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Micropaleontology of „Orbitolina Beds" of Lower Austria (Branderfleck Formation, Lower Cenomanian)

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2 Text-Figures, 1 Table and 2 Plates

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Niederösterreich
Nördliche Kalkalpen
Branderfleck-Formation
Mikropaläontologie
Stratigrafie

Contents

Zusammenfassung

Das mikropaläontologische Inventar der Orbitolinen-Sandsteine der niederösterreichischen Branderfleck-Schichten wird vorgestellt. Es setzt sich hauptsächlich aus benthonischen Foraminiferen und einigen Resten von Kalkalgen zusammen. Anhand der Orbitolinen-Vergesellschaftung mit *Mesorbitolina aperta* (ERMAN), *Conicorbitolina conica* (d´ARCHIAC) und *Orbitolina concava* (LAMARCK) können die Sandsteine und Feinbrekzien in das Unter-Cenomanium gestellt werden. Vergleiche werden angestellt zu zeitlich und faziell vergleichbaren Lithologien im Westteil der Nördlichen Kalkalpen; sie zeigen mehr oder weniger identische Vergesellschaftungen in der Mikrofauna und -flora.

Abstract

The micropaleontological inventory of "Orbitolina sandstones" of the Branderfleck Formation of Lower Austria is presented. The sandstones are composed mainly of benthic foraminifera and some calcareous algae. On the basis of the orbitolinid microfauna including *Mesorbitolina aperta* (ERMAN), *Conicorbitolina conica* (d´ARCHIAC) and *Orbitolina concava* (LAMARCK), these sandstones and fine-grained breccias can be ascribed to the Lower Cenomanian. Comparisons are made to time and facies equivalent lithologies of the Western part of the Northern Calcareous Alps showing more or less identical assemblages of microfauna and -flora.

1. Introduction

The Branderfleck Formation represents a transgressive sequence ranging from the Lower Cenomanian to Coniacian–Santonian and locally also into the Lower Campanian (WEIDICH, 1982). The type-section is situated at the Branderfleck in the Hohenschwangau Alps, Bavaria (GAUPP, 1980) with a stratigraphic range from the Cenomanian to the Coniacian–?Lower Santonian (WEIDICH, 1982). The lower part of the Branderfleck Formation consists of basal

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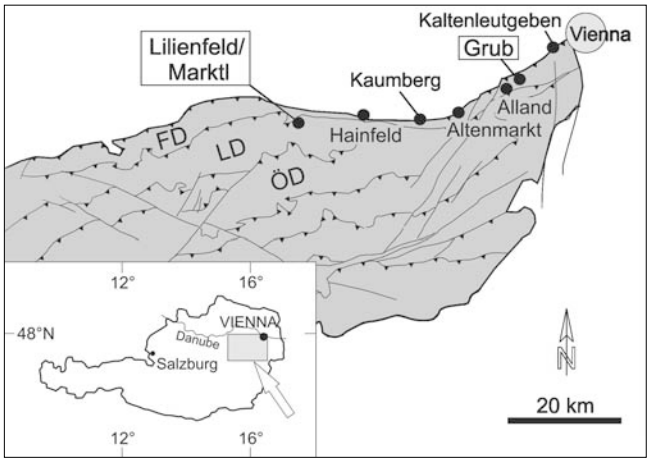


Text-Fig. 1.
Schematic map of the easternmost part of the Northern Calcareous Alps including the main localities of the Branderfleck Formation mentioned in the text.
FD = Frankenfels Nappe; LD = Lunz Nappe; ÖD = Ötscher Nappe System.

conglomerates, breccias and sandstones overlain by sandy marls, whereas the upper part is dominated by marls with intercalated turbidites and olistostromes. The Branderfleck Formation is restricted to the tectonically lowest nappes, including the Allgäu Nappe and Lechtal Nappe (e.g. WEIDICH, 1982; GAUPP & EYNATTEN, 1997). Lithologic and stratigraphic equivalent successions of the Reichraming Nappe and the Lunz Nappe in the eastern part of the Northern Calcareous Alps were included into the Branderfleck Formation by FAUPL & WAGREICH (1992) and WAGREICH (2003a).

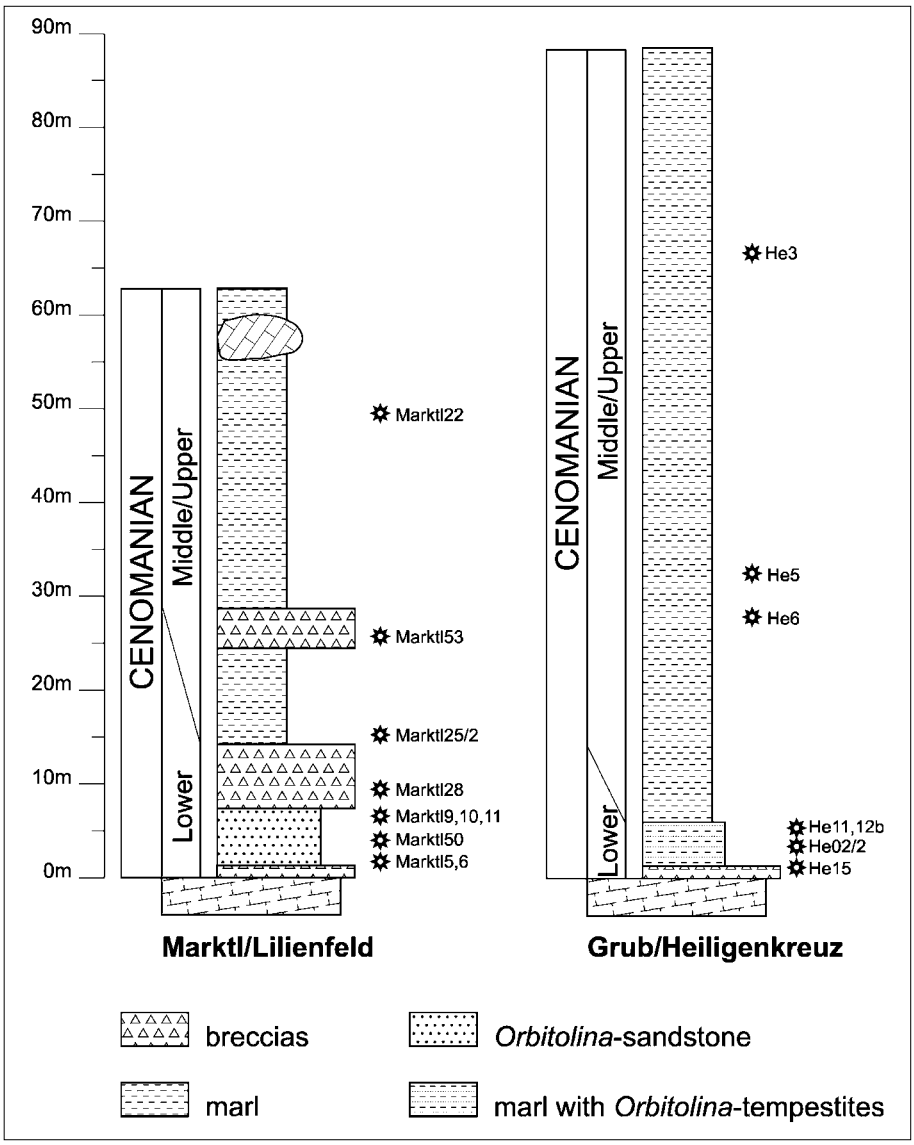
Data about the micropaleontological inventory of the orbitolinid sandstones and breccias of the basal Branderfleck Formation have been provided by WEIDICH (1985: p. 236) and SCHROEDER (1981). The Lower (Middle?) Cenomanian Orbitolina sandstones may also occur as clasts in Turonian olistostromes showing their early reworking after deposition (GAUPP, 1982; WEIDICH, 1985; SCHLAGINTWEIT, 1992).

