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GEOLOGIE UND PALÄONTOLOGIE

An Early Cretaceous radiolarian assemblage: palaeoenvironmental and palaeoecological implications for the Northern Calcareous Alps (Barremian, Lunz Nappe, Lower Austria)

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(With 4 text-figures and 12 tables)

Abstract

Detailed palaeontological and lithological studies of Lower Cretaceous sediments from Lower Austria uncovered spectra of Lower Barremian microfaunal elements, among them radiolarians. Lower Barremian radiolarians are figured for the first time from the Northern Calcareous Alps. The radiolarian assemblage from Sparbach was obtained from marly limestone beds of the *Karsteniceras* Level. The Early Barremian level is dominated by the ammonoid *Karsteniceras ternbergense* (*Coronites darsi* Zone). The geochemical results (TOC, S, and $CaCO_3$), combined with preservational features (e.g. different pyritization stages) of the radiolarian fauna, indicate that the *Karsteniceras* Level was deposited under oxygen-depleted conditions. These conditions, show eutrophic peaks and produce mass occurrences of pyritized radiolarians in laminated, dark sediments.

Key words: Radiolarians – Early Cretaceous (Early Barremian) – Northern Calcareous Alps

Zusammenfassung

Detailierte paläontologische und lithologische Untersuchungen an unterkretazischen Sedimentgesteinen Niederösterreichs erbrachten reiche Spektren an Mikrofossilien, besonders an Radiolarien. Radiolarien des Unter-Barremium werden zum ersten mal aus den Nördlichen Kalkalpen abgebildet und detailiert beschrieben. Die Radiolarien Vergesellschaftung wurde aus mergeligen Kalksteinen des *Karsteniceras*-Levels gewonnen. Das Unter-Barremium Level (*Coronites darsi* Zone) wird vom Ammoniten *Karsteniceras ternbergense* dominiert. Die geochemischen Ergebnisse (TOC, S, und $CaCO_3$) kombiniert mit den verschiedenen Erhaltungszuständen der Radiolarien, dokumentieren ein Sauerstoff-reduziertes Milieu zur Zeit der Ablagerung dieser Sedimentschichten. Die Bedingungen zeigen eutrophische Spitzen, woraus Massenvorkommen von pyritisierten Radiolarien in dunklen, laminierten Sedimenten abgelagert wurden.

Schlüsselworte: Radiolarien – Unterkreide (Unter-Barremium) – Nördliche Kalkalpen

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Introduction

Lower Cretaceous pelagic sediments cover wide areas within the Northern Calcareous Alps and form a major element of this alpine part the northernmost tectonic units (e.g. Frankenfels, Lunz, Ternberg, and Reichraming Nappes). They are mostly exposed within synclines as represented from east to west by the Flössel, Losenstein, Schneeberg, Anzenbach, Ebenforst and Rossfeld Synclines. The most recent publications by FAUPL et al. (1994), IMMEL (1987), LUKENEDER (1998, 1999, 2001, 2003a, b, 2004a, b, c, d, 2005a, b), LUKENEDER & HARZHAUSER 2003) and VAŠÍČEK & FAUPL (1998) deal with the stratigraphy of the latter synclines in the Reichraming, Frankenfels and Lunz Nappes.

The Early Cretaceous of the Flössel Syncline is considered to range from the Late Valanginian to the Early Barremian (LUKENEDER 2005b). The discovery of a Lower Cretaceous ammonoid mass-occurrence in the Flössel Syncline (Lunz Nappe, Northern Calcareous Alps, Lower Austria), of Early Barremian age, was recently published by LUKENEDER (2005b). The latter occurrence (*Karsteniceras* Level) is dominated by the heteromorph ancyloceratid *Karsteniceras*. An invasion of an opportunistic (r-strategist) *Karsteniceras* biocoenosis during unfavourable conditions over the sea-bed during the Early Barremian was proposed for the Sparbach section. As noted by LUKENEDER (2003b), the limestone deposition during this interval occurred in an unstable environment and was controlled by short- and long-term fluctuations in oxygen levels.

This paper focuses on a detailed description and stratigraphy of the known ammonoid zonation (LUKENEDER 2005b) correlated with new microfossil data. Radiolarian preservation and abundance reflect primary environmental conditions, and the described radiolarian fauna is therefore also investigated with respect to environmental patterns. Note, however, that radiolarian abundance and preservation depend on many factors, e.g. nutritional status of the sea-water surface and the amount of dissolution during sinking to the sea floor and in the sediment.

In dealing with the systematics and stratigraphy of Lower Cretaceous radiolarian faunas (mostly Europe) we refer to the extensive and accurate papers of BAK (1999), BAUMGARTNER (1984), BAUMGARTNER et al. (1995), GORIČAN (1994), JUD (1994), O'DOGHERTY (1994), SCHAAF (1984) and DE WEVER et al. (2000). Most of these papers also deal with biological, ecological and taphonomic issues. The most detailed compendium of the Jurassic and Lower Cretaceous radiolarian systematic framework was published by BAUMGARTNER et al. (1995), and their book remains state of the art even today.

Specific investigations on microfacies and changing environmental conditions during the Upper Jurassic and Lower Cretaceous within the Northern Calcareous Alps and adjacent areas in the Carpathians were undertaken by BOOROVÁ et al. (1999), ONDREJÍČKOVÁ et al. (1993), OŽVOLDOVÁ (1990), OŽVOLDOVÁ & PETERČÁKOVÁ (1992), PETERČÁKOVÁ (1990), REHÁKOVÁ (2000), REHÁKOVÁ et al. (1996), and VAŠÍČEK et al. (1994).

Study area and tectonic position

The outcrop is situated in the Frankenfels-Lunz Nappe System (Höllenstein Unit) in Lower Austria, about 1.5 km north of Sparbach (350 m, ÖK 1:50 000, sheet 58 Baden;

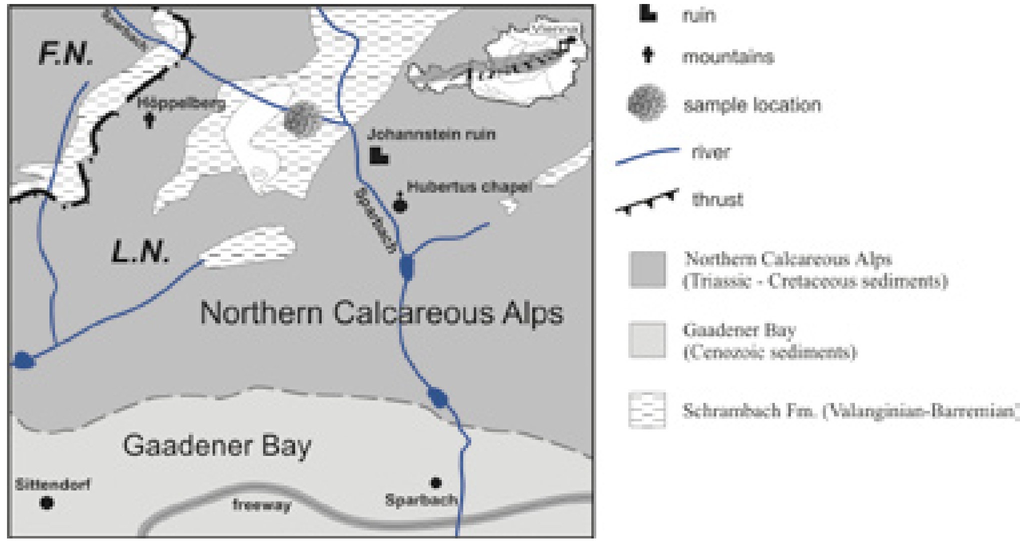

Fig. 1: Sketch map of the excavation site N of Sparbach and the geological situation and sediments of the Flössel Syncline. The Upper Austroalpine Northern Calcareous Alps extend from the Austrian western border to the city area of Vienna. Map after ÖK 1:50 000, sheet 58 Baden, Geological Survey Vienna, SCHNABEL 1997). F.N. = Frankenfels Nappe, L.N. = Lunz Nappe.

Fig. 1; SCHNABEL 1997). This outcrop is located in the south-easternmost part of the northeast-southwest striking Flössel Syncline, running between the Höppelberg (700 m) to the west and near the Heuberg (680 m) to the east. It lies at the southern side of the Sparbach stream, 300 m west of the Johannstein ruin within the nature park of Sparbach. The exact position of the radiolarian-occurrence was determined by GPS (global positioning system): N 48°05'15" and E 16°11'00" (Fig. 1).

The fossiliferous beds (metre 160, 0.3 m thickness, dipping 320/40°) are part of the Schrambach Formation (PILLER et al. 2004) within the Flössel Syncline (see TOULA 1886; RICHARZ 1905, 1908; SPITZ 1910; SCHWINGHAMMER 1975). The Flössel Syncline is formed of Upper Triassic dolomite, followed by a reduced Jurassic sequence (see also ROSENBERG 1965; PLÖCHINGER & PREY 1993). The core of the Flössel Syncline consists of the Lower Cretaceous Schrambach Formation, which occurs throughout the Northern Calcareous Alps. Within the Lunz Nappe the Schrambach Formation comprises Upper Valanginian to Lower Barremian sediments.

Lithology

The Lower Cretaceous Schrambach Formation is a sequence of limestones and marls marked by rhythmically intercalated turbiditic sandstones, sedimented under relatively deep-water conditions (LUKENEDER 2003a). A short-term sedimentation is proposed for the sandstone layers, whereas the limestone- and marl-beds reflect 'normal' sedimentation rates. Dark marls and grey, spotted limestones are highly bioturbated biogenic mudstones to wackestones (LUKENEDER 2005b).

