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An Early Eocene Fauna and Flora from “Rote Kirche” in Gschliefgraben near Gmunden, Upper Austria

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4 Text-Figures, 7 Plates, 4 Tables

Österreichische Karte 1:50.000
Blatt 66 Gmunden

Ultrahelveticum
Salzkammergut
Gschliefgraben
Palynomorphs
Nannofossils
Foraminifera
Brachiopods
Rote Kirche
Ypresian

Contents

Beiträge zur früheozänen Fauna und Flora der Lokalität Rote Kirche im Gschliefgraben bei Gmunden, Oberösterreich

Zusammenfassung

Erstmals wird eine Brachiopoden-Vergesellschaftung aus dem Eozän Österreichs beschrieben. Sie umfasst 6 Taxa (*Gryphus kickxii*, *Meznericsia hantkeni, Terebratulina tenuistriata*, *Orthothyris pectinoides*, *Megathiris detruncata*, *Argyrotheca sabandensis*?) und stammt aus mergeligen Kalken bzw. sandigen Mergeln des Ultrahelvetikums der Lokalität Rote Kirche im Gschliefgraben bei Gmunden. Die Dominanz der Genera *Gryphus* und *Terebratulina* spricht für einen relativ tieferen Ablagerungsraum, wahrscheinlich im äußeren Schelfbereich. Groß- und Kleinforaminiferen, kalkige Nannofossilien und Palynomorphen / Dinoflagellaten ermöglichen eine Einstufung der hangenden Ablagerungen des Aufschlusses Rote Kirche als frühes Eozän (spätes Ypresium). Eine neue Großforaminiferen-Chronosubpecies, *Orbitoclypeus multiplicatus gmundenensis*, die für die Zone SBZ 10 charakteristisch ist, wird beschrieben. Die Palynomorphen-Assoziation wird von marinen Dinoflagellaten dominiert. Es konnten aber auch Süß- bzw. Brackwasser-Algenzysten von Zygnemataceae (*Ovoidites elongatus*) nachgewiesen werden, die einen terrestrischen Einfluss bezeugen. Im Gegensatz zu den Pollen-Floren des Danium und des Thanetium Eurasiens stellen die ausgestorbenen Pollen-Leitformen der Normapolles im untersuchten (etwas jüngeren) Material lediglich einen geringen Anteil der Assoziation dar.

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Abstract

An integrated study of brachiopods, small and larger foraminifera (orthophragmines and nummulitids), calcareous nannofossils and palynomorphs / dinocysts was carried out from the marly limestones respectively sandy marls of the Ultrahelvetic zone at the locality Rote Kirche in the Gschliefgraben near to Gmunden in Upper Austria. Microfossils (including larger foraminifera) indicate the Early Eocene, more precisely the early-middle part of the late Ypresian (the NP 11 and NP 13 calcareous nannofossils, the P 7–8 planktonic foraminiferal and the SBZ 10 shallow benthic zones). Eocene brachiopods are described for the first time from Austria. Six species (*Gryphus kickxii*, *Meznericsia hantkeni, Terebratulina tenuistriata*, *Orthothyris pectinoides*, *Megathiris detruncata*, *Argyrotheca sabandensis*?) were identified, the taxonomic composition of which (based on the dominance of *Gryphus* and *Terebratulina*) refers to deeper water, probably outer shelf environment. These palaeoecological conditions are also confirmed by the composition of larger foraminifera. A new orthophragminid chronosubspecies, *Orbitoclypeus multiplicatus gmundenensis*, characteristic for the SBZ 10 Zone, is introduced. The palyno-association is dominated by marine dinoflagellates but freshwater-brackish algal cysts of Zygnemataceae (*Ovoidites elongatus*) are also present, testifying terrestrial input. In the Cretaceous and the Palaeocene (Danian and Thanetian) pollen floras of the Eurasian Normapolles Province Normapolles pollen are a characteristic element. In the investigated association, however, Normapolles are present only in low quantity.

Location and Geological Setting

The Gschliefgraben area comprises a large land slide (e.g. Koch, 1898; Baumgartner & Mostler,1978; Millahn et al., 2008; Weidinger, 2009; Weidinger & Niesner, 2009) SE of the town of Gmunden in Upper Austria, exposing rocks of Jurassic, Cretaceous and Palaeogene age, which are attributed to the Ultrahelvetic thrust unit. Due to the mass movement and an intense tectonic overprint by a major strike slip system (Egger et al., 2009), extended undisturbed sections do not exist. In the south, the Ultrahelvetic rocks are bordered by middle Triassic limestones of the northern rim of the Northern Calcareous Alps. In the north, Upper Cretaceous turbidites of the Rhenodanubian Flyschzone show a tectonic contact to the Ultrahelvetic unit (Text-Fig. 1).

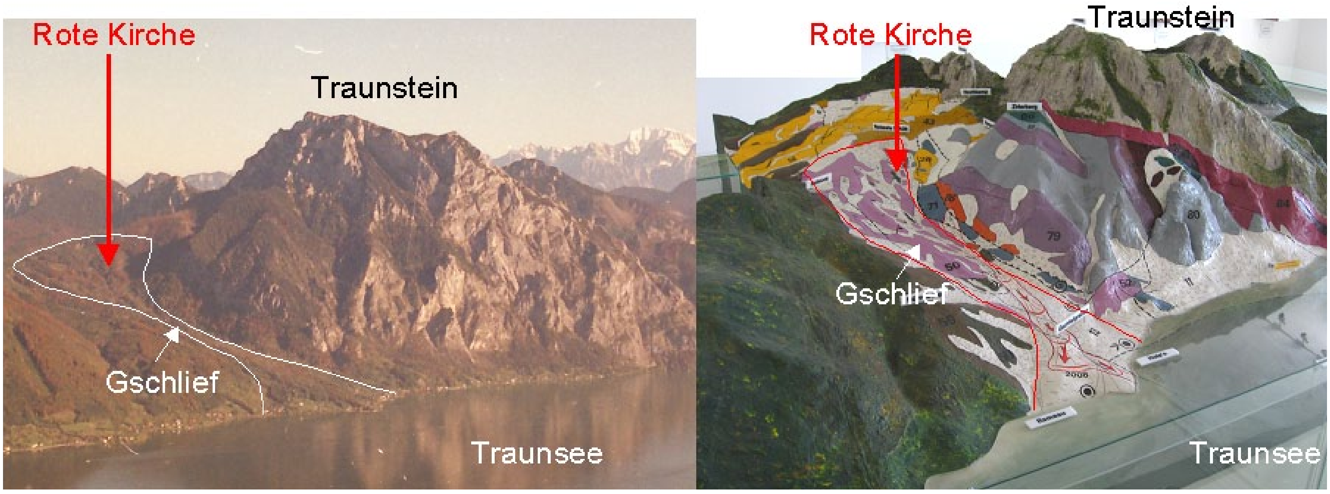
The slope, on which the Gschliefgraben is situated, extends from the eastern shore of Lake Traunsee (423 m) up to the small rock-cliff of the "Rote Kirche" (840 m), a famous site for the occurrence of Eocene fossils. The cliff consists mostly of yellow-orange coloured marly sandstones respectively sandy marls. On the top of the cliff limestones with nummulites, brachiopods, bivalves and echinoderms with intercalations of grey sandy marls, respectively brittle sandstones are cropping out (Text-Fig. 2). Glauconite is almost omnipresent, rarely also thin layers of "Bohnerz", i.e. finely distributed limonitic ooides.

Previous Work

In the early geological literature of the Salzkammergut region the Gschliefgraben is mentioned repeatedly. Among the earliest records are the papers by Joseph August Schultes (1809) and Paul von Partsch (1826). Carl Lill von Lilienbach (1830) was particularly surprised to find there nummulite-bearing sediments containing green mineral grains (glauconite). Ami Boué (1832) was the first who published a cross section through the Gschliefgraben. Finally Franz von Hauer (1858) described the complex lithologic sequence. He was also the first, who described in detail the Eocene sediments of the "Rote Kirche" location.

For a long period the sequence of the Gschliefgraben was considered being part of the Flysch zone or of the Upper Cretaceous / Palaeogene Gosau Group of the Northern Calcareous Alps (e.g. Fugger, 1903). However, Karl Götzinger in 1937 expressed the opinion, that from the palaeogeographic point of view this sequence is part of the Helvetic zone. From the tectonic point of view Ernst Kraus (1944) considered the Gschliefgraben as transgressively overlying the Flysch zone, while for Max Richter & Gotthold Müller-Deile (1940) it represents a tectonic window of the Helvetic zone underlying the Flysch unit.

Since 1951 the latter opinion was shared by Siegmund Prey. Prey's papers, published between 1949 and 1983, improved the biostratigraphic record of the lithologically



Text-Fig. 1.
Location, regional geology and tectonic position of "Rote Kirche" in Gschliefgraben.
Sketches courtesy Hans Weidinger, Kammerhofmuseum Gmunden.

Text-Fig. 2.
Uppermost stratigraphic sequence of the Rote Kirche section. Nummulite-limestone partly rich in **"Bohnerz" (limonite ooides) alternating with grey, glauconitic** sandy marls.

similar, but stratigraphically diverse rocks of the (Ultra)helvetic zone. In 1953 he argued that the Eocene sandy-marly-glauconitic sediments of "Rote Kirche" show Thanetian (Late Palaeocene) and probably also Ypresian (Early Eocene) age, while the top of this section is represented by a few meters of iron oolithic nummulitic limestones of Lutetian (Middle Eocene) age, which he considered as an equivalent of the "Roterz" beds in Bavaria (Prey, 1953). This opinion was supported later by an oral communication of Franz Traub (in Prey, 1975).

In his last paper Prey (1983) subdivided his Ultrahelveticum into two zones, namely the Northern Ultrahelvetic and the Southern Ultrahelvetic Klippen Zone. According to him "Rote Kirche" is part of his Northern Ultrahelvetic, which comprises a complex sequence of light to dark grey, partly variegated Albian to Maastrichtian marls, which are topped by Palaeocene to early Eocene glauconitic, more or less sandy marls and nummulitic limestones. Middle Eocene nummulitic limestones in Adelholzen facies and Clavulinoides szaboi Beds also occur regionally.

Rasser & Piller (2001) deal in detail with facies patterns, subsidence and sea-level changes in ferruginous and glauconitic environments of the Palaeogene Helvetic shelf. According to these authors the Rote Kirche exposures belong to the Southern Helvetic facies of the Austro-Bavarian Helvetic Zone, which is part of the Helvetic Shelf and as such part of the Alpine Foreland. During the Palaeogene a peculiar shallow water carbonate sedimentation took place on a wide carbonate platform. The sediments are characterized by the most intensive ferruginisation and glauconitisation known from Cenozoic shallow water carbonates of the Eastern Alps (Rasser & Piller, 2001).

According to Egger (2007), the Rote Kirche outcrop is the easternmost exposure of the South Helvetic zone. There the nummulitic limestone of the Frauengrube Member and in particular the underlying marly sandstone (Prey, 1983) yielded calcareous nannoplankton of zone NP 12. This nannoflora is considered to indicate, that after a sea-level rise the nummulitic marlstones and limestones were deposited on the shelf of the European Platform during the Ypresian transgression within Zone NP 12.

Studied Material

Two of the authors (Harald Lobitzer and Alfréd Dulai) have visited the locality on 29.04.2010, with the guidance of two local private collectors, namely Ferdinand Estermann and Karl Bösendorfer from Pinsdorf. Several macromorphic brachiopod specimens were found in the field, and four samples were collected for washing and checking micromorphic brachiopods (sample 1: upper nummulitic limestone; samples 2–3: middle glauconitic sandstone; sample 4: lower *Assilina* sandstone). György Less (Miskolc) has also studied two of these washed residues for larger foraminifers (samples 1 and 4). During the field work two additional samples were collected from the upper part of the section (more or less identical with sample 1), for palynological (Magda Konzalová, Prague), nannofossils (Lilian Švábenická, Prague) and small foraminifera (Lenka Hradecká, Prague) studies. Karl Bösendorfer, one of the private collectors made it possible to use and study his brachiopod material from Rote Kirche locality. Collection of the Kammerhofmuseum in Gmunden also contains about a dozen brachiopod specimens from the same locality.

The newly collected brachiopods and the photographed specimens are deposited in the collection of the Hungarian Natural History Museum, Budapest (inventory numbers of illustrated specimens: M 2010.477.1. – M 2010.509.1). Figured larger foraminifera specimens marked by E. are deposited in the Eocene collection of the Geological Institute of Hungary, Budapest. Samples for study of small foraminifers and calcareous nannofossils were prepared in the Laboratory and deposited in the Collections and Material Documentation Department of the Czech Geological Survey, Prague. The palynological preparations were made in the Institute of Geology v.v.i., Academy of Sciences of the Czech Republic in Prague and are also deposited there. The samples for the palynological investigation were prepared in the Laboratory of the Czech Geological Survey, the preparations are deposited in the Institute of Geology v.v.i., Academy of Sciences, Prague.

Brachiopods

Brachiopods are generally rare in Eocene benthic assemblages, but they were published from several localities and numerous papers demonstrate their wide geographical distribution within the Western Tethys. Eocene brachiopods are known from England to Ukraine and from Belgium to Egypt (see details of their distribution in Bitner & Boukhary, 2009, Bitner et al., in press, Dulai, submitted). However, until now Eocene brachiopods were unknown from Austria. In some cases brachiopods were mentioned in faunal lists, but no description of Eocene brachiopods was published from Austrian localities.

Recently Dulai (submitted) studied the Late Eocene (Priabonian) micromorphic brachiopods of two boreholes of the Upper Austrian Molasse zone (Helmberg-1 and Perwang-1). These samples, due to the solving method in acetic acid by Kamil Zágoršek (Prague) (Zágoršek & Vávra, 2000), yielded about 2000 very small, micromorphic brachiopods, representing 10 species of 7 genera, including three new species. The paper describing this fauna is submitted, but the date of appearance of the proceedings volume is uncertain (6th International Brachiopod Congress, Melbourne, 1.–5. February, 2010).

