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Biostratigraphy and correlation of the Lower Miocene Michelstetten and Ernstbrunn sections in the Waschberg Unit, Austria (Upper Egerian to Eggenburgian, Central Paratethys)

With 4 figs, 3 pls, 3 tabs

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Abstract

Biostratigraphical and micropalaeontological investigations for calcareous nannoplankton and foraminifera have been carried out in Lower Miocene sections of the Waschberg Unit, a tectonic unit at the Alpine-Carpathian junction in Lower Austria, continuing to north-east in the external Carpathian Flysch nappes. The sedimentary system belongs to the Central Paratethys basins. Samples from the type area of the Michelstetten Formation at Michelstetten show a range from nannoplankton Zone NN 1 to Zone NN 2 by the occurrence of *Sphenolithus delphix, Discoaster drugii*, and *Helicosphaera ampliaperta*. Planktonic foraminiferal assemblages are dominated by globigerinas and *Cassigerinella*. The occurrence of *Globorotalia praescitula* in the upper part of the section indicates plankton Zone N 5, Early Burdigalian or Eggenburgian. Mass occurrences of *Uvigerina popescui* correlate with similar horizons in the Boudky Formation (Southern Moravia) and Chechis Formation (Transylvanian Basin, Rumania). Agglutinated foraminifera, uvigerinas, and abundant radiolarians indicate probably upper bathyal deep water conditions. Sediments of the Michelstetten Formation are strongly influenced by mass transport and distal turbiditic conditions. Reworking from older sediments and transport of benthic foraminifera from shallow regions are common. In the Ernstbrunn section nannoplankton Zone NN 2 is indicated by *Helicosphaera ampliaperta, Calcidiscus jafari, C. rotula*, and *Coronosphaera mediterranea*. Planktonic foraminifera are only indicative of Lower Miocene. Floods of *Cassigerinella* and common *Tenuitellinata* are remarked. Benthic foraminifera are rare and small. *Uvigerina posthantkeni* indicates Eggenburgian age. Siliceous fossils (diatoms, radiolarians, sponge spicules) are very frequent. Planktonic foraminifera and siliceous fossils signalize up-welling conditions. Fine-laminated shales with thin silt and sand laminae, and common pyrite show predominantly quiet deep water sedimentation under dysoxic bottom conditions. The Ernstbrunn beds are included in the Boudky Formation. According to a palaeogeographic model, the Michelstetten Formation was deposited in an upper bathyal slope position with turbiditic influences, followed basin-ward by the typical undisturbed, well aerated Boudky Marls in the Pouzdrany Unit, and in the deepest position of the basin by the Ernstbrunn beds with dysoxic bottom conditions and up-welling of cool water. A new species of planktonic foraminifera, *Globigerina steiningeri* is described.

Key words: Lower Miocene, Michelstetten Formation, Boudky Formation, Waschberg Unit, Austria, Central Paratethys.

Zusammenfassung

Profile im Untermiozän von Michelstetten und Ernstbrunn, Niederösterreich, wurden mit kalkigem Nannoplankton und Foraminiferen biostratigraphisch untersucht. Sie liegen in der tektonischen Einheit der Waschbergzone, im Übergangsbereich der Alpin-Karpatischen Einheiten. Die Waschbergzone setzt sich gegen Nordosten in den externen Flyschzonen des Karpatenbogens fort. Die Proben aus der Michelstetten-Formation führen kalkiges Nannoplankton der Zonen NN 1–NN 2 mit *Sphenolithus delphix, Discoaster drugii* und *Helicosphaera ampliaperta*. Planktonische Foraminiferenvergesellschaftungen sind von Globigerinen und *Cassigerinella* dominiert. *Globorotalia praescitula* tritt ab der Planktonzone N 5 auf und weist auf unteres Burdigalium, bzw. Eggenburgium hin. Das gehäufte Vorkommen von *Uvigerina popescui* lässt sich mit Horizonten in der Boudky-Formation (Südmähren) und in der Chechis-Formation im transsylva-

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nischen Becken (Rumänien) vergleichen. Radiolarien sind häufig. Agglutinierte Foraminiferen, Uvigerinen und Radiolarien weisen auf tiefes Wasser, wahrscheinlich oberes Bathyal hin. Die Ablagerungsbedingungen waren durch Umlagerungen und turbiditischen Massentransport beeinflusst. Das Profil von Ernstbrunn führt kalkiges Nannoplankton der Zone NN 2 mit *Helicosphaera ampliaperta, Calcidiscus jafari, C. rotula* und *Coronosphaera mediterranea*. Planktonische Foraminiferen zeigen nur Untermiozän an, sind aber durch das Massenvorkommen von *Cassigerinella* und häufige *Tenuitellinata* bemerkenswert. Benthische Foraminiferen sind selten und klein. Das Vorkommen von *Uvigerina posthantkeni* weist auf Eggenburgium hin. Das häufige Vorkommen kieseliger Mikrofossilien (Diatomeen, Radiolarien, Schwammnadeln) und Foraminiferen sprechen für up-welling von kühlem Wasser. Laminierte Tonmergel mit dünnen Silt- und Sandlagen, sowie häufig Pyrit zeigen, dass die Ablagerung in ruhigem, tiefen Wasser mit reduziertem Sauerstoffgehalt am Boden erfolgte. Die Tonmergel von Ernstbrunn werden in die Boudky-Formation gestellt. Nach paläogeographischen Vorstellungen wurde die Michelstetten-Formation am Kontinentalabhang, im oberen Bathyal, unter Turbidit-Einfluß abgelagert. Beckenwärts folgte die Ablagerung der ungestörten, gut durchlüfteten Boudky Mergel. In der tiefsten Position im Becken erfolgte die Sedimentation der Tonmergel von Ernstbrunn unter up-welling und bei dysaeroben Bodenbedingungen. Eine neue Art planktonischer Foraminiferen, *Globigerina steiningeri*, wurde beschrieben.

Schlüsselworte: Unteres Miozän, Michelstetten Formation, Boudky Formation, Waschberg Einheit, Österreich, Zentrale Paratethys.

Introduction

The Central Paratethys as part of the giant intercontinental Oligocene to Miocene Eurasian Sea (fig. 1a) underwent a continuous change in connections with the oceans, showing varying transgressions and regressions. This development is expressed in lithologic sequences by sedimentation gaps and alternations between marine and non-marine deposits. Considering such problems, a regional stage system was developed (see discussion in Senes 1975, Steininger 1977, Steininger et al.1985, Rögl 1998). For the transition between Oligocene and Miocene the Egerian stage was introduced (Baldi & Senes 1975), whereas the stage Eggenburgian comprised already Lower Miocene (Steininger & Senes 1971). The problem in this stage system is the definition, which is based commonly on mollusc assemblages. Boundary stratotypes are missing.

The base of the Egerian stage is defined by the first appearance (FAD) of *Miogypsina (Miogypsinoides) complanata*, the FAD of *Globigerinoides*, and a mollusc fauna of, e.g., different species of *Chlamys*, "*Flabellipecten" burdigalensis,* and *Glycimeris latiradiata*. Baldi et al. (1999) revised molluscs and larger foraminifera around the boundary interval, which is younger than the Rupelian/Chattian boundary.

For defining the base of the Eggenburgian, molluscs have been important again, with assemblages of the Loibersdorf type (stratotype), e.g., *Chlamys gigas, Ch. holgeri, Anadara fichteli,* and *Laevicardium kuebecki*. Among ostracods the FAD of the genus *Falunia*, together with a characteristic assemblage marks the base. The foraminiferal assemblages show the appearance of *Uvigerina posthantkeni*, and in shallow environments distinct elphidiid species (e.g., *Elphidium felsense, E. ortenburgense*). Calcareous nannoplankton and planktonic foraminifera are commonly scarce, and index fossils (e.g., *Helicosphaera ampliaperta, Globigerinoides trilobus*) are missing in the stratotype Loibersdorf (Cicha et al. 1971, Steininger et al. 1976, Holcova 2002).

Continuous sections, crossing the Egerian-Eggenburgian (corresponding about the Aquitanian/Burdigalian) boundary are rare in the Central Paratethys (Holcova 2002). During investigation of the Waschberg Unit in Lower Austria (Krhovsky et al. 2001) it became obvious that some sections may cross the Egerian-Eggenburgian boundary. Therefore, research on sections in the area of Ernstbrunn and Michelstetten was performed within the Austrian Science Fund project P-13743-BIO.

Foraminifera are deposited in the collection of the Department of Geology, Natural History Museum Vienna.

Geological Setting

Within the Alpine-Carpathian nappe system, the Waschberg Unit comprises a distinct tectonic nappe, which is overthrust northwestward on the Molasse Basin and itself is overthrusted by the Rhenodanubian Flysch nappes. It extends between the Danube at Stockerau and the Austrian-Czech border in a northeasterly direction for about 50 km, with a width between 4 km and 12 km (fig. 1b). The unit itself is strongly imbricated and tectonized, formed by an Upper Oligocene-Lower Miocene sedimentary body with intercalated scales and klippen of older rocks (Jurassic, Cretaceous, Paleocene, Eocene, Lower Oligocene). Northward it continues in the Zdanice and Pouzdrany Units in Southern Moravia. The tectonic position of the Waschberg Unit is therefore better explained as an external Carpathian Flysch nappe, where all these units continue lithologically in the Subsilesian Flysch of the West Carpathians (comp. Grill 1953, Brix & Götzinger 1964, Stranik 1983, Elias et al. 1990, Krhovsky et al. 2001).

