs. 5, 16–17, 21.
2000 *Zhamoidellum (?) exquisita*; Wu, pl. 1, figs. 14–15.
2003 *Zhamoidellum exquisita*; Suzuki and Gawlick, p. 204, fig. 6.55.

Arcanicapsa funatoensis (Aita, 1987)
Figure 10.5–10.16

- 1987 *Sethocapsa funatoensis* Aita, p. 73, pl. 2, figs. 6a–7b.
2005b *Arcanicapsa funatoensis*; Nishihara and Yao, fig. 5.1.
2006 *Zhamoidellum funatoense*; O'Dogherty et al., p. 445, pl. 10, fig. 32. [See for complete synonymy]
2009 non *Zhamoidellum funatoense*; Yeh, p. 68, pl. 1, figs. 10–11, 17, 25.
2011 *Hiscocapsa funatoense*; Yeh, p. 16, pl. 7, figs. 19–20, 23, 26.

Arcanicapsa sp. aff. *A. funatoensis* (Aita, 1987)
Figure 11.27–11.28

Remarks.—The specimens resemble *A. funatoensis*, but differ by having stronger spines and larger shell size.

Arcanicapsa undulata (Heitzer, 1930)
Figure 10.20–10.22

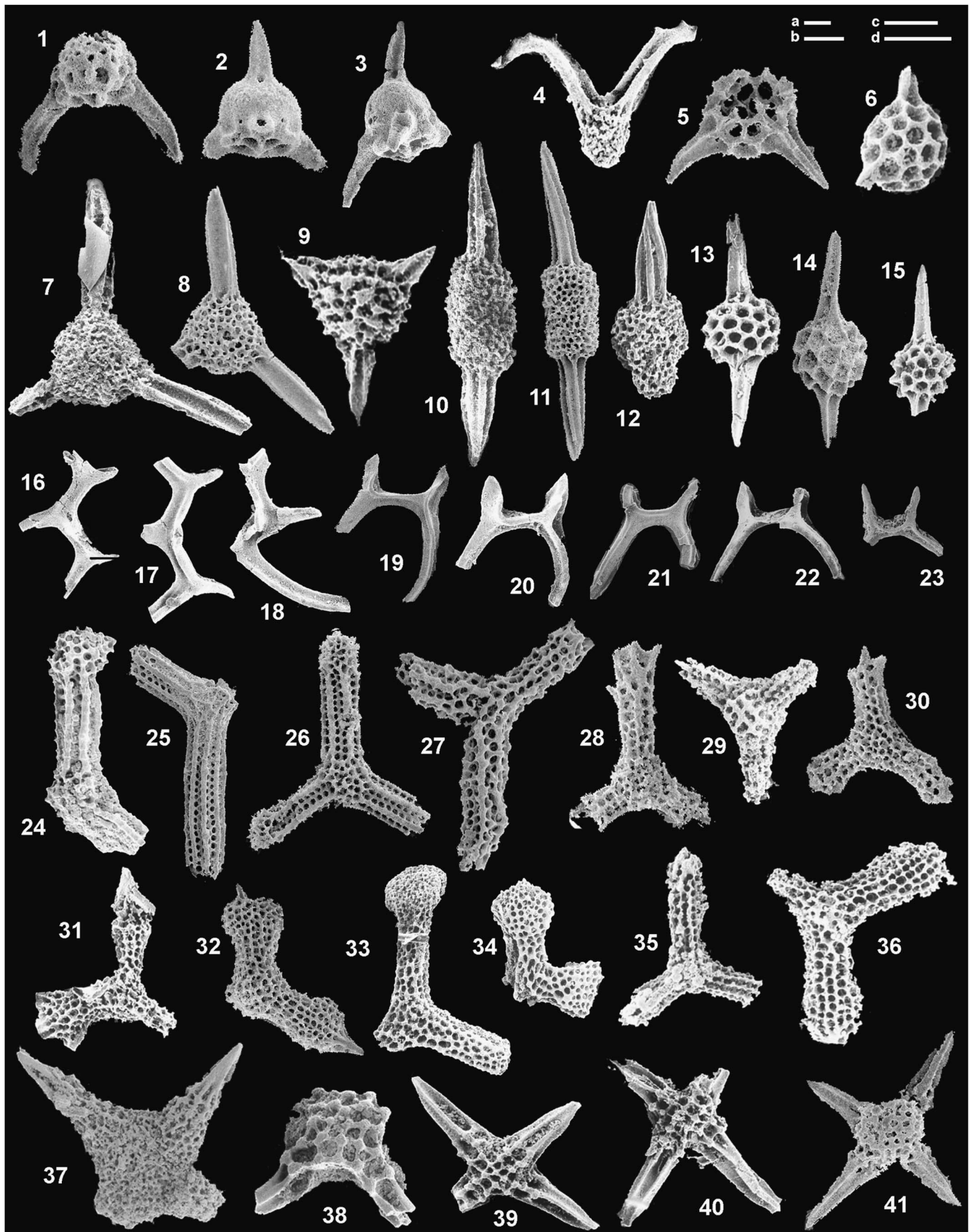
- 1930 *Lithobotrys undulata* Heitzer, p. 390, pl. 28, fig. 22.
2003 *Tricolocapsa undulata*; Suzuki and Gawlick, figs. 5.41, 6.39.
2006 *Tricolocapsa undulata*; Auer et al., fig. 6.44.
2007b *Tricolocapsa undulata*; Gawlick et al., fig. 8.41.
2008 *Tricolocapsa undulata*; Auer et al., fig. 9.78.
2009 *Tricolocapsa undulata*; Suzuki and Gawlick, p. 183, figs. 5.44A–B, 5.45A–B, 6.18A–B, 6.19A–B.

Remarks.—*Arcanicapsa undulata* differs from *A. funatoensis* by having a smoother surface. Circular pores are present only on tubercles.

Arcanicapsa sp. A
Figure 10.4

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Figure 11. Scale bars measure 50 µm for a magnification of x200 (a) and x250 (b). Each radiolarian scanning micrograph is designated by the sample and the specimen number followed by the corresponding scale. (1–3) *Gongylothorax marmoris* Kiessling in Kiessling and Zeiss, sample BMW-32 (1, 097/b; 2, 002/b; 3, 057/b). (4) *Japonocapsa* sp. A, sample BMW-13b (4, 072/b). (5–7) *Striatojaponocapsa conexa* (Matsuoka), sample EW-158 (5, 003/a; 6, 001/a; sample BMW-32 (7, 089/a). (8–9) *Striatojaponocapsa riri* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., sample BMW-32 (8, 056/b; 9, 008/b). (10–13) *Striatojaponocapsa synconexa* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., sample EW-158 (10, 006/a; 12, 056/b; 13, 071/b); sample BMW-26 (11, 023/b). (14–16) *Striatojaponocapsa* spp., sample BMW-32 (14, 101/b; 16, 060/b); sample BMW-34 (15, 030/b). (17–20) *Striatojaponocapsa?* spp., sample BMW-32 (17, 025/a; 19, 059/b); sample BMW-13b (18, 024/b); sample EW-158 (20, 073/b). (21–26) *Unuma latusicostatus* (Aita), sample BMW-13b (21, 059/a; 25, 069/a); sample EW-158 (22, 023/a); sample BMW-28 (23, 055/a; 24, 005/a; 26, 026/a). (27–28) *Arcanicapsa* sp. aff. *A. funatoensis* (Aita), sample BMW-28 (27, 011/a; 28, 031/a). (29–38, 45) *Unuma gordus* Hull 1997, sample BMW-31 (29, 054/b; 37, 031/a); sample BMW-28 (30, 039/a; 35, 048/a); sample EW-158 (31, 024/a; 36, 058/a); sample BMW-13b (32, 025/a; 34, 055/a); sample BMW-26 (33, 061/a; 38, 072/a); sample BMW-32 (45, 066/a). (39–40) *Protunuma turbo* Matsuoka, sample BMW-13b (39, 058/a; 40, 052/a). (41) *Protunuma japonicus* Matsuoka and Yao, sample BMW-33 (41, 014/a). (42) *Protunuma europeus* O'Dogherty, Goričan and Dumitrica in O'Dogherty et al., sample BMW-13b (42, 061/b). (?43–44) *Protunuma ochiensis* Matsuoka, sample BMW-33 (43, 013/a); sample BMW-28 (44, 052/a). (46) *Theocapsomella cordis* (Kocher in Baumgartner et al.), sample BMW-13b (46, 020/b). (47) *Theocapsomella medvednicensis* (Goričan in Halamić et al.), sample BMW-32 (47, 003/b).



Remarks.—This specimen is similar to *Arcanicapsa exquisita* but possesses a smaller abdomen; the constriction between thorax and abdomen (lumbar stricture) is less pronounced.

Subfamily Favosyringiinae Steiger, 1992

Genus *Spinocapsa* Ožvoldová, 1975

Type species.—*Spinocapsa ceblienica* Ožvoldová, 1975.

Occurrence.—Upper Carnian to lower Aptian.

Spinocapsa basilica (Hull, 1997)
Figure 8.28

1997 *Podobursa basilica* Hull, p. 100, pl. 41, figs. 7–8, 10, 18, 20–21.

Spinocapsa lata (Yang, 1993)
Figure 8.30

1993 *Syringocapsalata lata* Yang, p. 132, pl. 24, figs. 1–2, 16, 20–21; pl. 26, figs. 7, 11, 15.

1997 *Podobursa lata*; Hull, p. 102, pl. 42, fig. 6.

2007b *Syringocapsa lata*; Gawlick et al., fig. 19.37.

Spinocapsa spinosa (Ožvoldová, 1975)
Figure 8.31

1975 *Heitzeria spinosa* Ožvoldová, p. 78, pl. 101, fig. 2.

1995b *Podobursa spinosa*; Baumgartner et al., p. 426, pl. 3230, figs. 1–4. [See for complete synonymy]

Spinocapsa sp. cf. *S. triacantha* (Fischli, 1916)
Figure 8.29

2006 *Podobursa triacantha*; O'Dogherty et al., p. 437, pl. 7, fig. 4. [See for complete synonymy]

Remarks.—The assignment to *S. triacantha* is queried because the lateral spines are broken off in this specimen.

Family Eucyrtidiellidae Takemura, 1986

Genus *Eucyrtidiellum* Baumgartner, 1984

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

Occurrence.—Lower Pliensbachian to upper Tithonian.

Eucyrtidiellum nodosum Wakita, 1988
Figure 8.21–8.23

1988 *Eucyrtidiellum nodosum* Wakita, p. 408, pl. 4, fig. 29; pl. 5, fig. 16.

2003 *Eucyrtidiellum nodosum*; Suzuki and Gawlick, p. 217, figs. 5.20, 6.24–6.25, 6.29.

2006 *Eucyrtidiellum nodosum*; O'Dogherty et al., p. 442, pl. 3, fig. 3. [See for complete synonymy]

2007b *Eucyrtidiellum nodosum*; Gawlick et al., fig. 8.9; fig. 17.8.

Eucyrtidiellum ptyctum (Riedel and Sanfilippo, 1974)
Figure 8.20

1974 *Eucyrtidium ptyctum* Riedel and Sanfilippo, p. 778, pl. 5, fig. 7; pl. 12, fig. 14, not fig. 15.

2003 *Eucyrtidiellum ptyctum*; Suzuki and Gawlick, p. 218, figs. 6.26–6.27.

2006 *Eucyrtidiellum ptyctum*; Gawlick et al., figs. 8.10, 9.7.

2006 *Eucyrtidiellum ptyctum*; Auer et al., fig. 6.14.

2006 *Eucyrtidiellum ptyctum*; O'Dogherty et al., p. 442, pl. 3, figs. 1–2. [See for complete synonymy]

2007b *Eucyrtidiellum ptyctum*; Gawlick et al., fig. 7.3; fig. 19.18.

2009 *Eucyrtidiellum ptyctum*; Suzuki and Gawlick, p. 188, fig. 5.63.

Eucyrtidiellum pustulatum Baumgartner, 1984
Figure 8.26–8.27

1984 *Eucyrtidiellum pustulatum* Baumgartner, p. 765, pl. 4, figs. 4–5.

2003 *Eucyrtidiellum unumaense pustulatum*; Suzuki and Gawlick, p. 217, figs. 5.20, 6.24–6.25, 6.29. [See for complete synonymy]

2007b *Eucyrtidiellum unumaense pustulatum*; Gawlick et al., figs. 8.13, 17.12.

Eucyrtidiellum pyramis (Aita in Aita and Okada, 1986)
Figure 8.19

Figure 12. Scale bars (a, b, c, d) measure 50 µm; each radiolarian scanning micrograph is designated by sample and specimen number, followed by the corresponding scale. (1) *Saitoum pagei* Pessagno, sample BMW-28 (1, 015/c). (2–3) *Saitoum trichylum* De Wever, sample BMW-28 (2, 004/c); sample BMW-26 (3, 051/c). (4) *Bernoullius cristatus* Baumgartner, sample EW-158 (4, 038/d). (5–6) *Gorgansium silviesense* Pessagno and Blome, sample BMW-28 (5, 009/c); sample BMW-13b (6, 008/c). (7–8) *Alievium? longispineum* Yang and Wang, sample BMW-26 (7, 040/c); sample BMW-28 (8, 023/b). (9) *Alievium?* sp. aff. *A. crassum* (Kiessling), sample BMW-26 (9, 069/d). (10–12) *Archaeospongoprimum elegans* Wu, sample EW-158 (10, 051/b); sample BMW-28 (11, 035/b); sample BMW-34 (12, 023/b). (13–15) *Pantarellium riedeli* Pessagno, sample EW-158 (13, 050/b); sample BMW-28 (14, 036/b); sample BMW-31 (15, 001/b). (16–18) *Hexasaturnalis tetraspinus* (Yao), sample EW-158 (16, 033/a; 17, 039/a; 18, 035/c). (19–20) *Hexasaturnalis nakasekoi* Dumitrica and Dumitrica-Jud, sample BMW-28 (19, 021/a); sample EW-158 (20, 041/a). (21–22) *Hexasaturnalis suboblongus* (Yao), sample BMW-28 (21, 019/a); sample BMW-158 (22, 036/a). (23) *Hexasaturnalis minor* (Baumgartner in Baumgartner et al.), sample BMW-13c (23, 071/a). (24–27) *Tritrabs ewingi* (Pessagno), sample BMW-32 (24, 080/b); sample BMW-28 (25, 016/b; 26, 008/b; 27, 006/b). (28–30) *Angulobracchia* spp., sample BMW-28 (28, 002/c; 30, 018/c); sample BMW-26 (29, 057/c). (31) *Paronaella pristidentata* Baumgartner, sample EW-158 (31, 044/b). (32) *Homoeoparonaella elegans* (Pessagno), sample BMW-28 (32, 012/b). (33–34) *Paronaella kotura* Baumgartner, sample EW-158 (33, 042/a); sample BMW-34 (34, 033/a). (35–36) *Homoeoparonaella* spp., sample BMW-31 (35, 060/b; 36, 073/b). (37) *Crucella theokaftensis* Baumgartner, sample BMW-13c (37, 061/b). (38) *Emiluvia sedecimporata* (Rüst), sample BMW-32 (38, 069/b). (39–40) *Emiluvia salensis* Pessagno, sample BMW-26 (39, 044/b); sample EW-158 (40, 030/b). (41) *Emiluvia?* sp., sample BMW-28 (41, 024/c).