The distinct-laminated appearance of the rock is a result of wispy, discontinuous, flaser-like laminae of dark (organic) material and some sorting of radiolarian tests into the layers. Many of these tests have been partly to completely replaced by pyrite (secondarily limonitic) in a micritic carbonate matrix. Pyritized radiolarians seem to be predominantly preserved around ammonoid tests. This could be due to the altered 'micro-environment', specifically the higher organic content (soft-body). The laminae range in thickness from 0.07–0.1 mm to 0.7–2.4 mm. Contacts between them are gradational to sharp. Phosphatic debris is abundant and consists mainly of fish scales, bones and teeth. Laminated brown-black mudstone is rich in organic carbon. Dark material is wispy amorphous organic matter. Pale areas are laminae of flattened radiolaria now replaced by microcrystalline chalcedony.

Thin sections: 0 not laminated mudstone; 1a distinct laminated mudstone; 1b laminated mudstone; 2a–2c distinct laminated mudstone; 3a slightly bioturbated mudstone.

Constituent parts of marly limestones are: predominantly calcified radiolarians impregnated by Fe minerals, calcified sponge spicules, ostracods, rare bivalve fragments, rare roveacrinids, crinoid ossicles, fragments of fish (scales, teeth and bones, ichthyoliths), planktonic foraminifers (*Favusella* sp.) and benthic foraminifers (*Patellina* sp.). Small disintegrated floral fragments are also distributed in the matrix, along with framboidal pyrite, organic matter accumulated in the nests and very rare glauconite grains. Carefully selected and washed samples of distinct laminated limestones primarily contain fine silt-sized, angular quartz grains, some pyrite and phosphatic material.

The calcium carbonate contents within the radiolarian beds (K1 and K2) ($CaCO_3$ equivalents calculated from total inorganic carbon) vary between 73 and 83 %. The weight % TOC (Total Organic Carbon) values vary between 0.03 and 0.52 %. Sulphur ranges from 0.27 to 0.57 mg/g (Fig. 4).

Material and radiolarian fauna

Bed-by-bed collecting and a systematic-taxonomic approach provided the basic data for statistical analysis of the radiolarian faunas. Palaeontological and palaeoecological investigations, combined with studies of lithofacies in thin sections, peels from polished rock surfaces and geochemical investigations, yielded information about the environmental conditions in the area of deposition.

Radiolarian assemblages were extracted from the marly limestone by dissolution in the 12 % acetic acid (5 days). After sieving through a 40 µm screen and drying, the residue was prepared for removal of specimens under a binocular microscope. Species were determined using SEM.

The most abundant assemblage, obtained from sample 1a, comprises 10 species of radiolarians belonging to the order Nassellaria and 7 species to the Spumellaria (Fig. 2). The assemblage is dominated by the species *Holocryptocanium barbui* Dumitrica, a representative of spherical cryptothoracic and cryptocephalic Nassellaria from the family *Williriedellidae*. The assemblage also includes the nassellarians *Crolanium puga* (Schaaf), *Cryptamphorella clivosa* (Aliev), *Dibolachras tytthopora* Foreman, *Dictyomitra pseudoscalaris* (Tan), *Hiscocapsa asseni* (Tan), *Pseudodictyomitra lilyae* (Tan), *Sethocapsa dorysphaeroides* (Neviani), *Sethocapsa orca* Foreman, *Thanarla*

Fig. 2: Radiolarian spectrum from the Sparbach locality. Note the dominance of the genus *Holocryptocanium* (Nassellaria).

brouweri (Tan) and *Xitus clava* (Parona). Spumellarians, which are less common, are represented by *Acaeniotyle diaphorogona* Foreman, *Acaeniotyle umbilicata* (Rüst), *Archaeospongoprunum patricki* Jud, *Pantanellium squinaboli* Tan, *Paronaella cf. trifoliacea* Ožvoldová, *Suna hybum* (Foreman) and by the genus *Praeconosphaera* sp., the latter being predominant. The radiolarians are pyritized, which is a common condition in Lower Cretaceous literature (Bak 1995, 1996; Ožvoldová 1990; Pessagno 1977; Thurow 1988) but not well understood until the recent paper of Bak & Sawlowicz (2000).

The macrofauna from bed K1 (beds 1–2; samples 1a–2c) and K2 (bed A; sample Aa) is predominated by sculpture-moulds of cephalopods which are described by Lukeneder (2005b). The *Karsteniceras* Level at Sparbach yields important ammonoid taxa such as *Eulytoceras* sp., *Barremites (Barremites)* cf. *difficilis*, *Pulchellia* sp., *Holcodiscus* sp., *Anahamulina* cf. *subcincta* and *Karsteniceras ternbergense*. The cephalopod fauna is accompanied by aptychi (*Lamellaptychus*) and bivalves (*Propeamusium*).

The analysis of the fauna supports the interpretation of a soft to level bottom palaeoenvironment with a cephalopod-dominated community living near the epicontinental (epeiric) sea floor (Lukeneder 2005b).

Biostratigraphy

The ammonoid association indicates that the cephalopod-bearing beds in the Schrambach Formation belong to the latest Early Barremian (probably to the *Moutoniceras moutonianum* ammonoid Zone; according to the results of the Vienna meeting of the Lower Cretaceous Ammonite Working Group of the IUGS; Hoedemaeker & Rawson 2000). The *M. moutonianum* Zone was recently replaced (based on the Lyon meeting of the Lower Cretaceous Ammonite Working Group of the IUGS) by the *Coronites darsi* Zone (Hoedemaeker et al. 2003) (Fig. 3). Although *Moutoniceras moutonianum* and *Coronites darsi* are missing, the typical association hints at the latest Early Barremian. The radiolarian fauna of the Schrambach Formation belongs to the *Coronites darsi* ammonite Zone of the latest Early Barremian (Hoedemaeker et al. 2003; Lukeneder 2001). The biostratigraphic evaluation of radiolarian assemblages was based on the biozonation of Baumgartner et al. (1995). The composition of the association represents the longer stratigraphic range Early Hauterivian–earliest Late Aptian (sensu Baumgartner et al. 1995).

BARREMIAN	Upper	*P. waagenoides*	
		C. sarasini	
		I. giraudi	
		H. feraudianus	
		G. sartousiana	*G. provincialis*
			G. sartousiana
		A. vandenheckii	
	Lower	*C. darsi*	
		K. compressissima	
		N. pulchella	
		K. nicklesi	
		T. hugii auct.	

Fig. 3: Stratigraphic position within the Early Barremian (*C. darsi* Zone) of the Sparbach fauna (in grey). Table modified after HOEDEMAEKER et al. (2003).

Discussion and conclusions

The microfauna of the Lower Cretaceous beds in the Sparbach succession (Flössel Syncline) is represented especially by radiolarians. The abundance of pyritized radiolarian tests is restricted to the distinctly laminated beds. The radiolarian assemblage encompasses a stratigraphic range from Early Hauterivian - earliest Late Aptian. The stratigraphic investigation of the accompanying ammonoid fauna constricts the range and reveals that the investigated part of the Sparbach section comprises Lower Barremian sediments.

The geochemical results indicate that the assemblage was deposited under conditions of intermittent oxygen-depletion associated with stable water masses. The process was controlled by short- and long-term fluctuations in oxygen content, coupled with a poor circulation of bottom-water currents within an isolated, basin-like region. The brighter colour of the sediment and the lower content of TOC and sulphur at the Sparbach section indicate a less dysoxic environment than in comparable, darker beds elsewhere in the Northern Calcareous Alps (e.g. KB1-B, Upper Austria). No evidence for condensation can be found.

Nassellarians dominate the radiolarian assemblage, whereby the genera *Holocryptocanium, Sethocapsa, Thanarla, Dictyomitra* and *Xitus* are the most important taxa. The assemblage is characterized by little diversification but specimen richness. *Holocryptocanium barbui* DUMITRICA is the dominant species.

Holocryptocanium barbui DUMITRICA is a cryptocephalic and cryptothoracic representative of the family *Williriedellidae*; along with the thick-walled forms of the genus *Praeconosphaera*, they hint to a deep-water fauna. The latter forms predominate over the spumellarians, which show spiny tests (e.g. *Acaeniotyle umbilicata, Pantanellium squinaboli*) and indicate shallower levels in the water column.

BARTOLINI et al. (1999) showed that the reproductive rate of deep-water populations is much higher when mixed water layers containing a high nutrient supply prevail. Such conditions are proposed for the investigated radiolarian mass occurrence at Sparbach. We therefore assume that the radiolarian association at Sparbach indicates eutrophic conditions and a high flux of organic matter towards the sea-bottom. This is supported by the geochemical and faunal data given by LUKENEDER (2005b) for the same beds.

The spumellarian/nassellarian ratio of the Sparbach assemblage shows that nassellarians markedly dominate in specimen numbers and species occurrence versus spumellarians.