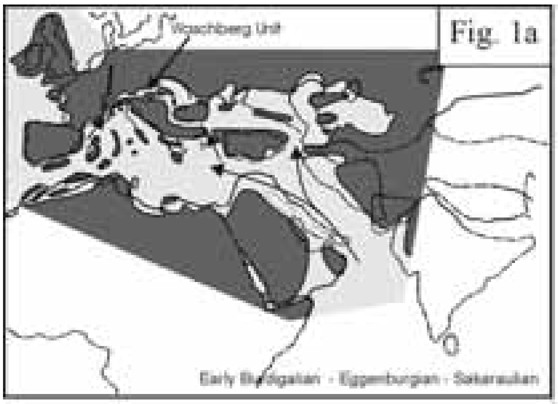


Fig. 1a: Palaeogeographic position of theWaschberg Unit in the Paratethys basin system during the Early Eggenburgian (modified after RÖGL 1999).

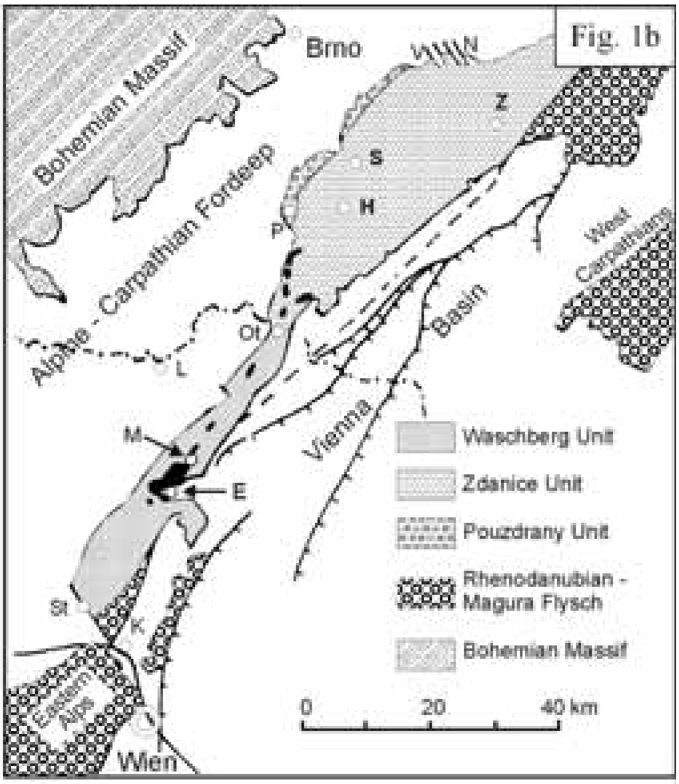


Fig. 1b: Geological situation and position of the Waschberg Unit between the Alpine-Carpathian Foredeep and the Vienna Basin (acc. RÖGL et al. 2001).

Explanations: black spots = Mesozoic klippen; E = Enstbrunn, M = Michelstetten, H = Hustopece, K = Korneuburg, L = Laa, N = Nesvacilka Graben, P = Pouzdrany, S = Sitborice, St = Stockerau, V = Vranovice Graben, Z = Zdanice.

Fig. 1c: Location of the Michelstetten section, 1100 m NW of the church (topographic map 1:50 000; Bundesamt f. Eich- und Vermessungswesen, Wien).

Fig. 1d: Location of the Ernstbrunn section, in the old brickyard, now sporting-ground (topographic map 1:50 000; Bundesamt f. Eich- und Vermessungswesen, Wien).

Investigated sections

Outcrops in the Michelstetten Formation (Michelstettener Schichten of GRILL 1952) and in the "Ernstbrunner Tonmergelserie" of BRIX & GÖTZINGER (1964), attributed to the "Schieferige Tonmergel" by GRILL (1953, 1968) have been the topic of this investigation. In both sedimentary sequences a continuation from Egerian to Eggenburgian may be possible. FUCHS et al. (2001) give a simplified cross-section of the Waschberg Unit in the area of Ernstbrunn. In seismic sections it was not possible to distinguish the different small scales and the position of investigated beds.

Michelstetten Formation

The Michelstetten Beds have been considered to be of an Early Oligocene age, later this was revised to Egerian (PAPP & STEININGER 1975, PAPP et al. 1978). The type locality lies in the fields NW of Michelstetten, and similar beds occur along the western rim of the Leiser Berge (hills of Leis, formed by Jurassic limestones). The lithology consists of light grey, greenish, silty marls with a knobby weathering, which contain a microfauna of large benthic species. PAPP (1960) described the foraminiferal fauna. The thickness of the Michelstetten Formation in deep drillings is approximately between 100 m and 150 m, with intercalations of sand, sandstones and gravels (FUCHS et al. 1980); nannoplankton zone NP25 was recorded. In the type locality Michelstetten nannoplankton zones NN1 to NN2–3 were ascertained also (KRHOVSKY et al. 2001). Following these results, a nearly south-north directed series of samples was collected by hand drilling for fresh sediment (sample distance 15 m). The section is situated 1100 m NW of Michelstetten between the two cart roads to Pyhra, beginning at a water retention basin (fig. 1c).

A different facies of soft, dark gray calcareous shales crops out at Haidhof W of Ernstbrunn, along the road to Simonsfeld, sampled in an excavation for a waste depository. These beds lay similarly west of the Jurassic Ernstbrunn limestone. GRILL (1953) has mapped this area as Michelstetten Beds imbricated with Middle Eocene sandstone, but by KRHOVSKY et al. (2001) the outcrop was correlated with the shales of Ernstbrunn.

Michelstetten section:

M-1 to M-3: indurated, grey, sandy-silty, micaceous marls, few thin bivalve shells. Washing residue of angular quartz and mica, some glauconite and partly limonitic ooids (reworked Eocene). Rare diatoms, radiolarians, sponge spicules, and few echinoid spines; in fine fraction mainly small, commonly crushed planktonic foraminifera, with blooms of *Cassigerinella*, coarser fraction dominated by *Lenticulina*.

The next boreholes in a distance of 15 m (no sample) and 10 m from M-3 did not hit Michelstetten Beds. Below dark soil, dark brown clay with sand and gravel was excavated, probably Thomasl Formation in a tectonic position.

M-4: non-calcareous, dark reddish-brown clay with rounded gravels. Residue of angular to rounded, limonitic coloured quartz, mica, glauconite, and some pyrite; barren of microfossils.

M-5 to M-6: light, greyish-brown, soft marl. Fine fraction of angular quartz and mica, some glauconite and pyrite; in coarse fraction unsorted, angular to rounded sand and fine gravels (quartz and crystalline). Rare diatoms, common radiolarians, rich foraminifera with dominance of small planktonics occur; only few large lenticulinas and agglutinated forms (e.g., *Reticulophragmium*).

M-7: grey to grey-brown, sandy marl; washing residue as above; few radiolarians and sponge spicules; in fine fraction rich planktonic assemblage, in coarser fraction only few worn benthic foraminifera; rare reworking of Cretaceous.

M-8: position of a land-mark; light grey-brown, soft marl; washing residue as above; common radiolarians, few sponge spicules, rich *Globigerina* assemblages; in fraction > 250 microns common benthic specimens.

M-9: grey-brown, partly sandy marl; residue as above; common radiolarians, few sponge spicules, scarce foraminiferal fauna, globigerinas crushed.

M-10: grey-brown, soft marl; residue as above; common radiolarians, few sponge spicules, rich foraminiferal assemblage, dominated by small planktonics; in coarse fraction common *Lenticulina*.

M-11 to M-012: grey-brown, soft marl; residue as above; few radiolarians and sponge spicules; scarce, corroded calcareous foraminifera, some agglutinated specimens.

M-13 to M-14: light grey, silty marl; residue as above; very rare radiolarians and sponge spicules; rather scarce foraminifera, dominated by small planktonics; benthic specimens often corroded or broken; in coarse fraction relatively common *Lenticulina* and in M-14 *Sphaerogypsina*.

M-15 (end of section north of cart road): light grey, silty marl; residue as above; common radiolarians, some sponge spicules, rich foraminiferal assemblage with small plankton and abundant *Uvigerina*.

Boudky Formation
(“Schieferige Tonmergel” – Ernstbrunn Beds)

In the clay pit of the old brickyard of Ernstbrunn (fig. 1d), which is now cultivated to a sports-ground, a section was sampled in soft, light grey to greenish calcareous shales. The outcrop lies on the east side of the Jurassic limestone klippen. As mentioned above, these sediments have been considered to be “Schieferige Tonmergel” (GRILL 1968). The main difference to the normal, wide spread development of those “Schieferige Tonmergel” is a rich microfossil content and absence of (turbiditic) sandstone layers. GRILL (1968) mentioned the richness of diatoms, radiolarians, sponge spicules, and small foraminifers, mainly globigerinas. Silicoflagellates have been described by BACHMANN (1971), the calcareous nannoplankton of zone NN 2 and planktonic foraminifera are reported by KRHOVSKY et al. (2001). Other outcrops in the village Ernstbrunn (e.g., building site Gartengasse 22 or road cross to Laa and Mistelbach) exhibited more strongly indurated light grey, silty marls with a scarcer microfauna and nannoplankton zone NN 2–3.

Ernstbrunn section:

The 14 m section was sampled along the west wall of the old clay pit, which has a dip of 45° in the lower part and of 22° in the upper part, piling up to a normal thickness of 11.5 m. The mean dipping is 40–43° to the SW (234°). These beds are cut by small faults of different directions (320/65°, 230–260/80–85°, 115/85°). The fault planes show a dark coating. The section consists of greenish-grey, silty, calcareous, soft shales, the lowermost part bedded in thick layers (E-1). Up-section follow 10–15 cm thick shale beds with interbedded thin, rusty fine sand layers and lenses, alternating with thinner shale beds (2–4 cm) and silty-sandy bedding planes (E-2 to E-24). The shale beds are finely laminated. In the upper part (E-25 to E-29) yellowish-grey and light-grey, laminated, sandy shale beds (3–4 cm) alternate.

The washing residue consists of fine angular quartz and mica, in some samples also with few glauconite grains, and is characterized by high amount of pyrite. The fossil content in all samples shows an abundance of diatoms, common radiolarians, and sponge spicules. The foraminiferal assemblages are dominated by small planktonics, with floods of *Cassigerinella*; benthic species are commonly small or juvenile, larger specimens often broken or corroded, and probably transported with reworked material.