Eocene deposits around Gmunden and their fossil contents are poorly known. PREY (1983) has listed fossils of different groups, including also two brachiopods from this area: *Terebratula aequivalvis* SCHAFHÄUTL and *T. hilarionis* MENEGHINI. Altogether 114 macromorphic brachiopods were collected during our fieldwork representing two species of large, smooth terebratulides: *Gryphus kickxii* (GALEOTTI, 1837) (108 specimen) and *Meznericsia hantkeni* (MEZNERICS, 1944) (6). Karl Bösendorfer's private collection also contains large-sized brachiopods of the same two species (70 *G. kickxii* and 5 *M. hantkeni*). The collection of the Kammerhofmuseum in Gmunden contains a dozen *Gryphus* specimens. All of the four washed samples yielded more or less small-sized, so-called micromorphic brachiopod specimens. The richest and most diverse fauna is from the uppermost sample, collected from the weathered part of nummulitic limestone (sample 1), where the macromorphic brachiopods were also collected: *Terebratulina tenuistriata* (LEYMERIE, 1846) (20), *Argyrotheca sabandensis*? (PAJAUD & PLAZIAT, 1972) (16), *Gryphus kickxii* juv. (3), *Orthothyris pectinoides* (KOENEN, 1894) (1) and *Megathiris detruncata* (GMELIN, 1791) (1). Two samples (sample 2 and 3) of the second outcrop (upper and lower part of a grey glauconitic sandstone) contain very fragmentary brachiopods. Sample 2 with *Terebratulina tenuistriata* (15) and *Gryphus kickxii* (5) and sample 3 with *Terebratulina tenuistriata* (28), *Gryphus kickxii* (15) and *Argyrotheca sabandensis*? (2). The lowest sample from yellow *Assilina* sandstone (sample 4) yielded only 2 fragments of *Terebratulina tenuistriata*.

All of the washed samples contain some other fauna elements, which are only partly studied in detail in this paper (larger foraminifers by Gy. Less).

Sample 1: small and larger foraminifers (several), worm tubes (several coiled and some straight), echinoderms (several echinoid needles and crinoid stalk fragments), bryozoans (several), decapods (some fragments).

Sample 2: small and larger foraminifers (several), echinoderms (several echinoid needles, some crinoid stalk fragments), fish teeth (few).

Sample 3: small and larger foraminifers (several), echinoderms (several echinoid needles, some crinoid stalk fragments), molluscs (few ostreid fragments), worm tubes (few), bryozoans (few), fish and shark teeth (few).

Sample 4: small and larger foraminifers (several), echinoderms (some echinoid needles and crinoid stalk fragments), molluscs (few ostreid and pectinid fragments), corals (few fragments), bryozoans (few), and decapods (few).

Systematic Notes on Brachiopods

Phylum Brachiopoda DUMÉRIL, 1806

Subphylum Rhynchonelliformea WILLIAMS, CARLSON, BRUNTON, HOLMER & POPOV, 1996

Class Rhynchonellata WILLIAMS, CARLSON, BRUNTON, HOLMER & POPOV, 1996

Order Terebratulida WAAGEN, 1883

Superfamily Terebratuloidea GRAY, 1840

Family Terebratulidae GRAY, 1840

Subfamily Gryphinae SAHNI, 1929

Genus *Gryphus* MEGERLE VON MÜHLFELD, 1811

Gryphus kickxii (GALEOTTI, 1837)

(Pl. 1, Figs. 1–11)

1843 *Terebratula Kickxii* GALEOTTI – NYST, p. 335, Pl. 19, Fig. 4.

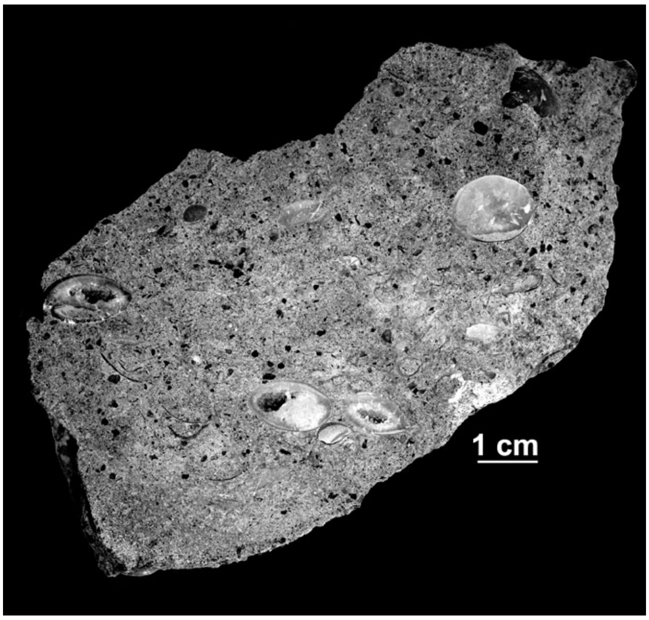
in press *Gryphus kickxii* (GALEOTTI) – BITNER et al. (p. X), Figs. 3D–I, 4, 5A, B (cum syn.).

? 2010 *Carneithyris subregularis* (QUENSTEDT) – SULSER et al. p. 261–264, Text-Figs. 3, 4, 5.

Material: 213 specimens.

Notes: *G. kickxii* is a medium-sized, smooth brachiopod with rectimarginate anterior commissure and short incurved beak. The outline is very variable: elongate oval to subpentagonal or subcircular, as demonstrated on the figures of Pl. 1. This is the most common brachiopod of the Rote Kirche locality and it was very widespread in the whole of Europe during the Eocene (BITNER et al., in press). About 70 percent of the studied Austrian specimens belong to this species, which has a very complex taxonomic history and was described under different names. The two species names mentioned by PREY (1983) from Rote Kirche (*T. aequivalvis*, *T. hilarionis*) are probably also synonyms of *G. kickxii*. Critical revision of this species was given just recently by BITNER et al. (in press) on the basis of an extensive Middle Eocene material from the Szőc Limestone of the Bakony Mts., Hungary. Very similar forms were mentioned from the Swiss and Austrian Alpine area in different names: *T. kickxii* by OOSTER (1863) and MOESCH (1878), *T. aequivalvis* and *T. picta* by SCHAFHÄUTL (1863) and *T. subregularis* by QUENSTEDT (1868–1871). All of these records may also refer to *G. kickxii*, but until now detailed study or revision of these faunas / localities is missing.

The online version of the SULSER et al. (2010) paper appeared just during the preparation of this manuscript. They have studied Lutetian (Middle Eocene) brachiopods from NE Switzerland. Beside some undetermined *Terebratulina* specimens, they have identified their common smooth terebratulides as *Carneithyris subregularis* (QUENSTEDT). They regarded *T. aequivalvis* SCHAFHÄUTL and *T. hilarionis* DAVIDSON as separate species, and also assigned them to the genus *Carneithyris*. However, the outer morphology of the Swiss specimens is similarly variable, than in case of Lutetian fauna of the Bakony Mts. (BITNER et al., in press) as in the case of the studied Rote Kirche fauna. The three assemblages seem to be overlapping in outer morphological characters and in variability. The same is true for *subregularis* / *aequivalvis* length / width comparisons (see Fig. 8 in SULSER et al., 2010). SULSER et al. (2010) attribute their material to the species *subregularis*, because *Gryphus kickxii* is "ill-defined" and its thorough revision is missing (although they also recognized the close relationship between *kickxii* and *subregularis*). However, a paper parallel to SULSER et al. (2010), a recent critical revision on *G. kickxii* is just prepared on a rich material from the Hungarian Middle Eocene by BITNER et al. (in press). As this latter paper justifies the



Text-Fig. 3.
Polished surface of nummulitic limestone from Rote Kirche upper locality. The small sample contains several macromorphic brachiopods (both double valves and separated valves; probably *Gryphus kickxii*). The thin sediment infillings in some specimens indicate the original position of the rock sample. The mostly sparitic infilling refer to relatively quick sedimentation. Scale bar: 1 cm.

validity of the *G. kickxii* species, and it has priority over *subregularis* as well as over *aequivalvis* and *hilarionis*, in my opinion the Swiss Lutetian material probably also represents a new record of *G. kickxii*. Concerning the generic assignment, on the basis of the internal morphological characters and the shell ultrastructure, the Hungarian specimens clearly belong to the short-looped *Gryphus* (Bitner et al., in press). The internal characters of the Swiss specimens seem to be poorly preserved (at least on the basis of Fig. 5a–b in Sulser et al., 2010). Therefore their generic assignment to the fundamentally Cretaceous *Carneithyris* on the basis of some selected sections seems to be uncertain. Supposedly, the internal morphological characters of these terebratulides are variable similar to the external ones. For a more certain species and generic assignment of Alpian Eocene short-looped terebratulides, we need more studies in the future, including statistical comparisons of outer morphological characters, and serial sections of well-preserved specimens.

The very limited time to prepare this paper inhibits the investigation of the internal morphology of the brachiopods by serial sections of the specimens at Rote Kirche. Later on it would be useful to check the intraspecific internal variability of specimens with different outer morphology. However, on the basis of the polished surface of the nummulitic limestone (Text-Fig. 3), most of the brachiopod specimens are infilled with sparitic calcite, therefore unfortunately the serial sectioning seems to be a little hopeless.

Distribution: Europe: Belgium, Italy, Switzerland, Austria, Hungary, Poland, Romania, Bulgaria, Ukraine and Turkey; Asia: Caucasus and Kazakhstan (see details in Bitner et al., in press).

Family Gibbithyrididae Muir-Wood, 1965

Subfamily Gibbithyridinae Muir-Wood, 1965

Genus *Meznericsia* Bitner, Dulai & Galácz, 2010

Meznericsia hantkeni (Meznerics, 1944)

(Pl. 2, Figs. 1–2)

1944 *Magellania* (s.l.) *Hantkeni* n. sp. – Meznerics, p. 46, Pl. 3, Figs. 13–16; Pl. 5, Figs. 21–23.

1975 *Gryphus inkermanicus* Zelinskaja sp. nov. – Zelinskaya, p. 94, Pl. 8, Fig. 1.

in press *Meznericsia hantkeni* (Meznerics, 1944) – Bitner et al., p. X, Figs. 5C, D, 6–8.

Material: 11 specimens.

Notes: *M. hantkeni* is a large-sized, strongly biconvex, smooth terebratulide with a massive, strongly incurved beak and paraplicate anterior commissure. The species was described by Meznerics (1944) as *Magellania* (s.l.) *Hantkeni*. However, on the basis of the distinctive external and internal morphological characters, Bitner et al. (in press) recently erected a new genus, *Meznericsia* for this species. Zelinskaya (1975) described the same morphology as *Gryphus inkermanicus* from the Ukraine and its smaller size probably refers to a juvenile specimen. The specimens from the Rote Kirche locality have widened the known palaeogeographical distribution of this rare species.

Distribution: Eocene of Hungary, Ukraine and Austria (see Bitner et al., in press).

Superfamily Cancellothyridoidea Thomson, 1926

Family Cancellothyrididae Thomson, 1926

Subfamily Cancellothyridinae Thomson, 1926

Genus *Terebratulina* d'Orbigny, 1847

Terebratulina tenuistriata (Leymerie, 1846)

(Pl. 3, Figs. 1–11)

2000 *Terebratulina tenuistriata* (Leymerie) – Bitner, p. 118–120, Figs. 2, 3, 4A–F, 5B–G (cum syn.).

in press *Terebratulina tenuistriata* (Leymerie, 1846) – Bitner et al., p. X, Fig. 3A–C (cum syn.).

Material: 65 specimens.

Notes: *T. tenuistriata* is relatively frequent at the Rote Kirche locality, mainly in the washed residues. This is the commonest species in the Eocene brachiopod assemblages of the Western Tethys. Bitner (2000) gave detailed analysis of this species and its great variability during the ontogeny. Different sized Rote Kirche specimens confirm this variability (see Pl. 3, Figs. 1–11). Adults of this species are characterized by numerous fine ribs and an elongated oval outline, while juveniles have only 10–12 granular ribs which increase rapidly in number with the age of brachiopods.

Distribution: Europe: Great Britain, Belgium, France, Spain, Italy, Poland, Hungary, Romania, Bulgaria, and Ukraine (see Bitner et al., in press; Dulai, submitted); Africa: Egypt (see Bitner & Boukhary, 2009).

Family Chlidonophoridae Muir-Wood, 1959

Subfamily Orthothyridinae Muir-Wood, 1965

Genus *Orthothyris* Cooper, 1955

Orthothyris pectinoides (Koenen, 1894)
(Pl. 2, Fig. 3)

1894 *Terebratulina pectinoides* Koenen – Koenen, p. 1354–1355, Pl. 99, Figs. 8–9.

2008 *Orthothyris pectinoides* (Koenen) – Bitner & Dulai, p. 35, Fig. 4.9–16 (cum syn.).

Material: 1 specimen.

Notes: This species seems to be very rare at the Rote Kirche locality, but it is a dominant faunal element in the recently studied nearby Helmberg and Perwang samples (Upper Austrian Molasse Zone, Late Eocene) (Dulai, submitted). The small, subcircular specimen agrees well with those hitherto described, however it is more similar to the Hungarian specimens (Bitner & Dulai, 2008, Figs. 4.10, 4.14) than to the more juvenile Austrian ones. Until recently, this species was attributed to the genus *Terebratulina*, but Bitner & Dieni (2005) and later Bitner & Dulai (2008) and Dulai (submitted) attributed it to the genus *Orthothyris* created by Cooper (1955) for Late Cretaceous brachiopods. On the basis of the Helmberg and Perwang materials, Dulai (submitted) recognized that *Orthothyris* and the very similar *Terebratulina* alternate with each other along the Upper Eocene layers and probably were competitors of the same ecological niches.

Distribution: Eocene of Germany (Koenen, 1894), Ukraine (Zelinskaya, 1975), Italy (Bitner & Dieni, 2005), Hungary (Bitner & Dulai, 2008) and Austria (Dulai, submitted; and this paper).