1986 *Eucyrtidium* (?) *pyramis* Aita in Aita and Okada, p. 109, pl. 6, figs. 8–13; pl. 7, figs. 1a–b.

1995b *Eucyrtidiellum pyramis*; Baumgartner et al., p. 216, pl. 3019, figs. 1–2. [See for complete synonymy]

2010 *Eucyrtidiellum pyramis*; Robin et al., fig. 4.14.

Eucyrtidiellum unumaense (Yao, 1979)

Figure 8.24–8.25

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

2003 *Eucyrtidiellum unumaense unumaense*; Suzuki and Gawlick, p. 216, fig. 6.28.

2006 *Eucyrtidiellum unumaense*; O’Dogherty et al., p. 443, pl. 3, figs. 4–6. [See for complete synonymy]

2007b *Eucyrtidiellum unumaense unumaense*; Gawlick et al., figs. 7.5, 17.11, 19.19.

2009 *Eucyrtidiellum unumaense*; Suzuki and Gawlick, p. 188, fig. 5.62.

Superfamily Williriedelloidea Dumitrica, 1970

Family Williriedellidae Dumitrica, 1970

Genus *Hemicryptocapsa* Tan, 1927

Type species.—*Hemicryptocapsa capita* Tan, 1927.

Other species.—*Hemicryptocapsa nonaginta* new species; *Praezhamoidellum yaoi* Kozur, 1984; *Praezhamoidellum buekkense* Kozur, 1984; *Tricolocapsa tetragona* Matsuoka, 1983; *Williriedellum?* *maruccii* Cortese, 1993; *Williriedellum carpathicum* Dumitrica, 1970.

Emended diagnosis.—Cryptothoracic tricyrtids lacking nodose outer surface are included in this genus. The shell surface can be ornamented with regular pore frames as in the type species, or smooth as in *Hemicryptocapsa buekkensis*. Also see extended discussion under the genus *Williriedellum*.

Occurrence.—Upper Tithonian to upper Aptian.

Hemicryptocapsa buekkensis (Kozur, 1984)

Figure 9.1–9.6

1984 *Praezhamoidellum buekkenses* Kozur, p. 54, pl. 3, figs. 1a–b.

1998 *Tricolocapsa?* *bukkense*; Cordey, p. 128, pl. 27, fig. 9.

2006 *Williriedellum buekkense*; O’Dogherty et al., p. 446, pl. 9, figs. 1–3

2008 *Williriedellum buekkense*; Auer et al., fig. 9.52.

2009 *Praezhamoidellum buekkense*; Gawlick et al., figs. 5.50A–B.

2012 *Hemicryptocapsa buekkensis*; Goričan et al., pl. 1, figs. 26, 34.

2012 *Williriedellum buekkense*; Djerić et al., pl. 3, fig. 2.

Hemicryptocapsa carpathica (Dumitrica, 1970)

Figure 9.20–9.23

1970 *Williriedellum carpathicum* Dumitrica, p. 70, pl. 9, figs. 56a–b; 57–59; pl. 10, fig. 61.

1995b *Williriedellum carpathicum*; Baumgartner et al., p. 626, pl. 4055, figs. 1–3.

2003 *Williriedellum carpathicum*; Suzuki and Gawlick, p. 200, fig. 6.74. [See for complete synonymy]

2008 *Williriedellum carpathicum*; Beccaro et al., pl. 3, fig. 29.

2012 *Hemicryptocapsa carpathica*; Goričan et al., pl. 2, fig. 20.

Hemicryptocapsa marucciae (Cortese, 1993)

Figure 9.12–9.16

1993 *Williriedellum* (?) *maruccii* Cortese, p. 180, pl. 7, figs. 6–7.

2006 *Williriedellum marucciae*; O’Dogherty et al., p. 446, pl. 9, figs. 28–36. [See for complete synonymy]

2008 *Williriedellum marucciae*; Auer et al., fig. 11.46.

2008 *Williriedellum* (?) *marucciae*; Beccaro et al., pl. 3, fig. 30.

2009 *Williriedellum marucciae*; Suzuki and Gawlick, fig. 5.25; fig. 6.28.

2010 *Williriedellum marucciae*; Robin et al., pl. 3, fig. 11.

2014 *Hemicryptocapsa marucciae*; Šegvić et al., pl. 1, figs. 28A–B.

Remarks.—Like other species in this paper, the absence of tubercles or nodes on the surface of this species justifies the transfer from *Williriedellum* to *Hemicryptocapsa*.

Hemicryptocapsa nonaginta new species

Figure 9.19

1993 *Tricolocapsa*(?) sp. A. Pessagno et al., p. 160, pl. 8, fig. 27.

1995b *Tricolocapsa* sp. S Baumgartner et al., p. 602, pl. 4057, figs. 1–3.

2004 *Tricolocapsa* sp. S; Ziabrev et al., fig. 5.25.

2006 *Tricolocapsa* sp. S; Auer et al., fig. 6.45.

?2008 *Tricolocapsa* sp. S; Auer et al., fig. 9.79.

2008 *Williriedellum* sp. cf. *W.* sp. S Baumgartner et al., pl. 1, fig. 4.

2009 *Tricolocapsa* sp. S; Kokubo and Matsuoka, figs. 4.4–4.6.

2009 non *Tricolocapsa* sp. S; Nishihara, pl. 11, fig. 270.

?2009 *Tricolocapsa* aff. *ruesti* Tan; Nishihara, pl. 11, fig. 268.

2009 *Tricolocapsa* sp. S; Suzuki and Gawlick, p. 183, figs. 5.47A–B.

Holotype.—Specimen MA7647 from sample MKS7A (illustrated in Baumgartner et al., 1995b pl. 4057, fig. 3) from Kashibara section (MA9), south of Hichiso town, Japan (see Matsuoka, 1995).

Diagnosis.—Large cryptothoracic tricyrtid with very well defined lumbar stricture and a large abdomen. Outer surface without nodes and covered by hexagonal pore frames. Distal aperture constricted circular without rim.

Occurrence.—Upper Bajocian to lower Bathonian.

Description.—Cryptothoracic subspherical form composed of three distinct segments. Cephalis and thorax partially incased in the abdomen, with a very well defined lumbar stricture. The thorax is truncate-conical and covered by small pores whereas the abdomen is quite large and spherical. The entire surface of the abdomen is covered by a latticed meshwork of polygonal pore frames and a constricted aperture is visible.

Etymology.—The name *Nonaginta* means ninety, in honor of the prodigious decade in contemporary history of radiolarian research.

Measurements.—(in micrometers; μm) maximum width of shell 112–142, mean 118; maximum length 113–133, mean 123, based on four specimens.

Remarks.—*Hemicryptocapsa nonaginta* n. sp. was published in open nomenclature in the Mesozoic radiolarian atlas (Baumgartner et al., 1995b) and since then it has been illustrated in many publications. This species differs from *H. yaoi* by having larger circular pores in the middle of polygonal areas. It differs from *H. carpathica* by having a simple circular aperture without a rim.

Hemicryptocapsa yaoi (Kozur, 1984)
Figure 9.31–9.37

- 1984 *Praezhamoidellum yaoi* Kozur, p. 53, pl. 3, fig. 3a–b.
2003 *Williriedellum dierschei* Suzuki and Gawlick; Suzuki and Gawlick, p. 201, fig. 6.73. [premature name]
2004 *Williriedellum dierschei* Suzuki and Gawlick in Gawlick et al., p. 311, pl. 4, figs. 1–6.
2006 *Williriedellum dierschei*; Auer et al., fig. 6.52.
2006 *Williriedellum yaoi*; O'Dogherty et al., p. 446, fig. 9, figures 6–12. [See for complete synonymy]
2007b *Williriedellum dierschei*; Gawlick et al., fig. 8.45, 17.32.
2009 *Williriedellum dierschei*; Suzuki and Gawlick, p. 179, figs. 5.27A–B, 5.28, 6.48A–B.
2010 *Williriedellum yaoi*; Robin et al., pl. 3, figs. 18, 20.
2012 *Hemicryptocapsa yaoi*; Goričan et al., pl. 1, fig. 25; pl. 2, fig. 12.

Genus *Williriedellum* Dumitrica, 1970

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

Included species.—*Cryptamphorella crepida* O'Dogherty, 1994; *Hemicryptocapsa polyhedra* Dumitrica, 1970; *Hemicryptocapsa prepolyhedra* Dumitrica, 1970; *Hemicryptocapsa tuberosa* Dumitrica, 1970; *Sethocapsa yahazuensis* Aita, 1987; *Tricolocapsa clivosa* Aliev, 1967; *Tricolocapsa formosa* Chiari,

Marcucci, and Prela, 2002; *Williriedellum? gilkeyi* Dumitrica, 1970; *Williriedellum crystallinum* Dumitrica, 1970; *Williriedellum nodosum* Chiari, Marcucci, and Prela, 2002; *Williriedellum peterschmittae* Schaaf, 1981; *Williriedellum sujkwskii* Widz and De Wever, 1993.

Emended diagnosis.—The genus *Williriedellum* originally contained cryptothoracic tricyrtids with an aperture regardless of the external ornamentation of the shell. We restrict the name *Williriedellum* to species with raised ridges or nodes on the outer surface of the abdomen. Species with a regular distribution of circular pores (each pore may be bounded by a simple polygonal pore frame) are assigned to *Hemicryptocapsa*. The same differentiation between these two genera was applied by O'Dogherty et al. (2009). The concept of that publication, however, did not allow for written definitions and comments.

Occurrence.—Upper Aalenian to lower Coniacian.

Williriedellum crystallinum Dumitrica, 1970
Figure 9.50–9.51

- 1970 *Williriedellum crystallinum* Dumitrica, p. 69, pl. 10, figs. 60 a–c, 62–63.
2009 *Williriedellum crystallinum*; Suzuki and Gawlick, p. 178, fig. 5.24. [See for complete synonymy]

Williriedellum sp. cf. *W. formosum* (Chiari, Marcucci, and Prela, 2002)
Figure 9.45–9.48

- 2002 *Tricolocapsa formosa* Chiari, Marcucci, and Prela, p. 83, pl. 5, figs. 3–8.
2011 *Williriedellum formosum*; Bandini et al., pl. 5, figs. 27–28.
2012 *Williriedellum formosum*; Goričan et al., pl. 1, fig. 23.

Remarks.—The external ornamentation of this species is very close to *W. formosum* but has a rounded aperture whereas in the type material the aperture is covered by a dish-like appendage. Moreover, some of our specimens also have groups of four small pores per frame area like occurring in *W. gilkeyi*.

Williriedellum yahazuense (Aita, 1987)
Figure 9.43–9.44

- 1987 *Sethocapsa yahazuense* Aita, p. 73, pl. 2, figs. 8a–9b; pl. 9, figs. 16–17.
1993 *Williriedellum sujkwskii* Widz and De Wever, p. 88, pl. 1, figs. 7–10.
2005 *Williriedellum yahazuense*; Šmuc and Goričan, p. 62, pl. 3, fig. 19.

Williriedellum sp. A
Figure 10.23–10.24

Remarks.—These specimens show very small and pointed nodes on the outer surface of the abdomen.

Williriedellum sp. B
Figure 9.49

Remarks.—This morphotype has very faintly developed ridges on the surface. These ridges do not build well-defined frame areas characteristic of *W. crystallinum*.

Williriedellum? sp. C
Figure 10.1–10.2

Remarks.—The genus is queried because the presence of the aperture is not confirmed. The ridges on the surface of the illustrated specimens are only very faintly developed compared to other species of this genus.

Genus *Zhamoidellum* Dumitrica, 1970

1992 *Complexapora* Kiessling in Kiessling and Zeiss.

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

Included species.—*Complexapora kozuri* Hull, 1997; *Complexapora tirolica* Kiessling in Kiessling and Zeiss 1992; *Zhamoidellum argandi* O’Dogherty, Goričan, and Dumitrica in O’Dogherty et al., 2006; *Zhamoidellum boehmi* Kiessling, 1999; *Zhamoidellum calamin* O’Dogherty, Goričan, and Dumitrica in O’Dogherty et al., 2006; *Zhamoidellum mikamense* Aita, 1986; *Zhamoidellum ovum* Dumitrica, 1970; *Zhamoidellum ventricosum* Dumitrica, 1970; *Zhamoidellum yehae* Dumitrica in Goričan et al., 2006.

Remarks.—As stated by O’Dogherty et al., 2006, the presence or absence of a sutural pore in *Zhamoidellum* can be regarded as character related to the intraspecific variability. Only species without tubercles are included. Species with spines and nodes are placed in *Arcanicapsa*.

Occurrence.—Lower Pliensbachian? to upper Tithonian.

Zhamoidellum ovum Dumitrica, 1970
Figure 10.31–10.40

- 1970 *Zhamoidellum ovum* Dumitrica, p. 79 pl. 9, figs. 52a–b, 53–54.
2009 *Zhamoidellum ovum*; Suzuki and Gawlick, p. 179, fig. 5.30A–B, 6.33A–B. [See for complete synonymy]

Zhamoidellum sp. aff. *Z. ovum* Dumitrica, 1970
Figure 9.10–9.11

Remarks.—These specimens are considered only *affinis* because they display less-pronounced constrictions and more elongated outline of the shell.

Zhamoidellum ventricosum Dumitrica, 1970
Figure 10.17–10.19

- 1970 *Zhamoidellum ventricosum* Dumitrica, p. 79, pl. 9, figs. 55a–b.