Micropalaeontological investigations

Calcareous nannoplankton

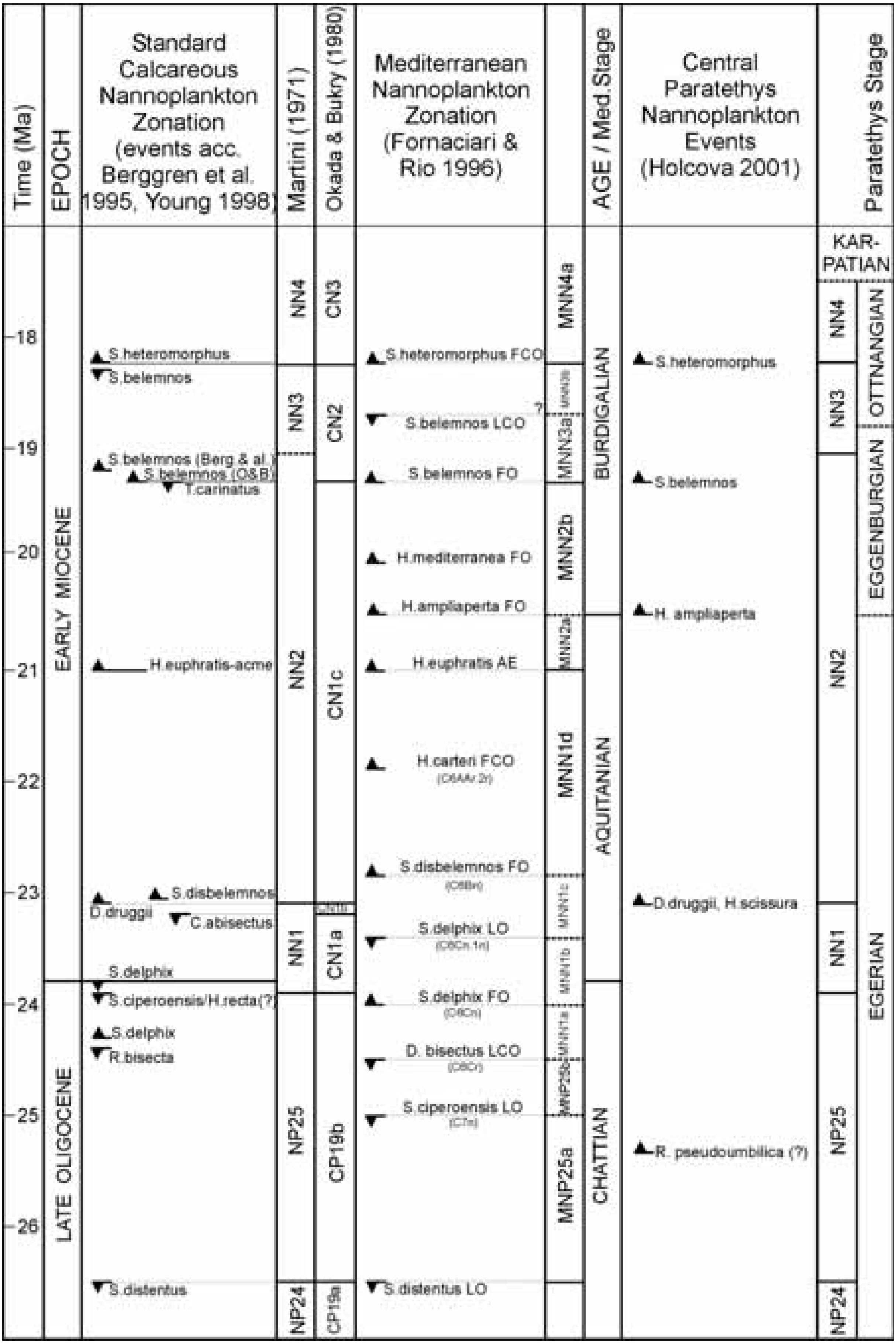
Reliability of nannoplankton datum levels at and around the Oligocene/Miocene boundary:

In most of the current nannoplankton zonations of the Cenozoic the transitional interval at and around the Oligocene-Miocene boundary is the most disputed. A lot of nannoplankton events are used to fix discrete time-levels, but there is not much agreement. Based on the mostly used nannoplankton zonations of MARTINI (1971) and OKADA & BUKRY (1980) a sequence of nannoplankton datum can be compiled for the lowermost Miocene (fig. 2). The levels of events are positioned according to BERGGREN et al. (1995) and YOUNG (1998) as they are correlated there to the geomagnetic time-scale, and only minor differences exist.

FORNACIARI & RIO (1996) presented a latest Oligocene to Middle Miocene calcareous nannoplankton zonation for the Mediterranean based on numerous quantitatively investigated Neogene profiles, exclusively from the Mediterranean. This work had a special emphasize on the Central Paratethys nannoplankton age determinations, since almost all water-masses of the world-seas (including their calcareous nannoplankton content) reached the Paratethys basins via the Mediterranean or they had access to mix with Mediterranean sea-water at least. The zonation of FORNACIARI & RIO (1996) differs in a number of features from those of MARTINI (1971) and OKADA & BUKRY (1980), e.g., they introduced the idea of FCO (first common occurrence) and LCO (last common occurrence). Their Mediterranean sequence of nannoplankton events is given by FO = first occurrence and LO = last occurrence (fig. 2). These events are not correlated to any geochronological time scale. It was necessary to compare the dating of this events with the geomagnetic results obtained at the Paleogene/Neogene global boundary stratotype (AUBRY & VILLA 1996, STEININGER & IACCARINO 1996). There are still major differences compared with the standard zonation.

A comparable sequence of nannoplankton events has not been established for the Central Paratethys, yet due to the rarity or absence of index fossils. A paper published by HOLCOVÁ (2001) recently made an attempt to fix such a system for the South-Slovakian region (fig. 2). Having a look at the present investigation, it is clear that a number of tropical and sub-tropical species used in the zonations cannot establish zonal boundaries at the mid or high latitudes (including the Paratethys) because of their rare occurrence or total absence. Anyhow, considering more than hundred publications from this region (including a lot of unpublished results) one can make an attempt to estimate the reliabilty in the Central Paratethys.

The LAD of *Sphenolithus ciperoensis* is a hardly traceable event since this species is rare. RIO et al. (1990) proved that the LAD of *Helicosphaera recta* extends far into the Early Miocene, sometimes until the zone NN 4. The LAD of *Reticulofenestra bisecta* is seriously masked in several parts of the Central Paratethys because of its permanent reworking from older Paleogene deposits due to a minor regression in the Upper Egerian and a major transgression during the Eggenburgian. This species is a permanent (reworked) component in great quantities of almost all Lower


Time (Ma)
EPOCH
Standard Calcareous Nannoplankton Zonation (events acc. Berggren et al. 1995, Young 1998)
Martini (1971)
Okada & Bukry (1980)
Mediterranean Nannoplankton Zonation (Fornaciari & Rio 1996)
AGE / Med.Stage
Central Paratethys Nannoplankton Events (Holcova 2001)
Paratethys Stage
18
19
20
21
22
23
24
25
26
EARLY MIOCENE
LATE OLIGOCENE
S.heteromorphus
S.belemnos
S.belemnos (Berg & al.)
S.belemnos (O&B)
T.carinatus
H.euphratis-acme
S.disbelemnos
D.druggii
C.abisectus
S.delphix
S.ciperoensis/H.recta(?)
S.delphix
R.bisecta
S.distentus
NN4
NN3
NN2
NN1
NP25
NP24
CN3
CN2
CN1c
CN1a
CP19b
CP19a
S.heteromorphus FCO
S.belemnos LCO
S.belemnos FO
H.mediterranea FO
H.ampliaperta FO
H.euphratis AE
H.carteri FCO
S.disbelemnos FO
S.delphix LO
S.delphix FO
D. bisectus LCO
S.ciperoensis LO
S.distentus LO
MNN4a
MNN3a
MNN2b
MNN2a
MNN1d
MNN1c
MNN1b
MNN1a
MNP25a
BURDIGALIAN
AQUITANIAN
CHATTIAN
S.heteromorphus
S.belemnos
H. ampliaperta
D.druggii, H.scissura
R. pseudoumbilica (?)
KAR-PATIAN
OTTNANGIAN
EGGENBURGIAN
EGERIAN

Miocene nannofloras, for example in North Hungary. The same can be proved on *Cyclicargolithus abisectus*.

Holcová (2001) suggested, that the FAD of *Helicosphaera kamptneri (=carteri)* should be a reliable nannoplankton event at the beginning of zone NN 1. However, in the Buda Basin the FAD of *H. carteri* precedes even the LAD of *S. ciperoensis*. The FCO of this species is much earlier in the Paratethys than in the Mediterranean (cf. Fornaciari & Rio 1996).

The FAD of *Reticulofenestra pseudoumbilica* is a very gradual event in the Central Paratethys. Rare specimens of *R. pseudoumbilica* var. *excavata* Lehotayová appear already in the Eggenburgian beds, but in a higher position as it was proposed by Holcová (2001). According to Fornaciari et al. (1996) the FO of "true" *Reticulofenestra pseudoumbilica* must be confined in the Mediterranean to the Middle Miocene.

FO-s and LO-s of *Sphenolithus delphix*, *S. disbelemnos,* and *S. belemnos* seem to be very reliable datum levels, but they occur only sporadically in the Paratethys region. The same can be stated on the LAD of *Triquetrorhabdulus carinatus*.

The FO of *Helicosphaera scissura* can be considered as a good tool for stratigraphy, however a number of unpublished data show, that this event precedes the FO of *Discoaster druggii*. *Helicosphaera ampliaperta* is also one of the bestindex fossils, but its exact determination is enhanced by the continuous evolutionary transition from the *H. scissura* to the *H. ampliaperta* morphology. The FO of *Helicosphaera mediterranea* seems to be an earlier event in the Central Paratethys than in the Mediterranean.