Superfamily Megathyridoidea Dall, 1870

Family Megathyrididae Dall, 1870

Genus *Megathiris* d'Orbigny, 1847

Megathiris detruncata (Gmelin, 1791)
(Pl. 2, Fig. 4)

2007 *Megathiris detruncata* (Gmelin) – Dulai, p. 2–3, Figs. 2, 1–2 (cum syn.).

2008 *Megathiris detruncata* (Gmelin) – Bitner & Dulai, p. 35–36, Figs. 5.1–4 (cum syn.).

Material: 1 specimen.

Notes: *M. detruncata* has very wide distribution both stratigraphically and geographically. It is one of the most common species in Palaeogene, Neogene and Recent shallow water assemblages. However, it is rare in deeper water environments, as it is also confirmed by the Helmberg and Perwang samples (Dulai, submitted), as well as the Rote Kirche locality (1 known juvenile specimen only).

Distribution: Eocene: Italy, Hungary, Austria (see details in Bitner & Dulai, 2008; Dulai, submitted); Oligocene: Hungary (Dulai, 2010); Miocene: Central Paratethys (see details in Bitner & Dulai, 2004 and Dulai, 2007); Recent: Mediterranean, Eastern Atlantic and Caribbean Sea (Logan, 1979; Brunton & Curry, 1979; Cooper, 1977).

Genus *Argyrotheca* Dall, 1900

Argyrotheca sabandensis? (Pajaud & Plaziat, 1972)
(Pl. 2, Figs. 5–11)

1972 *Cistellarcula sabandensis* nov. sp. – Pajaud & Plaziat, p. 450–451, Text-Figs. 2–3, Pl. 1, Fig. 2.

Material: 18 specimens.

Notes: This small sized micromorphic species is relatively frequent in the washed residues of the Rote Kirche locality. Although all of the studied specimens are small and not very well preserved, they show remarkable similarity with *A. sabandensis* described by Pajaud & Plaziat (1972) from the Late Palaeocene of Spain. The outline of the specimens, the shape of the beak area, the length of the hinge, the number and character of the ribs seem to be consistent with *A. sabandensis*. However, some uncertainties are caused by the very poor illustration of this species in the original description. Based on external and internal morphological characters, genus *Cistellarcula* was synonymised with *Argyrotheca* by Calzada & Urquiola (1994). If the identification of these specimens is correct, the known stratigraphical distribution of this species is widened by this record from Late Palaeocene to Early Eocene.

Distribution: Late Palaeocene (Thanetian) of Spain, and Early Eocene (Ypresian) of Austria (Gmunden).

Taxonomic Composition of the Brachiopod Fauna

Linguliformea and Craniiformea brachiopods are missing; all studied specimens belong to the Rhynchonelliformea subphylum. Within Rhynchonelliformea, all specimens belong to the order Terebratulida (rhynchonellides and thecideides are missing). Within terebratulides the short-looped superfamily Terebratuloidea is dominant (*Gryphus* 69 %, *Meznericsia* 3.6 %) but Cancellothyridoidea is also significant (*Terebratulina* 21 %, *Orthothyris* 0.3 %). Two genera belonging to the superfamily Megathyridoidea are much less numerous (*Argyrotheca* 5.8 %, *Megathiris* 0.3 %).

The above mentioned taxonomic composition is based on all studied specimens and therefore supposedly little biased against the micromorphic species: both the private collection and the material from the Kammerhofmuseum contain only macromorphic brachiopods (they did not examine washed materials). However, if we check only the new material of the upper nummulitic limestone (from where both macromorphic and micromorphic brachiopod specimens were intensively collected), the taxonomic composition does not change significantly: *Gryphus* 71 %, *Meznericsia* 3.9 %, *Terebratulina* 13.2 %, *Orthothyris* 0.7 %, *Argyrotheca* 10.5 % and *Megathiris* 0.7 %). The only significant difference is that *Argyrotheca* is more frequent, while *Terebratulina* is less common.

Palaeoecology, Palaeoenvironment

According to Logan (1979) and Logan et al. (2004) *Argyrotheca*, *Megathiris* and *Lacazella* dominate in shallow water environments (ranging down to about 200 m) of the Recent Mediterranean, while *Gryphus*, *Terebratulina*, *Platidia* and *Megerlia* characterize the eurybathic species, which are more typical of the bathyal zone. The absence of thecideids, the limited rate of Megathyridoidea (*Argyrotheca*, *Megathiris*) and the dominance of *Gryphus* and *Terebratulina* clearly refer to deeper water environment at the Rote Kirche locality, maybe in outer shelf environments, as suggested also by larger foraminifera (see later). The distributional pattern of Recent *Gryphus vitreus* along the Mediterranean upper bathyal continental slope was intensively studied by Emig & Arnaud (1988) and Emig (1989a, b).

Ecologically, the described brachiopods belong to three categories. Most of the species are attached by a strong and short pedicle to hard substrates: *Gryphus*, *Argyrotheca*, *Megathiris*, *Orthothyris*. However, *Terebratulina* is attached directly to the loose sediment by a root-like, divided pedicle. *Meznericsia* is an extinct genus without recent representatives, but the very convex valves, and extremely incurved small beak may refer to non functional pedicle, at least in the adult phase. It should mean that after the "normal", attached juvenile stage, the large-sized, nearly globular adult specimens secondarily became free-living, probably on soft substrate.

Larger brachiopods can offer hard substrate for epifaunal encrusters, but the amount of epibionts is very variable both on fossil and Recent forms. Only two out of 213 studied specimens (0.9 %) of *Gryphus kickxii* show remains of worm tubes (some similar worms were also seen on large nummulitids). Both coiled worm tubes are situated on the ventral valve, very near to the terminal part of the anterior margin (Pl. 1, Figs. 10–11). Taking into consideration the life position of *Gryphus*, the ventral valve and mainly the terminal part of the ventral valve is situated at the highest point. These brachiopods are sometimes densely packed, and only these parts of the shells are available as solid substrate for the settlement of larvae. It suggests that they encrusted the ventral valves of *Gryphus* during the life of the brachiopods. As they attached very near to the anterior margin, the worms probably benefited from the feeding currents of the brachiopod. Similar situations were reported e.g. on the Palaeozoic *Mucrospirifer* (Schumann, 1967), on the Devonian *Anathyris* (Alvarez & Taylor, 1987), on the Eocene *Paraplicirhynchia* (Bitner, 1996), on the Miocene *Argyrotheca* (Dulai, 2007) and on the Cenozoic and Recent *Tegulorhynchia* (Lee, 1980).

Small Foraminifera

Material and method

One sample from the locality Rote Kirche was collected for foraminiferal analysis. The sample was washed in the Laboratory of the Czech Geological Survey in Prague using the standard washing method. The size of the sieve of 0.063 mm and coarse fraction was kept. The foraminiferal assemblage was studied by a Nikon binocular microscope.

Results

The studied sample contains a relatively rich foraminiferal assemblage but the preservation of foraminiferal tests is mostly bad. Bryozoa and Echinodermata remains were also found, as well as some ostracods and fish teeth. In the anorganic part of the material grains of glauconite appear.

In the foraminiferal assemblage benthic species prevail, especially *Heterolepa eocaena* (Guembel). Among other benthonic foraminifers *Spiroplectammina pectinata* (Reuss), *Globorotalites* sp., *Planulina costata* (Hantken), *Pararotalia lithothamnica* (Uhlig) and *Textularia* sp. are present.

Planktonic species are less abundant. Specimens of *Truncorotalia aequa* (Cushman & Renz), *Subbotina triloculinoides* (Plummer), *Turborotalia primitiva* (Finlay) and *Globorotalia aragonensis* Nuttall were found. Some of the recognized species were mentioned in previous papers from the Palaeogene of the Austrian Helvetic Zone (Gohrbandt, 1963, 1967; Wille-Janoschek, 1966).

Stratigraphic interpretation

The presence of *G. aragonensis* in the studied sample allows to attribute this assemblage to the planktonic Zone P7 *(Globorotalia formosa)* to P8 *(Globorotalia aragonensis)* of the Early Eocene according to Blow (1969) and Berggren (1971).

Palaeoecological interpretation

Abundance of benthic foraminifers and a smaller amount of planktonic ones characterize shallow-water conditions at certain times.

Larger Foraminifera

Introduction

Larger foraminifera occur in great quantity in two samples. These are the uppermost nummulitic limestone (sample 1) and the lower outcrop with *Assilina* (sample 4). They are represented by nummulitids (genus *Nummulites* and *Assilina*) and orthophragmines, which is an informal collective term for Eocene orbitoidal forms uniting two systematically independent families, such as Discocyclinidae (consisting of genus *Discocyclina* and *Nemkovella*) and Orbitoclypeidae (with genus *Orbitoclypeus* and *Asterocyclina*). The preservation of fossils is average in both samples, megalospheric (A) forms are in great majority.

Methods

The inner morphology of larger foraminifera could be studied by opening them by the splitting method with pliers and painting with violet ink (described in detail in Less, 1981). In the determination of larger foraminifera the morphometric method (described in detail by Drooger, 1993) was followed, i.e. in each sample specimens were grouped into populations, the members of which are clearly distinguishable from the specimens of the other populations of the same sample. Taxonomic determinations are based on these populations (as a whole) and not on their separate individuals. These taxa are in most cases the members of a long-lasting and continuous evolutionary chain called lineage or phylum. In the case of orthophragmines lineages correspond to species while for the genus *Nummulites* and *Assilina* they form a series of chronospecies.

In the determination of orthophragmines we focused on the internal features found in the equatorial section, thus we adopted principles and nomenclature used by Less (1987) as illustrated in Text-Fig. 4 and explained in the header of Table 1. Numerous orthophragminid lineages (their validity is proven biometrically by Less & Ó. Kovács, 2009) are used for biostratigraphic purposes after being artificially segmented into chronosubspecies separated from each other by arbitrary biometric limits of the mean deuteroconchal size, the most rapidly evolving parameter. A synopsis of subspecies identification based on the outer cross-diameter of the deuteroconch (parameter d) is given in Özcan et al. (2010). A revised stratigraphy of late Ypresian to middle Lutetian orthophragmines is presented in Özcan et al. (2007b).

Representatives of nine orthophragminid lineages could be found in the Gmunden samples. They are figured in Pl. 4, biometric data are summarized in Table 1. Because of the limited space, a complete statistical evaluation with the number of specimens (№), arithmetical mean and standard error (s.e.) is given only for parameter d, the crucial parameter in subspecific determination. If the population consists of only a single specimen, no subspecies is determined, in the case of only two or three specimens, the subspecies is determined as "cf.". Since most orthophragmines found in the Gmunden samples are recently discussed in Özcan et al. (2007a, 2007b, 2010) and Less et al. (2007), we do not repeat here their description with the exception of *Orbitoclypeus multiplicatus gmundenensis* n. ssp. (see in the systematical part), which represents the most advanced developmental stage of the lineage known so far.

Nummulitids appeared to be less diverse in the Gmunden samples. Four lineages could be identified, some small *Nummulites* have not been determined on the specific level. The segmentation of lineages into chronospecies by Schaub (1981) is typological and based mainly on microspheric (B) forms, however we also could use the mean proloculus (the first chamber) diameter of the megalospheric (A) forms in the Schaub collection measured by Less (1998b). Nummulitids are figured in Pl. 5, biometric data of the inner cross-diameter of the proloculus (parameter P) are summarized in Table 2. The specific determination within lineages is briefly discussed at particular samples.

Results

Sample 1 consists of a relatively rich assemblage of larger foraminifera dominated by both orthophragmines and nummulitids. The specific composition is as follows:

Orthophragmines:

Discocyclinidae

Discocyclina archiaci cf. *archiaci* (Schlumberger) – Pl. 4, Fig. 6.
D. fortisi fortisi (d'Archiac) – Pl. 4, Figs. 1–3.
D. pulcra cf. *landesica* Less – Pl. 4, Fig. 5.
D. dispansa taurica Less – Pl. 4, Figs. 4, 7.
Nemkovella evae evae Less – Pl. 4, Figs. 8, 9.
N. strophiolata cf. *fermonti* Less – Pl. 4, Fig. 10.

Orbitoclypeidae

Orbitoclypeus schopeni crimensis Less – Pl. 4, Figs. 12–14.
O. multiplicatus gmundenensis n. ssp. Less – Pl. 4, Figs. 15–19.
Asterocyclina alticostata (Nuttall) indet. ssp. – Pl. 4, Fig. 11.

Nummulitidae

Nummulites nemkovi Schaub – Pl. 5, Figs. 1–4.
N. irregularis Deshayes – Pl. 5, Figs. 6–8.
N. indet. sp. (radiate forms)
Assilina plana Schaub – Pl. 5, Figs. 9, 10.

Comments on nummulitids: According to Schaub (1981) *Nummulites nemkovi*, *N. irregularis* and *Assilina plana* are members of the *N. distans*, *N. irregularis* and *A. spira* lineage, respectively. Specific identification within lineages is based on the measurements by Less (1998b). Concerning the *N. distans* lineage, the mean proloculus diameter (P_{mean}) given in Table 2 best fits to *N. nemkovi*. It is considerably larger than the characteristic values of *N. haymanensis*, the ancestor of *N. nemkovi*, and significantly smaller than those of *N. distans*, the offspring. In the case of the *N. irregularis* lineage, the dimension of the proloculus fits well *N. irregularis* and is considerably smaller than that of *N. maior*, the successor. Finally, the proloculus diameter of *Assilina* with an open spi-

Parameters		Outer cross-diameter of the embryon					Adauxiliary chamberlets			Equatorial chamberlets			Subspecific determination
		deuteroconch			protoconch		number	width	height	annuli/ 0.5 mm	width	height	
		d (µm)			p (µm)		N	W (µm)	H (µm)	n	w (µm)	h (µm)	
Species	Sample	N°.	range	mean±s.e.	range	mean	range	range	range	range	range	range	
Discocyclina archiaci	Gmunden 1	3	415–510	462	260–295	278	25–30	40–45	65–75	8–9	35–40	70–90	cf. *archiaci*
D. fortisi	Gmunden 1	18	550–910	719±26	260–440	352	38–52	40–55	50–70	8–10	35–40	65–80	*fortisi*
	Gmunden 4	1		800		–	–	45	60	9–14	40	70	indet. ssp.
D. dispansa	Gmunden 1	11	165–260	214±9	110–160	129	13–21	30–35	45–60	11–15	25–30	50–70	*taurica*
	Gmunden 4	4	160–260	205±18	90–150	122	13–20	30–35	45–55	12–15	25	45–60	*taurica*
D. pulcra	Gmunden 1	2	570–665	618		260	48	40–50	80–110	6–7	25	100–120	cf. *landesica*
Nemkovella evae	Gmunden 1	10	205–290	246±9	105–180	153	11–15	50–60	45–60	11–13	30–40	40–60	*evae*
N. strophiolata	Gmunden 1	2	115–145	130	60–90	75	6–7	40	25–30	18	25–30	30–35	cf. *fermonti*
Orbitoclypeus schopeni	Gmunden 1	17	295–550	418±13	150–335	235	28–40	40–50	50–60	8–10	30–40	60–100	*crimensis*
O. multiplicatus	Gmunden 1	11	455–790	613±32	250–430	318	32–48	45–80	50–70	6.5–8	40–45	75–100	*gmundenensis* n. ssp.
Asterocyclina alticostata	Gmunden 1	1		255		185	8	60–120	60	13	30–35	35–45	indet. ssp.