2. Geological Setting

Orbitolina-bearing strata have been known since TOULA (1882) und BITTNER (1897) from the eastern part of the Northern Calcareous Alps. These deposits, including breccias, sandstones and marls were attributed to the Branderfleck Formation by FAUPL & WAGREICH (1992) and WAGREICH (2003a).

Especially the sections of Marktl/Lilienfeld and Grub/Heiligenkreuz of the Lunz Nappe (Hochbajuvaric nappe system; Text-Fig. 1) are known for their „*Orbitolina* sandstones". The sections are characterized by carbonate-rich, badly sorted *Orbitolina*-bearing breccias and mixed carbonate-siliciclastic fine to medium-sized *Orbitolina* sandstones in their lower parts which have been interpreted as shelf tempestites (WAGREICH, 2003a). These sandstones are overlain by a fining-upward succession of silty-sandy grey marls, fine breccias and sandstone turbidites. The base of the Branderfleck Formation is marked by an angular unconformity, with erosion reaching down to Triassic Hauptdolomite. Heavy mineral assemblages with significant amounts of chrome spinel and blue amphiboles are a characteristic feature of the sandstones of the Branderfleck Formation (FAUPL & WAGREICH, 1992). Similar strata were described by PLÖCHINGER & SALAJ (1991) from outcrops between Altenmarkt and Hainfeld further to the west, and by WESSELY (1985) from the Gießhübl syncline south of Kaltenleutgeben to the east (Text-Fig. 1).

The investigated sections (Text-Fig. 2) are based on a quarry at Grub near Heiligenkreuz (PLÖCHINGER & PREY, 1993: 118f; WAGREICH, 2003a), and outcrops along forest roads and hiking paths at Marktl near Lilienfeld. (BITTNER, 1897; LÖCSEI, 1974; WAGREICH, 2003a). The lithologies include a variety of sandstones, mainly arenites, and largely unsorted breccias with clasts of different grain size up to



Text-Fig. 2.
Lithologic profiles of the Branderfleck Formation of Marktl and Grub and position of samples mentioned in the text (modified from WAGREICH, 2003a).

blocks with diameters of a few metres. The dominating element of the sandstones are the tests of the orbitolinids reaching sizes of several millimeters. Whereas in the finer-grained sandstones, the lithoclasts accompanying the orbitolinids cannot be specified, the clast-supported breccias contain fragments of Triassic dolomites and limestones and Jurassic radiolarites. The clasts are angular to rounded. In the latter case, the orbitolinid tests too show marginal rounding, often not allowing precise determination. Besides older Triassic and Jurassic lithoclasts, clasts of reworked orbitolinid sandstones and detrital limestones are also present.

Benthic foraminifera

Charentia cuvillieri NEUMANN, 1965
Conicorbitolina conica (d´ARCHIAC, 1837)
Gavelinella sp.
Mesorbitolina aperta (ERMAN, 1854)
Orbitolina concava (LAMARCK, 1816)
Trocholina gr. *lenticularis* HENSON, 1947

Calcareous Algae

Corallinaceae indet.
Polystrata alba (PFENDER) DENIZOT, 1968
Trinocladus tripolitanus RAINERI, 1922

Others

Carpathiella triangulata MISÍK, SOTÁK & ZIEGLER, 1999
Koskinobullina socialis CHERCHI & SCHROEDER, 1979
Microproblematicum 1
Calcisphaerulidae indet.

In addition there are rare textulariids, lenticulinids, miliolids, some agglutinating taxa fixed to the test of orbitolinids and also calcisphaerulids. Other bioclasts include bryozoans, oysters and debris of corallinacean red algae such as *Sporolithon* sp.

3. Systematic Micropaleontology

The following systematic part is based on the analysis of 30 thin-sections:

- 18 thin-sections from Marktl
- 9 thin-sections from Grub (sample numbers HE)
- 2 thin-sections from Alland
- 1 thin-section from Seewiese south of Kaltenleutgeben

Additional material from the Branderfleck-Formation of the Branderschrofen/Allgäu and Ruhpolding are incorporated.