- 2003 *Zhamoidellum ventricosum*; Suzuki and Gawlick, p. 205, fig. 6.96.
2006 *Zhamoidellum ventricosum*; Auer et al., fig. 6.57.
2006 *Zhamoidellum ventricosum*; O’Dogherty et al., p. 445, pl. 9, figs. 13–25. [See for complete synonymy]
2009 *Zhamoidellum ventricosum*; Suzuki and Gawlick, p. 179, fig. 5.29.

Zhamoidellum sp. A
Figure 9.7–9.8

Remarks.—This morphotype differs from other *Zhamoidellum* by its smaller size. The cephalis and thorax are imperforate, but the abdomen is covered by small circular pores set in polygonal pore frames. The collar and lumbar strictures are well marked on these specimens.

Zhamoidellum sp. B
Figure 10.27–10.30

Remarks.—This morphotype differs from *Z. ovum* by having a more deeply encased thorax. In addition, the collar stricture is very distinct and the thorax is not porous. The illustrated specimens display enough characters to be considered a new species. However, pictures showing the basal aperture are not available and for this reason this morphotype is not described as a new taxon in this paper.

Zhamoidellum sp. C
Figure 10.41–10.44

Remarks.—These specimens are very close to *Zhamoidellum* sp. B, but they differ by having a porous thorax and a less-marked collar stricture. The pores are more widely open and the surrounding ridges are thinner than in *Zhamoidellum* sp. B.

Family Japonocapsidae Kozur, 1984

Genus *Striatojaponocapsa* Kozur, 1984

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

Occurrence.—Lower Bajocian to upper Callovian.

Striatojaponocapsa conexa (Matsuoka, 1983)
Figure 11.5–11.7

- 1983 *Tricolocapsa conexa* Matsuoka, p. 20, pl. 3, figs. 3–7; pl. 7, figs. 11–14.
2003 *Tricolocapsa conexa*; Suzuki and Gawlick, p. 208, figs. 5.42, 6.43–45.
2006 *Striatojaponocapsa conexa*; O’Dogherty et al., p. 447, pl. 10, figs. 18–20. [See for complete synonymy]
2007 *Striatojaponocapsa conexa*; Hatakeda et al., pl. 2, figs. 1–10.
2007 *Striatojaponocapsa conexa*; Suzuki and Gawlick, p. 182, figs. 5.40, 6.32A–B.

- Striatojaponocapsa riri* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006
Figure 11.8–11.9
- 2006 *Striatojaponocapsa riri* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., p. 447, pl. 8, figs. 14–15.
- 2007 *Striatojaponocapsa riri*; Hatakeda et al., pl. 2, figs. 11–20.
- Striatojaponocapsa synconexa* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006
Figure 11.10–11.13
- 2006 *Striatojaponocapsa synconexa* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., p. 447, pl. 10, figs. 9–17. [See for complete synonymy]
- 2007 *Striatojaponocapsa synconexa*; Hatakeda et al., pl. 1, figs. 11–20.
- 2008 *Striatojaponocapsa synconexa*; Baumgartner et al., pl. 4, fig. 18.
- 2012 *Striatojaponocapsa synconexa*; Goričan et al., pl. 1, figs. 15, 35.
- 2013 *Striatojaponocapsa synconexa*; Chiari et al., p. 416, fig. 14c.
- Striatojaponocapsa* spp.
Figure 11.14–11.16
- Remarks.*—Various elongated forms of *Striatojaponocapsa* have been found in our samples. The small number of specimens does not allow the description of new species. They differ from other *Striatojaponocapsa* by the elongated outline and small size.
- Striatojaponocapsa?* spp.
Figure 11.17–11.20
- Remarks.*—The genus is queried because the distal part and the classical appendage on these forms are not preserved, but the surface ornamentation fits well with the general pore patterns of *Striatojaponocapsa*.
- Genus *Japonocapsa* Kozur, 1984
- Type species.*—*Tricolocapsa? fusiformis* Yao, 1979.
- Occurrence.*—Upper Aalenian to upper Bathonian.
- Japonocapsa* sp. A
Figure 11.4
- Remarks.*—This form is close to *Japonocapsa fusiformis* (Yao, 1979), but the basal dish-like appendage seems broken off in this specimen.
- Family Unumidae Kozur, 1984
- Included genera.*—*Guttacapsa* O'Dogherty, 1994; *Helvetocapsa* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006; *Protunuma* Ichikawa and Yao, 1976; *Quarticella* Takemura, 1986; *Spinunuma* Ichikawa and Yao, 1976 (syn. *Unuma*); *Turbocapsula* O'Dogherty, 1994; *Unuma* Ichikawa and Yao, 1976; and *Yamatoum* Takemura, 1986.
- Remarks.*—According to De Wever et al., 2001 (p. 265) and O'Dogherty et al., 2011 (p. 112) this family was placed under the superfamily Archaeodictyomitoidea. However, the family Unumidae as stated by Takemura, 1986 (p. 36) does not share the same cephalic structure. In this paper, we prefer to consider this family as more closely related to the Japonocapsidae. We also tentatively reassign the genera *Quarticella* and *Yamatoum* under this family because the cephalic structure (*Yamatoum*-type) is the same as in *Unuma*.
- Genus *Protunuma* Ichikawa and Yao, 1976
- Type species.*—*Protunuma fusiformis* Ichikawa and Yao, 1976
- Occurrence.*—Middle Toarcian to upper Tithonian.
- Protunuma europeus* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006
Figure 11.42
- 2006 *Protunuma europeus* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., p. 433, pl. 10, figs. 6–8.
- Protunuma japonicus* Matsuoka and Yao, 1985
Figure 11.41
- 1985 *Protunuma japonicus* Matsuoka and Yao, p. 130, pl. 1, figs. 11–15; pl. 3, figs. 6–9.
- 1995b *Protunuma japonicus*; Baumgartner et al., p. 434, pl. 3292, fig. 1–8.
- 2003 *Protunuma multicostatus* (Heitzer); Suzuki and Gawlick, p. 197, fig. 5.43. [See for complete synonymy]
- Protunuma ochiensis* Matsuoka, 1983
Figure 11.43?–11.44
- 1983 *Protunuma (?) ochiensis* Matsuoka p. 26, pl. 4, figs. 8–11; pl. 9, figs. 3–7.
- 2003 *Protunuma ochiensis*; Suzuki and Gawlick, p. 197, fig. 6.90.
- 2006 *Protunuma ochiensis*; O'Dogherty et al., p. 433, pl. 7, figs. 11–13. [See for complete synonymy]
- Protunuma turbo* Matsuoka, 1983
Figure 11.39–11.40
- 1983 *Protunuma turbo* Matsuoka, p. 24, pl. 4, figs. 4–7; pl. 8, figs. 16–18; pl. 9, figs. 1–2.
- 1995b *Protunuma turbo*; Baumgartner et al., p. 436, pl. 4034, figs. 1–3. [See for complete synonymy]
- 2008 *Protunuma turbo*; Baumgartner et al., pl. 4, figs. 2–3.
- 2012 *Protunuma turbo*; Goričan et al., pl. 1, fig. 28.
- Genus *Unuma* Ichikawa and Yao, 1976
- 1976 *Spinunuma* Ichikawa and Yao.

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

Occurrence.—Lower Toarcian to upper Bathonian.

Unuma gordus Hull, 1997
Figure 11.29–11.38, ?11.45

- 1997 *Unuma gorda* Hull, p. 172, pl. 43, figs. 9, 11–12.
2003 *Unuma gorda*; Suzuki and Gawlick, p. 98; figs. 5.36, 6.68.
2006 *Unuma gordus*; O’Dogherty et al., p. 434, pl. 7, figs. 15–18. [See for complete synonymy]
2007 *Unuma gorda*; Gawlick et al., fig. 7.21; fig. 8.44; figs. 17.30, 18.13.
2009 *Unuma gordus*; Suzuki and Gawlick, p. 177, figs. 6.2A–B.
2013 *Unuma gordus*; Chiari et al., fig. 14n.

Unuma latusicostatus (Aita, 1987)
Figure 11.21–11.26

- 1987 *Tricolocapsa latusicostata* Aita, p. 76, pl. 4, figs. 7a–8b; pl. 10, figs. 8–9.
1995b *Unuma latusicostatus*; Baumgartner et al., p. 622, pl. 4058, figs. 1–4.
2012 *Unuma latusicostatus*; Goričan et al., pl. 1, fig. 30.

Genus *Quarticella* Takemura, 1986

- 2009 *Minutusolla* Yeh, p. 72.

Type species.—*Quarticella ovalis* Takemura, 1986

Other species.—*Minutusolla yaoi* Yeh, 2009; *Quarticella dura* Takemura, 1986; *Stichocapsa cicciona* Chiari, Marcucci, and Prela, 2002.

Emended diagnosis.—We consider under this genus only those species possessing a latticed fourth inflated segment with somewhat spiny surface, but never with long and stout spines.

Occurrence.—Upper Aalenian–upper Bathonian.

Quarticella cicciona (Chiari, Marcucci, and Prela, 2002)
Figure 9.56

- 2002 *Stichocapsa cicciona* Chiari, Marcucci, and Prela, p. 76, pl. 3, figs. 8–12.
2006 *Stichocapsa cicciona*; O’Dogherty et al., p. 441, pl. 6, fig. 36.

Quarticella ovalis Takemura, 1986
Figure 9.52

- 1986 *Quarticella ovalis* Takemura, p. 58, pl. 8, figs. 17–21.
1995b *Quarticella ovalis*; Baumgartner et al., p. 466, pl. 4078, figs. 1–3.

- 2003 *Quarticella ovalis*; Suzuki and Gawlick, p. 199, fig. 5.40.

- 2005a *Quarticella ovalis*; Nishihara and Yao, fig. 2.24.

- 2008 *Quarticella ovalis*; Auer et al., fig. 9.57.

- 2009 *Quarticella ovalis*; Suzuki and Gawlick, figs. 5.23 A–B.

Quarticella sp. A
Figure 9.58

Remarks.—This specimen differs from *Q. ovalis* by having a smooth surface and more regular arrangement of pores. Circular pores are surrounded by polygonal pore frames. Very small pyramidal spines occur at vertices.

Quarticella sp. B
Figure 9.29–9.30

- ?1985 *Stichocapsa* sp. B Yamamoto et al., pl. 7, fig. 6.

Remarks.—These specimens differ from *Q. ovalis* by having meshwork of larger and equally sized pores. Distal segment has a wide aperture with characteristic flat rim.

Quarticella sp. C
Figure 9.54–9.55

- 1997 *Sethocapsa?* sp. D Yao, fig. 542.

- 1982 *Stichocapsa* (?) sp. α Mizutani and Koike, pl. 2, figs. 1, 2a–b.

- 1982 *Stichocapsa* (?) sp. A Wakita, pl. 3, fig. 8.

Remarks.—This species is very similar to *Quarticella* sp. D, but bears a row of tubercles in the equatorial part of the inflated postabdominal segment.

Quarticella sp. D
Figure 9.57

Remarks.—This species differs from *Q. ovalis* by having a smooth surface without spines and regular arrangement of circular pores.

Genus *Yamatoum* Takemura, 1986

Type species.—*Yamatoum elegans* Takemura, 1986.

Other species.—*Quarticella conica* Takemura, 1986; *Quarticella levis* Takemura, 1986; *Quarticella? quinaria* Takemura, 1986; *Quarticella spinosa* Takemura, 1986; *Yamatoum atlanticum* O’Dogherty, Goričan, and Dumitrica in O’Dogherty et al., 2006; *Yamatoum caudatum* Takemura, 1986; *Yamatoum connicinum* Takemura, 1986; *Yamatoum komamiensis* Takemura, 1986; *Yamatoum spinosum* Takemura, 1986.

Emended diagnosis.—*Yamatoum* is emended in order to include spindle-shaped forms with a large abdomen armed with numerous (three or more) radiate equatorial spines and, when preserved, a strong (frequently tapered to branched) terminal spines. The last inverted conical

segment may be missing in many specimens due to its delicate nature.

Occurrence.—Upper Aalenian to upper Bathonian.

Yamatoum spinosum (Takemura, 1986)
Figure 8.38–8.42

1986 *Quarticella spinosa* Takemura, p. 59, pl. 9, figs. 1–6.

Remarks.—This species has been transferred into *Yamatoum* because it bears strong lateral spines on its abdomen. Our specimens have shorter spines than the type-material.

Yamatoum sp. A
Figure 8.32

Remarks.—This species differs from *Y. spinosum* by having a narrower final segment and shorter spines.

Superfamily Archaeodictyomitoidea Pessagno, 1976
Family Hsuuidae Pessagno and Whalen, 1982

Genus *Hsuum* Pessagno, 1977a

1992 *Ogivus* El Kadiri.

Type species.—*Hsuum cuestaense* Pessagno, 1977a.

Occurrence.—Lower Pliensbachian to lower Cenomanian.

Hsuum arabicum Dumitrica in Dumitrica et al., 1997
Figure 7.54

1997 *Hsuum arabicum* Dumitrica in Dumitrica et al., p. 46, pl. 10, figs. 2–3.

1999 *Hsuum arabicum*; Hori, p. 82, fig. 7.14.

Hsuum obispoense Pessagno, 1977a
Figure 7.55

1977a *Hsuum obispoensis* Pessagno, p. 82, pl. 8, figs. 3–4.

1977b *Hsuum obispoensis*; Pessagno, p. 44, pl. 6, fig. 7.

Genus *Transhsuum* Takemura, 1986

Type species.—*Transhsuum medium* Takemura, 1986

Occurrence.—Lower Pliensbachian to upper Kimmeridgian.

Transhsuum brevicostatum (Ožvoldová, 1975)
Figure 8.1–8.3

1975 *Lithostrobos brevicostatus* Ožvoldová, p. 84, pl. 102, fig. 1.

1995b *Transhsuum brevicostatus* gr.; Baumgartner et al., p. 578, pl. 3181, figs. 1–5.

2009 *Hsuum brevicostatus* gr.; Suzuki and Gawlick, p. 168, fig. 5.6. [See for complete synonymy]

Transhsuum maxwelli (Pessagno, 1977a)
Figure 8.4–8.8, 8.10–8.18

1977a *Hsuum maxwelli* Pessagno, p. 81, pl. 7, figs. 14–16.