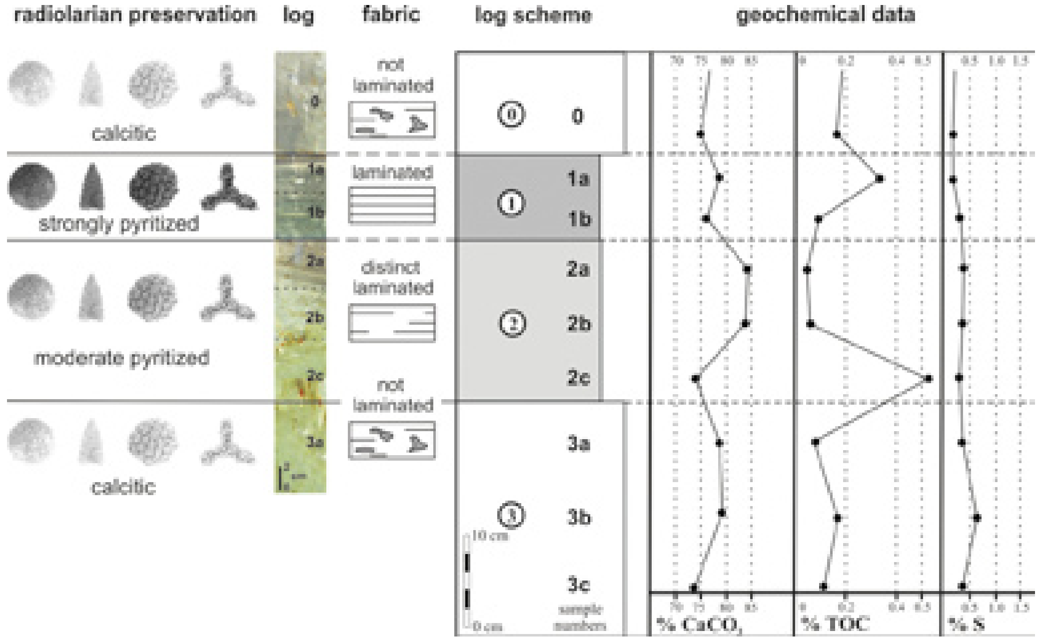

Fig. 4: The different preservational features of the radiolarian fauna. Correlated with the original log (longitudinal scan of the polished surface), the sediment fabric (laminated, distinct laminated and not laminated), and the geochemical parameters from the Sparbach section within and around the *Karsteniceras* Level.

From HAECKEL's time (1873–1887) up to the present, the opinion has been maintained that spumellarians are more abundant in shallow waters and nassellarians prefer deeper water and/or oceanic conditions. BARTOLINI et al. (1999), however, pointed out that the spumellarian/nassellarian ratio is a more complex issue in which many factors such as nutrient quantity, temperature and salinity gradients play a role.

Based on the described features from the Sparbach section, radiolarians show abundance peaks during times of oxygen depletion at the sea floor. We conclude that "plankton blooms" (e.g. radiolarian blooms) at the sea-water surface induced a drop in the oxygen content of deeper water layers at the sea floor. The increasing content of biogenic particles at the sea floor leds to oxygen depletion in such phases. Note that the abundance peaks of radiolarians and their increasing pyritization are associated with strong lamination and peaks in TOC (Fig. 4).

Dark, laminated deposits are preferentially enriched in radiolarians. We therefore suggest that phases of high nutrient availability and primary productivity are a motor for the formation of such radiolarian-rich, dark, laminated sediments. A distal, deeper environmental position of the accumulation site is assumed, and the facies point to eutrophication of the overlying water mass. BAK & SAWLOWICZ (2000) discussed the significance and the preservation of pyritized radiolarians. The pyritization of radiolarians described herein is too weak to presume formation while floating within the anoxic water column. Thise pyritization most probably took place on the sea floor and/or in the sediment. This supports the results of LUKENEDER (2005b), who proposed – in his recent investigations on the laminated sediments of the same locality – a low-oxygen environment combined with decreasing bottom-current activity.

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Plate 1

All specimens figured on plate 1 are Spumellaria from bed **1a**, except Fig. 9 which belongs to Nasselaria.

Fig. 1: *Paronaella* cf. *trifoliacea* OŽVOLDOVÁ – × 120

Figs. 2, 3: *Praeconosphaera* sp. – × 180

Fig. 4: *Pantanellium squinaboli* TAN – × 100

Fig. 5: *Archaeospongoprunum patricki* JUD – × 120

Fig. 6: *Suna hybum* (FOREMAN) – × 120

Fig. 7: *Acaeniotyle umbilicata* (RÜST) – × 125

Fig. 8: *Acaeniotyle diaphorogona* FOREMAN – × 130

Fig. 9: *Dibolachras tytthopora* FOREMAN – × 120

All specimens were collected at the Sparbach section, coated with gold before photographing (REM) and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0001 (REM stub).

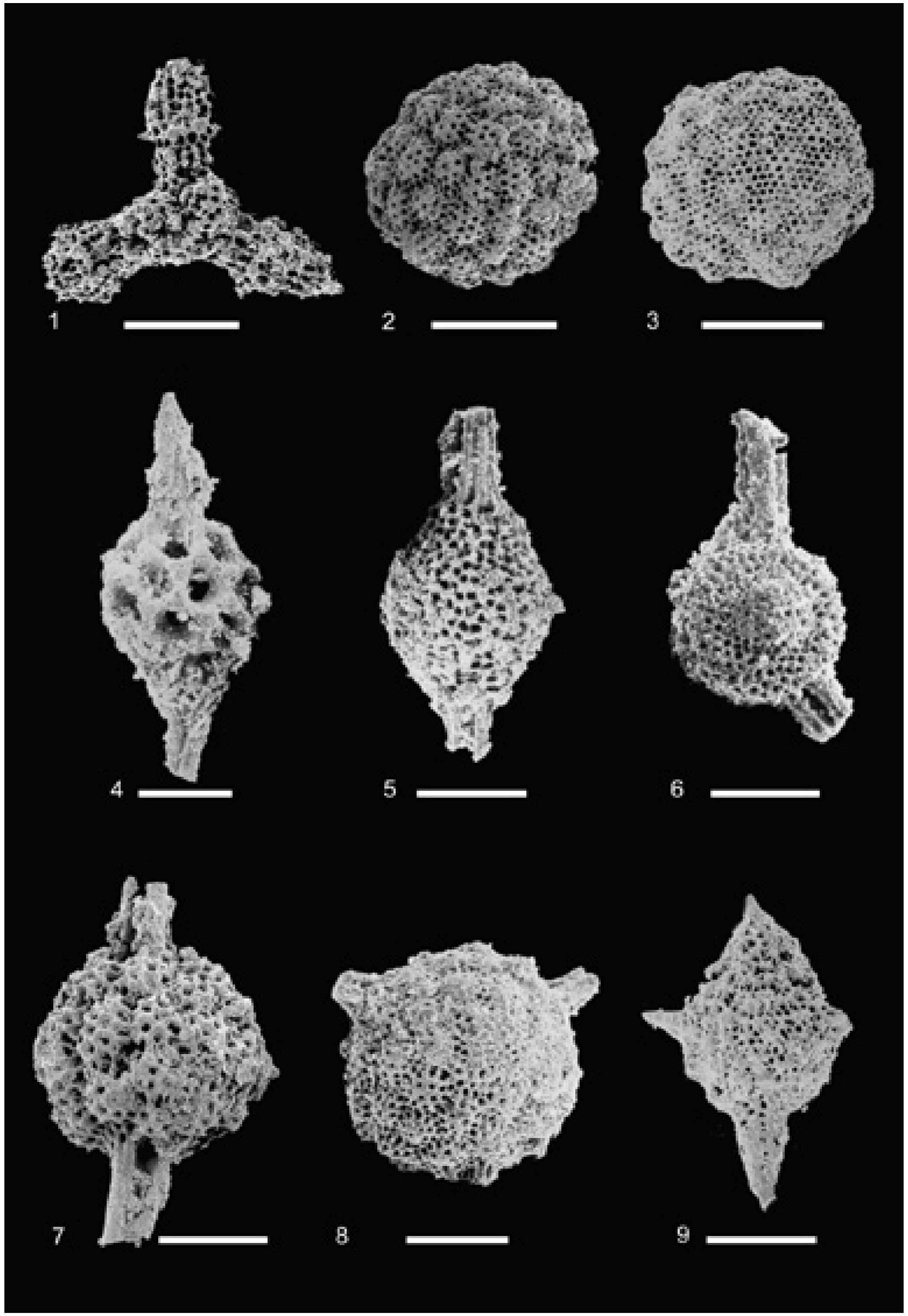


Plate 2

All specimens figured on plate 2 are Nasselaria from bed **1a**.

Fig. 1: *Pseudodictyomitra lilyae* (TAN) – × 130

Fig. 2: *Dictyomitra pseudoscalaris* (TAN) – × 120

Fig. 3: *Xitus clava* (PARONA) – × 110

Fig. 4: *Crolanium puga* (SCHAAF) – × 110

Fig. 5: *Thanarla brouweri* (TAN) – × 130

Fig. 6: *Sethocapsa orca* FOREMAN – × 110

Fig. 7: *Cryptamphorella clivosa* (ALIEV) – × 125

Fig. 8: *Sethocapsa dorysphaeroides* (NEVIANI) – × 125

Fig. 9: *Hiscocapsa asseni* (TAN) – × 160

Fig. 10, 11: *Holocryptocanium barbui* DUMITRICA – × 160

All specimens were collected at the Sparbach section, coated with gold before photographing (REM) and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0001 (REM stub).