3.1. Benthic Foraminifera

Genus: *Charentia* NEUMANN, 1965

Charentia cuvillieri NEUMANN, 1965

(Pl. 1, Fig. 6)

*1965 *Charentia cuvillieri* n. gen., n. sp. – NEUMANN: 93, Pl. 2, Figs. 6–12, Middle Cenomanian of France.
1985 *Nummoloculina* ? sp. – WEIDICH: Pl. 3, Fig. 8, *Orbitolina* sandstone of the Branderfleck Formation of the Allgäu area.
1985 *Charentia cuvillieri* NEUMANN – NEUMANN: 17, Pl. 3, Figs. 1–11, Middle Cenomanian of France.
1986 *Nautiloculina* sp. – CSÁSZÁR: Pl. 11, Fig. 1, Pl. 34, Figs. 1–2, Pl. 36, Fig. 4, Upper Albian of Hungary.
1991 *Charentia cuvillieri* NEUMANN – SCHLAGINTWEIT & WEIDICH: Pl. 2, Fig. 2, *Orbitolina* sandstone, Branderfleck Formation of Ruhpolding, Bavaria.
1991 *Charentia cuvillieri* NEUMANN – LOEBLICH & TAPPAN: 96, Pl. 3, Figs. 1–13,
1991 *Charentia cuvillieri* NEUMANN – SCHLAGINTWEIT: 34, Pl. 9, Figs. 6–9, Aptian Urgonian Limestones of Northern Calcareous Alps.
2004 *Nautiloculina bronnimanni* – LAWTON et al.: Fig, 9 D–F, Upper Aptian–Upper Albina Mural Limestone of Mexico.

Remarks: *Charentia cuvillieri* has been established from Cenomanian marls of Charente-Maritime, France by NEUMANN (1965). In contrast to the type-locality, the specimens of the *Orbitolina* sandstones are comparably small with equatorial diameters of 0.47–0.72 mm (NEUMANN [1965]: 1.3–1.6 mm; NEUMANN [1985]: 0.78–0.83 mm for small specimens) obviously reflecting disadvantageous environmental conditions. Though not very abundant, the species was already recorded from other occurrences of the Branderfleck Formation in the middle and western part of the Northern Calcareous Alps (see synonymy). It represents a species without specific stratigraphic value, known from the Lowermost Cretaceous–Middle Cenomanian (NEUMANN, 1985). Another poorly known form, that can hardly be distinguished from *Ch. cuvillieri*, is *Charentia evoluta* (GORBATCHIK) that was for example reported from the Uppermost Jurassic of Sicily/Italy (e.g. BUCUR et al., 1996).

Occurrences: Marktl-5, Marktl-28, Marktl-50.

Genus: *Gavelinella* BROTZEN, 1942

Gavelinella sp.

(Pl. 1, Fig. 11)

Remarks: *Gavelinella intermedia* (BERTHELIN) has been figured by WEIDICH (1985: Pl. 3, Fig. 7) from *Orbitolina* sandstones of the Branderfleck Formation of the Allgäu area and has also been mentioned by PLÖCHINGER & SALAJ (1991) from the Branderfleck Formation of Lower Austria. Apart from the difficulties of specific determinations in thin-sections, it documents that gavelinellas could tolerate the stress biotop of the abrasive *Orbitolina* sandstones/breccias. Gavelinellids, however, are very rare in the *Orbitolina* sandstones becoming more abundant in the following marly successions, indicating greater water depth than the former, where they form typical assemblages with other benthonic foraminifers (WEIDICH, 1982: p. 117).

Occurrences: Marktl-50.

Genus: *Orbitolina* d´ORBIGNY, 1850

Remarks: The species determinations are based on SCHROEDER (1985a,b,c). The subgenus concept of *Orbitolina* and other taxa of foraminifers was eliminated by LOEBLICH & TAPPAN (1988: p. 3) consequently by elevation to generic status or by synonymization with other taxa. Some workers accepted this approach (e.g. CHERCHI & SCHROEDER, 1999; SIMMONS et al., 2000) others, however, did not (e.g. HUSINEC et al., 2000; MANCINELLI et al., 2003). In the systematic part, the classification of LOEBLICH & TAPPAN (1988) is followed.

Orbitolina concava (LAMARCK, 1816)

(Pl. 1, Figs. 1, 10; Pl. 2, Fig. 1)

*1816 *Orbulites concava* LAMARCK – [fide SCHROEDER 1962: p. 185].
1981 *Orbitolina (Orbitolina) concava* (LAMARCK) – SCHROEDER: Pl. 2, Figs. 1–3, Upper Albian–Lower Cenomanian of Ruhpolding (Bavaria).
1985 *Orbitolina (Orbitolina) concava* (LAMARCK, 1816) – WEIDICH: Pl. 4, Fig. 4, *Orbitolina* sandstones of the Branderfleck Formation of the Allgäu area.

Remarks: The occurrence of *Orbitolina concava* in the Lilienfeld area of Lower Austria was already noted at the end of the 19th century (BITTNER, 1897). It is the most frequent orbitolinid occurring in our samples. The compara-

bly abundant occurrence of juvenile forms with only some chamber layers following the embryonic apparatus is worth mentioning.

Occurrences: Marktl-6, Marktl-9, ? Marktl-10, Marktl-11, Marktl-50, He-02/2, He-5, He-11, He-12B, IT-15.

Table 1.
Dimensions of the embryonic apparatus of the orbitolinids from the Branderfleck Formation of Lower Austria.

	Diameter embryonic apparatus	Diameter protoconch	Height protoconch	Sample
Orbitolina concava	0.68	0.29	0.21	Marktl-9
	0.35	0.16	0.11	Marktl-11
	0.42	0.19	0.1	Marktl-50
	0.6	0.22	0.21	He-5
	0.56	0.155	0.12	He-5
	0.1	0.3	0.18	IT-15
Mesorbitolina aperta	0.99	0.27	0.09	Marktl-5
	1.52	0.35	0.15	Marktl-6
Conicorbitolina conica	0.3	0.155	0.095	Marktl-50/2
	0.42	0.125	0.12	Marktl-6
	0.72	0.275	0.21	Marktl-9

Genus: *Mesorbitolina* SCHROEDER, 1962

Mesorbitolina aperta (ERMAN, 1854)

(Pl. 1, Fig. 5; Pl. 2, Fig. 9)

*1854 *Orbitulites apertus* – ERMAN: 603, Pl. 23, Figs. 1–3, Spain.

1981 *Orbitolina (Mesorbitolina) aperta* (ERMAN, 1854) – SCHROEDER: Pl. 2, Figs. 7, 9–10, Upper Albian–Lower Cenomanian of Ruhpolding (Bavaria).

1985a *Orbitolina (Mesorbitolina) aperta* (ERMAN) – SCHROEDER: 82, Pl. 38, Figs. 1–6, Upper Albian–Lower Cenomanian of Spain and France.