2006 *Transhsuum maxwelli* gr.; O'Dogherty et al., p. 433, pl. 2, figs. 14, 18–23, 25. [See for complete synonymy]

2009 *Hsuum maxwelli*; Suzuki and Gawlick, p. 168, fig. 5.7. [See for complete synonymy]

Transhsuum sp. E sensu (Yao, 1997)
Figure 8.9

1997 *Hsuum* sp. E sensu Yao, pl. 15, fig. 197.

Remarks.—The main characteristic of this morphotype is its short skeleton consisting of only five segments.

Genus *Parahsuum* Yao, 1982

Type species.—*Parahsuum simplum* Yao, 1982.

Occurrence.—Lower Hettangian to upper Kimmeridgian.

Parahsuum carpathicum Widz and De Wever, 1993
Figure 7.52–7.53

1993 *Parahsuum carpathicum* Widz and De Wever, p. 85, pl. 1, figs. 14–16.

1995b *Parahsuum* sp. S Baumgartner et al., p. 384, pl. 3240, figs. 1–5.

1999 *Parahsuum officerense* (Pessagno and Whalen); Hori, p. 82 fig. 7.15.

2003 *Parahsuum carpathicum*; Suzuki and Gawlick, p. 182, fig. 5.30.

2006 *Parahsuum carpathicum*; O'Dogherty et al., p. 432, pl. 2, figs. 6–13. [See for complete synonymy]

2009 *Parahsuum* sp. S; Suzuki and Gawlick, p. 167, fig. 5.5.

Parahsuum sp. aff. *P. probosum* (Pessagno and Whalen, 1982)
Figure 7.61

1982 *Droltus* (?) *probosus* Pessagno and Whalen, p. 122, pl. 6, figs. 12, 16–17; pl. 12, fig. 12.

Remarks.—This species differs from the typical *P. probosum* by having a longer shell with broadened last segment.

Parahsuum snowshoense (Pessagno and Whalen, 1982)
Figure 7.50

1982 *Lupherium snowshoense* Pessagno and Whalen, p. 136, pl. 6, figs. 6, 20; pl. 12, fig. 6.

2006 *Parahsuum snowshoense*; O'Dogherty et al., p. 432, pl. 1, figs. 1–3.

2007b *Parahsuum snowshoense*; Gawlick et al., fig. 18.6.

Remarks.—We also include forms with an apical horn (e.g., Takemura, 1986, pl. 5, fig. 16) in this species.

Parahsuum sp. aff. *P. snowshoense* (Pessagno and Whalen, 1982)
Figure 7.51

Remarks.—This species differs from *P. snowshoense* by having less-pronounced strictures and partly thickened costae.

Parahsuum sp. 1 sensu O’Dogherty et al., 2006
Figure 7.49

Remarks.—Our specimen is closely related to *P. snowshoense* (Pessagno and Whalen), but differs by having a slender shell not constricted distally. Segments are trapezoidal in outline and possess four longitudinal rows of pores.

Parahsuum sp. 2 sensu O’Dogherty et al., 2006
Figure 7.56–7.60

Remarks.—This species shows an irregular arrangement of costae over most of the shell. The linear arrangement of costae, characteristic of *Parahsuum*, is only visible in the distalmost part.

Parahsuum sp. 3 sensu O’Dogherty et al., 2006
Figure 7.62–7.63

Remarks.—Shell conical proximally, cylindrical distally. Costae sharp, high in relief, faintly disappearing proximally.

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

Type species.—*Hsuum?* *inexploratum* Blome, 1984.

Occurrence.—Lower Bajocian to upper Callovian.

Semihsuum amabile (Aita, 1987)
Figure 7.15–7.16

- 1985 *Archaeodictyomitra* (?) *amabilis* Aita, fig. 6.6.
2006 *Hsuum* (?) *amabile*; O’Dogherty et al., p. 431, pl. 1, figs. 21–22. [See for complete synonymy]
2009 *Archaeodictyomitra amabilis*; Suzuki and Gawlick, p. 169, figs. 5.10, 6.20 A–B.
2012 *Semihsuum amabile*; Djerić et al., pl. 1, fig. 28.
2013 *Archaeodictyomitra* (?) *amabilis*; Chiari et al., Fig. 12b.

Family Archaeodictyomitridae Pessagno, 1976

Genus *Belleza* Hull, 1997

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

Occurrence.—Upper Bajocian to upper Callovian.

Belleza decora (Rüst, 1885)
Figure 8.53

- 1885 *Stichocapsa decora* Rüst, p. 319, pl. 17, fig. 3.
1990 *Sethocapsa* (?) *lineaplana* Yang and Wang, p. 210, pl. 4, figs. 7?, 12–13.
1995b *Stichocapsa decora*; Baumgartner et al., p. 520, pl. 3269, figs. 1–2, not figs. 3–4.
1997 *Belleza decora* (Rüst); Hull, p. 142, pl. 47, figs. 5–6, 14, 22–23
2006 *Mictyoditra decora*; O’Dogherty et al., p. 431, pl. 1, fig. 23 [See for complete synonymy]
Genus *Archaeodictyomitra* Pessagno, 1976

Type species.—*Archaeodictyomitra squinaboli* Pessagno, 1976.

Occurrence.—Lower Pliensbachian to upper Campanian.

Archaeodictyomitra sp. cf. *A. annulata* Kozur and Mostler in Grill and Kozur, 1986
Figure 7.21

- 1986 *Archaeodictyomitra annulata* Kozur and Mostler in Grill and Kozur, p. 257, pl. 10, fig. 2.

Remarks.—As stated by the original authors, this species is very distinct by its hoop-like second-last segment.

Archaeodictyomitra minoensis (Mizutani, 1981)
Figure 7.40–7.42

- 1981 *Pseudodictyomitra minoensis* Mizutani, p. 178, pl. 58, fig. 4; pl. 63, figs. 9–10.
1995b *Archaeodictyomitra minoensis*; Baumgartner et al., p. 104, pl. 3305, figs. 1–5. [See for complete synonymy]
1999 *Archaeodictyomitra minoensis*; Hori, p. 81, fig. 7.12.
2008 *Archaeodictyomitra minoensis*; Auer et al., fig. 9.4.

Archaeodictyomitra praeapiarium Cordey, 1998
Figure 7.36–7.37

- 1982 *Archaeodictyomitra apiara* (Rüst); Nishizono et al., pl. 3, fig. 4.
1998 *Archaeodictyomitra praeapiarium* Cordey, p. 99, pl. 28, figs. 9–10.

Remarks.—According to Cordey 1998, this species differs from *A. apiarium* by less-pronounced constrictions and continuous costae, also in the most proximal part.

Archaeodictyomitra prisca Kozur and Mostler in Grill and Kozur, 1986
Figure 7.43–7.45

- 1986 *Archaeodictyomitra prisca* Kozur and Mostler in Grill and Kozur, p. 258, pl. 8, figs. 3–6; pl. 9, fig. 1.
2006 *Archaeodictyomitra prisca*; O’Dogherty et al., p. 430, pl. 1, figs. 4–5. [See for complete synonymy]

- Archaeodictyomitra publica* (Hull, 1997)
Figure 7.17
- 1997 *Combusta* (?) *publica* Hull, p. 84, pl. 34, figs 3, 13, 20–21.
- 2006 *Combusta* (?) *publica*; O'Dogherty et al., p. 431, pl. 1, fig. 26. [See for complete synonymy]
- 2011 *Parahsuum publicum*; Yeh, p. 11, pl. 2, fig. 18.
- Archaeodictyomitra rigida* Pessagno, 1977a
Figure 7.33–7.35
- 1977a *Archaeodictyomitra rigida* Pessagno, p. 81, pl. 7, figs. 10–11.
- 2003 *Archaeodictyomitra rigida*; Suzuki and Gawlick, p. 179, fig. 5.18; fig. 6.20.
- 2008 *Archaeodictyomitra rigida*; Auer et al., fig. 9.7.
- 2009 *Archaeodictyomitra rigida*; Suzuki and Gawlick, p. 168, fig. 5.9. [See for complete synonymy]
- Archaeodictyomitra spelae* Chiari, Cortese, and Marcucci in Chiari et al., 1997
Figure 7.48
- 1997 *Archaeodictyomitra spelae* Chiari, Cortese, and Marcucci in Chiari et al., p. 64, pl. 1, figs. 13–15.
- 2006 *Archaeodictyomitra spelae*; Danelian et al., pl. 1, fig. 11.
- Remarks.*—This species is distinguished from other Middle Jurassic *Archaeodictyomitra* species by its long slender shell and the marked strictures between adjacent segments.
- Archaeodictyomitra tyaughtonensis* Cordey, 1998
Figure 7.38–7.39
- Archaeodictyomitra tyaughtonensis* Cordey, 1998, p. 98, pl. 28, figs. 5–6.
- Remarks.*—According to Cordey (1998) this species is characterized by the well-visible segmentation and the fusiform shape.
- Archaeodictyomitra* sp. aff. *A. exigua* Blome, 1984
Figure 7.18–7.20
- aff. 1984 *Archaeodictyomitra exigua* Blome, p. 356, pl. 8, figs. 4, 7–8, 10, 12–13; pl. 15, figs. 14–15.
- Remarks.*—This species resembles *Archaeodictyomitra exigua* in its conical shape, but differs by lacking the constricted final segment.
- Archaeodictyomitra whalenae* Kozur and Mostler in Grill and Kozur, 1986
Figure 7.46–7.47
- 1986 *Archaeodictyomitra whalenae* Kozur and Mostler in Grill and Kozur, p. 260, pl. 9, figs. 2–5.
- 2006 *Archaeodictyomitra whalenae*; O'Dogherty et al., p. 430, pl. 1, figs. 8–9. [See for complete synonymy]
- Genus *Thanarla* Pessagno, 1977b
- Type species.*—*Phormocyrtis veneta* Squinabol, 1903.
- Occurrence.*—Lower Bathonian to upper Cenomanian.
- Thanarla patricki* gr. (Kocher, 1981)
Figure 7.22–7.32
- 1981 *Archaeodictyomitra patricki* Kocher, p. 57, pl. 12, figs. 14–17.
- 2003 *Archaeodictyomitra patricki*; Suzuki and Gawlick, p. 178, fig. 5.19.
- 2006 *Archaeodictyomitra patricki*; O'Dogherty et al., p. 430, pl. 1, figs. 15–17. [See for complete synonymy]
- 2007b *Archaeodictyomitra patricki*; Gawlick et al., fig. 19.13.
- 2013 *Archaeodictyomitra* sp. cf. *A. patricki*; Chiari et al., Fig. 12c.
- Superfamily Amphipyndacoidea Riedel, 1967
Family Amphipyndacidae Riedel, 1967
- Genus *Eoxitus* Kozur, 1985
- Type species.*—*Eoxitus hungaricus* Kozur, 1985.
- Other species.*—*Eoxitus baloghi* Kozur, 1985 (syn. *Eoxitus nodosus*); ?*Eoxitus brevis* Kozur, 1985; *Eoxitus elongatus* Kozur, 1985; *Eoxitus nodosus* Kozur, 1985; *Parvicingula dhimenaensis* Baumgartner, 1984, *Triversus kasinzovae* Vishnevskaya, 1991; ?*Triversus strobilatus* Vishnevskaya, 1991; ?*Triversus triquetrum* Vishnevskaya, 1991.
- Occurrence.*—The stratigraphic occurrence of *Eoxitus* should be considered as lower Bajocian to Tithonian (see discussion above). The last representative of *Eoxitus* is *E. dhimenaensis*, which goes extinct in the Tithonian.
- Remarks.*—*Eoxitus* is very similar to its allied *Tethysetta*, but is much more elongated and does not have the characteristic broad spindle shape frequently observed throughout the Cretaceous forms assigned in *Tethysetta*. By definition, *Tethysetta* species have well-developed circumferential ridges and do not have spines on tubercles, as is the case of older species of *Eoxitus*.
- The stratigraphic range of both genera in O'Dogherty et al. (2009) was lower Bajocian–lower Aptian. These two genera are clearly distinguishable both morphologically and stratigraphically. At that time, we included the only species bearing faint spines in the Cretaceous—*Parvicingula usotanensis* Tumanda, 1989. Nonetheless, we currently believe that this species should be assigned to *Tethysetta* because it displays the characteristic circumferential ridges, although it also possesses somewhat spiny tubercles. This morphotype is stratigraphically disconnected from other Jurassic spiny parvicingulids.

The genus *Tethysetta* includes at least the following species: *Dictyomitra boesii* Parona, 1890; *Lithocampe fasciata* Rüst, 1898; *Parvicingula mashitaensis* Mizutani, 1981; *Parvicingula usotanensis* Tumanda, 1989; *Tethysetta cingulifera* Dumitrica in Dumitrica et al., 1997; *Tethysetta hullae* Dumitrica in Dumitrica et al., 1997; *Tethysetta ovoidala* Dumitrica in Dumitrica et al., 1997; *Tethysetta pygmaea* Dumitrica in Dumitrica et al., 1997.

Eoxitus baloghi Kozur, 1985

Figure 6.7–6.11

- 1985 *Eoxitus baloghi* Kozur, p. 216, fig. 2c.
 1985 *Eoxitus nodosus* Kozur, p. 218, figs. 2a–b, not fig. 2d.
 1997 *Parvicingula dhimenaensis* ssp. A Baumgartner et al.; Arakawa, pl. 4, fig. 8, not fig. 4 (= *E. hungaricus*).
 1987 *Parvicingula* sp. B Aita, p. 66, pl. 5, figs. 9a–10b; pl. 11, fig. 1.
 1987 *Parvicingula* sp. C Aita, p. 66, pl. 5, figs. 12a–13b?; pl. 11, fig. 2.
 1989 *Triversus spinifer* Hattori and Sakamoto, pl. 12, fig. D.
 2006 *Tethysetta baloghi*; O'Dogherty et al., p. 436, pl. 3, figs. 20–21.

Eoxitus? brevis Kozur, 1985

Figure 7.9

- 1985 *Eoxitus brevis* Kozur, p. 217, figs. 2e–f.

Remarks.—This species is questionably assigned to *Eoxitus* because it has more than three rows of pores per segment.