Table 1.
Statistical data of orthophragminid populations. No: number of specimens, s.e.: standard error.

ral (the basic feature of their arrangement into the *A. spira* lineage) in sample Rote Kirche 1 falls between *A. adrianensis* (the ancestor) and *A. laxispira* (the offspring) and corresponds well to *A. plana*.

Age: This assemblage clearly determines the SBZ 10 Zone by SERRA-KIEL et al. (1998) and the OZ 6 Zone by LESS (1998a), indicating the early part of the late Ypresian (= Cuisian). Moreover, the OZ 6 Zone suggests the higher part of the SBZ 10 Zone. The correlation of orthophragminid (OZ) zones with shallow benthic (SBZ) and planktic zonations is given in ÖZCAN et al. (2010). *Discocyclina fortisi fortisi*, *Nummulites nemkovi* and *Assilina plana* are zonal markers, whereas the range of all the other taxa includes this zone. *Discocyclina archiaci archiaci* and *Orbitoclypeus multiplicatus* are not known from younger strata, moreover this latter species in older layers is represented by *O. m. kastamouensis*, a more primitive developmental stage than the newly described *O. m. gmundenensis*. In the meantime *Orbitoclypeus schopeni crimensis*, *Discocyclina dispansa taurica*, *D. pulcra*, *Nemkovella strophiolata*, *Asterocyclina alticostata* and *Nummulites irregularis* are unknown from older horizons.

Facies: The richness of orthophragmines and the presence of nummulitids with an open spiral in combination with the lack of *Nummulites* with granules and porcellaneous forms (alveolinids and genus *Orbitolites*) indicate the deeper part of the photic shelf, very probably the outer ramp.

Sample 4 contains a considerably less diverse assemblage, in which the genus *Assilina* dominates. Orthophragmines and the representatives of the genus *Nummulites* are subordinate. The specific composition is as follows:

Orthophragmines:

Discocyclinidae

Discocyclina dispansa taurica LESS
D. fortisi indet. ssp.
Nemkovella indet. sp. (only a B-form was found)

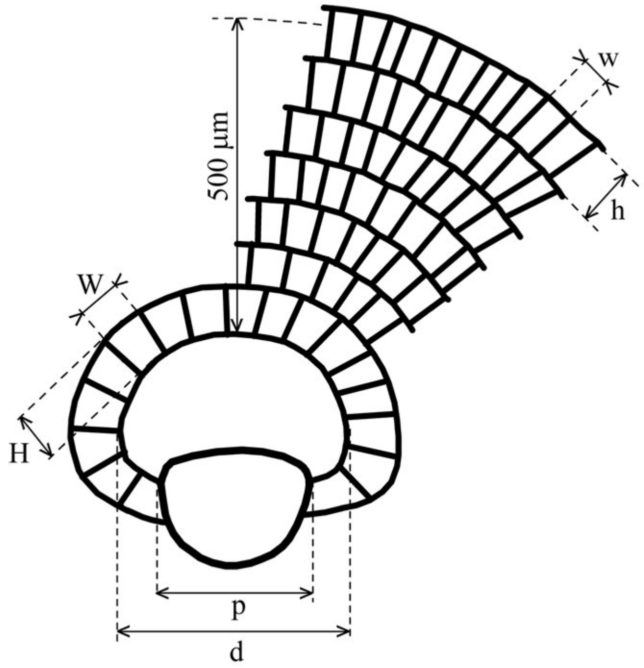
Nummulitidae:

Assilina aff. *placentula* (DESHAYES) – Pl. 5, Figs. 5, 11, 12.
Nummulites indet. sp. (small radiate forms).

Comments on *Assilina*: The representatives of this genus in sample 4 have a considerably tighter spiral than that in sample 1. Therefore, they are ranged into the *A. exponens* lineage. Based on the measurements by LESS (1998b), the proloculus diameter in the given sample (see Table 2) is intermediate between *A. placentula* (characteristic for the Lower Cuisian, see SERRA-KIEL et al., 1998) and *A. cuvillieri* (occurring in the Upper Cuisian). Such forms are determined by SCHAUB (1981) as *A.* aff. *placentula*, mainly from the Middle Cuisian.

Taxon	Sample	N°	Proloculus diameter (P) in mm	
			Range	Mean ± s.e.
Nummulites nemkovi	Gmunden 1	15	260 – 620	482,3 ± 17,6
N. irregularis	Gmunden 1	8	150 – 350	241,9 ± 22,6
Assilina plana	Gmunden 1	17	185 – 390	321,5 ± 18,8
A. aff. *placentula*	Gmunden 4	15	270 – 560	350,3 ± 21,5

Table 2.
Statistical data of the inner cross-diameter of the proloculus of nummulitid populations (in µm).
No: number of specimens, s.e.: standard error.



Text-Fig. 4.
The measurement system of megalospheric orthophragmines in equatorial section. See the header of Table 1 for explanation.

Age: Although the presence of *Assilina* aff. *placentula* suggests Middle Cuisian (SBZ 11) as discussed above, this rather narrow time-span cannot be confirmed by other larger foraminifera. The range of *Discocyclina dispansa taurica* is SBZ 10–12 (ÖZCAN et al., 2007b, updated by ZAKREVSKAYA et al., in review), i.e. the whole late Ypresian (SBZ 10–12), which is a more cautious age-estimate for sample 4.

Facies: This sample indicates a slightly less deep environment than that of sample 1, since orthophragmines are subordinate and *Assilina* aff. *placentula* with a tighter spiral replaces the representatives of the *A. spira* lineage with a more open spiral. Meanwhile forms, characteristic for the middle ramp (*Nummulites* with granules) or for the inner ramp (porcellaneous forms like alveolinids and the genus *Orbitolites*) are still missing. To sum up: the shallower part of the outer ramp seems to be the most realistic assumption.

Systematic Part

Order Foraminiferida EICHWALD, 1830

Family Orbitoclypeidae BRÖNNIMANN, 1946

Genus *Orbitoclypeus* Silvestri, 1907

Orbitoclypeus multiplicatus (GÜMBEL, 1870)

Emended diagnosis: Average-sized, inflated, unribbed forms with "marthae" type rosette. The medium-sized to moderately large embryon is excentrilepidine, rarely eulepidine. The numerous, "varians" type adauxiliary chamberlets are rather wide and medium high as well as the equatorial chamberlets. The annuli are usually moderately undulated; the growth pattern is of the "varians" type. *O. multiplicatus* is subdivided into four successive subspecies as defined below:

O. m. haymanaensis $d_{mean} < 310$ µm
O. m. multiplicatus $d_{mean} = 310–420$ µm
O. m. kastamonuensis $d_{mean} = 420–550$ µm
O. m. gmundenensis $d_{mean} > 550$ µm.

Orbitoclypeus multiplicatus gmundenensis n. ssp. Less

Pl. 4, Figs. 15–19.

Etymology: Named after the city of Gmunden.

Holotype: Specimen E.10.31 (Pl. 4, Figs. 18, 19.).

Depository: Geological Institute of Hungary, Budapest.

Paratypes: All the other specimens from Gmunden, sample 1, illustrated in Pl. 4, Figs. 15–17.

Type locality: Gmunden (Austria), sample Rote Kirche 1.

Type level: Lower Upper Ypresian, the OZ 6 orthophragminid and the SBZ 10 shallow benthic zone.

Diagnosis: *Orbitoclypeus multiplicatus* populations with d_{mean} exceeding 550 µm.

Description (see also Table 1): Moderately large (3–5 mm), inflated, unribbed forms with "marthae" type rosette. The embryon is rather large, mostly excentrilepidine, sometimes eulepidine. The numerous "varians" type adauxiliary chamberlets are rather wide and relatively high. The equatorial chamberlets are also fairly wide and moderately high. The annuli can be slightly undulated; their growth pattern is of the "varians" type.

Remarks: Representatives of the *Orbitoclypeus multiplicatus* lineage are mostly known from the Thanetian and early Ypresian (Ilerdian), in the SBZ 3 to 8 and OZ 1b to 4 Zones. Özcan et al. (2007b) reported one single specimen with similar characteristics as in Gmunden from the SBZ 10/11 or OZ 6/7 Zones corresponding to the lower part of the Upper Ypresian (Cuisian) of Kiriklar (N Turkey). Our material from Gmunden consisting of eleven specimens allows us to introduce the most advanced developmental stage of the lineage as a new chronosubspecies.

Orbitoclypeus multiplicatus gmundenensis is hardly distinguishable from *O. schopeni schopeni* and *O. zitteli* with similar embryonic size and type. Its equatorial chamberlets, however, is slightly wider than those of the other two taxa, which have a different stratigraphical position.

Range: Early part of the late Ypresian (Cuisian), the SBZ 10 and OZ 6 Zones. It may include the SBZ 9 and 11 as well as the OZ 5 and 7 Zones.

Gmunden (Austria) and very probably Kiriklar (Turkey).

Calcareous Nannofossils

Method

Nannofossils were investigated in the fraction of 2–30 µm, separated by decantation following the methodology described in Svobodová et al. (2004). Simple smear-slide was mounted by Canada Balsam and inspected at a 1000× magnification, using an oil-immersion objective on a Nikon Microphot-FXA transmitting light microscope. Biostratigraphic data were interpreted applying the zonations of Martini (1971) and Varol (1998).

Results

The studied fraction 2–30 µm (samples A and B) contained predominantly anorganic material. The nannofossil abundance in sample A was generally 10–20 specimens per 1 field of view of the microscope, whereas sample B was extremely poor, only 1–3 specimens per 1 field of view of the microscope. Calcareous nannofossils were poorly preserved in both samples. Discoasterids and large placoliths were mostly fragmented and discoasterids and the central fields of placoliths partly etched, partly overgrown with calcite. Some specimens cannot be identified due to the poor preservation especially in sample Rote Kirche B.

Sample A

The nannofossil assemblage is characterized by a higher number of discoasterids exclusively of rosette shape, and by the rare presence of specimens of the genera *Reticulofenestra, Helicosphaera* and *Lophodolithus* (Pl. 6).

The following species have been found*: Coccolithus pelagicus, C. eopelagicus, Sphenolithus radians, S. moriformis, S. editus, Campylosphaera dela, C. eodela, Helicosphaera seminulum, H. lophota, Neococcolithes protenus, N. protenus-dubius, Cyclococcolithus (Ericsonia) formosus, Zygrhablithus bijugatus, Calcidiscus protoannulus, Micrantholithus flos, Pontosphaera pulcheroides, P. pulchra, Thoracosphaera* sp.*, Discoaster barbadiensis, D. lodoensis* (7 rays, mostly in fragments)*, D. kuepperi, D.* sp.*, Toweius rotundus, T. crassus, Girgisia gammation, Clausicoccus fenestratus, Chiasmolitus solitus, C. eograndis* (fragments)*, C. consuetus, C.* sp.*, Lophodolithus mochloporus, L. nascens, Braarudosphaera turbinea* (probably reworked from the older sediments of the lowermost Palaeocene, Danian age).

Sample B

Poor nannofossils are characterized by a higher number of specimens of the genus *Toweius*. The assemblage consists of species *Coccolithus pelagicus, C. eopelagicus,* rare *Ellipsolithus macellus, Chiasmolithus solitus, C. bidens, C. eograndis, Discoaster binodosus, D. barbadiensis, D. kuepperi, D. multiradiatus, Zygrhablithus bijugatus, Neochiastozygus junctus, Lophodolithus nascens, Sphenolithus moriformis, Campylosphaera eodela, Pontosphaera pulchra, Coronocyclus* sp., rare pentaliths of *Braarudosphaera bigelowii bigelowii*, *B. bigelowii parvula* and *Micrantholithus* sp., *Clausicoccus fenestratus, Toweius crassus, T. rotundus, T. pertusus.*

The assemblage also contained reworked species from older sediments of the lower and middle Palaeocene age, such as *Fasciculithus* cf. *ulii, Cruciplacolithus tenuis, Sullivania danica* and *Markalius astroporus* (Danian).

Stratigraphic interpretation

Sample A: Upper part of Lower Eocene (Ypresian), zone NP 13 sensu Martini (1971) according to the presence of *Discoaster lodoensis* (7 rays), rare *Lophodolithus mochloporus* and *Reticulofenestra dictyoda*.

Sample B: Lower Eocene (Ypresian), the uppermost part of zone NP 11 (Martini, 1971), i.e. NNTe1D (sensu Varol, 1998) according to the joint presence of *Discoaster kuepperi* and *Ellipsolithus macellus,* and the relative abundance of *Toweius* spp.

Palaeoecologic interpretation

The presence of calcareous nannofossils indicates a sea of average salinity, with an abundance of discoasterids, relatively warm waters, the presence of the genera *Pontosphaera, Helicosphaera* and penthaliths shallow-water conditions; the etching of placoliths and discoasterids may be the result of carbonate dissolution caused by the release of carbon dioxide during the oxidation of organic matter (ŠVÁBENICKÁ et al., 2010).