Remarks: The species is characterized by a comparably large embryonic apparatus with a proloculus showing a flattened base and a well developed subembryonic zone (see SCHROEDER, 1985a, for further details). In the Branderfleck Formation of Ruhpolding, the tests of *Mesorbitolina aperta* can reach sizes of some centimetres.

Occurrences: Marktl-5, Marktl-6, Marktl-50/2, He-02/2.

Genus: *Conicorbitolina* SCHROEDER, 1973

Conicorbitolina conica (d´ARCHIAC, 1837)

(Pl. 1, Figs. 7, 8)

*1837 *Orbitolites conica* n. sp. – d´ARCHIAC: p. 178.

1981 *Orbitolina (Conicorbitolina) conica* – SCHROEDER: Pl. 2, Fig. 8, Upper Albian–Lower Cenomanian of Ruhpolding (Bavaria).

1985c *Orbitolina (Conicorbitolina) conica* (d´ARCHIAC) – SCHROEDER.

1999 *Conicorbitolina conica* (d´ARCHIAC) – CHERCHI & SCHROEDER: 320, Pl. 1, Figs. 1–2, 5–6, 10, Lower Cenomanian from Cantabria, Spain.

Remarks: In the samples studied, *Orbitolina conica* is clearly distinguished from *Orbitolina concava* and *Mesorbitolina aperta* (both low conical to discoidal) by high conical tests. In the same manner, the upper part of the embryonic apparatus at the apex is rounded. Three different species of *Conicorbitolina* were established (e.g. SCHROEDER 1985c; MANCINELLI et al., 2003) but only *C. conica* has so far been reported from the Northern Calcareous Alps.

Occurrences: Marktl-5, Marktl-6, Marktl-9, He-02/20.

Genus: *Trocholina* PAALZOW, 1922

Trocholina gr. *lenticularis* HENSON, 1947

(Pl. 1, Figs. 2, 4)

*1947 *Trocholina lenticularis* n. sp. – HENSON: 452, Pl. 11, Fig. 1, Pl. 12, Figs. 1–3, 5–6, 7?, 8?, Middle East.

1988 *Trocholina lenticularis* HENSON – ARNAUD-VANNEAU et al.: 362, Pl. 1, Figs. 6–10, Pl. 6, Figs. 22–27, Upper Albian–Lower Cenomanian of Oman.

2003 *Trocholina lenticularis* HENSON – MANCINELLI et al.: Fig. 5m, Uppermost Albian–Lower Cenomanian of Italy.

Remarks: The species has also been observed in *Orbitolina* sandstones of the Branderschrofen, the type-locality of the Branderfleck Formation (unpubl. data). *Trocholina lenticularis* is known from the Upper Albian–Lower Cenomanian (ARNAUD-VANNEAU et al., 1988).

Dimensions (data from Marktl-53):
Diameter: 0.9 mm / 0.7 mm / 0.85 mm / 0.75 mm / 0.55 mm / 0.7 mm.
Height: 0.36 mm / – / 0.51 mm / 0.48 mm / 0.31 mm / 0.48 mm.

Occurrences: Marktl-9, Marktl-10, ? Marktl-28, Marktl-50.

3.2. Calcareous Algae

The calcareous algae of the *Orbitolina* sandstones include the dasycladale *Trinocladus tripolitanus* RAINIERI, undeterminable remains of coralline red algae and the peysonelliacea *Polystrata alba* (PFENDER) DENIZOT.

Trinocladus tripolitanus RAINIERI, 1922

(Pl. 2, Figs. 4, 7–8, 11 partim)

*1922 *Trinocladus tripolitanus* n. gen., n. sp. – RAINIERI: 79, Pl. 3, Figs. 15–16, Upper Cretaceous of Lybia.

1992 *Trinocladus tripolitanus* RAINIERI – SCHLAGINTWEIT: 6, Pl. 2, Figs. 6–9, 11, Cenomanian–Turonian of Branderfleck Formation, Northern Calcareous Alps, Germany.

1983 *Trinocladus tripolitanus* RAINIERI – SCHROEDER & WILLEMS: Figs. 4.11, 4.12, Upper Albian of Spain.

N.F.1999 *Trinocladus tripolitanus* RAINIERI – CHERCHI & SCHROEDER: Lower Cenomanian of N-Spain.

2004 *Trinocladus tripolitanus* RAINIERI – SCHLAGINTWEIT: Pl. 1, Figs. 2, 5, 8, Santonian Hochmoos Formation, Lower Gosau Subgroup of Austria.

Remarks: *T. tripolitanus*, known from the Cenomanian–Santonian interval (e.g. BUCUR, 1999), is the only calcareous green alga (Dasycladale) being rather common in the *Orbitolina* sandstones, predominantly within those varieties where the siliclastics are reduced and a more micrite-dominated matrix occurs.

Occurrences: Marktl-5, Marktl-10, Marktl-50,

Polystrata alba (PFENDER) DENIZOT, 1968

(Pl. 2, Fig. 10)

*1936 *Pseudolithothamnium album* n. gen., nov. sp. – PFENDER: 330, Pl. 19.

1988 *Pseudolithothamnium album* PFENDER – MOUSSAVIAN: 100, Pl. 2/2–3, Textfig. 1, Upper Eocene of the Northern Calcareous Alps.

1991 *Pseudolithothamnium album* PFENDER – SCHLAGINTWEIT: 46, Pl. 16, Fig. 7 p.p., Fig. 9), Lower Cretaceous Urgonian Limestones of the Northern Calcareous Alps.

1996 *Pseudolithothamnium album* PFENDER – TRAGELEHN: 186, Text-Fig. 27, Pl. 49, Figs. 1–4, Paleocene Kambühel Formation of Northern Calcareous Alps.

1997 *Polystrata alba* (PFENDER) DENIZOT – BASSI: 311, Fig. 1-4b, Upper Eocene of N-Italy.

2001 *Polystrata alba* (PFENDER) DENIZOT, 1968 – RASSER: Fig. 2 A-G, Late Eocene Alpine Foreland, Austria.

Remarks: *Polystrata alba* occurs with rare fragments in the *Orbitolina* sandstones of the locality Marktl. In the Northern Calcareous Alps it has been reported from the Lower Cretaceous (Rossfeld Formation, Urgonian Limestones), the Upper Cretaceous Gosau Group, the Paleocene (Kambühel Formation) and the Upper Eocene carbonates of the Eisenrichterstein.