Eoxitus dhimenaensis (Baumgartner, 1984)

Figure 6.15–6.16

- 1976 *Amphipyndax* sp. Baumgartner and Bernoulli, p. 611, figs. 12 e, i, m.
 1981 *Parvicingula boesii* (Parona); De Wever and Caby, pl. 2, fig. C.
 1981 *Parvicingula boesii*; Kocher, p. 81, pl. 15, fig. 11 only.
 1982 *Parvicingula* sp. C Aita, pl. 1, figs. 13, 14.
 1982 *Amphipyndax* ? sp. Nishizono et al., pl. 3, fig. 16.
 1984 *Parvicingula dhimenaensis* Baumgartner, p. 778, pl. 7, figs. 2–3, not fig. 4.
 1985 *Parvicingula dhimenaensis*; De Wever and Miconnet, p. 389, pl. 4, figs. 4, 6–8.
 1985 *Parvicingula dhimenaensis*; Yamamoto et al., p. 36, pl. 6, fig. 1.
 1986 *Parvicingula dhimenaensis*; Conti, pl. 1, fig. 1.
 1986 *Parvicingula dhimenaensis*; Kishida and Hisada, fig. 2.4; fig. 8.2.
 1986b *Parvicingula dhimenaensis*; Matsuoka, pl. 2, fig. 12.
 1987 *Parvicingula dhimenaensis*; Aita, p. 66, ?pl. 2, figs. 3a–b, 5a–b; pl. 9, figs. 12–13.

- 1987 *Parvicingula dhimenaensis*; Goričan, p. 185, pl. 3, figs. 13–14.
 1988 *Parvicingula dhimenaensis*; Wakita, pl. 4, fig. 10; pl. 5, fig. 7.
 1991b *Parvicingula dhimenaensis*; Matsuoka, pl. 1, fig. 7.
 1995b *Parvicingula dhimenaensis dhimenaensis*; Baumgartner et al., p. 406, pl. 4072, only fig. 1.
 1998 *Parvicingula dhimenaensis dhimenaensis*; Arakawa, pl. 9, fig. 416.
 1998 *Parvicingula* ? sp. B0 Arakawa, pl. 9, fig. 448.
 2009 *Parvicingula dhimenaensis*; Suzuki and Gawlick, p. 169, figs. 6.9A–B.
 2012 *Eoxitus dhimenaensis*; Goričan et al., pl. 1, figs. 12–13.

Eoxitus hungaricus Kozur, 1985

Figure 6.1–6.6

- 1982 *Amphipyndax* (?) sp. A Kido et al., pl. 4, figs. 1–2.
 1982 *Parvicingula* sp. J Kishida and Sugano, pl. 12, figs. 6–7.
 1982 *Parvicingula* (?) sp. Imoto et al., pl. 3, 6–7.
 1985 *Eoxitus elongatus* Kozur, p. 217, fig. 1h.
 1985 *Eoxitus hungaricus* Kozur, p. 216, figs. 1a–b, d–e.
 1985 *Parvicingula spinosa* Aita, figs. 6.12–6.13.
 1992 *Eoxitus hungaricus*; Ožvoldová, pl. 1, fig. 14; pl. 4, fig. 8.
 1994 *Parvicingula dhimenaensis* Baumgartner; Goričan, p. 80, pl. 24, figs. 12–13.
 1995 *Parvicingula dhimenaensis*; Takahashi and Ishii, pl. 1, fig. 27.
 1995b *Parvicingula dhimenaensis* ssp. A Baumgartner et al., p. 406, pl. 4071, only fig. 1–3.
 1997 *Parvicingula dhimenaensis*; Arakawa, pl. 4, fig. 4, not fig. 8 (= *E. baloghi*).
 1998 *Parvicingula dhimenaensis*; Arakawa, pl. 9, fig. 417.
 2003 *Triversus hungaricus*; Suzuki and Gawlick, p. 195, fig. 6.58–6.60.
 2009 *Triversus hungaricus*; Suzuki and Gawlick, p. 170, fig. 5.14; figs. 6.6A–B, 6.7–6.8.

Eoxitus? sp. A

Figure 6.17

- 1982 *Parvicingula decora* Pessagno and Whalen; Aubrecht and Ožvoldová, 1994, pl. 4, fig. 1.
 1995b *Parvicingula(?) spinata*; Baumgartner et al., p. 412, pl. 3187, fig. 1 only, fig. 2?
 1998 *Parvicingula* sp. E0 Arakawa, pl. 10, fig. 430.
 1998 *Parvicingula* sp. E1 Arakawa, pl. 10, fig. 431.

Remarks.—The apical horn and pointed nodes enable differentiation from *Praeparvicingula* Pessagno, Blome, and Hull in Pessagno et al., 1993.

Eoxitus? sp. B

Figure 6.28

Remarks.—This morphotype is easily distinguished from other species of *Eoxitus* by its enormous apical horn.

Family Canoptidae Pessagno in Pessagno et al., 1979

Type species.—*Canoptum poissoni* Pessagno in Pessagno et al., 1979.

Occurrence.—Ladinian to upper Bajocian.

Genus *Canoptum* Pessagno, 1979

Remarks.—Includes generic concepts of *Paracanoptum* Yeh, 1987b and *Pseudocanoptum* Suzuki, 1997.

Canoptum krahsteinense (Suzuki and Gawlick in
Gawlick et al., 2004)
Figure 6.33

- 1985 *Canoptum* sp. Yamamoto et al., p. 34, pl. 3, fig. 10.
2003 *Spongocapsula krahsteinensis* Suzuki and Gawlick,
p. 189, fig. 6.95. (Premature name)
2004 *Spongocapsula krahsteinensis* Suzuki and Gawlick in
Gawlick et al., p. 313, figs. 4.7–4.10.
2007b *Spongocapsula krahsteinensis*; Gawlick et al., fig. 7.14.
2009 *Spongocapsula krahsteinensis*; Ishida, figs. 10.18,
10.35.
2011 *Spongocapsula* cf. *krahsteinensis*; Ishida, fig. 6.23.
2014 *Canoptum krahsteinense*; Šegvić et al., pl. 1, figs. 8–9.

Genus *Cinguloturris* Dumitrica in Dumitrica and Mello, 1982

Type species.—*Cinguloturris carpatica* Dumitrica in Dumitrica and Mello, 1982.

Occurrence.—Upper Bathonian to lower Valanginian.

Cinguloturris carpatica Dumitrica in Dumitrica and
Mello, 1982
Figure 6.29–6.30

- 1982 *Cinguloturris carpatica* Dumitrica in Dumitrica and
Mello, p. 23, pl. 4, figs. 7–11.
2006 *Cinguloturris carpatica*; O'Dogherty et al., p. 435, pl. 3,
figs. 8–9. [See for complete synonymy]
2009 *Cinguloturris carpatica*; Suzuki and Gawlick, p. 167,
figs. 5.2, 6.1A–B.

Cinguloturris getsensis O'Dogherty, Goričan, and Dumitrica in
O'Dogherty et al., 2006
Figure 6.31–6.32

- 2006 *Cinguloturris getsensis* O'Dogherty, Goričan, and
Dumitrica in O'Dogherty et al., p. 435, pl. 3,
figs. 10–12. [See for complete synonymy]

Cinguloturris latiannulata (Grill and Kozur, 1986)
Figure 6.34

- 1986 *Canoptum latiannulatum* Grill and Kozur, p. 250, pl. 7,
figs. 4–5.

Remarks.—This species is closely related morphologically to *C. carpatica*, but differs by having no pores in the intersegmental depressions at strictures.

Family Obeliscoitidae O'Dogherty, 1994

Genus *Olanda* Hull, 1997

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

Occurrence.—Lower Bajocian to middle Albian.

Olanda sp.
Figure 7.14

Remarks.—The single specimen found in sample BMW-28 from the lower Bathonian is broken and cannot be determined at species level, but the proximal part is in good agreement with the genus *Olanda*.

Family Parvicingulidae Pessagno, 1977a

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

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

Occurrence.—Lower Kimmeridgian to upper Tithonian.

Caneta hsui (Pessagno, 1977a)
Figure 6.25

- 1977a *Ristola hsui* Pessagno, p. 85, pl. 8, figs. 15–16; pl. 9,
figs. 1–5.
1984 *Ristola hsui*; Pessagno et al., p. 29, pl. 4, figs. 2–3.
1993 *Parvicingula* sp. cf. *hsui*; Yang, p. 119, pl. 19,
figs. 4–5, 14, 17, 21.
1995 *Caneta hsui*; Hull, p. 16, pl. 1, figs. 6, 10, 18, 22; pl. 6,
fig. 10.
1996 *Caneta hsui*; Kiessling and Scasso, pl. 1, fig. 17.
1999 *Caneta hsui* s.l.; Kiessling, p. 48, pl. 10, figs. 12–13.
2003 *Wrangellium hsuei*; Suzuki and Gawlick, p. 194,
fig. 6.99.
2007b *Wrangellium hsuei*; Gawlick et al., fig. 8.48.

Remarks.—Our specimen does not have a constricted last segment as illustrated in the holotype.

Genus *Takemuraella* new name

- 1986 *Triversus* Takemura, preoccupied name (non *Triversus*
Sher 1973, Nematoidea).

Type species.—*Triversus japonicus* Takemura, 1986.

Other species.—*Praeparvingula tlellensis* Carter in Goričan et al., 2006; *Triversus fastigatus* Hull, 1997; *Triversus schardti* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006; *Triversus spinifer* Takemura, 1986; *Triversus preconicus* Vishnevskaya, 1991.

Diagnosis.—Multicyrtid having three rows of circular pores by segment, which are externally weakly defined by ridges or strictures, and usually without apical horn or occasionally a very faint apical horn is present (e.g., *Triversus fastigatus* Hull 1997, pl. 51, fig. 5).

Occurrence.—Upper Pliensbachian to upper Bathonian.

Etymology.—In honor of our friend and colleague Prof. Atsushi Takemura, for his great contribution of the taxonomy and stratigraphy of Paleozoic and Mesozoic radiolarians.

Remarks.—Takemura (1986) emphasized the *Amphipyndax*-type cephalic skeletal structure of this genus as a distinction from *Parvingula*. In addition, we note that *Takemuraella* shares with other parvingulids the three rows of pores per segment, but it lacks the typical circumferential ridges always visible in *Praeparvingula* and *Parvingula*.

Takemuraella japonica (Takemura, 1986)
Figure 6.49–6.50

- 1986 *Triversus japonicus* Takemura, p. 62, pl. 16–20.
not *Triversus japonicus*; Hattori and Sakamoto, pl. 12,
1989 figs. B–C.
2006 *Triversus japonicus*; O'Dogherty et al., 434, pl. 4, fig. 3.
2013 *Triversus japonicus*; Chiari et al., p. 418, fig. 14k.

Takemuraella schardti (O'Dogherty, Goričan, and Dumitrica in
O'Dogherty et al., 2006)
Figure 6.18–6.21

- 1997 *Ristola* (?) *turpicula* Pessagno and Whalen; Arakawa,
pl. 4, fig. 18.
2006 *Stichocapsa tuscanica* Chiari, Cortese, and Marcucci;
Danelian et al., pl. 2, fig. 8.
2006 *Triversus schardti* O'Dogherty, Goričan, and Dumitrica
in O'Dogherty et al., p. 434, pl. 4, figs. 4–10. [See for
complete synonymy]
2008 *Parvingula spinata* (Vinassa de Regny); Auer et al.,
fig. 9.47.
2009 *Triversus hexagonatus* (Heitzer); Suzuki and Gawlick,
p. 170, figs. 5.15; 6.11A–B.

Takemuraella sp. cf. *T. schardti* (O'Dogherty, Goričan, and
Dumitrica in O'Dogherty et al., 2006)
Figure 7.10–7.11

Remarks.—This species differs from *T. schardti* by having fewer segments, a wider conical shell, and larger pores.

Takemuraella spinifera (Takemura, 1986)
Figure 6.22–6.24

- 1982 *Amphipyndax* sp. A Kido et al., pl. 4, figs. 1, 2.
1982 *Amphipyndax* (?) sp. Kojima, p. 88, pl. 1, fig. 4.
1986 *Triversus spinifer* Takemura, p. 63, pl. 10, figs. 21–23;
pl. 11, figs. 1–2.
1987 *Ristola* sp. E Hattori, pl. 19, fig. 6.
1987 *Triversus* aff. *T. spinifer* Hattori, pl. 20, fig. 7.
1989 *Parvingula* (?) sp. Hattori and Sakamoto, pl. 12, fig. A.
1989 *Ristola* spp. Hattori, pl. 14, fig. H.
1997 *Parvingula* aff. *spinifer*; Yao, pl. 13, fig. 609.
1998 *Parvingula* sp. H0 Arakawa, pl. 9, fig. 434.
2003 *Parvingula spinifer*; Goričan et al., p. 297, pl. 5, fig. 5.
2004 *Triversus spinifer*; Matsuoka, fig. 239.
2006 *Praeparvingula?* *spinifera*; Goričan et al., p. 338,
pl. TVS01, figs. 1–5.
2012 *Eoxitus spinifer* (Takemura); Goričan et al., pl. 1, fig. 40.
2013 *Triversus* sp. cf. *T. spinifer* Takemura; Chiari et al.,
fig. 14l.

Remarks.—As in *Takemuraella schardti*, the presence or absence of a delicate and narrower last segment (even broken, see Fig. 6.17–18) is not considered a significant characteristic to separate two morphotypes belonging to different subspecies.

Family Pseudodictyomitridae Pessagno, 1977b

Genus *Loopus* Yang, 1993

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

Other species.—*Candissa mexicana* Hull, 1997; *Cinguloturris?* *venusta* Chiari, Cortese, and Marcucci in Chiari et al., 1997; *Loopus doliolum* Dumitrica in Dumitrica et al., 1997; *Loopus doliolum martae* Beccaro, 2004; *Loopus yangi* Dumitrica in Dumitrica et al., 1997; *Pseudodictyomitra blabla* Schaaf, 1981.

Occurrence.—Lower Bathonian to lower Aptian.

Remarks.—Includes generic concepts of *Candissa* Hull, 1997.

Loopus martae Beccaro, 2004
Figure 7.64–7.66

- 2004 *Loopus doliolum martae* Beccaro, p. 13, pl. 1, figs. 3–5.
2008 *Loopus doliolum martae*; Beccaro et al., pl. 3, fig. 17.

Remarks.—In this paper the record of the taxon is raised to species level. This new taxonomic assignment is justified by the clear morphological distinction and different stratigraphic ranges between *Loopus doliolum* Dumitrica in Dumitrica et al., 1997 and *Loopus martae* Beccaro.

Loopus mexicanus (Hull, 1997)
Figure 7.71

- 1997 *Candissa mexicana* Hull, p. 144, pl. 47, figs. 11–12, 17,
21, 24.

Remarks.—*Loopus mexicanus* is distinguished from other *Loopus* included by having a lobate outline with well-pronounced constrictions.