The NN 2 zone-defining FAD of *Discoaster druggii* hardly can be traced in the Paratethys because of the tropical character of this fossil. The wide variability of the taxon does not make easy to fix it, this is the cause why one can find a lot of *D.* cf. *druggii* at several author's nannoplankton lists.

Michelstetten section:

The nannofloras of the Michelstetten section display medium diversities and abundances in general (table 1). However, both values may change between wide extremities. While the samples M-1 to M-3 show the highest diversity values, the assemblages of other samples (e.g., samples M-12 to M-15) represent much lower diversities. A few samples (e.g., M-4 and M-11) do not contain any autochthonous nannoplankton, only some reworked specimens.

Fig. 2: Nannoplankton datum levels around the Oligocene/Miocene boundary and in the Early Miocene. Position of events in comparison with the zonations of Martini (1971) and Okada & Bukry (1980) is based on correlations to the geomagnetic polarity time-scale as presented by Berggren et al. (1995) and Young (1998). For the zonation of Fornaciari & Rio (1996) the events are corrected partly according to Aubry & Villa (1996) and Steininger & Iaccarino (1996).

Diagnostic species are rare, sometimes only 1-2 specimens per sample, and therefore, a semi-quantitative estimation could not have been done for most of the samples. A low Paleogene and a strong Cretaceous reworking often can be observed. The preservation is quite bad, etched, and broken specimens occur in extreme numbers (pl. 1).

Most common elements of the nannofloras are placoliths, e.g., *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, and *Reticulofenestra lockeri*. Less common forms of placoliths, as *Cyclicargolithus abisectus* and *Reticulofenestra minuta* occur only sporadically. The diagnostic *Reticulofenestra bisecta* occurs only in the lowermost three samples, *R. pseudoumbilica* var. *excavata* only in sample M-7.

Helicosphaeras are common elements of the nannoflora. Their relatively great diversity may be due to the temporary temperature drop at the Oligocene-Miocene boundary, as well as to their evolutionary acceleration during the Early Miocene, when a half dozen of new *Helicosphaera* species appeared in a short time-interval.

Most common helicosphaeras are *H. carteri*, *H. mediterranea*, and *H. scissura*. Rare specimens of *Helicosphaera perch-nielseniae* and *H. recta* appear only in the lowermost samples. The zone-diagnostic form, *H. ampliaperta* has its first appearance in sample M-6 and occurs higher up only in sample M-12. However, its non-typical variety, *Helicosphaera* ex aff. *ampliaperta* can be observed throughout the whole profile.

Tropical forms as sphenoliths and discoasters are extremely rare. One specimen of the diagnostic *S. ciperoensis* has been observed in the lowermost sample and the other diagnostic form, *S. delphix* occurred only in sample M-2. A younger index-sphenolith, *S. disbelemnos* has its first and only occurrence in sample M-12. One broken specimen of the zone-index fossil *D. druggii* has been observed in the sample M-3.

The lowermost samples (M-1 and 2) may belong to the zone NN 1. The presence of *S. delphix, H. perch-nielseniae* and *H. scissura* refer to an age of latest Egerian. In opposition of this, the occurrence of *H. mediterranea* refers already to NN 2 zone. The occurrence of one specimen of *S. ciperoensis* in sample M-2 can be explained only by reworking from older sediments, which seems to be very probable concerning the evolution of an accretional wedge of the Outer Carpathians at this time.

Discoaster druggii appears in sample M-3, thus defining the lower boundary of zone NN 2 in this sample. This datum is followed by the FAD of *H. ampliaperta* in sample M-6. This event and higher up, specimens of *T. milowii* (sample M-6) and *S. disbelemnos* (sample M-12) confirm the NN 2 age (or even a higher part of zone NN 2).

Although the age of the Michelstetten beds earlier was thought to be Egerian, some former nannoplankton investigations already suggested a younger, latest Egerian to Eggenburgian age. Krhovsky et al. (1995) described *H. ampliaperta* and *H. mediterranea* from the Michelstetten Formation (FAD in NN 2) and proved its synchronous

Table 1: Calcareous nannoplankton distribution in the Michelstetten section.

MICHELSTETTEN SECTION															
sample numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coccolithus eopelagicus (Bramlette & Riedel) Bramlette & Sullivan						x						x			x
Coccolithus pelagicus (Wallich) Schiller	x	x	x		x	x	x	x	x	x		x	x	x	x
Coronocyclus nitescens (Kamptner) Bramlette & Wilcoxon					x										
Cyclicargolithus abisectus (Müller) Wise						x									
Cyclicargolithus floridanus (Roth & Hay) Bukry	x	x	x			x	x	x	x	x		x	x	x	x
Discoaster druggii Bramlette & Wilcoxon			x												
Helicosphaera ampliaperta Bramlette & Wilcoxon						x						x			
Helicosphaera ex aff. *ampliaperta* Bramlette & Wilcoxon	x	x	x			x	x		x				x		x
Helicosphaera carteri (Wallich) Kamptner		x	x		x		x		x	x			x		x
Helicosphaera mediterranea Müller	x		x			x		x						x	x
Helicosphaera obliqua Bramlette & Wilcoxon	x							x							
Helicosphaera perch-nielseniae (Haq) Jafar & Martini	x														
Helicosphaera recta (Haq) Jafar & Martini			x												
Helicosphaera scissura Miller	x	x			x		x	x		x					x
Helicosphaera sp.			x			x				x					
Pontosphaera discopora Schiller							x								
Pontosphaera japonica (Takayama) Nishida										x					
Reticulofenestra bisecta (Hay) Roth	x	x													
Reticulofenestra lockeri Müller	x	x	x		x	x	x	x	x	x		x	x	x	x
Reticulofenestra minuta Roth								x					x		
Reticulofenestra ornata Müller															x
Reticulofenestra pseudoumbilica var. *excavata* Lehotayova							x	x		x			x		
Sphenolithus ciperoensis Bramlette & Wilcoxon		x													
Sphenolithus conicus Bukry														x	
Sphenolithus delphix Bukry	x	x										x			
Sphenolithus disbelemnos Fornaciari & Rio												x			
Sphenolithus moriformis (Brönnimann & Stradner) Bramlette & Wilcoxon									x			x			
Syracosphaera sp.	x														
Triquetrorhabdulus milowii Bukry						x									
Zygrhablithus bijugatus (Deflandre) Deflandre		x				x		x				x			
reworking from Cretaceous	x	x	x	x	x	x	x	x	x	x		x	x	x	x
reworking from Paleogene	x				x	x	x	x	x		x	x			x

deposition with the Boudky Marl in Moravia. A more detailed investigation of the Boudky Marl (KRHOVSKY et al. 2001) confirmed the NN 2 age and the similarity of its nannofloras to the Michelstetten Fm.

Ernstbrunn section:

The nannofloras of the Ernstbrunn section (tab. 2) show low to medium diversities and medium to rich abundances. Strong reworking from the Cretaceous and a medium reworking from Paleogene beds is observable. An extremely high amount of diatom tests can be observed in the 1 to 40 μm fraction of the samples.

The bulk of the nannofloras consists of small placoliths. The most common forms are *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, and *Reticulofenestra lockeri*. Throughout the whole section species occur (e.g., *Reticulofenestra bisecta*, *R. hesslandii,* and *R. callida*), which presumably have been reworked from Paleogene beds.

Another group of placoliths appears from sample E-9 upwards, which belongs to the new, Miocene generation of placoliths: *Calcidiscus jafari*, *Calcidiscus rotula, Coronosphaera mediterranea*, *R. pseudoumbilica*, and *R. pseudoumbilica* var. *excavata*.

The role of helicosphaeras is somewhat sub-ordinate than in the nannofloras of the Michelstetten beds. *Helicosphaera* ex aff. *ampliaperta*, *H. carteri*, and *H. scissura* occur throughout the whole section, but only 1–2 specimens per sample. The "true" *H. ampliaperta* has its first appearance in sample E-5 and it appears again in sample E-9. The usually common Lower Miocene *H. mediterranea* is missing in this section.

Sub-tropical and tropical diagnostic species such as *Sphenolithus capricornutus*, *S. conicus*, and *S. delphix* are rare. *Discoaster druggii* is represented only by one specimen in sample E-23.

The rather poor nannoflora makes age determination difficult. *S. delphix* in sample E-1 refers still to NN 1, but the FAD of *H. ampliaperta* in sample E-5 is proving an age of NN 2. Another zone index fossil, *D. druggii* occurs only in sample E-23.

Foraminifera

Michelstetten section:

The foraminiferal fauna in the Michelstetten Section is moderately well preserved and shows strong varying

Table 2: Calcareous nannoplankton distribution in the Ernstbrunn section.