Occurrences: Marktl-5, Marktl-6, Marktl-50.

3.3. Others

The microproblematica include rare remains of *Koskinobullina socialis* CHERCHI & SCHROEDER (not illustrated), *Pienina oblonga* BORZA & MISÍK (not illustrated), problematicum 1 and *Carpathiella triangulata* MISÍK, SOTÁK & ZIEGLER, a problematic serpulid tube.

Problematicum 1

(Pl. 2, Figs. 2–3, 6)

Remarks: This problematicum occurs flat-encrusting preferentially on orbitolinid test. It has a convex upper side and shows complete and incomplete vertical elements. Any connection between the cells or chambers were not observed. The systematic position is unclear. The same incertae sedis has been observed in the Upper Albian Zirc Limestone of the Transdanubian Central Range of Hungary also fixed on orbitolinid tests (SCHLAGINTWEIT 1990); see Pl. 2, Figs. 2, 6.

Occurrences: Marktl-6.

Genus: *Carpathiella* MISÍK, SOTÁK & ZIEGLER, 1999

Carpathiella triangulata MISÍK, SOTÁK & ZIEGLER, 1999

(Pl. 1, Fig. 9)

*1999 *Carpathiella triangulata* n. sp. – MISÍK et al.: 309, Pl. 2, Figs. 3–9, Upper Jurassic–Barremian of the Western Carpathians, Slovakia.

2003 *Carpathiella triangulata* MISÍK, SOTÁK & ZIEGLER – SCHLAGINTWEIT, GAWLICK & SANDERS: 95, Figs. 2–3, Pl. 4, Figs. 4–12, Upper Jurassic to Paleocene of the Northern Calcareous Alps (with synonymy).

Remarks: Remains of *Carpathiella*, interpreted as serpulid tubes by MISÍK et al. (1999) are very rare in the *Orbitolina* sandstones and breccias of the Branderfleck Formation. In the Northern Calcareous Alps, they were reported from Upper Jurassic to Paleocene strata (SCHLAGINTWEIT et al., 2003).

Occurrences: Marktl-9, He-15.

Calcisphaerulidae indet.

(Pl. 2, Fig. 5)

Remarks: Comparably large representatives with an outer diameter of 0.07 to 0.1 and an inner diameter of 0.05 mm to 0.065 mm. Round shape and a double wall, an outer radial calcitic and an inner dark, micritic layer both more or less equal in thickness. These forms previously termed cadosinids or stomiosphaerids are interpreted as calcified cysts of dinoflagellates (e.g. REHAKOVÁ & MICHALÍK, 1996; IVANOVÁ & KEUPP, 1999).

Occurrences: Marktl-10.

4. Stratigraphy

PLÖCHINGER & SALAJ (1991) mentioned the following orbitolinid taxa from the Branderfleck Formation: *Orbitolina mamillata* d´ARCHIAC, *Orbitolina plana* d´ARCHIAC and *Orbitolina conica* d´ARCHIAC. According to SCHROEDER (1985c: p. 76), *O. mamillata* represents the microspheric generation of *Conicorbitolina conica* d´ARCHIAC and *O. plana* is identical with the B-form of *Orbitolina concava* (LAMARCK). Based on the mentioned orbitolinids and some planktonic foraminifers, PLÖCHINGER & SALAJ (1991) concluded a Middle to Late Cenomanian age. It is worth mentioning, that the planktonic foraminifers identified by the authors (*Thalmanninella brotzeni* SIGAL, *Rotalipora montsalvensis* MORNOD) do not exclude a (late) Early Cenomanian age (for details see WEIDICH, 1982); moreover, the marly lithologies with planktonic foraminifera usually occur in parts of the profiles higher than the *Orbitolina* sandstones.

Acccording to SCHROEDER & NEUMANN (1985) the stratigraphic ranges of the orbitolinids from the Lower Branderfleck Formation that we observed in our material can be indicated as follows:

- *Mesorbitolina aperta* (ERMAN): Upper Albian – lower part of the Lower Cenomanian.
- *Orbitolina concava* (LAMARCK): Lower Cenomanian.
- *Conicorbitolina conica* (d´ARCHIAC): Lower–Middle Cenomanian.

As we never observed *Conicorbitolina conica* (d´ARCHIAC) alone, the studied samples indicate an Early Cenomanian age. We also observed reworked clasts of orbitolinid sandstones within orbitolinid sandstones/breccias indicating an intra-Early Cenomanian resedimentation. Biostratigraphic data from other microfossils also fit with our conclusion. The benthic foraminifer *Trocholina* gr. *lenticularis* HENSON, for example, is known from the Upper Albian–Lower Cenomanian interval (ARNAUD-VANNEAU et al., 1988) and the dasycladale *Trinocladus tripolitanus* RAINIERI from the Cenomanian to Santonian (e.g. BUCUR, 1999).

Nannofossil assemblages from marls of the Branderfleck Formation are rather poor, especially in the lower, *Orbitolina*-bearing part of the successions of the section at Grub, where marls have high sand and silt content. Samples from above the *Orbitolina*-sandstones at Marktl (comp. Fig. 2) contain the marker *Prediscosphaera cretacea, Eprolithus floralis*, and *Lucianorhabdus* cf. *quadrifidus*, which indicate standard nannofossil zones CC 10–CC 11 (PERCH-NIELSEN, 1985) and zones UC 1–UC 3 of BURNETT (1998). *Prediscosphaera cretacea* has its first occurrence in the Early Cenomanian. According to the correlations by BURNETT (1998) a late Early to Late Cenomanian age can be inferred from these nannofossil assemblages, although several Cenomanian marker species such as *Lithraphidites acutus* or *Corollithion kennedyi* are missing due to the bad preservation.

Combining these biostratigraphic data an Early Cenomanian age is suggested for the lower part of the Branderfleck Formation at Marktl and Grub, including the *Orbitolina* sandstones. The overlying marl with minor breccia layers and olistoliths is of late Early to Middle Cenomanian age. Marker species indicative of a Late Cenomanian or Turonian age are missing.