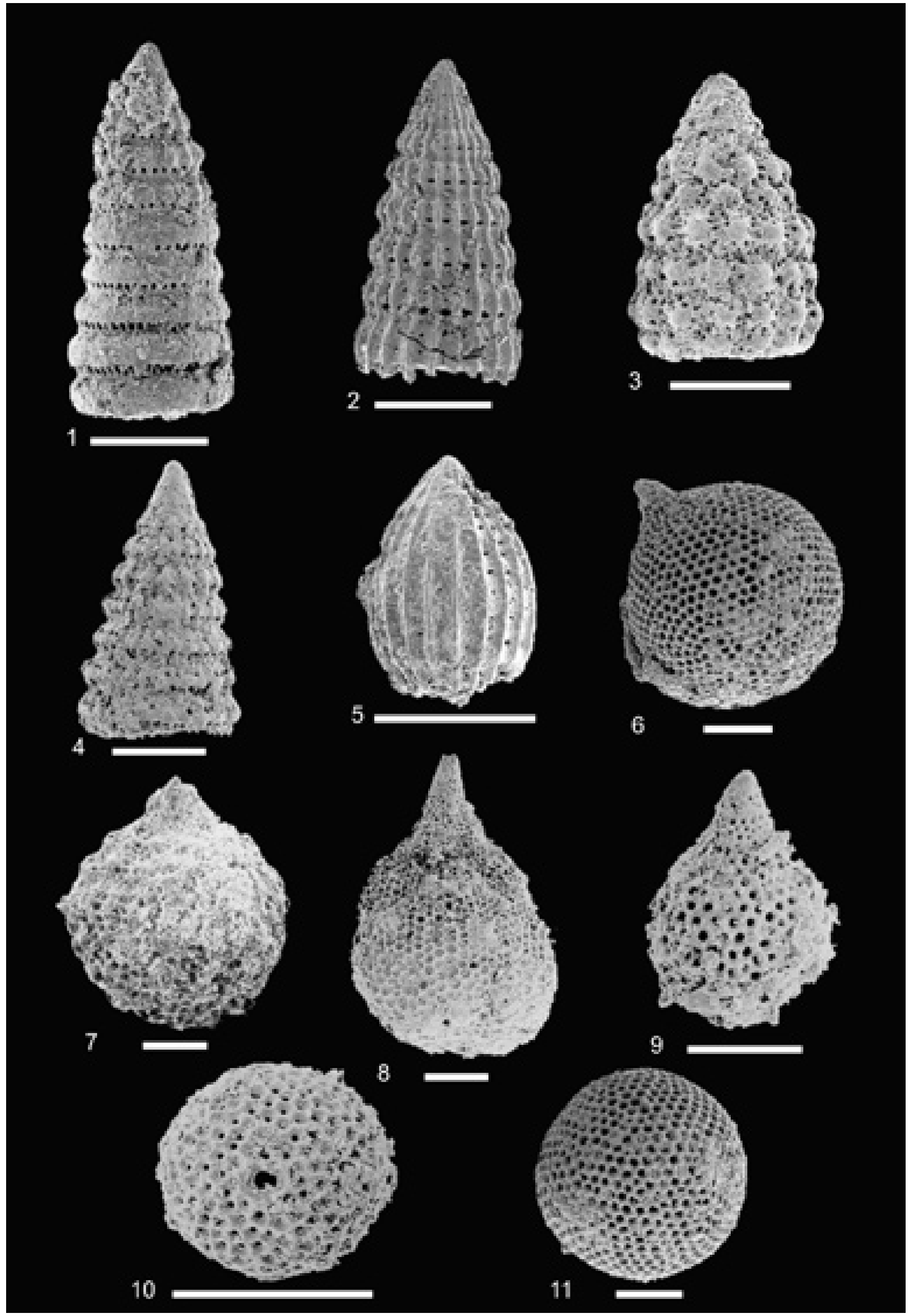


Plate 3

Fig. 1: enlarged part of pl.1, fig.1, *Paronaella* cf. *trifoliacea* OŽVOLDOVÁ

Figs. 2, 4, 5, 7: enlarged details of pl.1, figs 2 and 3, *Praeconosphaera* sp.

Fig. 3: broken specimen of *Praeconosphaera* sp., note pyritized areas in the inner area and the pyrite framboids in the lower part

Fig. 6: wall structures on a broken surface pl. 2, fig. 3, *Praeconosphaera* sp.

Fig. 8: enlarged part of on spine of pl.1, fig. 7, *Acaeniotyle umbilicata* (RÜST)

All specimens were collected at the Sparbach section, coated with gold before photographing (REM) and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0001 (REM stub).

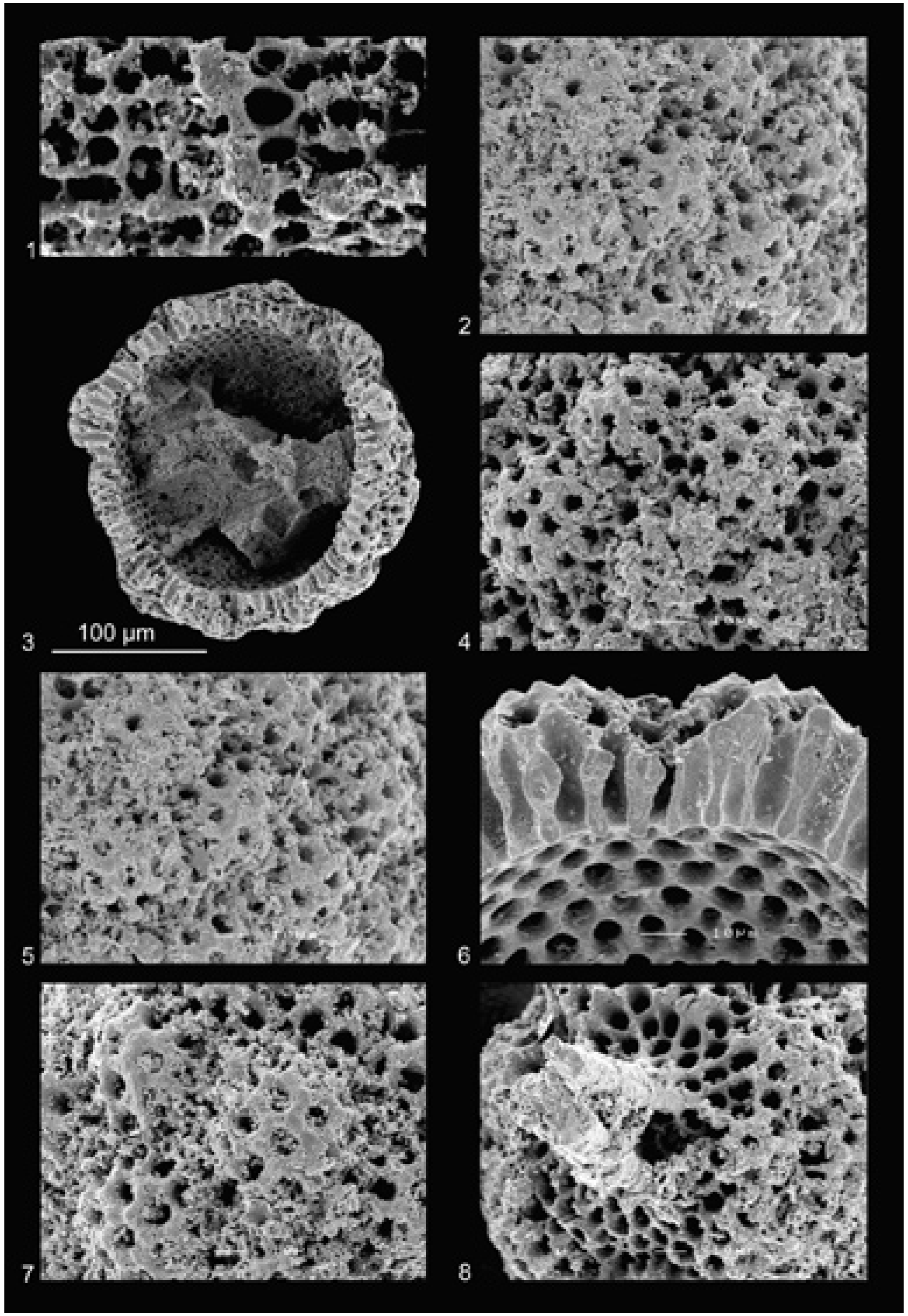


Plate 4

Fig. 1: detail of the aperture of pl. 2, fig. 1, *Pseudodictyomitra lilyae* (TAN)

Fig. 2: detail of the outer surface of pl. 2, fig. 1, *Pseudodictyomitra lilyae* (TAN)

Fig. 3: detail of the aperture of pl. 2, fig. 2, *Dictyomitra pseudoscalaris* (TAN)

Fig. 4: detail of the outer surface of pl. 2, fig. 4, *Dictyomitra pseudoscalaris* (TAN)

Fig. 5: detail of the aperture of pl. 2, fig. 3, *Xitus clava* (PARONA)

Fig. 6: detail of the outer surface of pl. 2, fig. 3, *Xitus clava* (PARONA)

Fig. 7: detail of the outer surface of pl. 2, fig. 4, *Crolanium puga* (SCHAAF)

Fig. 8: detail of the outer surface of pl. 2, fig. 5 *Thanarla brouweri* (TAN)

All specimens were collected at the Sparbach section, coated with gold before photographing (REM) and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0001 (REM stub).