Loopus venustus (Chiari, Cortese, and Marcucci in Chiari et al., 1997)

Figure 7.67–7.70

- 1982? Unnamed multicyrtoid nassellaria Adachi, pl. 2, fig. 7.
 1986a *Pseudodictyomitra* (?) sp. D Matsuoka, pl. 4, only figs. 2–6.
 1986b *Pseudodictyomitra* (?) sp. D Matsuoka, pl. 2, fig. 11; pl. 3, figs. 12a–b.
 1988 *Pseudodictyomitra* sp. D Wakita, pl. 1, fig. 12.
 1988 *Pseudodictyomitra* (?) sp. D Wakita, pl. 4, fig. 12.
 1990 *Pseudodictyomitra* (?) sp. D Matsuoka and Oji, pl. 1, fig. 8.
 1997 *Cinguloturris* (?) *venusta* Chiari, Cortese, and Marcucci in Chiari et al., p. 66, pl. 2, figs. 4–5.
 1997 *Cinguloturris* (?) sp. Chiari, Cortese, and Marcucci in Chiari et al., pl. 2, fig. 6.
 2006 *Dictyomitrella* (?) sp. 3 O'Dogherty et al., p. 436, pl. 3, fig. 16.
 2006 *Loopus venustus*; Danelian et al., p. S40, pl. 1, figs. 21–23.

Remarks.—We group a large variety of *Loopus* with complex irregular ornamentation of disconnected short costae and small polygonal depressions in *L. venustus*. This species clearly differs from *L. primitivus*, which has regularly distributed vertical costae, no polygonal depressions, and stronger strictures.

Genus *Mizukidella* new genus

Type species.—*Dictyomitrella? kamoensis* Mizutani and Kido, 1983.

Other species.—*Canoptum hungaricum* Grill and Kozur, 1986; *?Canoptum rudabanyaense* Grill and Kozur, 1986; *Mizukidella mokaensis* new species.

Diagnosis.—Multicyrtid conical to subcylindrical shell. Cephalis dome-shaped without horn. Abdomen and post-abdominal cylindrical segments separated by nodose circumferential ridges, with paired pores just below and above the ridges. Abdomen and post-abdominal chambers have more or less regularly arranged rows of circular pits.

Etymology.—Achronym of parts of Mizutani, Kido, and *Dictyomitrella*; feminine gender.

Occurrence.—Bajocian to upper Berriasian.

Remarks.—*Mizukidella* n. gen. is distinguished from other parvicingulids by having a characteristic surface with pits (very small depressions) on the medial part of post-abdominal segments, which are bounded by circumferential ridges and limited by one row of pores below and above. A possible origin from *Canoptum* is suspected. Through the latest Jurassic, this genus may have

given rise to *Svinitzium* by the regularization of the size and arrangement of pores and pits around the circumferential ridges.

Mizukidella kamoensis (Mizutani and Kido, 1983)

Figure 6.12–6.14

- 1983 *Dictyomitrella* (?) *kamoensis* Mizutani and Kido, p. 258, pl. 53, figs. 2–4b.
 2006 *Dictyomitrella* (?) *kamoensis*; O'Dogherty et al., p. 435, pl. 3, fig. 15. [See for complete synonymy]
 2009 *Wrangellium oregonense* Yeh; Yeh, p. 59, pl. 17, figs. 13, 22.
 2013 *Svinitzium kamoense*; Chiari et al., fig. 14d.

Mizukidella mokaensis new species

Figure 6.26–6.27

- 1998 *Praecaneta* ? sp. 6 Matsuoka, pl. 9, fig. 129.

Holotype.—The specimen illustrated on figure 6.27 from sample BMW-35, upper Tithonian of Sillenkopf Formation (Northern Calcareous Alps, Austria).

Diagnosis.—Parvicingulid with very small depressions (pits) arranged linearly on the medial part of post-abdominal segments. A middle row of pores is always present in distal segments.

Occurrence.—Middle Oxfordian to upper Berriasian.

Description.—Shell as with genus having commonly a conical shell with eight segments. Cephalis and thorax poreless, conical, and separated by rows of small pores. Distal segments increase gradually in width. Circumferential ridges strong and bearing vertical bars displaying a typical “H-linked” structure. Each segment has two rows of pits at the ridges and a row of small pores in the middle part. Two rows of bigger pores are always present just above and below the ridges. In well-preserved specimens (e.g., Mariana trench, Matsuoka, 1998, pl. 9, fig. 129), a velum on the distalmost segment may be preserved.

Etymology.—Mokaensis is an anagram of kamoensis, which is the other species included into this genus (see above).

Measurements.—(in micrometers; μm) maximum diameter of conical shell 226–263, mean 240; maximum length 113–119, mean 116, based on three specimens.

Remarks.—*Mizukidella mokaensis* differs from *M. kamoensis* by having a more regular shell structure. The pits are linearly arranged, pores are larger, ridges are stronger, and a middle row of pores is always present in distal segments.

Family Xitidae Pessagno, 1977b

Genus *Xitus* Pessagno, 1977b

Type species.—*Xitus plenus* Pessagno, 1977b.

Occurrence.—Upper Bajocian to upper Campanian.

Remarks.—Includes generic concepts of *Antexitus* Yeh, 2009.

Xitus skenderbegi (Chiari, Marcucci, and Prela, 2002)

Figure 7.1–7.3

- 1993 *Xitus?* sp. A Cortese, p. 181, pl. 7, figs. 6–7.
 1997 *Xitus* sp. Matsuoka and Baumgartner, pl. 3, fig. 16.
 1999 *Xitus* sp. A Halamić et al., pl. 3, figs. 1–4.
 2002 *Neorelumbra skenderbegi* Chiari, Marcucci, and Prela, p. 68, pl. 1, figs. 14–21.
 2003 *Neorelumbra skenderbegi*; Suzuki and Gawlick, p. 190, fig. 6.32.
 2004 *Neorelumbra skenderbegi*; Chiari et al., pl. 2, fig. 2.
 2005 *Xitus skenderbegi*; Šmuc and Goričan, p. 62, pl. 4, figs. 15–16.
 2008 *Xitus skenderbegi*; Auer et al., fig. 9.42
 2009 *Xitus skenderbegi*; Suzuki and Gawlick, fig. 5.11.

Xitus sp. A
 Figure 7.12–7.13

Remarks.—This species differs from *X. skenderbegi* by having a more slender shape; it differs from *X. magnus* Baumgartner in Baumgartner et al., 1995 in being smaller and having fewer segments.

Family Xitomitridae new family

Type genus.—*Xitomitra* new genus.

Included genera.—*Campanomitra* new genus; *Parvimitrella* new genus; *Pseudodictyomitrella* Grill and Kozur, 1986; *Xitomitra* new genus.

Diagnosis.—Multicyrtid nassellarians with small poreless cephalis and all other segments covered by a latticed meshwork of uniform size polygonal pore frames. Shell largely open distally and lacking any kind of distal projections or appendages. The genera are distinguished on the basis of presence or absence of apical horn and presence or absence of stricture at intersegmental constrictions. Only one genus, *Xitomitra* n. gen., may develop a secondary layer of very faint nodes on distal segments.

Occurrence.—Aalenian to Maastrichtian.

Remarks.—The Xitomitridae n. fam. is related to the Canoptidae, Parvicingulidae, and Xitidae. It differs from the Canoptidae by having a latticed shell with larger pores. It differs from Parvicingulidae by lacking the typical arrangement of horizontal rows of pores per segment. Xitomitridae n. fam. is also distinguished from Xitidae by lacking the typical double layer latticed meshwork bearing large tubercles on the entire surface.

Genus *Campanomitra* new genus

Type species.—*Stichocapsa praepulchella* Hori, 1999.

Other species.—*Amphipyndax awaensis* Nakaseko and Nishimura in Nakaseko et al., 1979; *Amphipyndax conicus* Nakaseko and Nishimura, 1981; *Amphipyndax ellipticus* Nakaseko and Nishimura, 1981; *Archicorys pulchella* Rüst, 1885; *Parvicingula cappa* Cortese, 1993; *?Pseudoencyrtis buekkensis* Grill and Kozur, 1986, *Quarticella hunzikeri* O'Dogherty, Goričan, and Dumitrica in O'Dogherty et al., 2006; *?Stichocapsa labyrinthica* Dumitrica in Dumitrica et al., 1997; *Stichocapsa tuscanica* Chiari, Cortese, and Marcucci in Chiari et al., 1997; *Stichocapsa ulivii* Chiari, Cortese, and Marcucci in Chiari et al., 1997; *Stichocapsa devorata arctica* Vishnevskaya and Murchev, 2002; forms included as *Stichocapsa* spp. by Matsuoka (1998, figs. 35, 37–40).

Diagnosis.—Campanulate shell composed of four to ten segments. Largely open distally. Small, poreless cephalis without apical horn. Other segments covered by a latticed meshwork consisting of relatively large polygonal pore frames. The strictures between junctions of the segments are never present.

Etymology.—Genus name derived from *campano* (bell) and *mitra* (ecclesiastical headgear: miter). Feminine gender.

Occurrence.—Bajocian to Cenomanian.

Remarks.—*Campanomitra* n. gen. differs from *Pseudodictyomitrella* by lacking an apical horn. It differs from *Parvimitrella* and *Xitomitra* in having larger pores and no intersegmental constrictions. *Campanomitra* n. gen. differs from *Takemuraella* by lacking the arrangement of three rows of pores per segment and having no circumferential ridges.

A common character of the genus in Cretaceous species is the presence of a large sutural pore on the surface of the shell. *Stichocapsa labyrinthica* Dumitrica in Dumitrica et al., 1997 is tentatively assigned in this genus because it lacks the distinctive sutural pore present in all other Cretaceous representatives of the genus.

Campanomitra sp. aff. *C. buekkensis* (Grill and Kozur, 1986)
 Figure 6.44

- 1986 *Pseudoencyrtis buekkensis* Grill and Kozur, p. 251, pl. 6, fig. 4.

Remarks.—This specimen is characterized by an irregular arrangement of circular pores throughout the entire shell. It differs from typical *C. buekkensis* in which the pores are arranged in horizontal rows distally.

Campanomitra tuscanica (Chiari, Cortese, and Marcucci in Chiari et al., 1997)
 Figure 6.65–6.69

- 1986 *Pseudodictyomitrella hexagonata*; Grill and Kozur, pl. 4, fig. 2.
 1997 *Stichocapsa tuscanica* Chiari, Cortese, and Marcucci in Chiari et al., p. 70, pl. 4, figs. 8–9.

- 2003 *Triversus hexagonatus*; Suzuki and Gawlick, p. 194, figs. 5.48, 6.61.
- 2006 *Pseudodictyomitrella tuscanica*; O'Dogherty et al., p. 440, pl. 5, figs. 7–9.
- 2006 *Triversus hexagonatus*; Gawlick et al., fig. 8c.40; fig. 9b.20.
- 2006 *Triversus hexagonatus*; Auer et al., fig. 6.48.
- 2007b *Triversus hexagonatus*; Gawlick et al., fig. 17.29.
- 2013 *Pseudodictyomitrella tuscanica*; Chiari et al., p. 415, fig. 13t.

Campanomitra sp. aff. *C. tuscanica* (Chiari, Cortese, and Marcucci in Chiari et al., 1997)
Figure 6.62–6.64

Remarks.—This species differs from *C. tuscanica* by having cylindrical instead of conical shell distally.

Campanomitra sp. aff. *C. ulivii* (Chiari, Cortese, and Marcucci in Chiari et al., 1997)
Figure 6.70–6.73

- 1997 *Stichocapsa ulivii* Chiari, Cortese, and Marcucci in Chiari et al., p. 70, pl. 4, figs. 10–11.
- ?1997 *Stichocapsa* sp. aff. *S. ulivii* Chiari, Cortese, and Marcucci in Chiari et al., p. 72, pl. 4, fig. 12.

Remarks.—This species resembles *C. ulivii* in shape and pore size, but differs by having a smoother surface without raised pore frames.

Campanomitra? sp. A
Figure 6.40–6.43

Remarks.—The specimens included in this species have a barrel-shape outline (fusiform) and consist of six or more segments.

Campanomitra? spp.
Figure 6.56–6.61

- 1982 *Stichocapsa* sp. A Sashida et al., pl. 2, fig. 2.
- 1989 *Bagotum* sp. A Hattori and Sakamoto, pl. 13, fig. J.

Remarks.—Various species of *Campanomitra* n. gen. with fewer than five segments commonly occur in our material. Similar forms have been previously illustrated (see synonymy). However, more in depth taxonomical research is needed to describe new species. This morphotype vaguely resembles the Cretaceous species *Trimulus parmatus* O'Dogherty, 1994.

Genus *Parvimitrella* new genus

Type species.—*Pseudodictyomitrella wallacheri* Grill and Kozur 1986 (syn. *Parvifavus irregularis* Takemura, 1986).

Included species.—*Amphipyndax plousios* Foreman, 1968; *Parvifavus irregularis* Takemura, 1986; *Pseudodictyomitrella wallacheri* Grill and Kozur, 1986; *Stichomitra? angulata*

Bragin and Tekin in Bragin et al., 2002; *Stichomitra cathara* Foreman, 1968; *Stichomitra? cechena* Foreman, 1968; *Stichomitra communis* Squinabol, 1903; *Stichomitra compsa* Foreman, 1968; *Stichomitra magna* Squinabol, 1904; ?*Stichomitra navalis* O'Dogherty, 1994.

Diagnosis.—Thick-walled shell, multisegmented, having a single hexagonal closely packed layer of pores per segment. Strictures between segments usually well marked.

Etymology.—The generic name comes from a combination of *Pseudodictyomitrella* and *Parvifavus*, to which the type species was originally assigned.

Occurrence.—Aalenian to Maastrichtian.

Remarks.—*Parvimitrella* n. gen. is erected to replace the genus *Stichomitra* Cayeux, 1897, sensu O'Dogherty, 1994, due to problems related to the poor definition of the type species (see discussion regarding this subject in O'Dogherty, 1994; O'Dogherty et al., 2009).

Parvimitrella n. gen. (ex. *Stichomitra*) is easily distinguished from other Jurassic and Cretaceous multi-segmented forms by its typical pattern of hexagonal close-packed layer of pores per chamber and its frequently dome-shaped cephalis, divided into two chambers by a transverse internal ledge. *Parvimitrella* n. gen. is distinguished from *Amphipyndax* in lacking two structurally distinct layers of test material and if circumferential ridges develop, they never occur at segmental divisions.