5. Conclusions

The Lower Cenomanian *Orbitolina* sandstones of the Branderfleck Formation are characterized by a comparably weakly diversified microfauna and -flora. The micropaleontologic assemblages are rather homogeneous when comparing localities from the Allgäu area, the middle part and the eastern part of the Northern Calcareous Alps. In contrast to the transgression of the Lower Gosau Subgroup,

that shows a shifting in stratigraphic levels, becoming younger from west to east (WAGREICH & FAUPL, 1994), all data from the basal Branderfleck Formation indicate an Early Cenomanian age. It can be concluded that this transgression is strongly controlled by the tectonic evolution of the northern tectonic units of Northern Calcareous Alps. The sedimentation in the north-lying Tannheim-Losenstein basin within the Allgäu-Ternberg-Frankenfels Nappe System was terminated during the Early Cenomanian (e.g. WEIDICH, 1990; WAGREICH, 2003b) by overthrusting of the higher nappes from the south-southeast (e.g. GAUPP, 1982). During this more or less synchronous tectonism, piggyback basins evolved contemporaneously on top of these thrust sheets in the western and the eastern parts of the Northern Calcareous Alps (GAUPP, 1982; WAGREICH, 2003a,b). Provenance studies on sandstones and breccias indicate both northern and southern source areas (WAGREICH, 2003). Transgression from the north into these basins controlled the deposition of *Orbitolina*-bearing breccias and sandstones during the Early to Middle Cenomanian.

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Plate 1

Microfossils from the *Orbitolina* Sandstones of Lower Austria

Figs. 1,10: *Orbitolina concava* (LAMARCK).
Fig. 1: Sample Kuppe.
Fig. 10: Grub, He-5.

Figs. 2,4: *Trocholina* gr. *lenticularis* HENSON.
Sample Marktl 50.

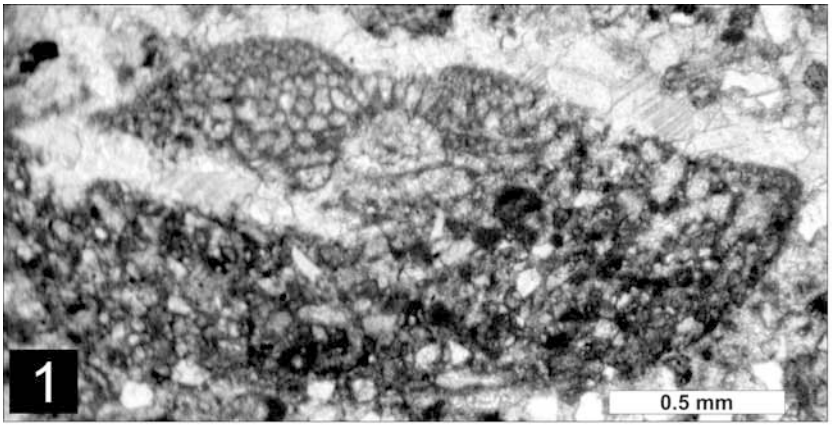
Figs. 3,5: *Mesorbitolina aperta* (ERMAN).
Fig. 3: Axial section.
Fig. 5: Detail from Fig. 3 showing embryonic apparatus.
Sample Marktl-6.

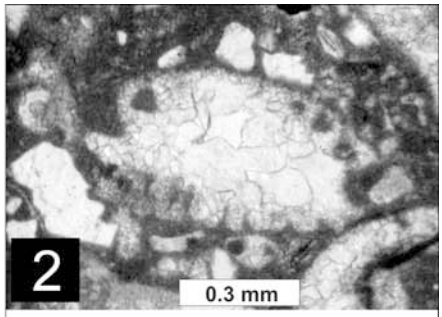
Fig. 6: *Charentia cuvillieri* NEUMANN.
Axial section.
Sample Marktl-50.

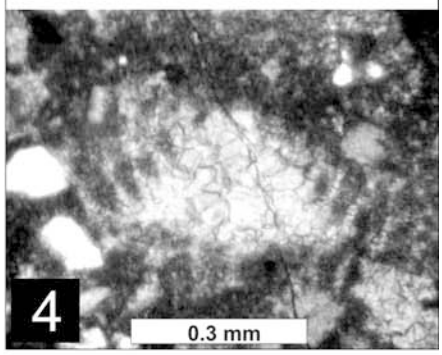
Figs. 7,8: *Conicorbitolina conica* (D´ARCHIAC).
Fig. 7: Sample Marktl 50-2.
Fig. 8: Sample Marktl 6.

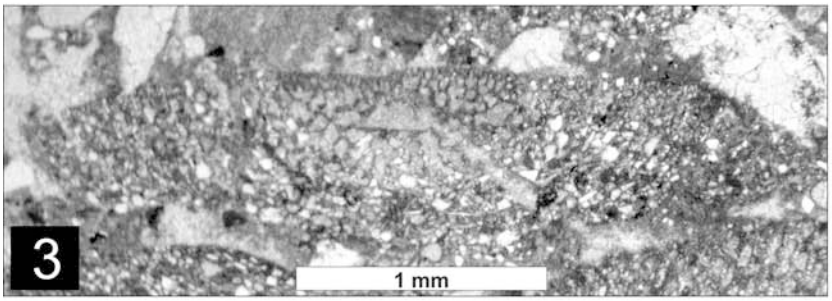
Fig. 9: *Carpathiella triangulata* MISÍK, SOTÁK & ZIEGLER, 1999.
Longitudinal section.
Sample He-15.

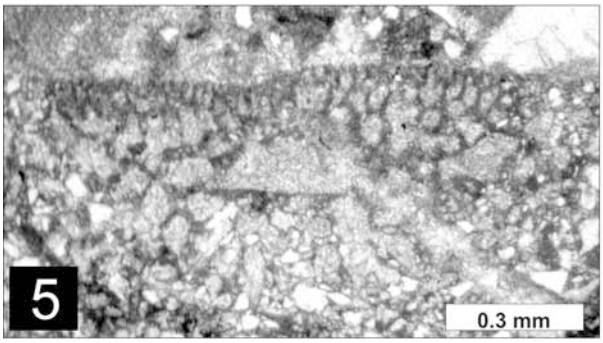
Fig. 11: *Gavelinella* sp.
Sample Marktl 50.