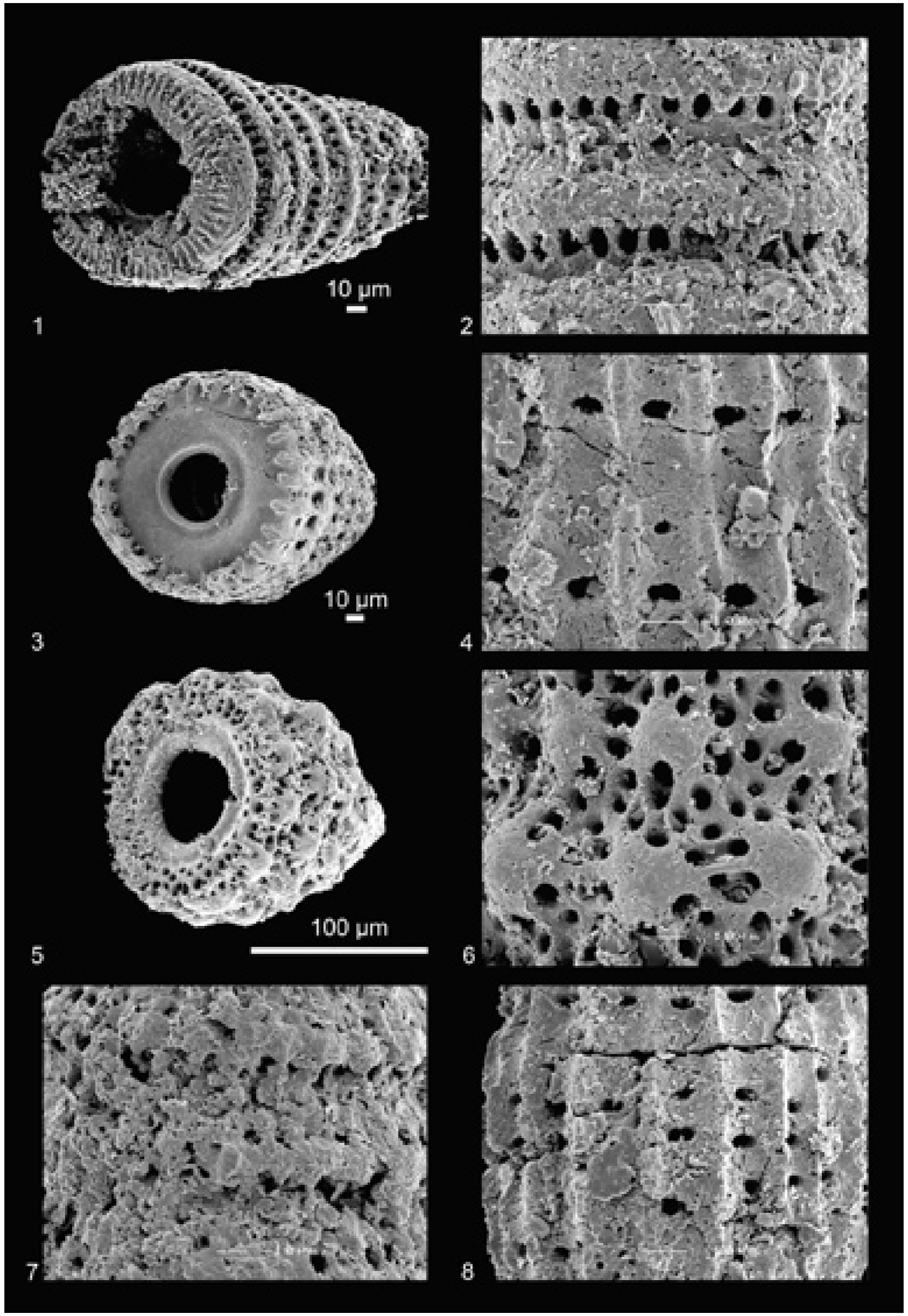


Plate 5

Figs. 1, 3, 4: details of the internal structure of *Thanarla brouweri* (TAN)

Fig. 2: enlarged apex area of pl. 5, fig. 1, *Thanarla brouweri* (TAN)

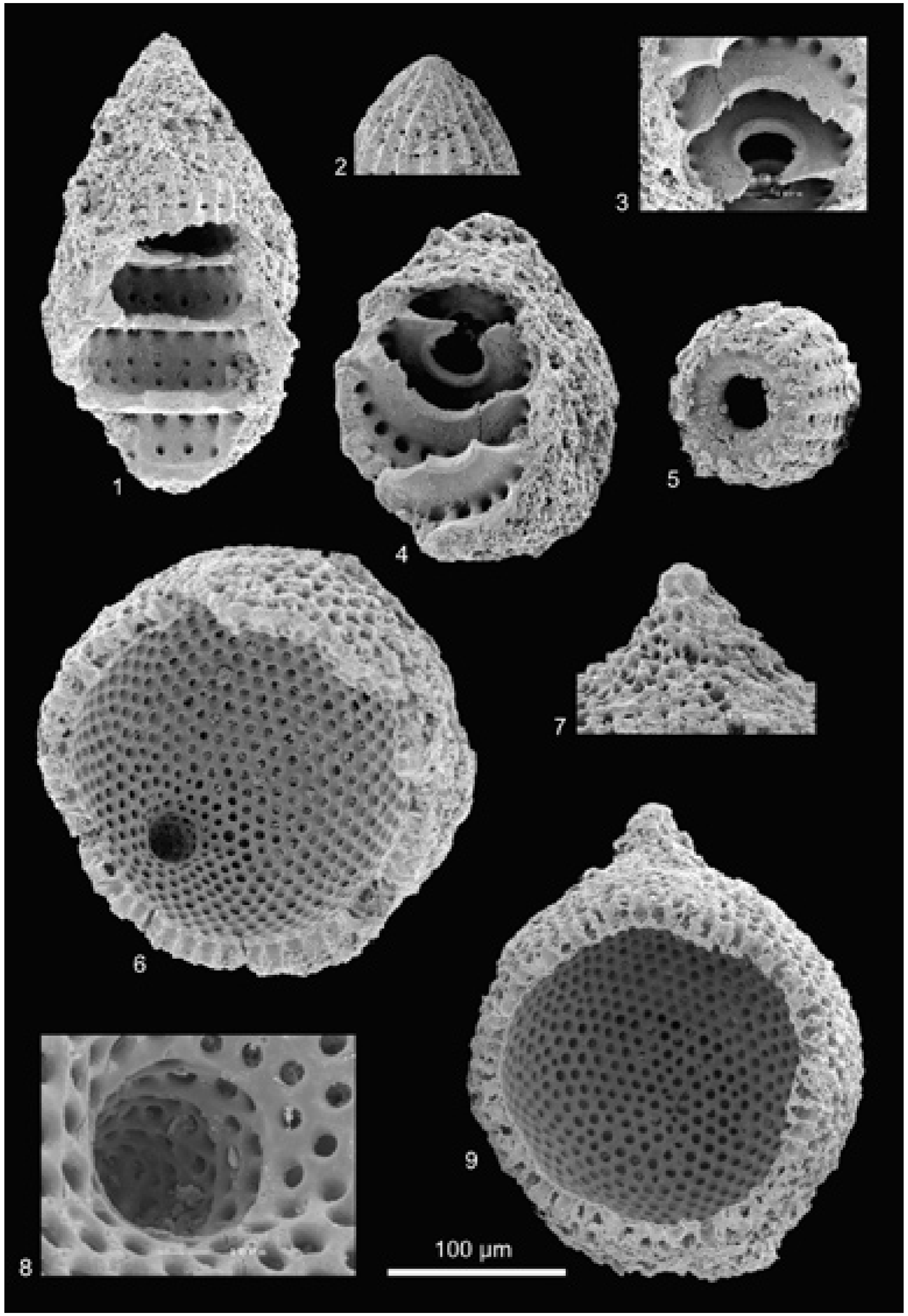
Fig. 5: detail of the aperture of pl. 2, fig. 5, *Thanarla brouweri* (TAN)

Figs. 6, 9: broken specimen of *Sethocapsa orca* FOREMAN. Note the black hole at the position of the spine in fig. 6

Fig. 7: enlarged area around the apex of pl. 5, fig. 9, *Sethocapsa orca* FOREMAN

Fig. 8: enlarged area around the inner apex of pl. 5, fig. 6, *Sethocapsa orca* FOREMAN

All specimens were collected at the Sparbach section, coated with gold before photographing (REM) and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0001 (REM stub).