Parvimitrella n. gen. differs from *Pseudodictyomitrella* by having a rounded cephalis and strictures at segmental divisions. As mentioned above, many species originally included under the genus *Stichomitra* (especially in the Cretaceous) belong at least to three distinct described genera: *Amphipternis* Foreman, 1973a; *Schaafella* Vishnevskaya in Basov and Vishnevskaya, 1991; and *Eostichomitra* Empson-Morin, 1981.

Species frequently ascribed to *Stichomitra*, but now considered as belonging to other genera: *Amphipternis: Dictyomitra mediocris* Tan, 1927; *Stichocapsa? stocki* Campbell and Clark, 1944; and *Stichomitra tosaensis* Nakaseko and Nishimura, 1981.

Schaafella: Schaafella deweveri Vishnevskaya in Basov and Vishnevskaya, 1991; *Schaafella nodosa* Vishnevskaya in Basov and Vishnevskaya, 1991; *Schaafella tochilinae* Vishnevskaya in Basov and Vishnevskaya, 1991; *Stichomitra tosaensis* Nakaseko and Nishimura in Nakaseko et al., 1979; and *Stichopilium bonum* Kozlova in Kozlova and Gorbovetz, 1966.

Eostichomitra: Eostichomitra warzigita Empson-Morin, 1981; *Stichomitra asymbatos* Foreman, 1968; *Vistularia magna* Gorka, 1989; and ?*Cyrtocapsa pseudacerra* Tan, 1927.

Parvimitrella wallacheri (Grill and Kozur, 1986)
Figure 6.39

- 1986 *Pseudodictyomitrella wallacheri* Grill and Kozur, p. 253, pl. 4, figs. 5–7.
- 1986 *Parvifavus irregularis* Takemura, p. 9, pl. 10, figs. 10–13.
- 2008 *Parvifavus wallacheri*; Auer et al., fig. 9.48.
- 2011 *Parvifavus irregularis*; Yeh, p. 8, pl. 2, figs. 1–2.

Remarks.—Because the paper by Grill and Kozur was published in January 1986 but the paper by Takemura in December 1986, the species name of *P. wallacheri* has priority. It is also considered the type species of this genus.

Genus *Pseudodictyomitrella* Grill and Kozur, 1986

Type species.—*Pseudodictyomitrella spinosa* Grill and Kozur, 1986.

Other species.—*Parvicingula limana* Cortese, 1993; *Pseudodictyomitrella badouxi* O’Dogherty, Goričan and Dumitrica in O’Dogherty et al., 2006; *Pseudodictyomitrella escheri* O’Dogherty, Goričan and Dumitrica in O’Dogherty et al., 2006; *Pseudodictyomitrella renevieri* O’Dogherty, Goričan and Dumitrica in O’Dogherty et al., 2006.

Remarks.—All species here included under *Pseudodictyomitrella* have a conical shell with an acute cephalis tapering in an apical horn. For a detailed description of all these species the reader is referred to O’Dogherty et al., 2006.

Occurrence.—Lower Bajocian to upper Bathonian.

Pseudodictyomitrella limana (Cortese, 1993)
Figure 6.45–6.48

- 1985 *Parvicingula* ? sp. Yamamoto et al., p. 36, pl. 6, fig. 5.
1993 *Parvicingula limana* Cortese; p. 177; pl. 4, figs. 5–7.
2003 *Parvicingula cappa* Cortese; Suzuki and Gawlick, p. 187, fig. 6.84 only.
2006 *Pseudodictyomitrella limana*; O’Dogherty et al., p. 440, pl. 5, fig. 18.

Pseudodictyomitrella renevieri O’Dogherty, Goričan, and Dumitrica in O’Dogherty et al., 2006
Figure 7.5–7.7

- 1998 *Parvicingula* ? sp. A1 Arakawa, pl. 10, fig. 454.
1998 *Parvicingula* ? sp. J0 Arakawa, pl. 10, fig. 462.
2006 *Pseudodictyomitrella renevieri* O’Dogherty, Goričan, and Dumitrica in O’Dogherty et al., p. 440, pl. 5, figs. 19–22.

Pseudodictyomitrella sp. cf. *P. renevieri* O’Dogherty, Goričan, and Dumitrica in O’Dogherty et al., 2006
Figure 7.8

Remarks.—The specimen has a pointed cephalis but supposedly due to preservation it lacks the apical horn.

Genus *Xitomitra* new genus

Type species.—*Stichomitra tairai* Aita, 1987.

Other species.—*Stichomitra annibill* Kocher, 1981 (syn. *Stichomitra? matsuokai* Hull, 1997).

Diagnosis.—Shell conical with four or more segments and a large distal aperture. Very large cephalis, imperforate and usually bearing a small apical horn. Subsequent segments increasing gradually in height, with well-defined external strictures. All segments covered by a regular pattern of polygonal (mostly hexagonal) pore frames. Distalmost segments may bear thick nodes.

Etymology.—Arbitrary combination of letters (ICZN, Art. 11.3) plus *mitra* (from Latin, meaning cap); feminine gender.

Remarks.—*Xitomitra* n. gen. differs from other genera included in this family by having a more lobate outline with well-marked strictures. It differs from *Parvimitrella* n. gen. by having a thick, wider and pointed cephalic region (see pl. 3, fig. 8a of Aita, 1987).

Occurrence.—Middle Bathonian to lower Callovian.

Xitomitra annibill (Kocher, 1981)
Figure 6.51–6.54

- 1981 *Stichomitra annibill* Kocher, p. 96, pl. 16, figs. 24–26.
1989 Gen 2 sp. B Hattori and Sakamoto, ? pl. 14, fig. E.
1996 *Stichomitra tairai* Aita; Marcucci and Prella, pl. 2, fig. 14.
1997 *Stichomitra* (?) *matsuokai* Hull, p. 164, pl. 49, figs. 2–3, 13–14, 19–20.
2003 non *Stichomitra annibill*; Suzuki and Gawlick, figs. 6.35–6.36. [= *X. tairai*]
2005 *Stichomitra annibill*; Šmuc and Goričan, pl. 4, fig. 24.
2006 *Stichomitra annibill*; O’Dogherty et al., p. 442, pl. 5, figs. 1–3.
2006 non *Stichomitra annibill*; Auer et al., fig. 6.37. [= *X. tairai*]
2008 non *Stichomitra annibill*; Auer et al., fig. 9.66. [= *X. tairai*]
2009 non *Stichomitra annibill*; Suzuki and Gawlick, fig. 5.16. [= *X. tairai*]

Remarks.—*Xitomitra annibill* differs from *Xitomitra tairai* by having a smaller cephalis and a four-segmented shell. Furthermore, the shell does not have the outer characteristic layer of ornamentation as developed in the Japanese species.

Xitomitra tairai (Aita, 1987)
Figure 6.35–6.38

- 1987 *Stichomitra* (?) *tairai* Aita, p. 72, pl. 3, figs. 7a–9; pl. 10, figs. 3–4.
1989 *Stichomitra* (?) sp. cf. *S. tairai*; Okada et al., pl. 32, fig. 12.
1996 non *Stichomitra tairai*; Marcucci and Prella, pl. 2, fig. 14. [= *X. annibill*]
2002 *Stichomitra* (?) *tairai*; Bragin et al., fig. 6.19.
2002 *Stichomitra* (?) sp. aff. *S. (?) takanoensis* Aita; Bragin et al., fig. 6.20.
2003 *Stichomitra annibill* Kocher; Suzuki and Gawlick, figs. 6.35–6.36.

- 2005 *Stichomitra* (?) *tairai*; Šmuc and Goričan, pl. 4, fig. 23.
 2006 *Stichomitra* (?) *tairai*; O'Dogherty et al., p. 442, pl. 5, fig. 4–5.
 2006 *Stichomitra annibill*; Auer et al., fig. 6.37.
 2008 *Stichomitra annibill*; Auer et al., fig. 9.66.
 2009 *Stichomitra annibill*; Suzuki and Gawlick, fig. 5.16.

Remarks.—*Xitomitra tairai* is distinguished from its allied *X. annibill* by having a characteristic and delicate double layer of rhomboidal pore frames covering the post-thoracic segments. This ornamentation is specially marked on proximal segments, which fade out distally where very faint nodes tend to regularly cover the surface.

Xitomitra? sp. A
 Figure 6.55

Remarks.—This very small species is characterized by proximally conical to distally subcylindrical shell covered by a double-layered pore pattern similar to that of *X. tairai*. The specimen is questionably assigned to *Xitomitra* because it lacks the well-defined strictures and the thick large cephalis.

Order Spumellaria Ehrenberg, 1876
 'Actinommids with single medulary shell'
 Superfamily Actinommoidea Haeckel, 1862
 Family Pantanelliidae Pessagno, 1977b
 Subfamily Pantanelliinae Pessagno, 1977b

Genus *Pantanellium* Pessagno, 1977a

Type species.—*Pantanellium riedeli* Pessagno, 1977a.

Occurrence.—Upper Carnian to upper Aptian.

Pantanellium riedeli Pessagno, 1977a
 Figure 12.13–12.15

- 1977a *Pantanellium riedeli* Pessagno, p. 78, pl. 6, figs. 5–11.
 2006 *Pantanellium riedeli*; O'Dogherty et al., p. 460, pl. 11, figs. 9–14. [See for complete synonymy]

Genus *Gorgansium* Pessagno and Blome, 1980

Type species.—*Gorgansium silviesense* Pessagno and Blome, 1980.

Occurrence.—Upper Norian to upper Valanginian.

Gorgansium silviesense Pessagno and Blome, 1980
 Figure 12.5–12.6

- 1980 *Gorgansium silviesense* Pessagno and Blome, p. 235, pl. 11; figs. 2–3, 11, 24.
 1982 *Gorgansium silviesense*; Mizutani and Koike, pl. 1, fig. 3.
 1987 *Gorgansium silviesense*; Goričan, p. 182, pl. 3, fig. 4.
 2006 *Gorgansium silviesense*; O'Dogherty et al., p. 460, pl. 11, fig. 22.

'Actinommids with multiple medulary shell'
 Superfamily Pylonioidea Haeckel, 1881 emend Dumitrica, 1989
 Family Dactyliosphaeridae Squinabol, 1904
 Subfamily Hagiastriinae Riedel, 1971

Genus *Crucella* Pessagno, 1971

Type species.—*Crucella messinae* Pessagno, 1971.

Occurrence.—Lower Carnian to upper Campanian.

Crucella theokaftensis Baumgartner, 1980
 Figure 12.37

- 1980 *Crucella theokaftensis* Baumgartner, p. 308, pl. 8, figs. 19–22; pl. 12, fig. 1.
 2003 *Crucella theokaftensis*; Suzuki and Gawlick, p. 174, fig. 6.17.
 2006 *Crucella theokaftensis*; O'Dogherty et al., p. 464, pl. 12, fig. 16. [See for complete synonymy]

Subfamily Emiluviinae Dumitrica, 1995

Genus *Emiluvia* Foreman, 1973b

Neosophia Özdikmen 2009 pro *Sophia* Whalen and Carter in Carter et al., 1998 (preoccupied name).

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

Occurrence.—Lower Sinemurian to upper Valanginian.

Emiluvia salensis Pessagno, 1977a
 Figure 12.39–12.40

- 1977a *Emiluvia salensis* Pessagno, p. 77, pl. 5, figs. 9–11.
 1995b *Emiluvia salensis*; Baumgartner et al., p. 210, pl. 3215, figs. 1–3.
 2006 *Emiluvia salensis*; O'Dogherty et al., p. 468, pl. 12, figs. 12–15. [See for complete synonymy]

Emiluvia sedecimporata (Rüst, 1885)
 Figure 12.38

- 1885 *Staurosphaera sedecimporata* Rüst, p. 288, pl. 28(3), fig. 1.
 1994 *Emiluvia sedecimporata*; Goričan, p. 67, pl. 4, fig. 4.
 1995b *Emiluvia sedecimporata*; Baumgartner et al., p. 210, pl. 3216, figs. 1–3. [See for complete synonymy]
 1997 *Emiluvia sedecimporata*; Chiari et al., pl. 2, fig. 9.
 2004 *Emiluvia peteri* Beccaro, p. 16, fig. 4a; pl. 2, figs. 6–8.

Emiluvia? sp.
 Figure 12.41

Remarks.—This form is questionably assigned to *Emiluvia*. Similar forms have been assigned to *Staurolonche* Rüst, 1885 (e.g., *Staurolonche robusta*), but this genus must be considered as *nomen dubium* (O'Dogherty et al., 2009). Further taxonomic

studies are required in order to fix the taxonomic position of this species.

Family Patulibracchiidae Pessagno, 1971
Subfamily Angulobracchinae Baumgartner, 1980

Genus *Angulobracchia* Baumgartner, 1980

Type species.—*Paronaella? purisimaensis* Pessagno, 1977a.

Occurrence.—Upper Aalenian to lower Albian.

Remarks.—Includes generic concept of *Cavabracchia* Kito and De Wever, 1992.

Angulobracchia spp.
Figure 12.28–12.30

Remarks.—These forms are very rare and badly preserved in our material; hence they have not been studied in depth in this publication.

Genus *Paronaella* Pessagno, 1971

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

Occurrence.—Lower Rhaetian to upper Coniacian.

Paronaella kotura Baumgartner, 1980
Figure 12.33–12.34

1980 *Paronaella kotura* Baumgartner, p. 302, pl. 9, figs. 15–19; pl. 12, fig. 8.

2006 *Paronaella kotura*; O'Dogherty et al., p. 468, pl. 12, figs. 12–15. [See for complete synonymy]

Paronaella pristidentata Baumgartner, 1980
Figure 12.31

1980 *Paronaella pristidentata* Baumgartner, p. 304, pl. 9, fig. 7; pl. 12, fig. 3.

1992 *Paronaella pristidentata*; Steiger, p. 44, pl. 10, figs. 8–9.

1995b *Paronaella pristidentata*; Baumgartner et al., p. 396, pl. 3138, figs. 1–2.

1993 *Paronaella cleopatrensis* Pessagno, Blome, and Hull in Pessagno et al., p. 122, pl. 2, figs. 3, 25.

1997 *Paronaella pristidentata*; Yao, pl. 7, fig. 309.

2001 *Paronaella pristidentata*; Vishnevskaya, pl. 46, figs. 3–4; pl. 91, figs. 4–5.