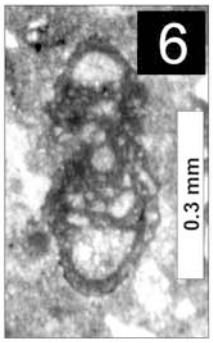


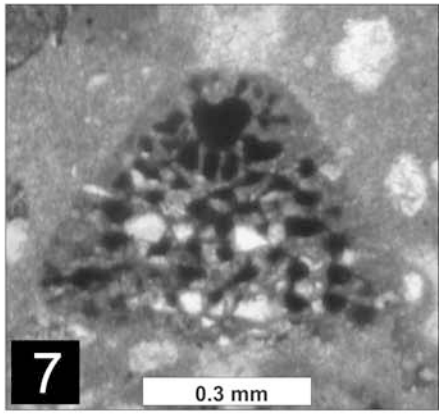


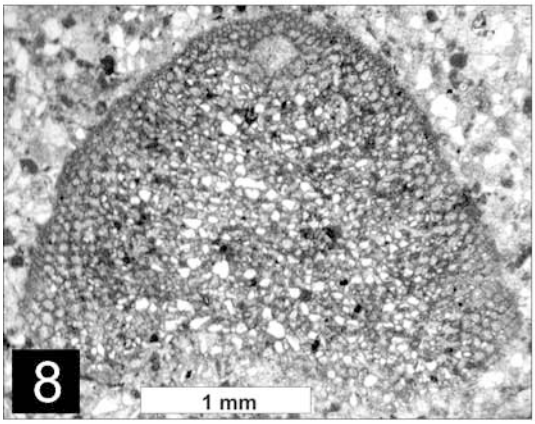


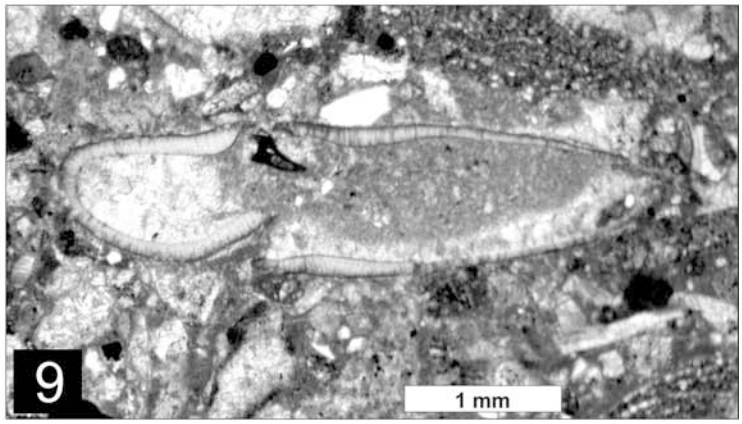


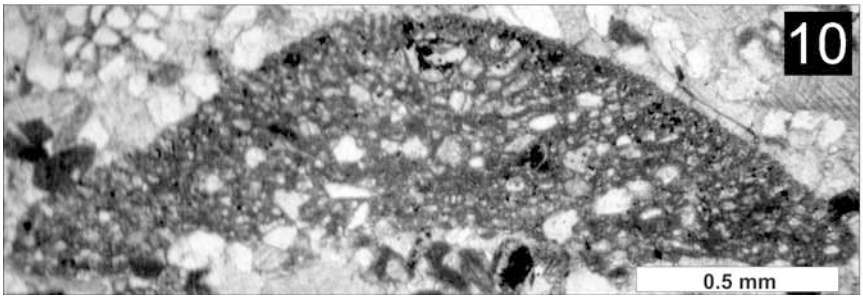












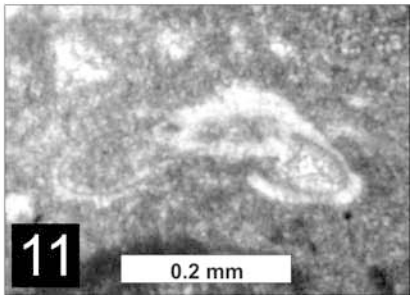


Plate 2

Microfossils from the *Orbitolina* Sandstones of Lower Austria and Hungary (Figs. 2 and 6)

Fig. 1,10: *Orbitolina concava* (LAMARCK).
Sample Grub, He-5.

Figs. 2,3,6: Problematikum 1.
Figs. 2, 6: E-Member Zirc Limestone of Hungary.
Fig. 3: Sample Marktl-6.

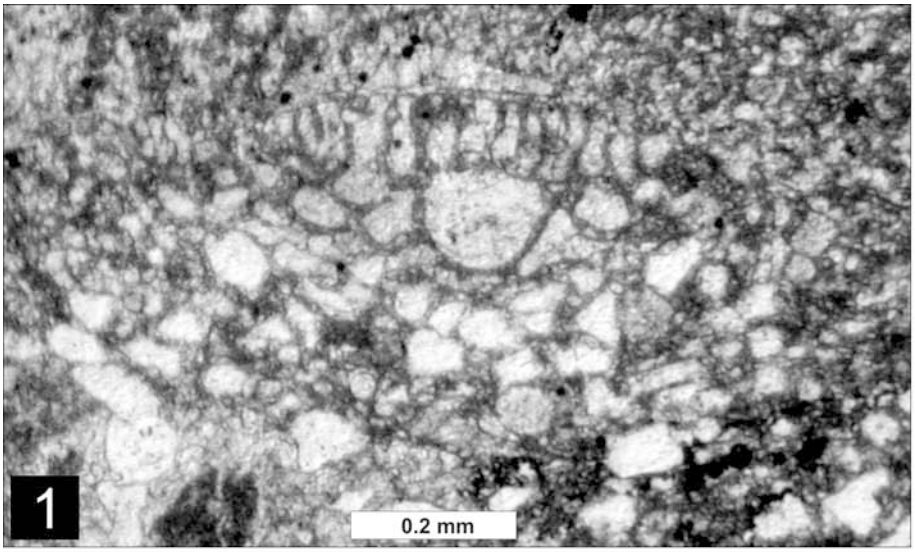
Figs. 4,7,8: *Trinocladus tripolitanus* RAINIERI.
All sample Marktl-50.

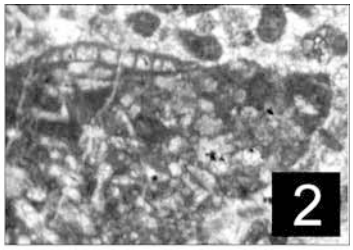
Fig. 5: Calcisphaerulidae.
Sample Marktl-50.