Discussion

Calcareous nannofossils of the Rote Kirche outcrop have already been studied by EGGER et al. (2009). They mentioned an assemblage of zone NP 12 with *Discoaster lodoensis* and *Tribrachiatus orthostylus* (Type B). Sample Rote Kirche A of the present study provided nannofossils of zone NP 13 with the genus *Reticulofenestra.* This small difference in results might be caused by taking samples from dissimilar places of outcrop.

VAROL (1998) mentioned the first occurrence of the genus *Reticulofenestra* within zone NNTe5 and correlated it with the uppermost part of the standard nannoplankton zone NP 12, i.e. with the upper part of the Lower Eocene. The first occurrence of *Lophodolithus mochloporus* is stated by PERCH-NIELSEN (1985) within NP 13.

Joint occurrence of *Discoaster kuepperi* and *Ellipsolithus macellus* in sample B delimits the short stratigraphic range within zone NNTe1D (VAROL, 1998). This is supported also by the occurrence of *Discoaster multiradiatus,* its last occurrence known from NP 11 (PERCH-NIELSEN, 1985).

The nannofossil content and stratigraphic interpretation of samples published by EGGER et al. (2009) different from this study (samples A and B) may indicate a deposition in a longer period of time, spanning an interval from NP 11 (upper part) up to NP 13.

Microflora – Preliminary Results

Taxonomically varied microfossils of dinocysts, spores, pollen, remains of foram linings, tiny cuticles and xylitic splinters were obtained from the aleuritic sample derived from the section at Rote Kirche. Marine dinocysts, lack of typical Mesozoic cheirolepidaceous conifers and rare Normapolles characterize the assemblage. Reworked specimens from the Upper Cretaceous, composition of pollen taxa (Icacinaceae, cf. Sapotaceae) and comparable Dino-Zones point to the early Palaeogene. Observable organic matter originated rather in a near-shore than a far offshore environment.

Characteristic of the assemblage

Residues obtained by solution and maceration of the sample (Laboratory of the Geological Survey, Prague; geology and location of the sample site, EGGER, 1996, 2007) contained no rich assemblage of palynomorphs. They are mainly composed of dinocyst microplankton (Table 3), with co-occurrence of foraminiferal linings and accessories of terrestrial plants, spores, pollen and other organic debris (Table 4).

Fern spores belong to the Osmundaceae, Schizaeaceae, Lygodiaceae, Gleicheniaceae and document presence of the terrestrial flora of the nearby coastland area.

Conifers are represented by at least two groups. The first is documented by inaperturate pollen, resembling taxodiaceous pollen, the second comprises pollen provided with a bisaccate apparatus (bladders), grouped within Pinaceae. Both are commonly known from the Cretaceous and Tertiary pollen assemblages.

Characteristic feature of the present microflora is a small number of coniferous pollen. Cheirolepidaceae pollen grains, common in the Cretaceous deposits, were not recorded. This could be in good accordance with their disappearing in the Palaeogene.

Flowering-plant pollen genera (Normapolles and other angiospermous pollen) were represented by solitary species and single records (Table 4), in contrast to the non marine environments (e.g. Menat, Borna, Geiseltal a.o.).

Dinocysts dominated in the assemblage, pointing together with other organic remains to the ample nutrient supply. Some of dinocysts show poor preservation (broken cysts or only partly preserved specimens). These features may be interpreted as the result of reworking and/or transport on the shelf.

Striking is relatively abundant dark organic matter, amorphous or with preserved structure.

According to the residual phyto- and microzoo-remains, the flourishing associations can be considered in the time of silty clay deposition.

Conclusions

The pollen and several dinocyst records provided data for the preliminary evaluation of the relative age of the investigated assemblage (CHATEAUNEUF, 1980; KEDVES, 1969, 1970; KEDVES & RUSSEL, 1982; KRUTZSCH, 2004; KRUTZSCH & VANHOORNE, 1977; DAVEY et al., 1966; KÖTHE, 1990; LENTIN & WILLIAMS, 1993; STANLEY, 1965 ex WILLIAMS et al., 1998); based on the dinocysts and several flowering plant taxa, it is obviously the Palaeogene age, mostly the Palaeocene (Zone D 3) and Early Eocene (Zone D 4, D 5, D 6). The Early Eocene (Ypresian) age has also been supported by nannofossil zones NP 11 with *Discoaster kuepperi* and *Ellipsolithus macellus* and NP 13 with *Discoaster lodoensis* and *Reticulofenestra dictyoda,* as well as larger benthic foraminifera indicating the SBZ 10 Zone. Dinocysts, preliminarily recorded, show their range often within the Zone D 4, D 5, in comparison with the palynological investigation of the borehole sections in NW Germany, Lower Saxony area (KÖTHE, 1990). The fragmentary remains of some plankton specimens and taxa predominantly known from Cretaceous deposits (ILYINA et al., 1994; MARHEINECKE, 1986) are considered as results of reworking and bioturbation processes, possible also at a very short time scale and within thin layers.

The observation of amorphous organic matter and evidently organic remains allows to consider rather bay or near shore sedimentation, not a far offshore environment. Calcareous nannofossils indicate a warmer sea of normal salinity. The presence of organic remains in the depositional area is supported also by the mode of nannofossil preservation: carbonate dissolution of coccoliths is usually caused by the release of carbon dioxide during oxidation of organic matter.

Dinoflagellates	**Remarks**	**Age**	**D Zones and Subzones**	**References**
cf. *Adnatosphaeridium vittatum* WILLIAMS & DOWNIE 1966	partly preserved	Early Eocene	D 6b	KÖTHE (KÖ), 1990, NW Germany, Gartow, Early Eocene (E Eo)
cf. *Achomosphaera* aff. *triangulata* (GERLACH 1961) DAVEY & WILLIAMS 1969		Early Eocene		KÖ, 1990, Gartow, E Eo
cf. *Apteodinium* sp.	partly preserved	Early Eocene		KÖ, 1990, Gartow, E Eo
Cordosphaeridium sp. – compared with *C. fibrospinosum* DAVEY & WILLIAMS 1966 and *C. trompetum* (COOKSON & EISENACK 1982) LENTIN & WILLIAMS 1985 Pl. 7, Figs. 1, 2 in present paper		Late Palaeocene, Early Eocene, Late Eocene (LO?) Palaeocene	D 4, D 5b D 3	KÖ, 1990, D 4 Late Palaeocene, Gartow, D 5b E Eo; (D 7 a. D 8 Late Eo, more in KÖ, 1990) Palaeocene, bore Söhlingen, ibid.
Areoligera senonensis LEJEUNE-CARPENTIER 1938 sensu KÖTHE 1990 [now *Areoligera (Achomosphaera) danica*] Pl. 7, Fig. 6 in present paper	probably reworked	Early Eocene, whole Palaeocene D 4 Upper Cretaceous, particularly in L./U. Maastrichtian	D 5b D 4, 4na, nb	KÖ, 1990; D 5b E Eo, Gartow D 4 Palaeocene, bore Penningsehl, KÖ, 1990 Cretaceous, MARHEINECKE, 1986
Dipsilidinium pastielsii (DAVEY & WILLIAMS 1966) BUJAK, DOWNIE, EATON, WILLIAMS 1980		Early Eocene	D 5b	KÖ, 1990, Gartow
cf. *Odontochitina* sp.	partly preserved	Palaeocene	D 4a (rare)	KÖ, 1990
? *Ceratiopsis* sp.	partly preserved	Palaeocene (e.g.)	D 4	KÖ, 1990
Isabelidinium sp. (former *Chatangiella* VOZZHENIKOVA 1967)	probably reworked	Upper Cretaceous (Campanian, Maastrichtian); Palaeocene, Early Eocene (another type, with broad cingulum)		e.g. Canada, Siberia, ILYINA et al., 1994; *Chatangiella* ?, Palaeocene, South Dakota, STANLEY, 1965 (ex WILLIAMS et al., 1998); Isabelidinium sp., Early Eocene, NW Germany, KÖ, 1990
Isabelidinium cf. *cooksoniae* (ALBERTI 1959) LENTIN & WILLIAMS 1977	reworked	Cretaceous	Coniacian, Campanian	Late Cretaceous, Coniacian, Campanian, e.g. Siberia, ILYINA et al., 1994
cf. *Homotryblium* aff. *tenuispinosum* DAVEY et al. 1966		Eocene	London Clay	DAVEY et al., 1966
Thalassiphora cf. *pelagica* (EISENACK 1954) EISENACK & GOCHT 1960, *T. delicata* DAVEY et al. 1966		Cretaceous, Palaeogene, Neogene	London Clay	KÖ, 1990, e.g. Early Eocene, NW Germany, Gartow, DAVEY et al., 1966, Eocene
? *Fromea* sp.	vermiculate surface			
Chlorophyta – Zygnemataceae, freshwater green algae				
Ovoidites elongatus (HUNGER 1952) KRUTZSCH 1959		Cretaceous, Tertiary, Pleistocene	freshwater and brackish water	genus commonly known from the basinal deposits

Table 3.
Plankton (selected taxa).

Filicinae – ferns		
Leiotriletes adriennis (Potonié & Gelletich 1933) Krutzsch 1959	Mesozoic, Tertiary	Schizaeaceae, *Lygodium* type
Leiotriletes microadriennis Krutzsch 1959	Palaeocene (e.g. Menat), Eocene (Geiseltal, Messel) and other sites of Tertiary deposits	Schizaeaceae, *Lygodium* type
Gleicheniidites sp.	Mesozoic, Palaeogene (predominantly)	Gleicheniaceae
Appendicisporites cf. *auritus* Aggassie in Singh 1983	Mesozoic, reworked	Schizaeaceae
Cicatricosisporites sp.	Mesozoic, Palaeogene	Schizaeaceae
Trilites menatensis Kedves 1982	Palaeocene, Eocene	Lygodiaceae (after Kedves in Kedves & Russel, 1982)
Rugulatisporites quintus Pflug 1953	Mesozoic, Tertiary	Osmundaceae
Conifers		
Pityosporites sp. – *Pityosporites minutus* (Zaklinskaja 1957) Nagy 1985, ?*Pityosporites strobipites* (Woodehouse 1933) Krutzsch 1971	?Palaeocene, Eocene, Neogene	Pinaceous conifers
Pityosporites sp. Pl. 7, Fig. 3 in present paper	Cretaceous, Tertiary	Pinaceae
Inaperturopollenites Thomson & Pflug 1953 *Inaperturopollenites hiatus* (Potonié 1931) Thomson & Pflug 1953 (as *Taxodiaceaepollenites* sp.) in Mesozoic	Cretaceous, Tertiary	Taxodiaceous pollen – commonly known from Cretaceous and Tertiary
Angiospermae - Flowering plants **Normapolles**	Cretaceous, Palaeogene	extinct Upper Cretaceous, Palaeocene, Early Eocene common
Minorpollis sp.	Cretaceous, Palaeogene	extinct
cf. *Complexiopollis vancampoe* Diniz et al. 1974, smaller-sized form	Cretaceous reworked	Portugal, Upper Cretaceous, L. to M. Turonian is considered
Angiospermae - Flowering plants		
cf. *Triporopollenites robustus* Pflug 1953 subfsp. *minor* Kedves 1970		cf. Betulaceae (after Kedves, 1970)
cf. *Compositoipollenites* sp.	Palaeogene	cf. Icacinaceae
aff. *Intratriporopollenites* sp.	Palaeogene, Neogene	cf. Malvaceae, Tilioideae
Tricolpites, Tricolpopollenites – Tricolpo(roi)pollenites group – reticulate morphotypes s.l.	Early Cretaceous, Tertiary	Hamamelidaceae, Platanaceae, partly extinct
Tricolporopollenites exactus (Potonié 1931) Thomson & Pflug 1953	Palaeogene, Neogene	Fagaceae, Castaneoideae
Tricolporopollenites cf. *gracillimus* Krutzsch & Vanhoorne 1977	Palaeogene, Epinois „Bild“ sensu Krutzsch	Late Landenian, palynozone 11 after Krutzsch (in Krutzsch & Vanhoorne, 1977), Early Eocene
aff. *Tricolporopollenites globus* Deák 1960 Pl. 7, Fig. 4 in present paper	Eocene (Hungary)	Incertae sedis; Sapotaceae (after Kedves, 1969)
Tetracolporopollenites sp. Pl. 7, Fig. 5 in present paper		Incertae sedis, ?Sapotaceae
Other plant remains		
filamentous Algae or Cyanobacteria	Precambrian – Recent, environmentally controlled	
charcoal splinters (rare)		
tiny cuticle fragments		
Remains of zoo-plankton		
different linings of microforaminifera		
Animal cuticle / epidermis remains		

Table 4.
Vascular plants

Plate 1

Fig. 1: *Gryphus kickxii* (Galeotti, 1837).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 11.4 mm, W: 10.8 mm, Th: 5.5 mm.
M 2010.477.1., 2×.

Fig. 2: *Gryphus kickxii* (Galeotti, 1837).
Dorsal view.
Rote Kirche 1; L: 12.4 mm, W: 9.7 mm, Th: 6.3 mm.
M 2010.478.1., 2×.

Fig. 3: *Gryphus kickxii* (Galeotti, 1837).
a – dorsal view, b – anterior view.
Rote Kirche 1; L: 18.8 mm, W: 17.3 mm, Th: 10.0 mm.
M 2010.479.1., 2×.

Fig. 4: *Gryphus kickxii* (Galeotti, 1837).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 19.5 mm, W: 20.5 mm, Th: 12.1 mm.
M 2010.480.1., 2×.

Fig. 5: *Gryphus kickxii* (Galeotti, 1837).
Dorsal view.
Rote Kirche 1; L: 19.2 mm, W: 16.1 mm, Th: 10.1 mm.
M 2010.481.1., 2×.

Fig. 6: *Gryphus kickxii* (Galeotti, 1837).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 24.4 mm, W: 24.5 mm, Th: 12.9 mm.
M 2010.482.1., 2×.