ERNSTBRUNN, OLD BRICKYARD															
sample numbers	E1	E3	E5	E7	E9	E11	E13	E15	E17	E19	E21	E23	E25	E27	E29
Calcidiscus jafari (Müller)										x					
Calcidiscus rotula (Kamptner)					x										
Coccolithus miopelagicus Bukry					x			x							
Coccolithus pelagicus (Wallich) Schiller	x	x	x	x	x	x	x		x	x	x	x		x	x
Coronosphaera mediterranea (Lohmann) Gaarder										x	x				x
Cyclicargolithus abisectus (Müller) Wise											x				
Cyclicargolithus floridanus (Roth & Hay) Bukry	x	x	x	x	x	x	x	x		x	x	x		x	x
Discoaster deflandrei Bramlette & Riedel												x			
Discoaster druggii Bramlette & Wilcoxon												x			
Helicosphaera ampliaperta Bramlette & Wilcoxon			x		x										
Helicosphaera ex aff. *ampliaperta* Bramlette & Wilcoxon			x		x	x	x		x		x	x	x	x	x
Helicosphaera bramlettei Müller						x									
Helicosphaera carteri (Wallich) Kamptner										x	x			x	x
Helicosphaera obliqua Bramlette & Wilcoxon			x			x									
Helicosphaera scissura Miller			x			x			x	x	x			x	x
Pontosphaera sp.									x						
Pontosphaera multipora (Kamptner) Roth			x		x	x			x	x	x	x		x	
Reticulofenestra bisecta (Hay) Roth	x		x		x		x			x		x		x	
Reticulofenestra callida (Perch-Nielsen) Bybell	x		x	x											
Reticulofenestra hesslandii (Haq) Roth	x							x	x		x			x	
Reticulofenestra lockeri Müller	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Reticulofenestra ornata Müller					x		x	x						x	
Reticulofenestra pseudoumbilica (Gartner) Gartner										x	x				x
Reticulofenestra pseudoumbilica var. *excavata* Lehotayova	x			x	x	x			x						
Sphenolithus capricornutus Bukry & Percival											x				
Sphenolithus conicus Bukry									x						
Sphenolithus delphix Bukry	x														
Sphenolithus moriformis (Brönnimann & Stradner) Bramlette & Wilcoxon			x	x	x	x			x		x	x		x	x
Zygrhablithus bijugatus (Deflandre) Deflandre						x			x						
reworking from Cretaceous			x		x	x	x		x	x	x	x			x
reworking from Paleogene	x	x	x	x	x	x	x	x	x	x	x	x		x	x

abundances. Planktonic assemblages are dominated by globigerinas. Most common are some benthic species: large *Lenticulina* (M-1, 5, 6, 8, 10, 15), *Marginulina hirsuta* (M-1, 5, 6, 8, 10, 15), *Siphonina reticulata* (M-5, 6, 8, 10, 12), *Fontbotia wuellerstorfi* (M-8, 12, 13), and *Hoeglundina elegans* (M-1, 10). A mass occurrence of *Uvigerina popescui* (sample M-15) was found also in a comparative sample south of M-1, and in a horizon of the Boudky Formation of Kolby Hill at Pouzdrany (Southern Moravia). In a few samples large agglutinated species (e.g., *Bathysiphon, Reticulophragmium, Vulvulina haeringensis*) are more common. The accumulation of *Sphaerogypsina globulus* in sample M-14 is explained by transport from the shallow. Reworking of Upper Cretaceous and Eocene faunal elements was observed.

Planktonic foraminifera and some stratigraphically important benthic species are compiled in tab. 3, but do not give precise age. Upper Oligocene or possibly Aquitanian was proposed by Papp (1960). The microperforate species *Tenuitellinata pseudoedita* and *Tenuitella brevispira* range from Oligocene to Lower Miocene (Cicha et al. 1998). The best index species represents *Globorotalia praescitula* with an FAD at the base of planktonic foraminiferal Zone N 5 (Blow 1969), corresponding to Early Burdigalian, and is reported from the Eggenburgian of the Bavarian Molasse Basin (Wenger 1987). The presence of *G. praescitula* in sample M-7 may indicate the lower boundary of Eggenburgian in the Michelstetten section.

The benthic species *Uvigerina posthantkeni* has been believed to have a FAD in the Eggenburgian, and similarly *Uvigerina popescui* is present in the Chechis Formation of the Transylvanian Basin (Eggenburgian, Popescu 1998). A further indication is given by *Fontbotia wuellerstorfi,* which seems to appear in the Eggenburgian of the Central Paratethys.

From a palaeoecological point of view, the sediments of the Michelstetten section are strongly influenced by mass transport, with common transported, corroded, and damaged benthic specimens, and some reworking from older beds. The high number of radiolarians, abundant globigerinas, and some autochthonous elements (e.g., *Bathysiphon, Reticulophragmium*, *Hoeglundina, Amphicoryna, Siphonina*, and heavily costate *Uvigerina*) indicate a greater water depth of about 500 m, upper bathyal, in a slope position. Bottom conditions were well aerated.

Ernstbrunn section:

The foraminiferal fauna of the Ernstbrunn section is dominated by small planktonic species. Stratigraphically important species and markers for Egerian or Eggenbur-

Sample Number	*Globigerina steiningeri* n.sp.	*Globigerina ottnangiensis* Rögl	*Tenuitellinata angustiumbilicata* (Bolli)	*Cassigerinella boudecensis* Pokorny	*Catapsydrax unicavus* Bolli et al.	*Globigerina praebulloides* Blow	*Tenuitellinata juvenilis* (Bolli)	*Tenuitellinata pseudoedita* (Subbotina)	*Tenuitella brevispira* (Subbotina)	*Cassigerinella spinata* Rögl	*Globigerina gnaucki* Blow & Banner	*Globigerina dubia* Egger	*Globorotalia praescitula* Blow	*Globigerinella* cf. *obesa* (Bolli)	*Globoquadrina langhiana* Cita & Gelati	*Globorotaloides* sp. (cf. *suteri* Bolli)	*Globigerina lentiana* Rögl	*Globoturborotalita connecta* (Jenkins)	*Globoturborotalita* sp.	*Paragloborotalia? inaequiconica* (Subbotina)	*Fontbotia wuellerstorfi* (Schwager)	*Uvigerina mantaensis* Cushman & Ellisor	*Uvigerina posthantkeni* Papp	*Uvigerina* cf. *spinulosa* Hadley	*Uvigerina popescui* Rögl	*Uvigerina nuttalli* Cushman & Edwards
Michelstetten																										
M-1	x	x	x	x	x																x	x				
M-2	x	x	x	x		x	x	x	x	x											x	x	x	x		
M-3	x	x		x			x	x														x			x	
M-4																										
M-5	x	x	x	x		x	x	x	x		x										x				x	
M-6	x	x	x	x		x	x	x	x	x	x										x			x		
M-7	x	x	x	x		x	x	x	x	x	x	x	x													
M-8	x	x	x	x		x	x	x	x		x	x									x					
M-9	x	x	x	x		x	x															x				
M-10	x	x	x	x		x	x	x			x		x								x				x	
M-11																										
M-12	x	x		x		x	x	x			x										x					
M-13	x	x	x	x		x	x	x	x	x			x								x					x
M-14	x	x	x	x		x	x	x	x	x			x								x					x
M-15	x	x	x	x			x	x	x												x				x	
Ernstbrunn																										
E-1		x		x		x	x	x		x	x	x		x	x	x										
E-2	x	x		x		x	x	x	x	x	x	x			x		x						x			
E-3	x	x		x		x	x	x		x	x															
E-4	x	x		x		x	x	x	x	x		x		x	x			x	x				x			
E-5	x	x		x		x	x	x		x	x	x		x	x			x	x			x				
E-6	x	x	x	x		x	x	x		x	x	x						x								
E-7	x	x	x	x		x	x	x	x	x	x	x						x					x			
E-8	x	x		x		x	x	x		x	x	x			x			x								
E-9	x	x		x		x	x	x		x								x								
E-10	x	x		x		x	x	x		x					x			x					x			
E-11	x	x		x		x	x	x	x	x								x								
E-12	x	x	x	x		x	x	x		x								x								
E-13	x	x		x		x	x	x	x	x							x	x	x				x			
E-14	x	x		x		x	x	x		x	x			x						x			x			
E-15	x	x		x																						
E-16	x	x		x		x	x	x		x		x											x			
E-17	x	x		x		x	x	x		x																
E-18	x	x		x		x	x	x		x	x			x			x	x					x	x		
E-19	x	x		x		x	x	x		x	x				x								x			
E-20	x	x		x						x	x			x			x	x					x			
E-21	x	x		x		x	x	x		x							x									
E-22	x	x		x		x	x	x		x	x	x				x	x		x							
E-23	x	x		x		x	x	x	x	x		x					x	x								
E-24	x	x		x		x	x	x		x	x															
E-25		x		x		x																				
E-26	x	x		x		x	x	x		x	x			x	x				x							
E-27	x	x	x	x		x	x	x		x	x			x	x			x								
E-28	x	x		x		x	x	x		x	x				x			x								
E-29	x	x		x		x	x	x	x	x																

gian are missing. Additionally to the *Tenuitellinata* species, reported from the Michelstetten section, *Globoquadrina langhiana* and *Paragloborotalia? inaequiconica* have their first appearance in the Upper Egerian. *Uvigerina posthantkeni* is present, the only so-called Eggenburgian species. The distribution of plankton and selected benthic species is shown in table 3.

Floods of *Cassigerinella*, frequent *Globigerina ottnangiensis*, and common *Tenuitellinata* may be caused by up-welling conditions. This proposition is supported by the very rich occurrence of siliceous microfossils (diatoms, radiolarians, sponge spicules). The strongly reduced benthic assemblage, only juvenile and very small specimens, high amount of pyrite, and fine lamination of the sediment indicate dysoxic bottom conditions. Transport from shallow regions and reworking is rare. The sediments were deposited in a quiet environment of greater water depth as in Michelstetten, probably middle bathyal (high amount of radiolarians and planktonic foraminifera). The scarceness of benthic species does not allow precise palaeodepth estimation.

Discussion

Similarities in the age of the Michelstetten and Ernstbrunn nannofloras rise the question about their relation. Since the age of nannoplankton of both formations seems to be almost the same, one must suppose that both were deposited during NN 2. In this case, all FAD-s of *Discoaster druggii* and *H. ampliaperta* must be considered as "false FAD-s", in fact, these occurrences only seem to be first ones since there is no permanent record of these species in the local sedimentary column. Otherwise, the FAD of *H. ampliaperta* seems to be a marker for the base of the Eggenburgian as demonstrated by Holcova (2002).

Probably, the lowermost beds of the Michelstetten section may be NN 1 (based on the occurrence of a few specimens of *S. delphix*), while the other part belongs to NN 2. The age of the Ernstbrunn series is still NN 2, but somewhat younger as it is suggested by the appearance of younger Miocene placoliths (*Calcidiscus jafari, C. rotula, Coronosphaera mediterranea*).