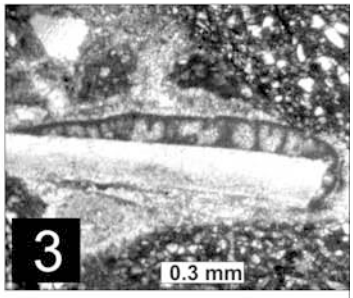
Fig. 9: *Mesorbitolina aperta* (ERMAN).
Sample Marktl-5.

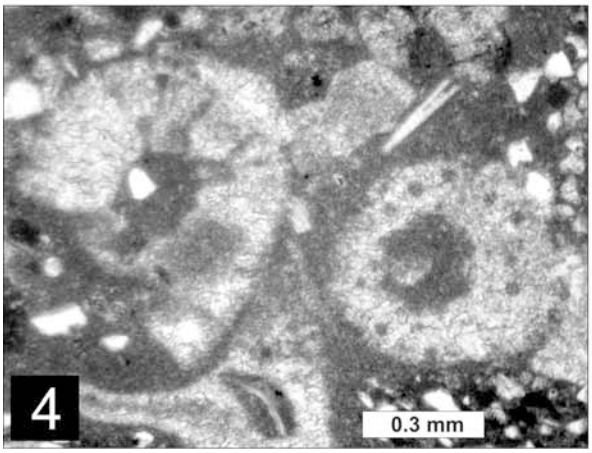
Fig. 10: *Polystrata alba* (PFENDER) DENIZOT.
Sample Marktl-50.

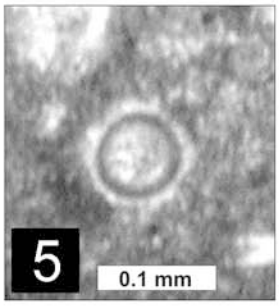
Fig. 11: Facies with *Lenticulina* sp. and *Trinocladus tripolitanus* RAINIERI.
Sample Marktl-53.

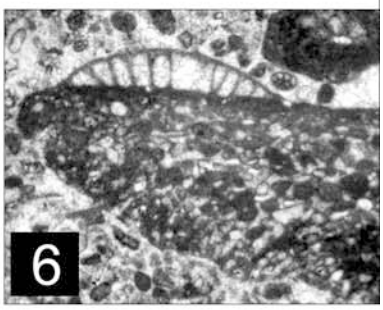


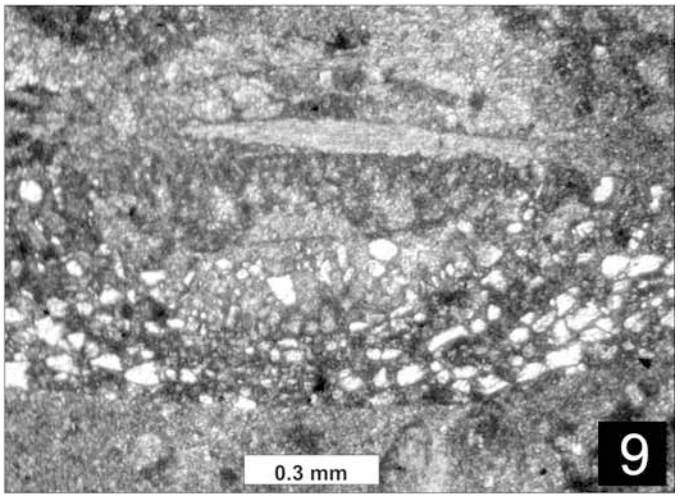


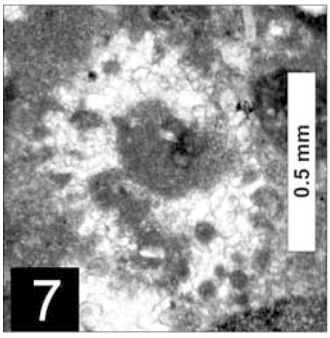


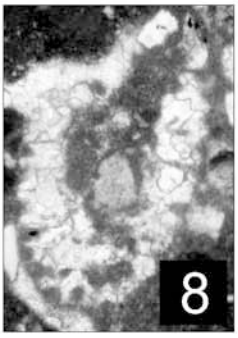


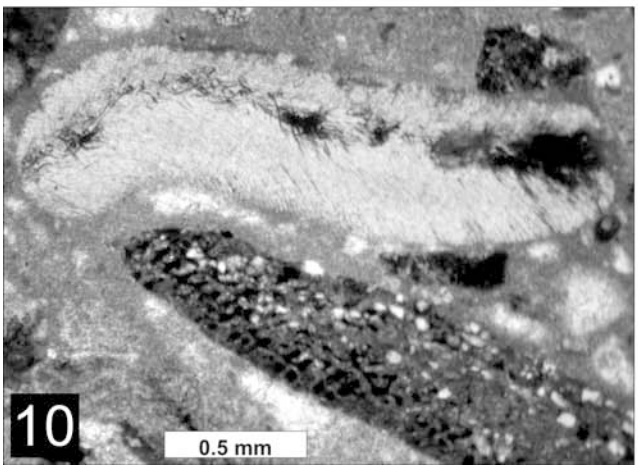


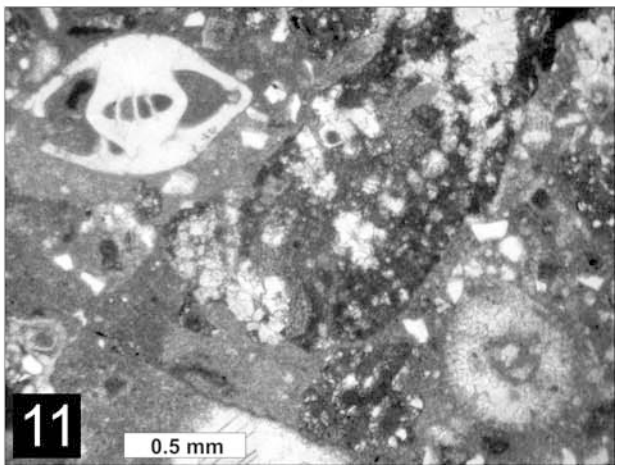












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