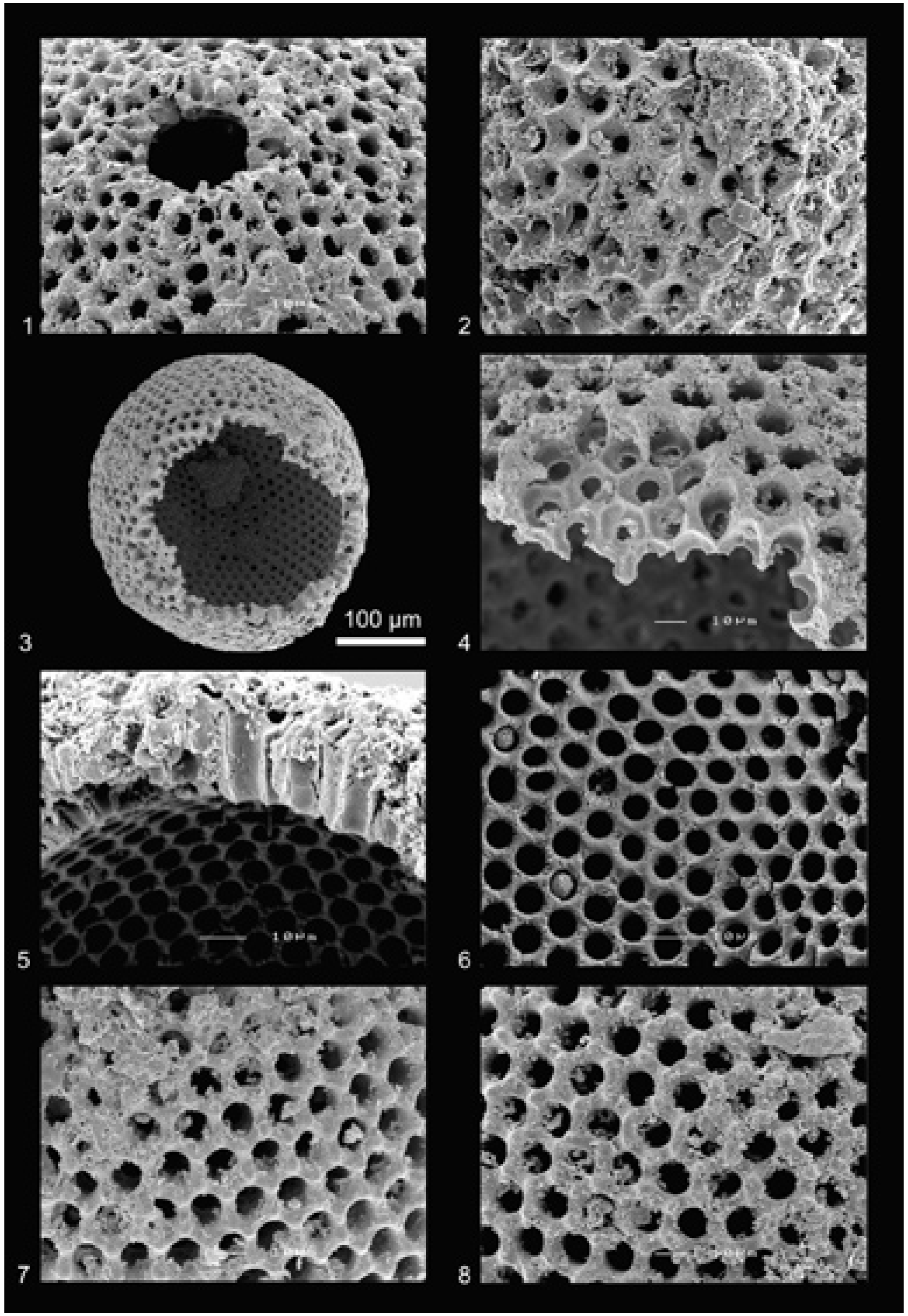


Plate 6

Figs. 1–4 and 7, 8: different preservational stages of the outer surface of *Holocryptocanium barbui* DUMITRICA. Fig 2 shows enlarged detail of pl. 2, fig. 10. Fig. 4 shows enlarged part of the broken specimen of pl. 6, fig. 3

Fig. 5: enlarged wall structure of pl. 6, fig. 5, *Holocryptocanium barbui* DUMITRICA

Fig. 6: small pyrite framboids in the pores of the inner surface of *Holocryptocanium barbui* DUMITRICA

All specimens were collected at the Sparbach section, coated with gold before photographing (REM) and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0001 (REM stub).

Plate 7

All figures on plate 7 are from thin sections from bed **1a**.

Fig. 1: *Paronaella* cf. *trifoliacea* OŽVOLDOVÁ

Fig. 2–6, 10: different preservational stages and sections of *Praeconosphaera* sp.

Fig. 7, 9, 12: different preservational stages and sections of *Hiscocapsa asseni* (TAN)

Fig. 8: ?*Crolanium puga* (SCHAAF)

Fig. 11: ?*Dibolachras tytthopora* FOREMAN

All specimens were collected at the Sparbach section and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0002-4 (thin sections).

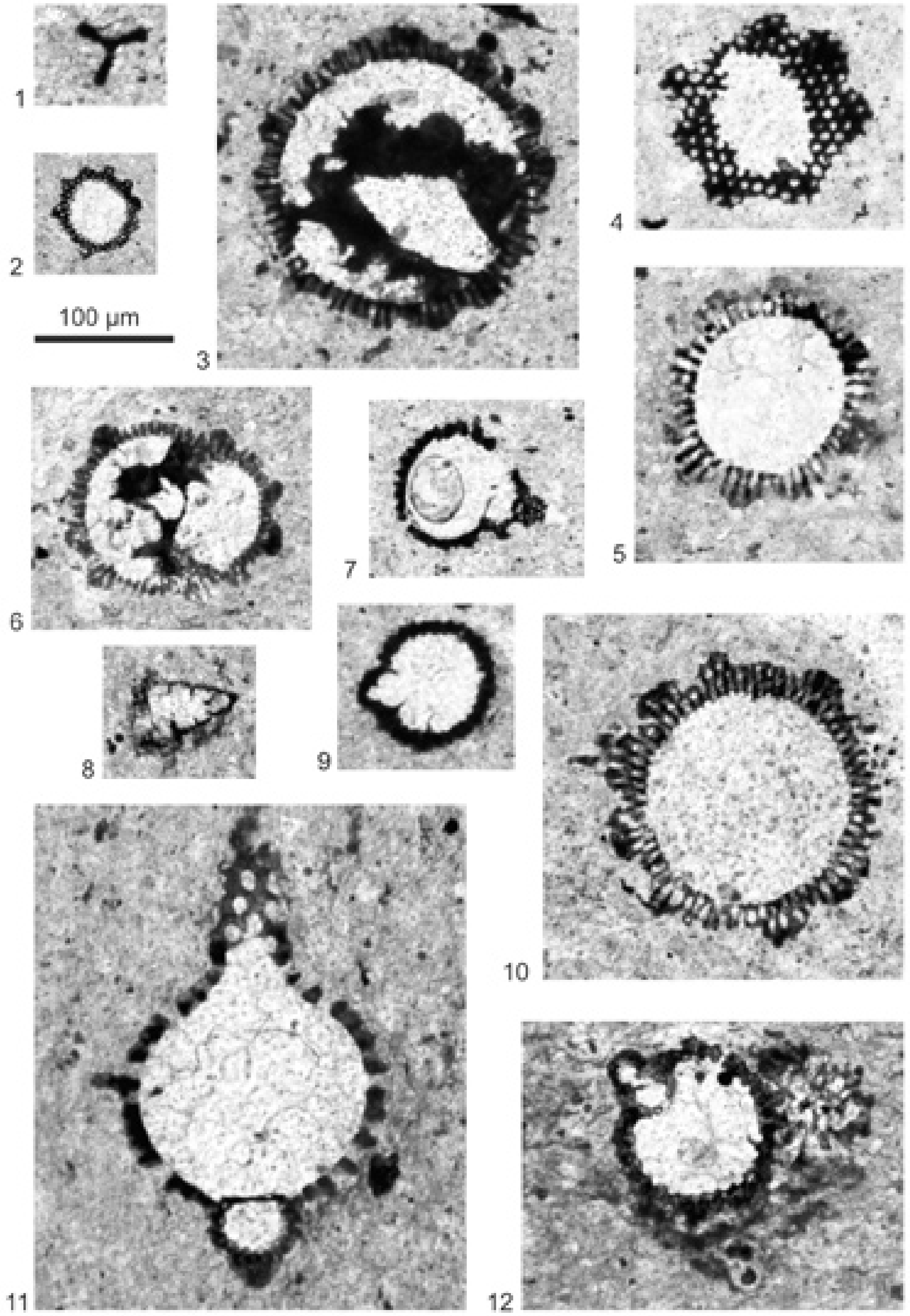


Plate 8

All figures on plate 8 are from thin sections from bed **1a**.

Figs. 1, 3, 4, 6, 9: different preservational stages and sections of *Holocryptocanium barbui* DUMITRICA

Fig. 2: ?*Thanarla brouweri* (TAN)

Fig. 5: *Cryptamphorella clivosa* (ALIEV)

Fig. 8: *Sethocapsa orca* FOREMAN

All specimens were collected at the Sparbach section and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0002-4 (thin sections).

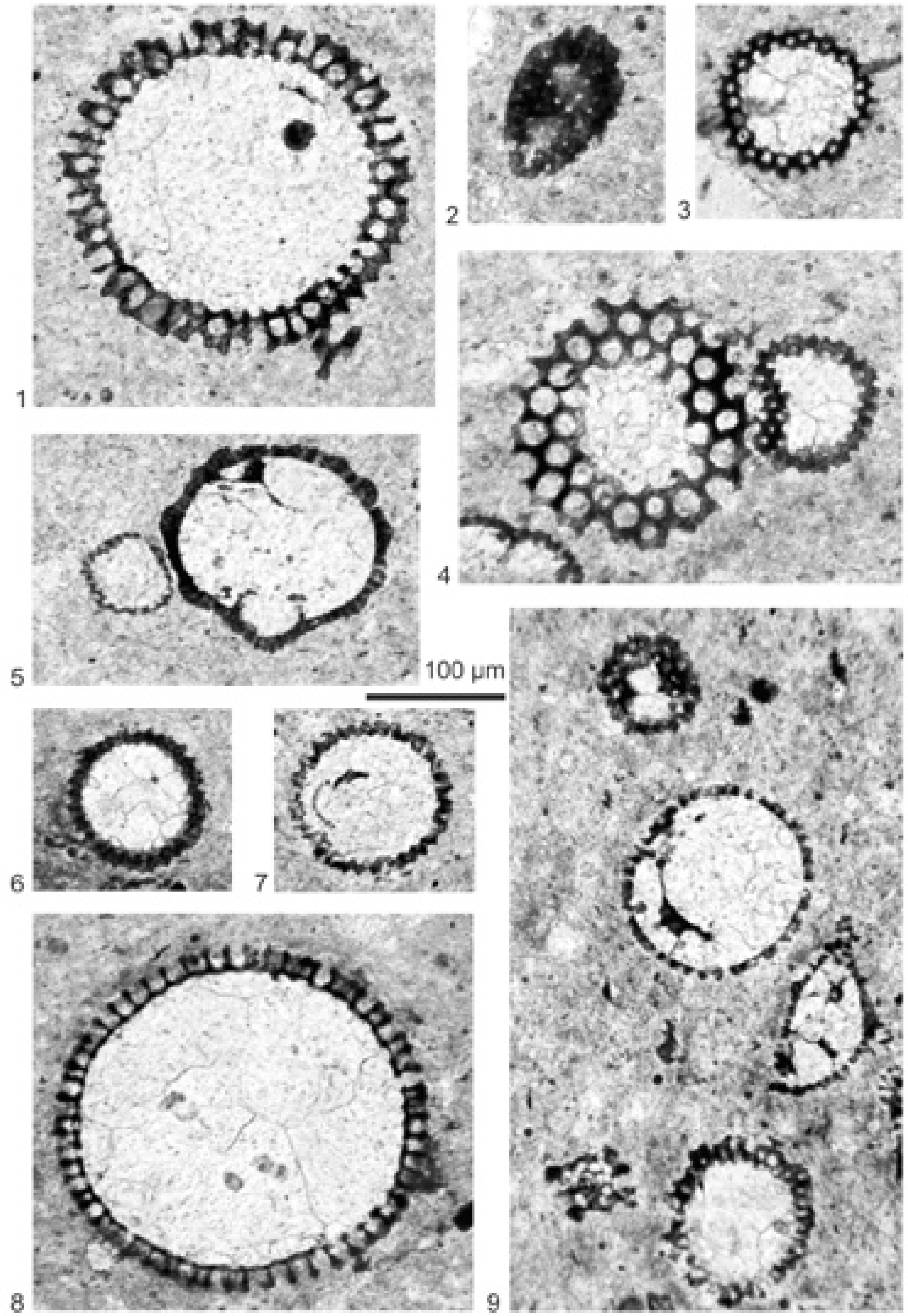


Plate 9

All figures on plate 9 are from thin sections from bed **1a**.