According to foraminifera, *Globorotalia praescitula* indicates an Eggenburgian age (Zone N 5) only in the upper part of the section of Michelstetten. The stratigraphic range of benthic species is not well correlated to plankton stratigraphy. Similar planktonic and benthic assemblages as in Michelstetten are observed in the Boudky Formation, Pouzdrany Unit in Southern Moravia, dated as nannoplankton Zone NN 2 (Krhovsky et al. 1995; Krhovsky et al. 2001). The frequent occurrence of *Uvigerina popescui* in some horizons of Michelstetten correlates with the Chechis Formation (Eggenburgian) in the Transsylvanian Basin, and also with those in the Boudky Fm. Planktonic assemblages of the Ernstbrunn section with blooms of *Cassigerinella* also show a strong similarity with the Boudky Fm. Mass occurrences of *Cassigerinella* in some samples are also reported from shallow deposits of the Eggenburgian type area (Jenke 1993). Only *Uvigerina posthantkeni* may indicate an Eggenburgian age in the benthic fauna of Ernstbrunn.

Microfossils show different facies and sedimentation processes. Evidence for sediment transport is found in the Michelstetten section. Unsorted sand and gravel in the coarse fraction and damaged foraminifera point to turbiditic mass flows. This is indicated also by coarse clastics within the Michelstetten Fm. (Fuchs et al. 1980). Strong reworking of Cretaceous and Paleogene calcareous nannoplankton and foraminifera support this interpretation. The probably autochthonous part of benthic foraminifera and the abundance of radiolarians indicate greater water depth (probably upper bathyal). The high amount of diatoms, radiolarians, small planktonic foraminifera, and a reduced benthic fauna in the Ernstbrunn section indicate high surface productivity and dysaerobic bottom conditions. The fine lamination of the sediment hints to quiet bottom conditions, disturbed only by transport of silt and fine sand, deposited in thin layers.

In a palaeogeographic interpretation, the succession from a slope facies in the Michelstetten Fm. to a deeper water facies of the Boudky Fm., and to dysaerobic conditions in the deepest basin part (Ernstbrunn beds) is proposed. According to this model, the Ernstbrunn shales are correlated with and thus included in the Boudky Fm. A transitional facies between Boudky Marls and Ernstbrunn beds is present in the so-called Michelstetten Fm. of Haidhof (Grill 1968), west of Ernstbrunn. Marly shales are deposited there in a quiet environment with reduced oxygen content at the bottom, as indicated by the high amount of pyrite. Some large lenticulinas as well as *Marginulina, Dentalina, Cibicidoides,* and *Bolivina* are present (comparable with the fauna of the Boudky Marl), but also indicators of reduced oxygen conditions (*Globobulimina, Chilostomella, Hidina, Valvulineria*) can be found. The plankton is dominated by *Cassigerinella, Tenuitellinata,* and *G. ottnangiensis*. Otherwise, diatoms and radiolarians are absent. Because of the autochthonous sedimentation and plankton content, these beds are correlated with the Ernstbrunn beds and included now in the Boudky Formation.

The Michelstetten Fm. is distinguished from the Boudky Fm. by clastic components and a probably turbiditic sedimentation. These results indicate, that the Ernstbrunn beds (Boudky Fm.) are different from the "Schieferige Tonmergel" (Grill 1968) of the more western parts of the Waschberg Unit with turbiditic sedimentation and a younger (Eggenburgian – Ottnangian) age.

Table 3: Planktonic foraminifera and stratigraphically important benthic foraminifera in the sections of Michelstetten and Ernstbrunn.

According to our results only the lower part of the Michelstetten section (M 1-2) may belong to nannoplankton Zone NN 1, the other part belongs to NN 2. According to foraminifera (*G. praescitula, Uvigerina popescui*), the upper part (M 7-15) is correlated with the Eggenburgian. In sample M7 also *R. pseudoumbilica* var. *excavata* occurs for the first time. A boundary between Egerian and Eggenburgian can not be defined exactly, but may be positioned between samples M6 and M7, within NN 2. The Michelstetten Formation is thereby extended stratigraphically to the Early Eggenburgian, and correlates in its higher part with the Boudky Fomation.

The beds of Ernstbrunn belong to nannoplankton Zone NN 2, are included in the Boudky Formation, and have an Eggenburgian age.

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Appendix 1: Remarks to planktonic foraminifera

Globigerina cf. ***bulloides*** d'Orbigny
(pl. 3, fig. 8)

cf. 1826 *Globigerina bulloides* d'Orbigny: 277, no.1
cf. 1846 *Globigeina bulloides* d'Orbigny – d'Orbigny: 163, pl. 9, figs 4–6.
1960 *Globigerina* cf. *bulloides* d'Orbigny – Papp: 226, pl. 9, fig. 11.

This species, in comparison to *Globigerina globularis* Roemer was discussed by Papp, who also compared the material from Michelstetten with *G. bulloides* from the Vienna Basin. The general shape and wall texture of this species differ somewhat from typical *bulloides*, but also from *G. steiningeri* n.sp. ("*globularis*" of Papp). In the distribution chart (tab. 3) it is included in *G. praebulloides*.

Globigerina dubia Egger
(pl. 3, fig. 6)

1857 *Globigerina dubia* Egger: 281, pl. 9, fig. 7–9.
1994 *Globigerina dubia* Egger – Rögl: 138, pl. 1, figs 17–19.

This high-spired species was described from the Eggenburgian and Ottnangian of the Molasse Basin, but is rather scarce in the present samples.

Globigerina lentiana Rögl
(pl. 3, fig. 9)

1969 *Globigerina bollii lentiana* Rögl: 220, pl. 2, figs 1–2; pl. 3, figs 1–2 (printed as pl. 4).
1998 *Globigerina lentiana* Rögl – Cicha et al.: 100, pl. 34, figs 21–23.

It is very common in Lower Miocene deposits of the Molasse Basin and Carpathian Foredeep, but rare in the Ernstbrunn section.

Globigerina gnaucki Blow & Banner
(pl. 3, fig. 10)

1962 *Globigerina ouchitaensis gnaucki* Blow & Banner: 91, pl. IX, figs L–N.
1969 *Globigerina ouchitaensis gnaucki* Blow & Banner – Blow: 320, pl. 2, figs 1–3.
1994 *Globigerina gnaucki* Blow & Banner - Spezzaferi: 27, pl. 2, figs 4 a–c.

In contrast to *G. ouachitaensis* this species has a distinctly lower spiral coiling and an umbilical – extra-umbilical aperture. Distribution according to Blow from Zone P 17 to basal Zone P 20, but ranges up into the Miocene according to Spezzaferri.

Globigerina ottnangiensis Rögl
(pl. 2, fig. 30, pl. 3, figs 1–5)

1969 *Globigerina ciperoensis ottnangiensis* Rögl: 221, pl. 2, figs 7–10; pl. 4, figs 1–7 (printed as pl. 3)
1994 *Globigerina ottnangiensis* Rögl: 137, pl. 1, figs 11–16; pl. 4, fig. 2.

The species is characterized by a flat initial spire with five or more chambers; the position of the final chamber is strongly varying, sometimes it is turned bulla-like to the umbilicus. Very common are thin-walled specimens in the Ernstbrunn section, but they can not be separated as a different species. Distribution: Upper Egerian to lowermost Badenian.

Globigerina praebulloides Blow
(pl. 3, fig. 7)

1959 *Globigerina praebulloides* Blow: 180, pl. 8, fig.47; pl. 9, fig. 48.

A common Neogene species, which is of larger size in Michelstetten than in the Ernstbrunn section.

Globigerina steiningeri Rögl, n.sp.
(pl. 2, figs 31–33, pl. 3, figs 13–20, text-fig. 3)

non 1838 *Globigerina globularis* Roemer: 390, pl. 3, fig. 57.
1960 *Globigerina globularis* Roemer – Papp: 223, pl. 9, figs 1-4.
1960 *Globigerina* cf. *unicava* Bolli – Papp: 224, pl. 9, figs 5-9.
non 1985 *Globigerina globularis* Roemer – Rögl: 321, figs 4.9-4.10.

Holotype: pl. 2, figs 31–32, pl. 3, fig. 14, text-fig. 3; Ernstbrunn, sample E-5.

Paratypes: pl. 3, figs 13, 15–20; non-figured paratypes: Ernstbrunn: sample E-4 (6 specimens); sample coll. P. Gottschling (21 specimens, measured); Michelstetten: sample M-5 (30 specimens, measured); sample M-8 (24 specimens); sample Rö 3-89 (11 specimens); Kolby Hill: sample Rö 39-93 (10 specimens); sample Rö 41-93 (9 specimens).

Description: Test of medium size, with a flat trochospire, two to two-and-a-half whorls, with five chambers in the primary whorl and three-and-a-half to four in the final whorl; predominantly left coiling. Chambers increase slowly in size; final chamber is commonly smaller as the pre-last chamber or reduced to a *kummerform* chamber in an umbilical position. Test shape stout, slightly lobate. Wall thick, strongly calcified, with a *Globigerina* wall texture; sutures in umbilical view broad, deeply incised, commonly with a sharp border (comp. pl. 3, fig. 13); in spiral view weekly impressed. Aperture umbilical, forms a low and broad arch, with a thickened, glassy, knobby rim (no lip).

Size: **holotype**: length of test 0.39 mm, width of test 0.30 mm, height of spire 0.20 mm; left coiling.

paratypes:	length:	width:	height:
Ernstbrunn:	0.20–0.37 mm	0.18–0.28 mm	0.13–0.21 mm
mean:	0.29 mm	0.24 mm	0.18 mm
Michelstetten:	0.16–0.28 mm	0.14–0.24 mm	0.10–0.18 mm
mean:	0.23 mm	0.19 mm	0.15 mm

Derivatio nominis: In honour of Friedrich F. Steininger, director of the Senckenberg Research Institute and Museum, Frankfurt am Main.

Distribution: as far as known, Egerian to Lower Eggenburgian deep water sediments.