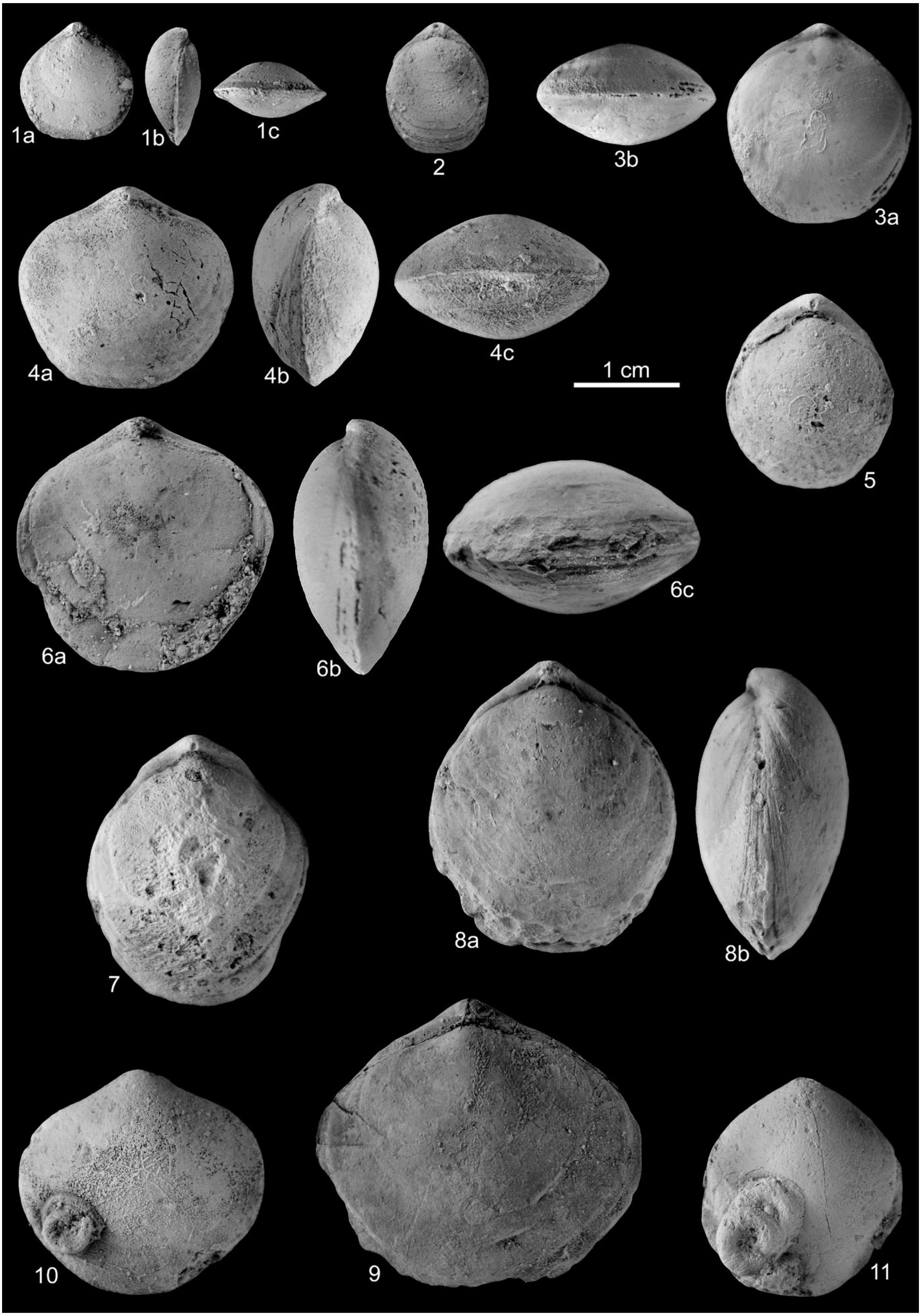
Fig. 7: *Gryphus kickxii* (Galeotti, 1837).
Dorsal view.
Rote Kirche 1; L: 25.8 mm, W: 20.9 mm, Th: 11.8 mm.
M 2010.483.1., 2×.

Fig. 8: *Gryphus kickxii* (Galeotti, 1837).
a – dorsal view, b – lateral view.
Rote Kirche 1; L: 28.5, W: 24.0 mm, Th: 14.6 mm.
M 2010.484.1., 2×.

Fig. 9: *Gryphus kickxii* (Galeotti, 1837).
Dorsal view.
Rote Kirche 1; L: 27.7 mm, W: 31.2 mm, Th: 14.0 mm.
M 2010.485.1., 2×.

Fig. 10: Tube worm on *Gryphus kickxii* (Galeotti, 1837).
Ventral view.
Rote Kirche 1; L: 21.8 mm, W: 23.6 mm, Th: 12.0 mm.
M 2010.486.1., 2×.

Fig. 11: Tube worm on *Gryphus kickxii* (Galeotti, 1837).
Ventral view.
Rote Kirche 1; L: 21.2 mm, W: 19.3 mm, Th: 10.6 mm.
M 2010.487.1., 2×.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6a
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6c
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8a
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11

Plate 2

Fig. 1: *Meznericsia hantkeni* (Meznerics, 1944).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 30.8 mm, W: 27.8 mm, Th: 18.2 mm.
M 2010.488.1., 2×.

Fig. 2: *Meznericsia hantkeni* (Meznerics, 1944).
a – dorsal view, b – lateral view, c – posterior view.
Rote Kirche 1; L: 29.1 mm, W: 25.6 mm, Th: 19.0 mm.
M 2010.489.1., 2×.

Fig. 3: *Orthothyris pectinoides* (Koenen, 1894).
Dorsal view.
Rote Kirche 1; L: 2.7 mm, W: 2.6 mm.
M 2010.490.1., 20×.

Fig. 4: *Megathiris detruncata* (Gmelin, 1791).
Dorsal view.
Rote Kirche 1; L: 1.8 mm, W: 2.1 mm.
M 2010.491.1., 20×.

Fig. 5: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Dorsal view.
Rote Kirche 1; L: 2.4 mm, W: 2.0 mm.
M 2010.492.1., 20×.

Fig. 6: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Dorsal view.
Rote Kirche 1; L: 2.3 mm, W: 2.0 mm.
M 2010.493.1., 20×.

Fig. 7: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Dorsal view.
Rote Kirche 1; L: 1.6 mm, W: 1.5 mm.
M 2010.494.1., 20×.

Fig. 8: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Lateral view.
Rote Kirche 1; L: 2.0 mm, Th: 1.0 mm.
M 2010.495.1., 20×.

Fig. 9: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Oblique lateral view.
Rote Kirche 1; L: 2.6 mm, Th: 1.4 mm.
M 2010.496.1., 20×.

Fig. 10: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Ventral view.
Rote Kirche 1; L: 2.4 mm, W: 2.2 mm.
M 2010.497.1., 20×.

Fig. 11: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Ventral view.
Rote Kirche 1; L: 2.0 mm, W: 1.8 mm.
M 2010.498.1., 20×.

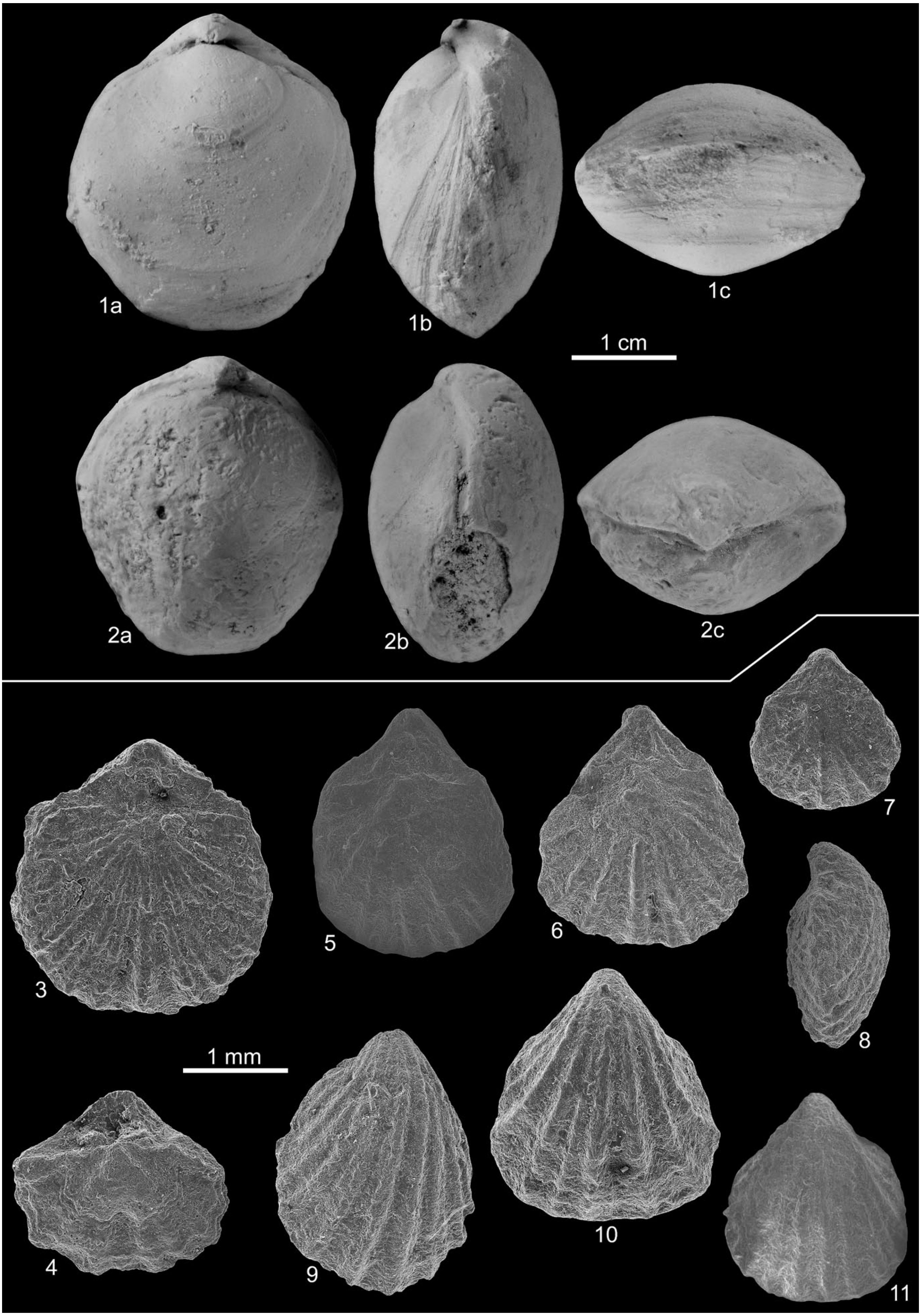
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Plate 3

Fig. 1: *Terebratulina tenuistriata* (LEYMERIE, 1846). Dorsal view. Rote Kirche 1; L: 2.1 mm, W: 1.5 mm. M 2010.499.1., 20×.

Fig. 2: *Terebratulina tenuistriata* (LEYMERIE, 1846). Dorsal view. Rote Kirche 1; L: 3.1 mm, W: 2.6 mm. M 2010.500.1., 20×.

Fig. 3: *Terebratulina tenuistriata* (LEYMERIE, 1846). Dorsal view. Rote Kirche 1; L: 2.5 mm, W: 1.8 mm. M 2010.501.1., 20×.

Fig. 4: *Terebratulina tenuistriata* (LEYMERIE, 1846). Ventral view. Rote Kirche 1; L: 2.6 mm, W: 1.9 mm. M 2010.502.1., 20×.

Fig. 5: *Terebratulina tenuistriata* (LEYMERIE, 1846). Ventral view. Rote Kirche 1; L: 2.5 mm, W: 2.2 mm. M 2010.503.1., 20×.

Fig. 6: *Terebratulina tenuistriata* (LEYMERIE, 1846). Lateral view. Rote Kirche 1; L: 2.6 mm, Th: 1.1 mm. M 2010.504.1., 20×.

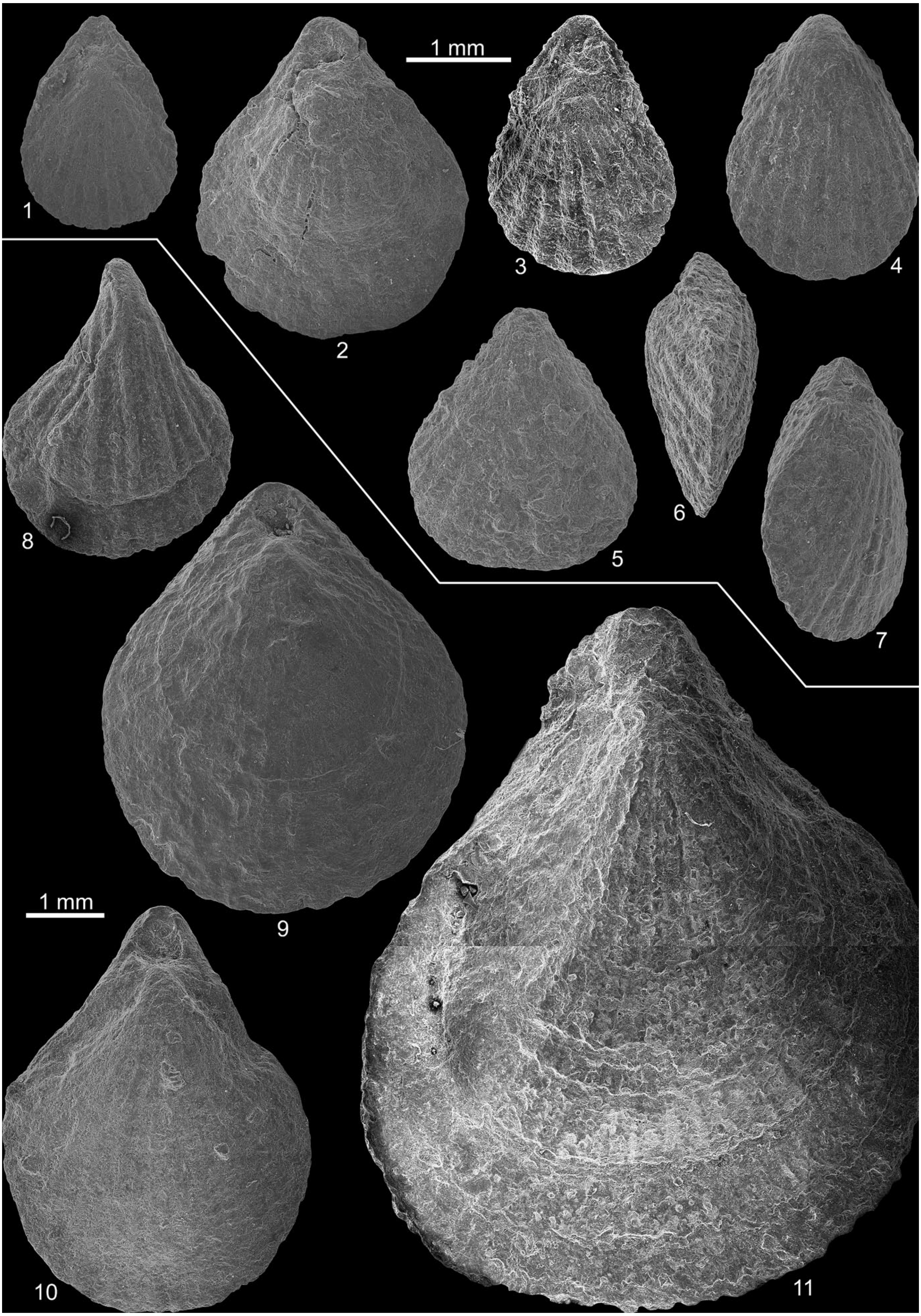
Fig. 7: *Terebratulina tenuistriata* (LEYMERIE, 1846). Oblique lateral view. Rote Kirche 1; L: 2.7 mm, W: 1.3 mm. M 2010.505.1., 20×.