Fig. 1: *Praeconosphaera* sp. right, fragments of *Holocryptocanium barbui* DUMITRICA and an indet radiolaria left

Fig. 2: *Holocryptocanium barbui* DUMITRICA right and *Praeconosphaera* sp. left

Fig. 3: crushed and broken fragments of different radiolarians containing *Holocryptocanium barbui* DUMITRICA

All specimens were collected at the Sparbach section and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0002-4 (thin sections).

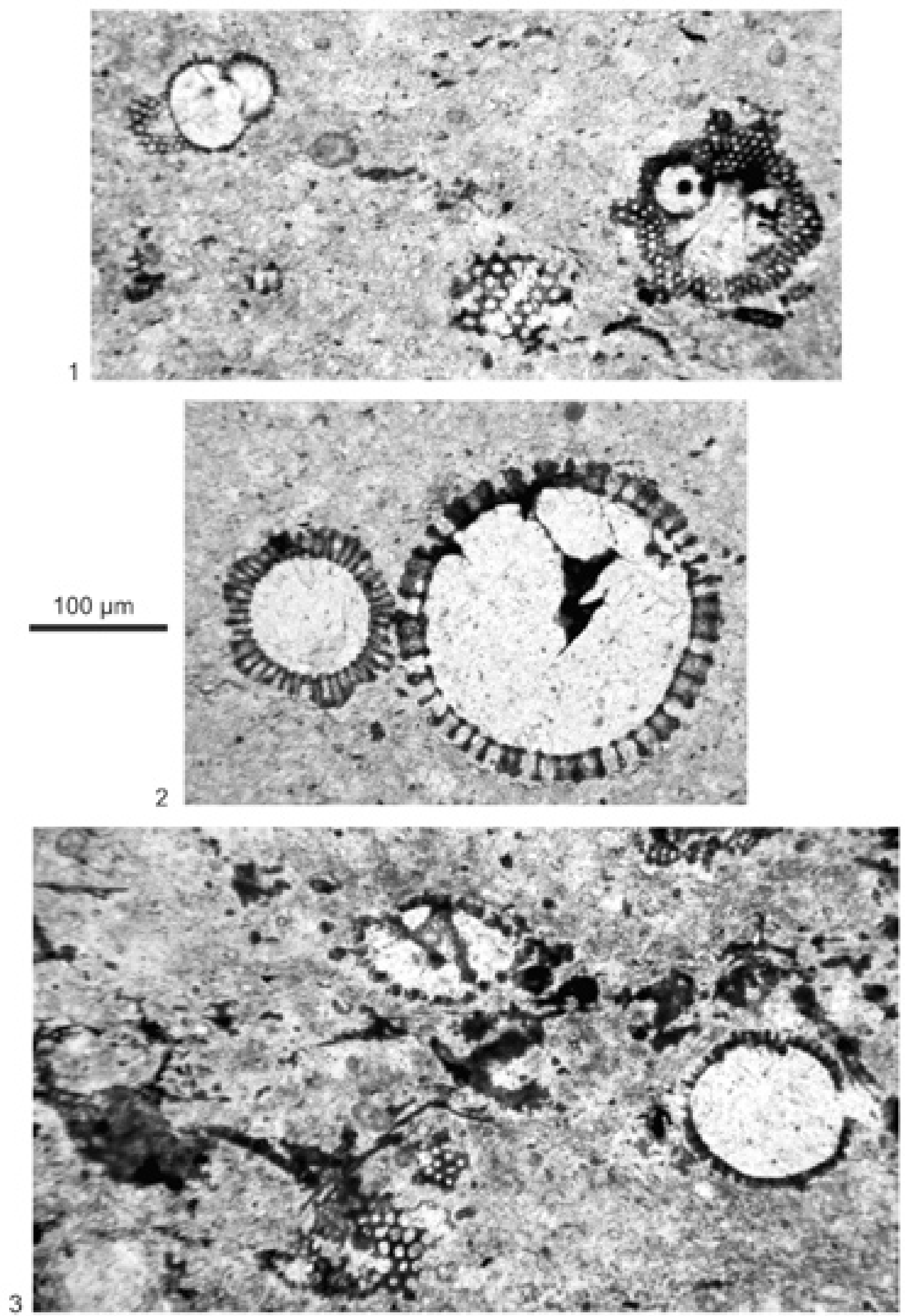


Plate 10

All figures on plate 10 are from thin sections from bed **1b**.

Fig. 1: *Praeconosphaera* sp.

Figs. 2, 3, 5, 7: *Hiscocapsa asseni* (TAN) – × 160

Figs. 4, 6 and **11–13:** different preservational stages and sections of *Holocryptocanium barbui* DUMITRICA. Note pyrite framboids in Fig. 4, dark, round. Fig. 12 shows a crushed specimen of *Holocryptocanium barbui* DUMITRICA. Fig. 13 left is an indet. radiolaria.

Fig. 9: indet. radiolaria

All specimens were collected at the Sparbach section and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0005-6 (thin sections).

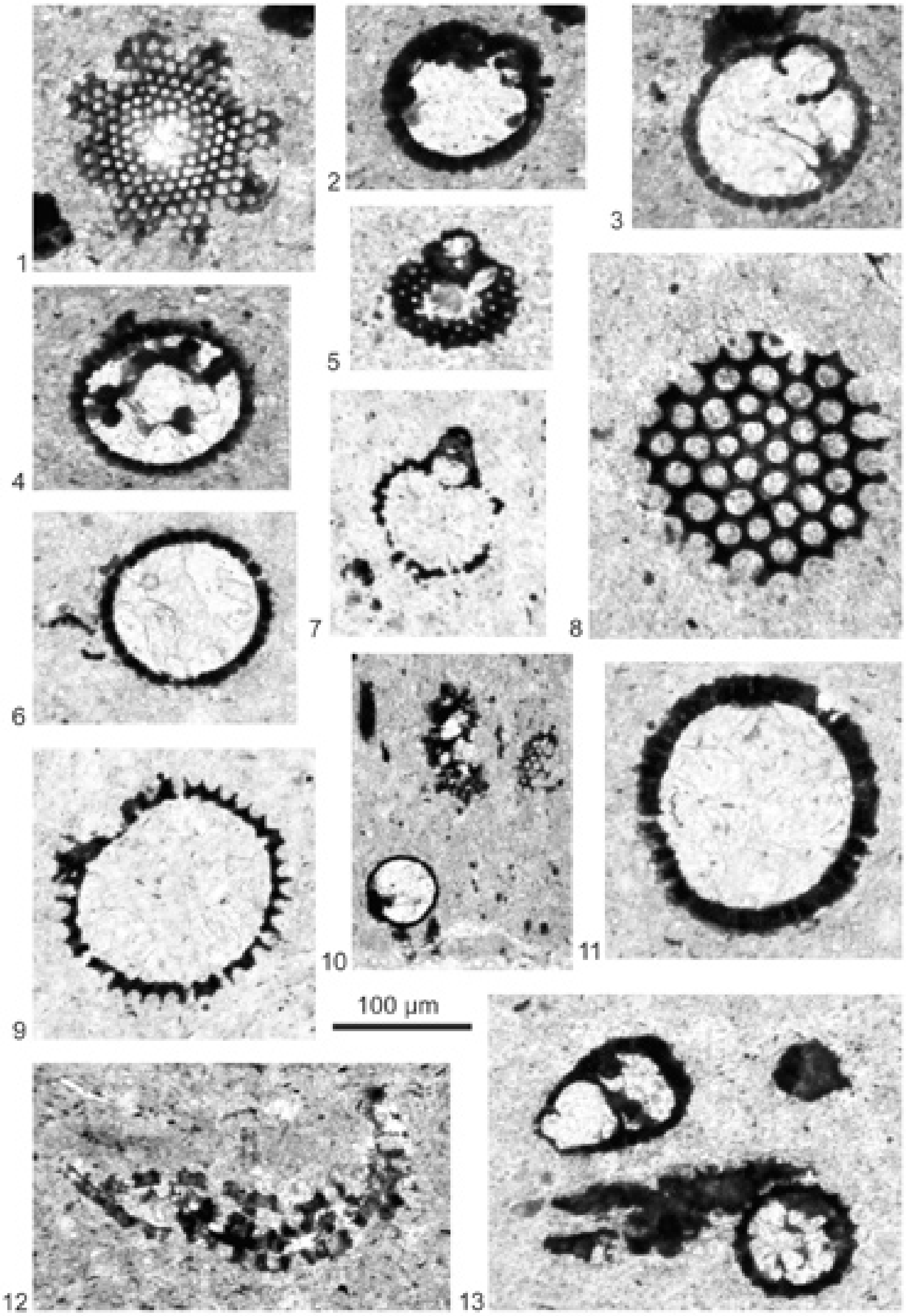


Plate 11

All figures on plate 11 are from thin sections from bed **2a**.