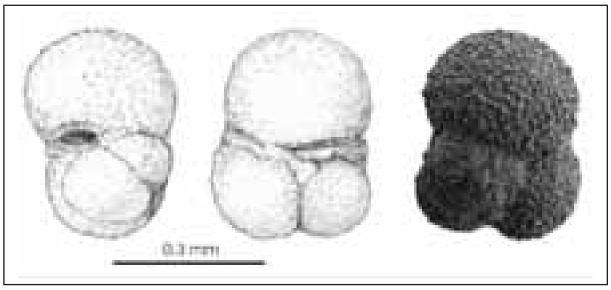


Fig. 3: *Globigerina steiningeri* Rögl, n.sp., holotype. Ernstbrunn, sample E-5; fig. 2a: umbilical view, fig.2b: lateral view, fig. 2c: spiral view.

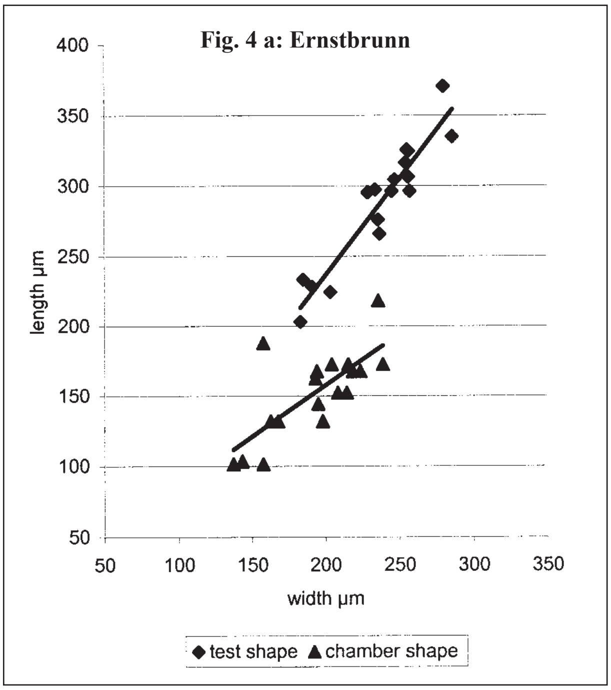
Remarks: This species was described by Papp as *G. globularis* from the Michelstetten Formation, and discussed with different species from the Oligocene of Trinidad. Most probably *G. globularis* Roemer represents forms which are now attributed to *Subbotina tapuriensis* (Blow & Banner). The morphotype, which Papp described as *G.* cf. *unicava*, was differentiated from *"G. globularis"* by a small, umbilical final chamber. Such chambers represent typical *kummerform*-chambers, which can not be compared with the bulla present in *Catapsydrax*. Bolli's (1957) species, *Catapsydrax unicavus* has a non-spinose, cancellate wall texture and is not related to spinose globigerinas. In the investigated samples, only one specimen of *C. unicavus* was present.

Some elongated specimens of the new species have similarities with *Globoturborotalita connecta*, but are distinguished by a globigerinid and not a cancellate wall texture. In contrast to *G. praebulloides* and *G. bulloides*, the new species has a strongly calcified wall, a low arched aperture with a thickened rim, and a stout test. Measurements of the stout test and the shape of the final chamber are in agreement in both sections (figs 4 a-b) and do not differentiate in different species.

Globorotalia (Obandyella) praescitula Blow
(pl. 2, figs 20–21)

1959 *Globorotalia (Turborotalia) scitula praescitula* Blow: 221, pl. 19, figs 128 a–c.
1969 *Globorotalia (Turborotalia) scitula praescitula* Blow – Blow: 158, pl. 4, figs 21–23; pl. 39, fig. 9.
1983 *Globorotalia (Globoconella) praescitula* Blow – Kennett & Srinivasan: 108, pl. 25, figs 4–6.

This species has a range from the base of Zone N 5 to near the Zone N 9-N 10 boundary according to Blow (1969), whereas Kennett & Srinivasan report it in temperate regions from the Early Miocene *Catapsydrax dissimilis* Zone to the Middle Miocene *Gr. peripheroronda-peripheroacuta* Zone, and in the tropics from Zone N 6 to N 10. Their taxonomical positioning of the species within the sub-genus *Globoconella* is not followed because of the near relation to *G. scitula*. It occurs only in the upper part of Michelstetten section.



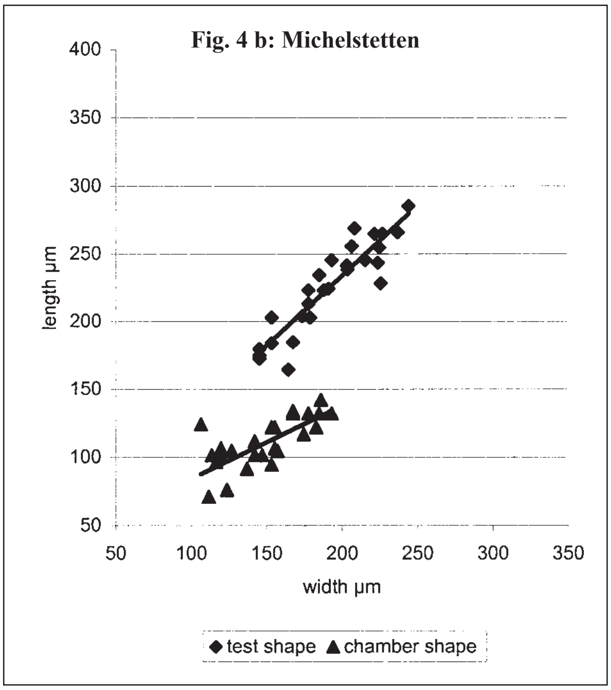


Fig. 4: *Globigerina steiningeri* Rögl, n.sp. Measurements of length and width of test (test shape), compared with the chamber shape (height and width of final chamber). The trend line shows similarities between the measured two populations; some specimens show a *praebulloides*-like elongated chamber shape but otherwise all species characteristics.

Fig. 4a: Ernstbrunn population of old sample collected by P. Gottschling; fig. 4b: Michelstetten population of sample M-5.

Globoturborotalita connecta (Jenkins)
(pl. 3, figs 11–12)

1964 *Globigerina woodi* Jenkins subsp. *connecta* Jenkins: 72, textfig. 1.
1994 *Zeaglobigerina connecta* (Jenkins) – Spezzaferri: 32, pl. 4, figs 4 a–c.
1998 *Globoturborotalita connecta* (Jenkins) – Cicha et al.: 104, pl. 35, figs 12–13.

Three, strongly appressed chambers are present in the final whorl, separated by deeply incised sutures; wall texture cancellate (pl. 3, fig. 12), sometimes difficult to identify in corroded specimens. Distribution in the Central Paratethys: Upper Egerian to Lower Badenian.

Globoturborotalita sp.
(pl. 2, figs 26–27)

In the Ernstbrunn section a very small species is present, which belongs to *Globoturborotalita*. In size and appearance it shows similarities with *G. druryi*, which appears in the open ocean already in Lower Miocene (Spezzaferri 1994).

Paragloborotalia? inaequiconica (Subbotina)
(pl. 2, fig. 22)

1960 *Acarinina inaequiconica* Subbotina: 202, pl. 7, figs 13–14.
1998 *Paragloborotalia inaequiconica* (Subbotina) – Cicha et al.: 115, pl. 39, figs 17–20.

This small species was described by Subbotina from the Lower Miocene of the Polyanitskaya and Lower Vorotyshchenskaya Formations in the Fore-Carpathian Basin. It occurs scarcely in the Ernstbrunn samples. The generic position is not yet veryfied.

Globoquadrina langhiana Cita & Gelati
(pl. 2, figs 23–25)

1960 *Globoquadrina langhiana* Cita & Gelati: 242, textfig. 1.

A small, four-chambered form which compares best with this species; a bulla is present sometimes. The species was found in the Ernstbrunn section and appears in the Central Paratethys from Egerian to Karpatian.

Tenuitella brevispira (Subbotina)
(pl. 2, figs 17–19)

1960 *Globigerina brevispira* Subbotina in Subbotina et al.: 56, pl. 11, figs 4–5 (not fig. 6).

not 1987 *Tenuitella minutissima* (Bolli) – LI Qianyu: 309, pl. 3, figs 6–9, 11–12.
1998 *Tenuitella? brevispira* (Subbotina) – Cicha et al.: 130, pl. 30, figs 28–34.

The species is present in both sections. According to the position of the aperture it is considered to belong to *Tenuitella*. The proposed synonymy of Li Qianyu with *T. minutissima* is not followed. The species *T. brevispira* has a much stronger compressed test, mainly with four to four-and-a-half chambers in the final whorl. This microperforate species was described from the Polyanitskaya and Lower Vorotyshchenskaya Formations in the Fore-Carpathian Basin and occurs in the Central Paratethys from the Oligocene to the Lower Eggenburgian.

Tenuitellinata juvenilis (Bolli)
(pl. 2, figs 8–11)

1957 *Globigerina juvenilis* Bolli: 110, pl. 24, figs 5–6.
1987 *Tenuitellinata juvenilis* (Bolli) – Li Qianyu: 311.
1992 *Tenuitellinata juvenilis* (Bolli) – Li Qianyu et al.: 579, pl. 2, figs 3–6.

This species belongs to the microperforate group. The proposed evolutionary lineage from *T. juvenilis* to bullate *Globigerinita glutinata* (from Oligocene to Lower Miocene) is supported by the presence of high-spired specimens in the investigated samples. Originally described from the Miocene of Trinidad, the range is given by Li Qianyu as Oligocene (P 20) to Quaternary.

Tenuitellinata pseudoedita (Subbotina)
(pl. 2, figs 12–14)

1960 *Globigerina pseudoedita* Subbotina in Subbotina et al.: 55, pl. 11, figs 1–3.
not 1987 *Tenuitellinata* cf. *T. pseudoedita* (subbotina) – Li Qianyu: 312, pl. 3, figs 1–5; pl. 4, figs 11–13; pl. 5, figs 1, 4, 7, 11.
1998 *Tenuitellinata? pseudoedita* (Subbotina) – Cicha et al.: 131, pl. 31, figs 5–6.