2009 *Paronaella pristidentata*; Nishihara, pl. 8, fig. 186.

Subfamily Patulibracchiinae Pessagno, 1971

Genus *Homoeoparonaella* Baumgartner, 1980

Type species.—*Paronaella elegans* Pessagno, 1977a.

Occurrence.—Upper Sinemurian to upper Cenomanian.

Homoeoparonaella elegans (Pessagno, 1977a)
Figure 12.32

1977a *Paronaella elegans* Pessagno, p. 70, pl. 1, figs. 10–11.

1995b *Homoeoparonaella elegans*; Baumgartner et al., p. 272, pl. 3104, figs. 1–5. [See for complete synonymy]

1999 *Homoeoparonaella elegans yangi* Kiessling, p. 32, pl. 6, figs. 13–14, 16.

2008 *Homoeoparonaella elegans*; Beccaro et al., pl. 1, fig. 22.

Homoeoparonaella spp.
Figure 12.35–12.36

Remarks.—Our specimens are badly preserved, with ray tips broken off, therefore determination at species level is not possible.

Family Pseudoaulophacinae Riedel, 1967

Genus *Alievium* Pessagno, 1972

Type species.—*Theodiscus superbus* Squinabol, 1914.

Occurrence.—Upper Bajocian to upper Maastrichtian.

Alievium? sp. aff. *A. crassum* (Kiessling, 1999)
Figure 12.9

1999 *Tripocyclia crassa* Kiessling, p. 40, pl. 8, figs. 14, 22.

Remarks.—Our specimen has shorter spines and somewhat larger nodes on the surface than the Antarctic specimens. The genus is queried because the name *Tripocyclia* is not valid (*nomen dubium* see O'Dogherty et al., 2009, p. 288) and these forms belong to a new genus not described yet.

Alievium? longispineum Yang and Wang, 1990
Figure 12.7–12.8

1990 *Alievium longispineum* Yang and Wang, p. 204, pl. 2, figs. 2, 4.

Remarks.—This form has high generic affinity with the previous species and the genus is queried for the same reasons.

Family Tritabidae Baumgartner, 1980

Genus *Tritrabs* Baumgartner, 1980

Type species.—*Paronaella? casmaliaensis* Pessagno, 1977a.

Occurrence.—Lower Aalenian to lower Aptian.

Tritrabs ewingi (Pessagno, 1971)
Figure 12.24–12.27

1971 *Paronaella (?) ewingi* Pessagno, p. 47, pl. 19, figs. 2–5.

2006 *Tritrabs ewingi*; O'Dogherty et al., p. 472, pl. 11, figs. 37, 43. [See for complete synonymy]

Superfamily Sponguroidea Haeckel, 1862
Family Archaeospongoprunidae Pessagno, 1973

Genus *Archaeospongoprunum* Pessagno, 1973

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

Occurrence.—Upper Permian to upper Campanian.

Archaeospongoprunum elegans Wu, 1993
Figure 12.10–12.12

1993 *Archaeospongoprunum elegans*, p. 118, pl. 1, figs. 5, 7, 23.

1997 *Archaeospongoprunum* aff. *elegans* Wu; Hull, p. 27, pl. 8, figs. 4, 9, 18–19.

2001 *Archaeospongoprunum* sp. Nishizono, pl. 1, fig. 3.

2002 *Archaeospongoprunum elegans*; Beccaro et al., pl. 1, fig. 22.

2006 *Archaeospongoprunum elegans*; O'Dogherty et al., p. 472, pl. 11, figs. 24–25.

Remarks.—*Archaeospongoprunum elegans* differs from *A. imlayi* Pessagno, by its subrectangular shape and massive spines with prominent subsidiary grooves. We considered specimens showing slightly torsioned spines distally to be included in this species (see Fig. 12.11–12 and Hull's 1997 material).

Family Bernoulliidae Pessagno, Blome, and Hull in Pessagno et al., 1993

Genus *Bernoullius* Baumgartner, 1984

Type species.—*Eucyrtis ? dicera* Baumgartner in Baumgartner et al., 1980.

Occurrence.—Lower Toarcian to lower Aptian.

Bernoullius cristatus Baumgartner, 1984
Figure 12.4

1984 *Bernoullius cristatus* Baumgartner, p. 760, pl. 2, figs. 14–15.

1993 *Bernoullius cristatus*; Pessagno et al., p. 119, pl. 1, fig. 14.

1995b *Bernoullius cristatus*; Baumgartner et al., p. 122, pl. 3221, figs. 1–3.

2003 *Bernoullius cristatus*; Suzuki and Gawlick, p. 172, fig. 5.10. [See for complete synonymy]

Superfamily Saturnaloidea Deflandre, 1953

Family Saturnalidae Deflandre, 1953

Subfamily Hexasaturnalinae Kozur and Mostler, 1983

Genus *Hexasaturnalis* Kozur and Mostler, 1983

Type species.—*Spongosaturnalis ? hexagonus* Yao 1972.

Occurrence.—Middle Toarcian to upper Valanginian.

Remarks.—Includes generic concepts of *Kozurastrum* De Wever, 1984 and *Yaosaturnalis* Kozur and Mostler, 1983.

Hexasaturnalis minor (Baumgartner in Baumgartner et al., 1995b)
Figure 12.23

1995b *Acanthocircus suboblongus minor* Baumgartner in Baumgartner et al., p. 66, pl. 3085, only fig. 1–3, not fig. 4 (*H. nakasekoi*)

2005 *Hexasaturnalis minor*; Dumitrica and Dumitrica-Jud, pl. 2, figs. 6, 9–13.

2008 *Hexasaturnalis minor*; Beccaro et al., pl. 1, fig. 18.

Hexasaturnalis nakasekoi Dumitrica and Dumitrica-Jud 2005
Figure 12.19–12.20

2005 *Hexasaturnalis nakasekoi* Dumitrica and Dumitrica-Jud, p. 161, pl. 1, figs. 3–13; pl. 2, figs. 1–4, 7–8. [See for complete synonymy]

2006 *Hexasaturnalis nakasekoi*; O'Dogherty et al., p. 473, pl. 12, fig. 31. [See for complete synonymy]

2008 *Hexasaturnalis minor*; Beccaro et al., pl. 1, fig. 19.

Hexasaturnalis suboblongus (Yao, 1972)
Figure 12.21–12.22

1972 *Spongosaturnalis (?) suboblongus* Yao, p. 29, pl. 3, figs. 1–6; pl. 10, figs. 3a–c.

1995b *Acanthocircus suboblongus suboblongus*; Baumgartner et al., p. 68, pl. 3088, fig. 2–4, non fig 1 [= *H. nakasekoi*].

2005 *Hexasaturnalis suboblongus*; Dumitrica and Dumitrica-Jud, pl. 1, figs. 1–2.

2013 *Hexasaturnalis suboblongus*; Chiari et al., p. 411, fig. 12r.

Hexasaturnalis tetraspinus (Yao, 1972)
Figure 12.16–12.18

1972 *Spongosaturnalis? tetraspinus* Yao, p. 29, pl. 4, figs. 1–6; pl. 11, figs. 1–2.

1995b *Hexasaturnalis tetraspinus* (Yao); Baumgartner et al., p. 254, pl. 3089, figs. 1–3.

2006 *Hexasaturnalis tetraspinus*; Goričan et al., p. 190, pl. 3089, figs. 1–5. [See for complete synonymy]

2013 *Hexasaturnalis tetraspinus*; Chiari et al., fig. 12s.

Table 2. Assigned ages and zones of studied samples.

| Locality | Sample Number | UAZone | Assigned Age |
|----------|---------------|--------|------------------------------------|
| EW | 158 | 5 | latest Bajocian–early Bathonian |
| BMW | 28 | 5 | latest Bajocian–early Bathonian |
| BMW | 32 | 7 | late Bathonian–early Callovian |
| BMW | 34 | 7 | late Bathonian–early Callovian |
| BMW | 31 | 5–7 | latest Bajocian–early Callovian |
| BMW | 30 | 8–9 | middle Callovian–late Oxfordian |
| BMW | 35 | 9–11 | middle Oxfordian–late Kimmeridgian |
| BMW | 33 | 12 | early–early late Tithonian |
| BMW | 26 | 5 | latest Bajocian–early Bathonian |
| BMW | 13b | 5 | latest Bajocian–early Bathonian |
| BMW | 13c | 8 | middle Callovian–early Oxfordian |

Age of radiolarian samples

In this section, we present the radiolarian age and results obtained for the Hallstatt Mélange in four localities at Bad Mitterndorf area (Table 2). Only the stratigraphically most important species are discussed. For the complete inventory of all samples, see Table 1.

Kumitzberg.—In this area, the massive dark-gray radiolarite beds (sample EW-158) are intercalated by thin layers of cherty shales. The co-occurrence of *Unuma latusicostatus* (Aita) with *Bernoullius cristatus* Baumgartner (Table 1) suggests assignment to UAZ 5 (latest Bajocian–early Bathonian) of Baumgartner et al. (1995a). *Pantanellium riedeli* Pessagno, which first appears in UAZ 7, was also found. This species has a very large variability that overlaps with other *Pantanellium* species. Its range is thus ignored in the age determination.

Steinwand north.—In this area two sections accurately determine the age of the radiolarite succession. The most complete section, in the northeastern part of the syncline structure (Fig. 4), records continuous radiolarite deposition from Bathonian to the Oxfordian. The lowermost part of the radiolarite succession (near the entrance of the valley, sample BMW-28, Fig. 4) yielded a radiolarian assemblage of latest Bajocian–early Bathonian age (UAZ 5 of Baumgartner et al., 1995a), defined on the co-occurrence of *Protunuma ochiensis* Matsuoka with *Unuma latusicostatus* (Aita). The conflicting range of *Pantanellium riedeli* Pessagno (UAZ 7–12) was ignored for the same reason as in the aforementioned sample EW-158 from Kumitzberg.

The youngest part of the succession is preserved in the core of the syncline (sample BMW-35, Fig. 4) and yielded a radiolarian assemblage of middle–late Oxfordian to late Kimmeridgian–early Tithonian age (UAZs 9–11 of Baumgartner et al., 1995a), based on the occurrence of *Archaeodictyomitra minoensis* (Mizutani), *Zhamoidellum ovum* Dumitrica, and *Emiluvia sedecimporata* (Rüst). The interval between these two ages was also recognized. UAZ 7 (late Bathonian–early Callovian) or UAZ 8 (middle Callovian–early Oxfordian) was determined in samples BMW-32 and BMW-34. *Striatojaponocapsa conexa* (Matsuoka) in sample BMW-32 and *Preawilliriedellum robustum* (Matsuoka) in sample BMW-34 suggest that these two samples are not younger than UAZ 7, but *Gongylothorax favosus* Dumitrica, which first occurs in UAZ 8 is also associated.

At the end of the valley is located the second stratigraphic section outcropping in this area. The radiolarian assemblage in the youngest investigated sample (BMW-33) indicates a Tithonian age. Early–early late Tithonian UAZ 12 is inferred from the co-occurrence of *Eucyrtidiellum pyramis* (Aita in Aita and Okada) with *Protunuma japonicus* Matsuoka and Yao.

Area between Krautmoos and Mischenirwiese.—The thick succession of mass-flow deposits in this area is dated by the assemblages studied in the intercalated radiolarite matrix. The radiolarite sample BMW-26 collected below the first debris-flow deposit is dated latest Bajocian–early Bathonian age (UAZ 5

of Baumgartner et al., 1995a). This age is constrained with *Semihsum amabile* (Aita), *Saitoum trichylum* De Wever, and *Mizukidella kamoensis* (Mizutani and Kido). The same age (UAZ 5) was obtained from a chert clast (sample BMW-13b) in the upper part of the succession. The age-diagnostic species in this clast are *Theocapsomella cordis* (Kocher), *Eucyrtidiellum pustulatum* Baumgartner, and *Unuma latusicostatus* (Aita). The matrix between the chert clasts (sample BMW-13c) yielded a significantly younger radiolarian fauna of middle Callovian–early Oxfordian age (UAZ 8 of Baumgartner et al., 1995a), as indicated by co-occurrence of *Spinocapsa spinosa* (Ožvoldová) with *Hemicryptocapsa marcucciae* (Cortese).

As proven by radiolarian dating, the resedimentation of the Hallstatt Limestone started in the region of Bad Mitterndorf area since the Bathonian and prevailed at least until the Oxfordian. The area of the Hallstatt Limestone mass flows and slide blocks is separated from the coeval radiolarite succession without mass-flow deposits (the Steinwand section) by a younger thrust or fault.

Discussion

The time span of deposition of the radiolarite basin, which contains the far-traveled Hallstatt Limestone blocks, is determined as Bathonian to Oxfordian. Redeposition started in the ?late Bathonian and ended in the Oxfordian, as proven by the radiolarite matrix age and the age of the overlying sediments (O'Dogherty and Gawlick, 2008). Radiolarian ages and component spectrum define this redeposit as part of the Sandlingalm Basin (Sandlingalm Formation: Fig. 2), one of the oldest basins formed in a relative early stage of compression of the Neotethys (see Gawlick et al., 2007a, 2009, 2012; Missoni and Gawlick, 2011b for details).

The depositional areas of the radiolarites of the section Steinwand-Mischenirwiese (Fig. 4) mass flows are missing. In the more northern areas of the Northern Calcareous Alps (Fig. 3), radiolarite deposition starts relatively early, indicating an early deepening event due to the tectonic load of the advancing Hallstatt nappes. First imbricates started to form in the Bathonian–Callovian (I and II in Fig. 5), as indicated by age dating of the matrix radiolarites. In the Oxfordian (III–IIIa in Fig. 5) the mass flows also contain components of the older radiolarite “mélange” basins and the section Mischenirwiese attained a more basal position, as indicated by the sedimentological features of the radiolarite succession. In the late Oxfordian the nappe front reached the depositional area of the Mischenirwiese section, as shown in the overlying mélange (IV in Fig. 5). In the Kimmeridgian–Tithonian, nappe propagation stopped and the nappe stack was sealed by a carbonate platform. In the Kimmeridgian, coarse reefal debris was shed into this deep-water basin (O'Dogherty and Gawlick, 2008) with a general fining-upward trend. Due to uplift and demise of the southern Platform in the late Tithonian (Fig. 5; Gawlick and Missoni 2011a), only fine-grained siliceous limestones were deposited in the basin, as proven with radiolarian dating in this study (see the youngest radiolarian sample of the Steinwand locality).

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