Fig. 8: *Terebratulina tenuistriata* (LEYMERIE, 1846). Ventral view. Rote Kirche 1; L: 3.9 mm, W: 2.9 mm. M 2010.506.1., 15×.

Fig. 9: *Terebratulina tenuistriata* (LEYMERIE, 1846). Dorsal view. Rote Kirche 1; L: 5.5 mm, W: 4.6 mm. M 2010.507.1., 15×.

Fig. 10: *Terebratulina tenuistriata* (LEYMERIE, 1846). Dorsal view. Rote Kirche 1; L: 5.2 mm, W: 3.9 mm. M 2010.508.1., 15×.

Fig. 11: *Terebratulina tenuistriata* (LEYMERIE, 1846). Dorsal view. Rote Kirche 3; L: 9.1 mm, W: 7.5 mm. M 2010.509.1., 15×.


1
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1 mm
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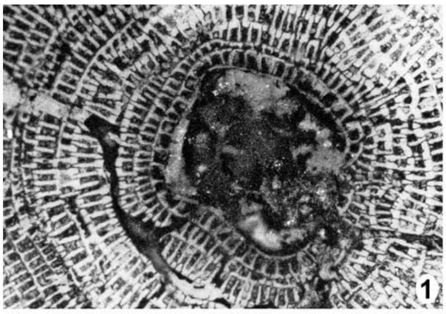
Plate 4

Megalospheric orthopragmines (A-forms) from Gmunden, Gschliefgraben, sample Rote Kirche 1.

Figs. 1–3: *Discocyclina fortisi fortisi* (d’Archiac)
Fig. 1: E.10.16.
Fig. 2: E.10.17.
Fig. 3: E.10.18.
Figs. 4, 7: *Discocyclina dispansa taurica* Less.
Fig. 4: E.10.20.
Fig. 7: E.10.21.
Fig. 5: *Discocyclina pulcra* cf. *landesica* Less.
E.10.05.
Fig. 6: *Discocyclina archiaci* cf. *archiaci* (Schlumberger).
E.10.19.
Figs. 8, 9: *Nemkovella evae evae* Less.
Fig. 8: E.10.22.
Fig. 9: E.10.23.
Fig. 10: *Nemkovella strophiolata* cf. *fermonti* Less.
E.10.32.
Fig. 11: *Asterocyclina alticostata* (Nuttall) indet. ssp.
E.10.24.
Figs. 12–14: *Orbitoclypeus schopeni crimensis* Less.
Fig. 12: E.10.26.
Fig. 13: E.10.27.
Fig. 14: E.10.25.
Figs. 15–19: *Orbitoclypeus multiplicatus gmundenensis* n. ssp. Less.
Fig. 15: E.10.28.
Fig. 16: E.10.29.
Fig. 17: E.10.30.
Figs. 18, 19: holotype, E.10.31.

Figs. 1–18: Equatorial sections, 40×.
Fig. 19: External view, 25×.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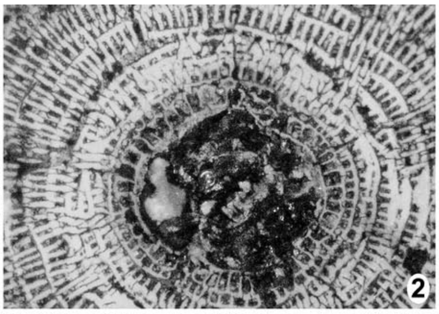
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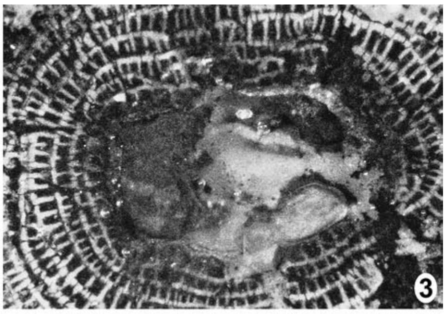
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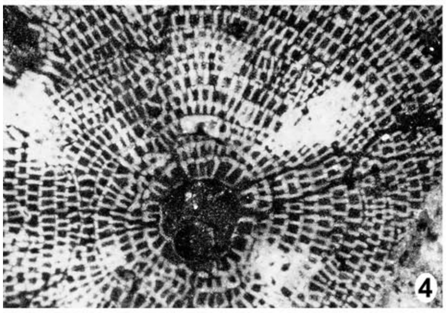
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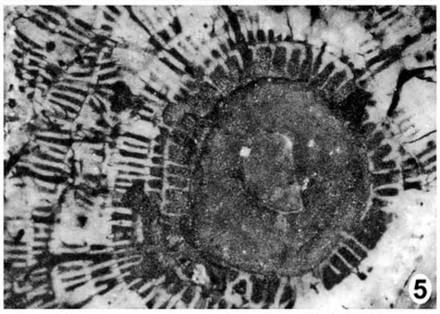
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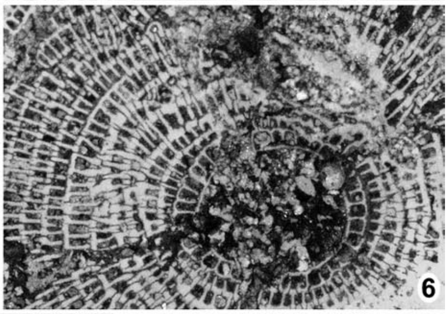
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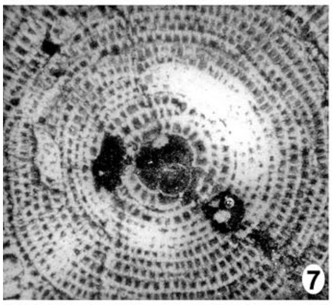
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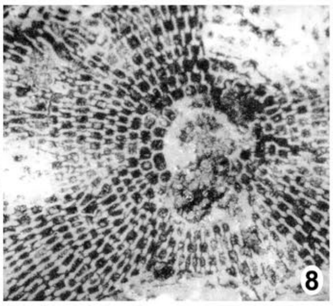
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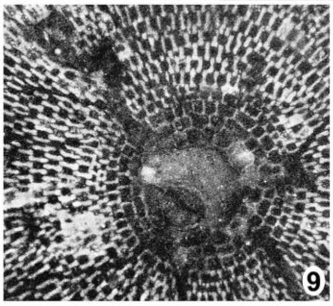
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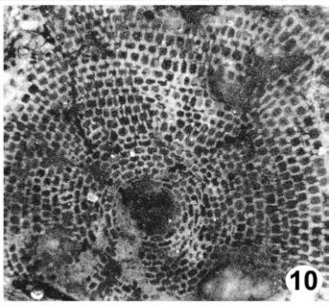
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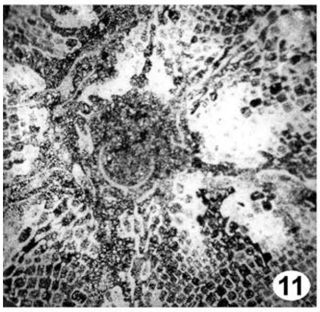
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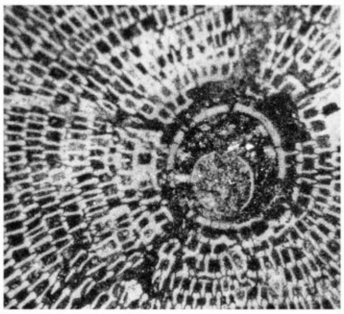
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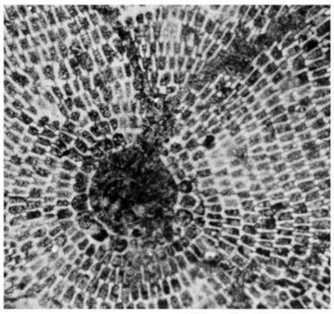
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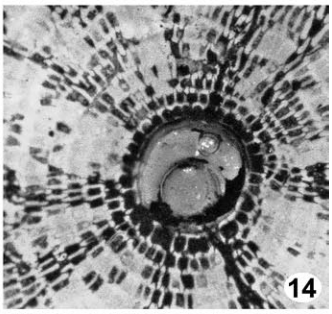
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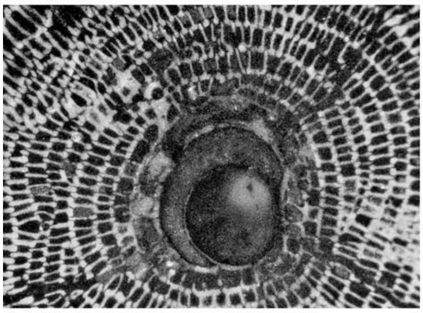
All but 19: 1 mm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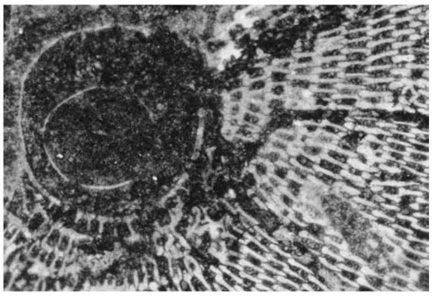
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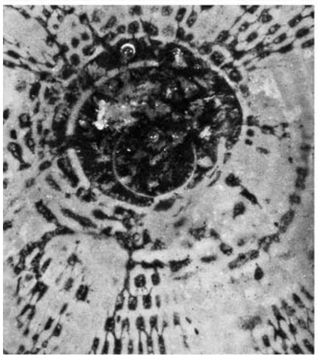
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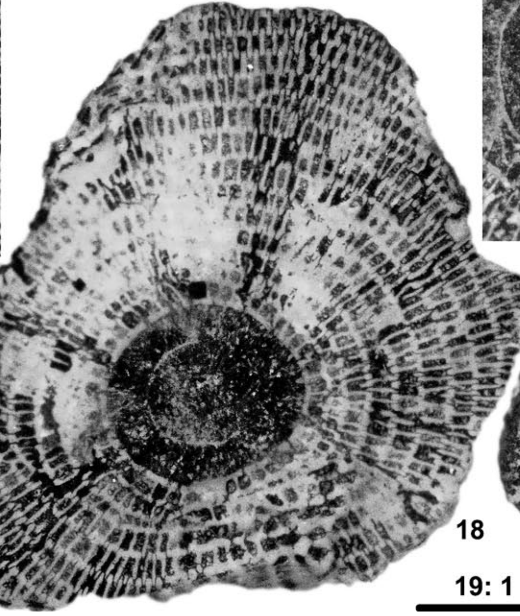
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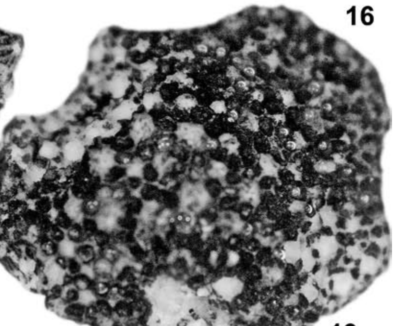
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19: 1 mm

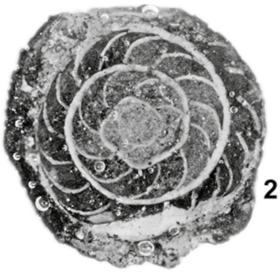
Plate 5

Nummulitids from Gmunden, Gschliefgraben.

Figs. 1–4: *Nummulites nemkovi* SCHAUB.
sample Rote Kirche 1.
Figs. 1, 2: E.10.06.
Fig. 3: E.10.07.
Fig. 4: E.10.08.
Figs. 5, 11, 12: *Assilina* aff. *placentula* (DESHAYES).
sample Rote Kirche 4.
Fig. 5: E.10.11.
Fig. 11: E.10.12.
Fig. 12: E.10.13.
Figs. 6–8: *Nummulites irregularis* DESHAYES.
sample Rote Kirche 1.
Figs. 6, 7: E.10.09.
Fig. 8: E.10.10.
Figs. 9, 10: *Assilina plana* SCHAUB.
sample Rote Kirche 1.
Fig. 9: E.10.14.
Fig. 10: E.10.15.

Fig. 5: B-form, 5×, all the others are A-forms, 10×.
Figs. 1, 5, 6: External views, all the others are equatorial sections.