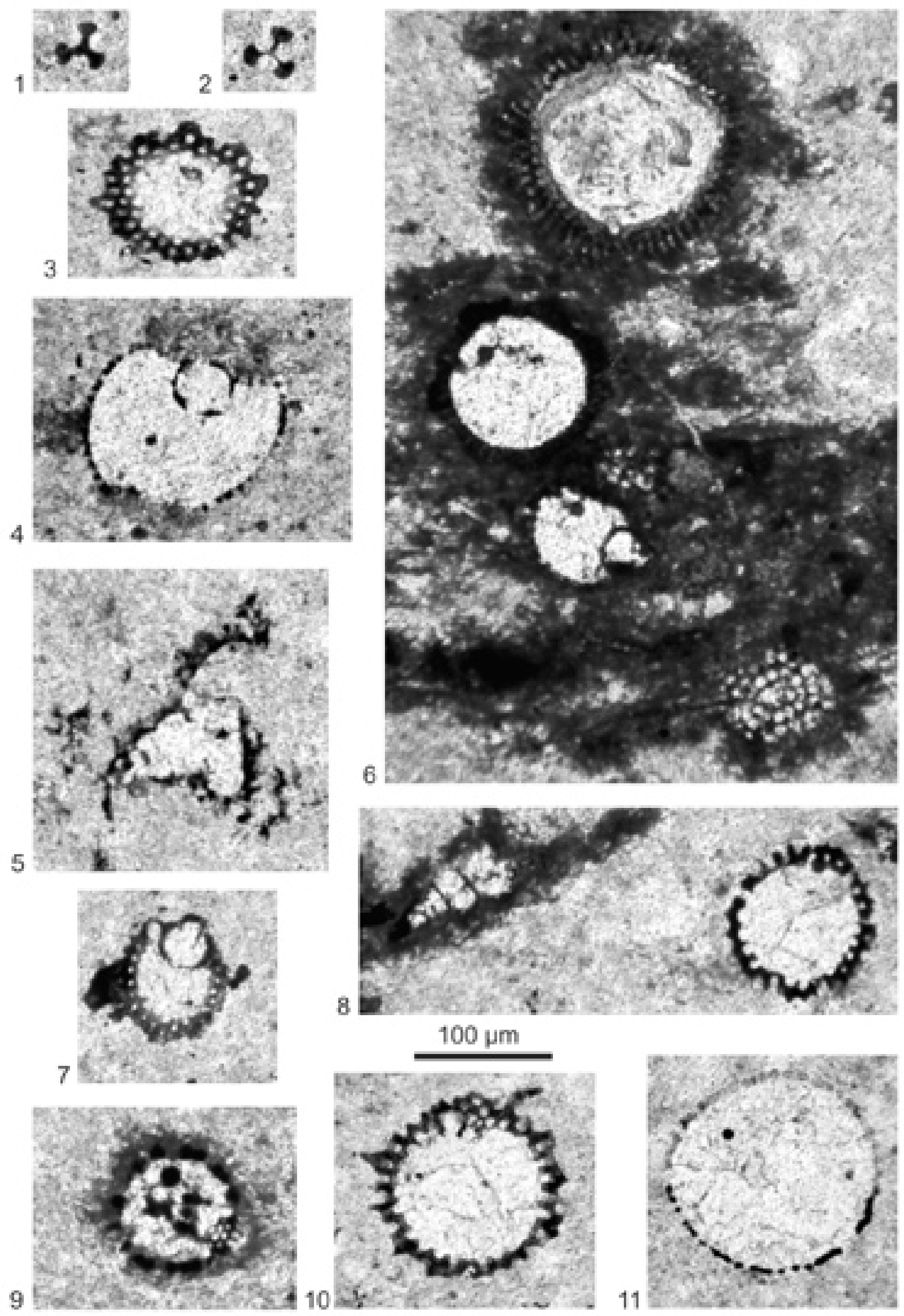
Figs. 1, 2: *Paronaella* cf. *trifoliacea* OŽVOLDOVÁ

Fig. 3: *Praeconosphaera* sp.

Figs. 4–7: different preservational stages and sections of *Hiscocapsa asseni* (TAN). Fig. 6 shows an accumulation of different radiolarians. Three specimens of *Holocryptocanium barbui* DUMITRICA and the third specimen from the top is *Hiscocapsa asseni* (TAN). The dark material is a pyrite cloud

Figs. 8–11: different preservational stages and sections of *Holocryptocanium barbui* DUMITRICA. Note pyrite framboids in Fig. 9, dark, round. Fig. 8 shows in the upper left corner ?*Pseudodictyomitra* sp.

All specimens were collected at the Sparbach section and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0007 (thin section).



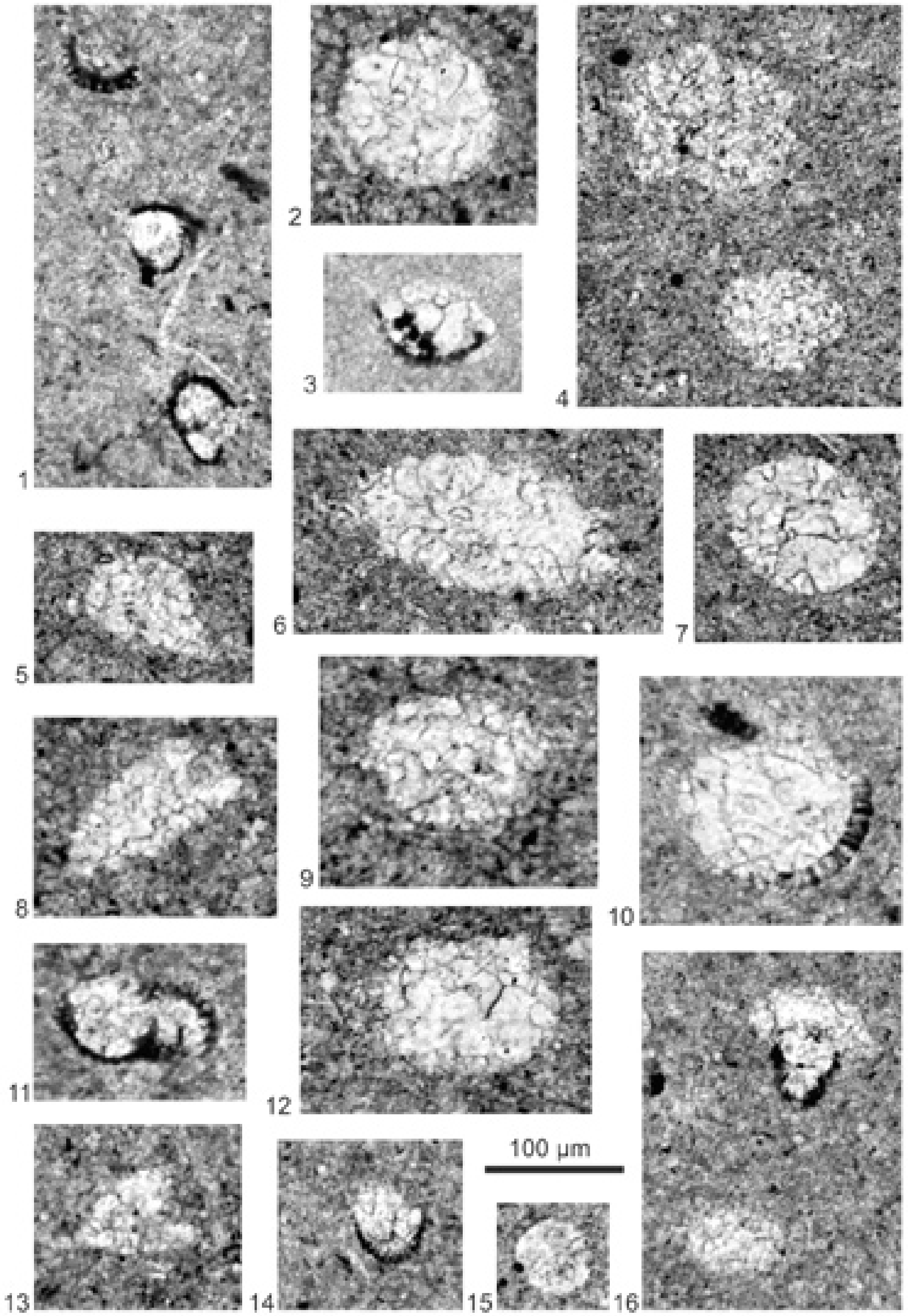


Plate 12

All figures on plate 12 are from thin sections from bed **3a**. Note that the main difference between the specimens on this plate and plate 1–11 is the low pyritization factor in bed 3a. In most cases radiolarians are only calcitic (white) and only in few cases partly pyritized (black).

Figs. 1, 3, 4, 6: indet radiolaria

Figs. 2, 7, 9–11, 14, 15: different preservational stages and sections of *Holocryptocanium barbui* DUMITRICA

Figs. 5, 12, 16: different preservational stages and sections of *Hiscocapsa asseni* (TAN)

Fig. 8: ?*Pseudodictyomitra* sp.

Fig. 13: ?*Thanarla* sp.

All specimens were collected at the Sparbach section and are stored at the Museum of Natural History Vienna (Burgring 7, A-1010, Vienna), 2005z0081/0008 (thin section).