1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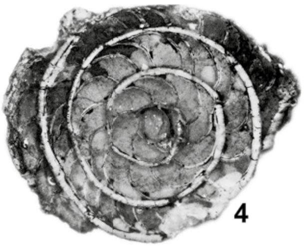
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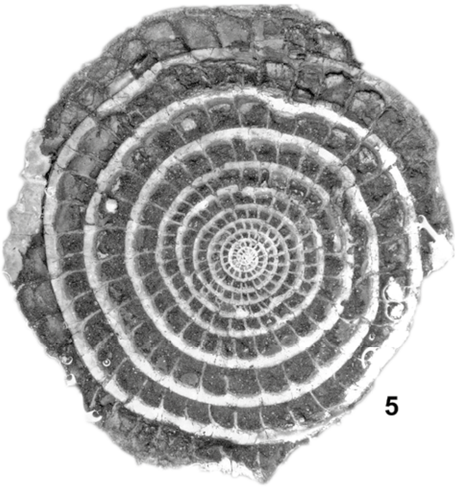
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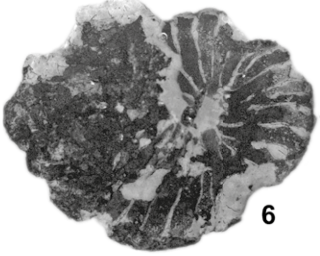
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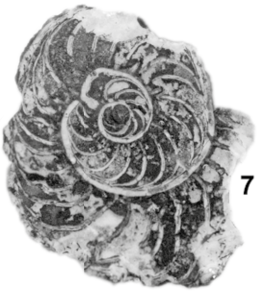
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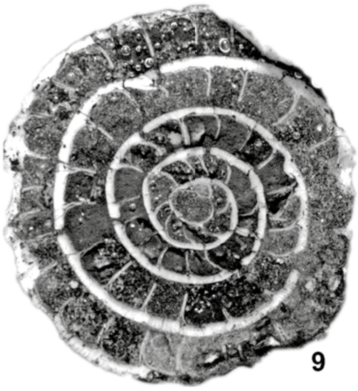
5: 4 mm
rest: 2 mm


8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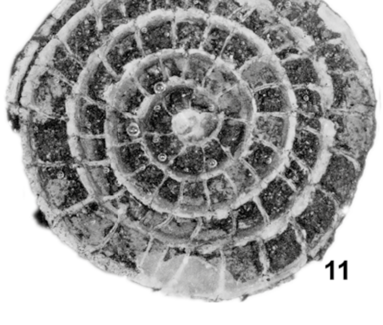
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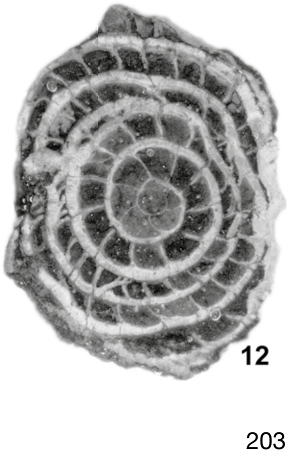
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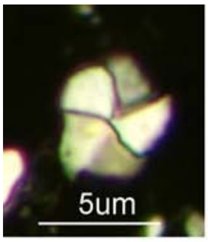
Plate 6

Calcareous nannofossils, samples Rote Kirche A, B.
PPL – plane-polarized light, XPL – cross-polarized light. For magnification see Fig. 1.

Fig. 1: *Braarudosphaera turbinea* Stradner.
Sample A, XPL.
Fig. 2: *Markalius astroporus* (Stradner) Hay & Mohler.
Sample B, XPL.
Fig. 3: *Girgisia gammation* Bramlette & Sullivan.
Sample A, XPL.
Fig. 4: *Toweius crassus* (Bramlette & Sullivan) Perch-Nielsen.
Sample B, XPL.
Fig. 5: *Toweius rotundus* Perch-Nielsen.
Sample A, XPL.
Fig. 6: *Clausicoccus fenestratus* (Deflandre & Fert) Prins.
Sample A, XPL.
Fig. 7: *Ellipsolithus macellus* (Bramlette & Sullivan) Sullivan.
Sample B, XPL.
Fig. 8: *Lophodolithus nascens* Bramlette & Sullivan.
Sample A, XPL.
Fig. 9: *Lophodolithus mochloporus* Deflandre.
Sample A, XPL.
Fig. 10: *Helicosphaera seminulum* Bramlette & Sullivan.
Sample A, XPL.
Fig. 11: *Helicosphaera lophota* Bramlette & Sullivan.
Sample A, XPL.
Fig. 12: *Calcidiscus protoannulus* (Gartner) Loeblich & Tappan.
Sample A, XPL.
Fig. 13: *Discoaster multiradiatus* Bramlette & Riedel.
Sample B, PPL.
Fig. 14: *Discoaster binodosus* Martini.
Sample B, PPL.
Fig. 15: *Discoaster barbadiensis* Tan.
Sample A, PPL.
Fig. 16: *Discoaster* sp.
Sample A, PPL.
Figs. 17, 18: *Discoaster kuepperi* Stradner.
Sample B, PPL.
Fig. 17: high focus.
Fig. 18: low focus.
Fig. 19: *Discoaster lodoensis* Bramlette & Riedel.
Sample A, PPL.
Fig. 20: *Chiasmolithus bidens* (Bramlette & Sullivan) Hay & Mohler.
Sample B, XPL.
Fig. 21: *Chiasmolithus solitus* (Bramlette & Sullivan) Locker.
Sample A, XPL.
Fig. 22: *Chiasmolithus* sp.
Sample A, XPL.
Fig. 23: *Reticulofenestra dictyoda* (Deflandre) Stradner.
Sample A, XPL.
Fig. 24: *Reticulofenestra* sp. cf. *R. dictyoda* (Deflandre) Stradner.
Sample A, XPL.
Figs. 25, 26: *Sphenolithus moriformis* (Brönnimann & Stradner), Bramlette & Wilcoxon.
Sample A, XPL, 25–0°, 26–45°.
Figs. 27, 28: *Sphenolithus radians* Deflandre.
Sample A, XPL, 27–0°, 28–45°.
Fig. 29: *Rhabdosphaera* sp.
Sample A, XPL.
Fig. 30: *Zygrhablithus bijugatus* (Deflandre) Deflandre.
Sample A, XPL.



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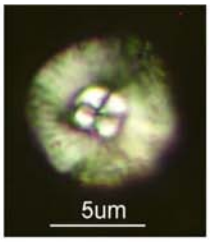

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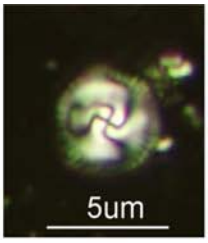

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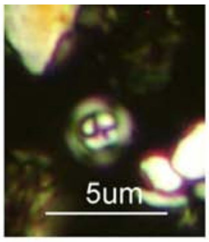

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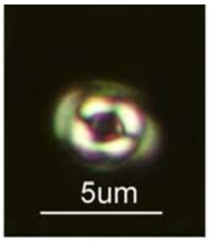

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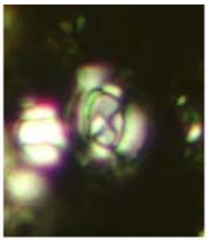

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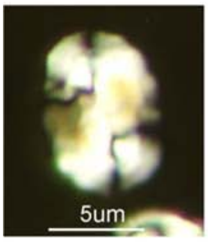

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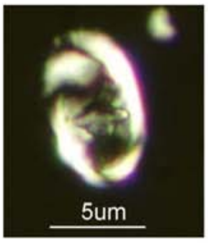

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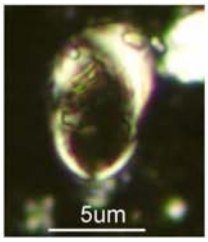

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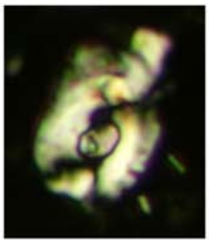

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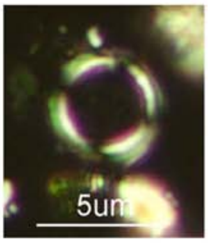

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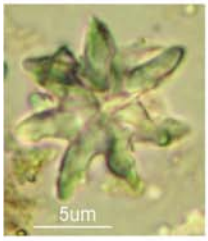

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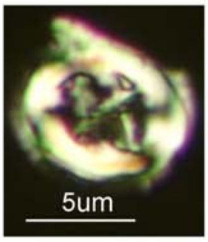

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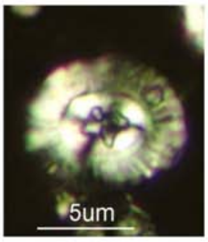

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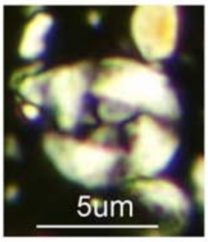

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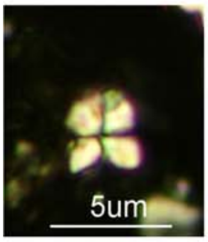

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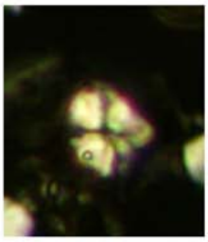

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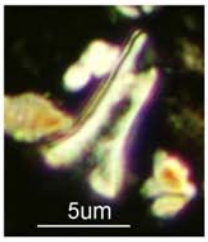

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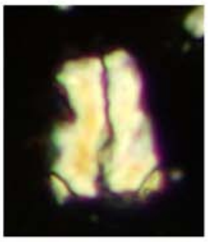

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Plate 7

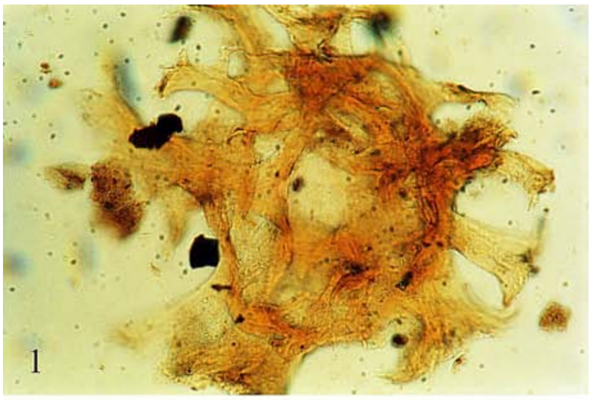
Figs. 1, 2: *Cordosphaeridium* sp.
Dinocyst, one specimen at two optical levels.
Size 110 µm. Light microscope photo.

Fig. 3: *Pityosporites* sp.
Pollen of Pinaceae.
Size 90 µm. Light microscope photo.

Fig. 4: aff. *Tricolporopollenites globus* DEÁK 1960.
Angiospermous pollen, incertae sedis vel Sapotaceae.
Size 30 µm. Light microscope photo.

Fig. 5: *Tetracolporopollenites* sp.
Angiospermous pollen, incertae sedis vel ?Sapotaceae.
Size 44 µm. Light microscope photo.

Fig. 6: Remains of dinocyst.
?*Areoligera (Achomosphaera) danica* type. Probably reworked.
Size of the remains 75 µm. SEM micrograph.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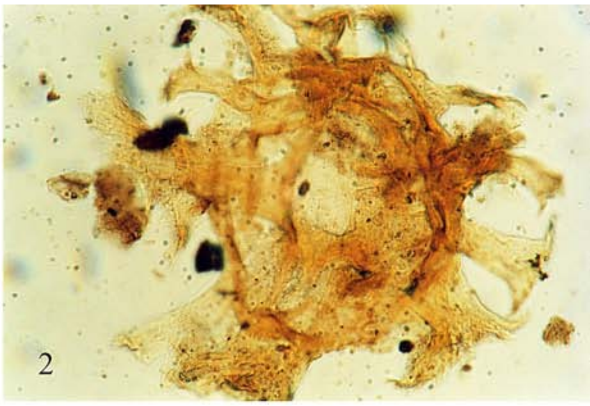
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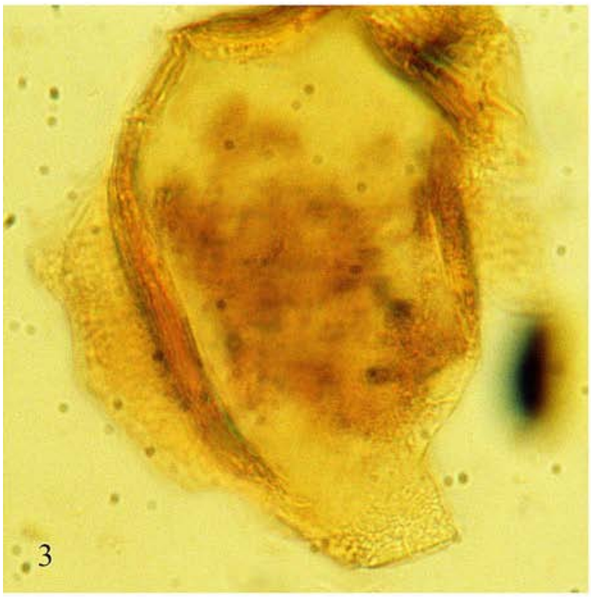
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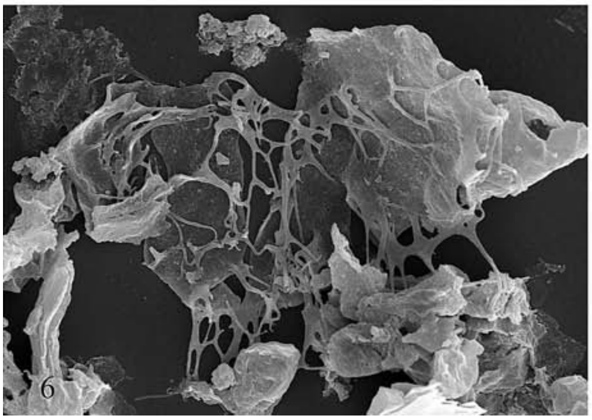
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