This species is a small, microperforate species, distinctly high-spired, which is not the case in the specimens figured by Li Qianyu. The present material is well preserved and shows more details as the specimen figured by Cicha et al. Like the above mentioned other microperforate species of Subbotina, also *T. pseudoedita* is described from the Polyanitskaya and Lower Vorotyshchenskaya Formations. The exact stratigraphic range in the Central Paratethys is uncertain, from Egerian to Lower Miocene.

Cassigerinella spinata Rögl
(pl. 2, figs 5–7)

1998 *Cassigerinella spinata* Rögl in Cicha et al.: 77, pl. 30, figs 11–15, text-fig. 55.

This species is small, compared with the co-occurring *Cassigerinella boudecensis* Pokorny, and distinguished by a compressed initial spire and peripheral spikes, originally described from the Ottnangian. The stratigraphic range is extended here from Upper Egerian to Karpatian.

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Plate 1

Light microscope pictures of nannofossils from the Michelstetten (M) and Ernstbrunn (E) sections.

Figs 1–2: *Sphenolithus delphix* Bukry. – sample M-1; fig. 1 parallel nicols, fig. 2 at angle 45° to crossed nicols; magnification: 3000x

Figs 3–4: *Sphenolithus disbelemnos* Fornaciari. – sample M-12; fig. 3 parallel nicols, fig. 4 at angle 45° to crossed nicols; magnification: 5000x

Fig. 5: *Discoaster druggii* Bramlette & Wilcoxon. – sample Nr. 3; parallel nicols; magnification: 3000x

Figs 6–8: *Helicosphaera ampliaperta* Bramlette & Wilcoxon. – fig. 6: sample M-33, figs 7-8: sample M-12; figs 6–7 crossed nicols, fig. 8 parallel nicols; magnification: 3000x

Figs 9–10: *Helicosphaera scissura* Miller. – sample M-1; fig. 9 crossed nicols; fig. 10 parallel nicols; magnification: 3000x

Figs 11–12: *Helicosphaera mediterranea* Müller. – fig. 11: sample M-3, fig. 12: sample M-6; crossed nicols; magnification: 3000x

Fig. 13: *Triquetrorhabdulus milowii* Bukry. – sample M-6; crossed nicols, magnification: 4500x

Fig. 14: *Zygrhablithus bijugatus* (Deflandre) Deflandre. – sample M-1; crossed nicols; magnification: 3000x

Figs 15–16: *Coccolithus miopelagicus* Bukry. – sample E-12; fig. 15 crossed nicols; fig. 16 parallel nicols; magnification: 2000x

Fig. 17: *Helicosphaera ampliaperta* Bramlette & Wilcoxon. – sample E-12; crossed nicols; magnification: 2500x

Fig. 18: *Helicosphaera* ex aff. *ampliaperta* Bramlette & Wilcoxon (small). – sample E-12; crossed nicols; magnification: 2500x

Fig. 19: *Coccolithus pelagicus* (Wallich) Schiller. – sample E-12; crossed nicols, magnification: 2000x

Fig. 20: *Sphenolithus moriformis* (Brönnimann & Stradner) Bramlette & Wilcoxon. – sample E-12, crossed nicols, magnification: 2500x

Fig. 21: *Pontosphaera multipora* (Kamptner) Roth. – sample E-18, crossed nicols; magnification: 3000x

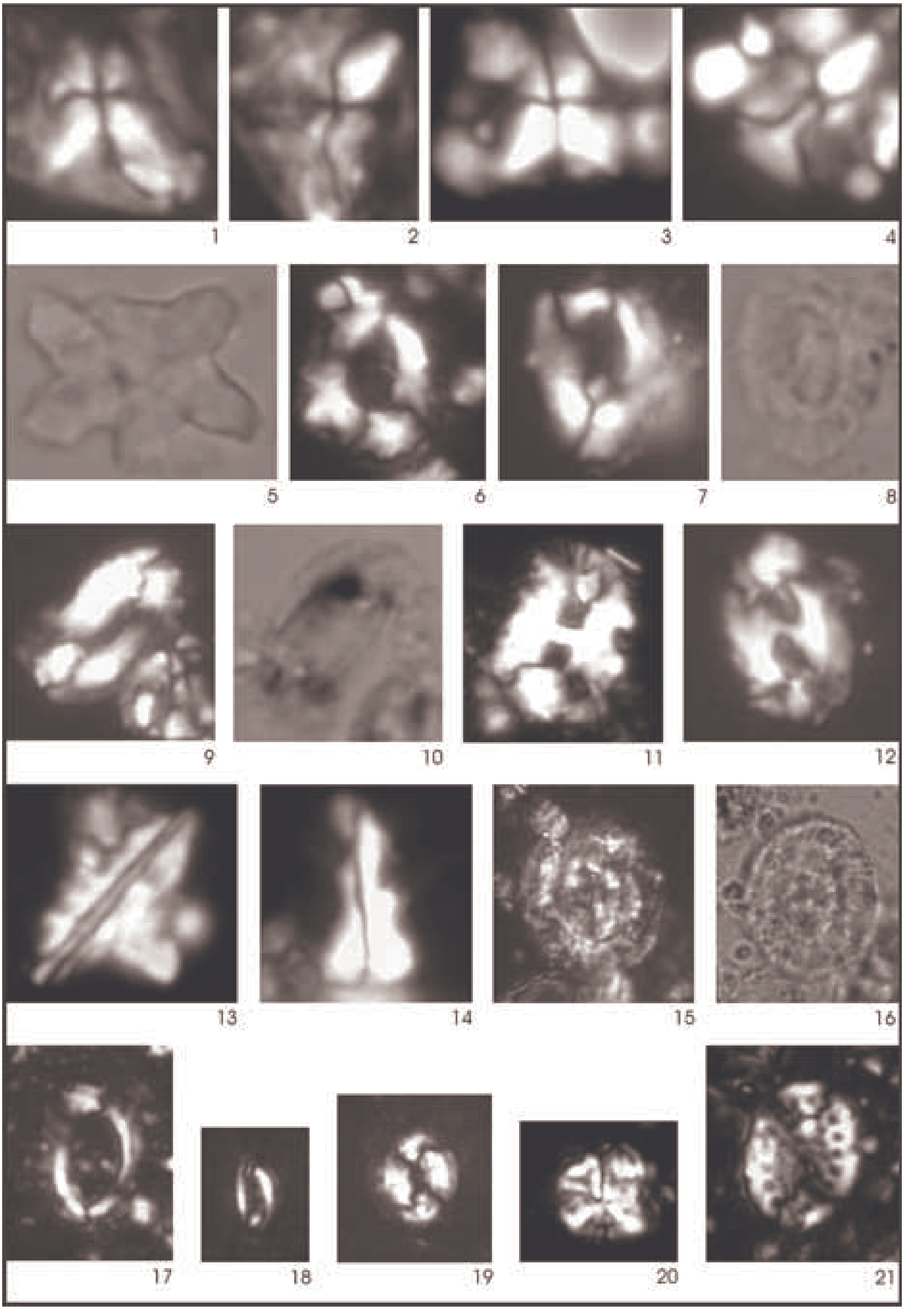
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Plate 2

Figs 1–4: *Cassigerinella boudecensis* Pokorny. – Ernstbrunn; figs 1–2, 4: sample E-2; fig. 3: sample E-14.

Figs 5–7: *Cassigerinella spinata* Rögl. – Ernstbrunn; figs 5–6: sample E-14; fig. 7: sample E-3.

Figs 8–11: *Tenuitellinata juvenilis* (Bolli). – Ernstbrunn; figs 8–10: sample E-2; fig. 11: sample E-14.

Figs 12–14: *Tenuitellinata pseudoedita* (Subbotina). – Ernstbrunn; fig. 12: sample coll. P. Gottschling; fig. 13: sample E-2; fig. 14: sample E-14.

Figs 15–16: *Tenuitellinata angustiumbilicata* (Bolli). – Ernstbrunn; sample coll. P. Gottschling.

Figs 17–19: *Tenuitella brevispira* (Subbotina). – Michelstetten; fig. 17: sample M-5; figs 18–19: sample M-14.

Figs 20–21: *Globorotalia (Obandyella) praescitula* Blow. – Michelstetten; fig. 20: sample M-7; fig. 21: sample M-13.

Fig. 22: *Paragloborotalia? inaequiconica* (Subbotina). – Ernstbrunn; sample coll. P. Gottschling.

Figs 23–25: *Globoquadrina langhiana* Cita & Gelati. – Ernstbrunn; sample coll. P. Gottschling.

Figs 26–27: *Globoturborotalita* sp. – Ernstbrunn; sample coll. P. Gottschling.

Fig. 28: *Tenuitellinata pseudoedita* (Subbotina). – Wall texture of the final chamber with very small, irregularly distributed pores and pustules, typical for microperforate planktonic foraminifera (see pl. 2, fig. 13).

Fig. 29: *Tenuitella brevispira* (Subbotina). – Final chamber with microperforate wall texture; wall thickly covered by pustules (see pl. 1, fig. 17).

Fig. 30: *Globigerina ottnangiensis* Rögl. – Wall texture of a bulla-like final chamber of a thin-walled specimen (see pl. 3, fig. 1). Pores and spine bases are smaller than in the earlier chambers.

Figs 31–32: *Globigerina steiningeri* Rögl, n. sp. – Globigerinid wall texture in the final chamber, with pores of normal size and distribution, and spine bases, partly amalgamating into ridges (see pl. 3, fig. 14).

Fig. 33: *Globigerina steiningeri* Rögl, n. sp. – Specimen with bulla-like final chamber. The wall texture of the pre-last chamber is globigerinid (see pl. 3, fig. 20).

Magnification: figs. 1–27: scale bar 100 µm (figs 5–7 are of double size); figs 28–33: scale bar 10 µm

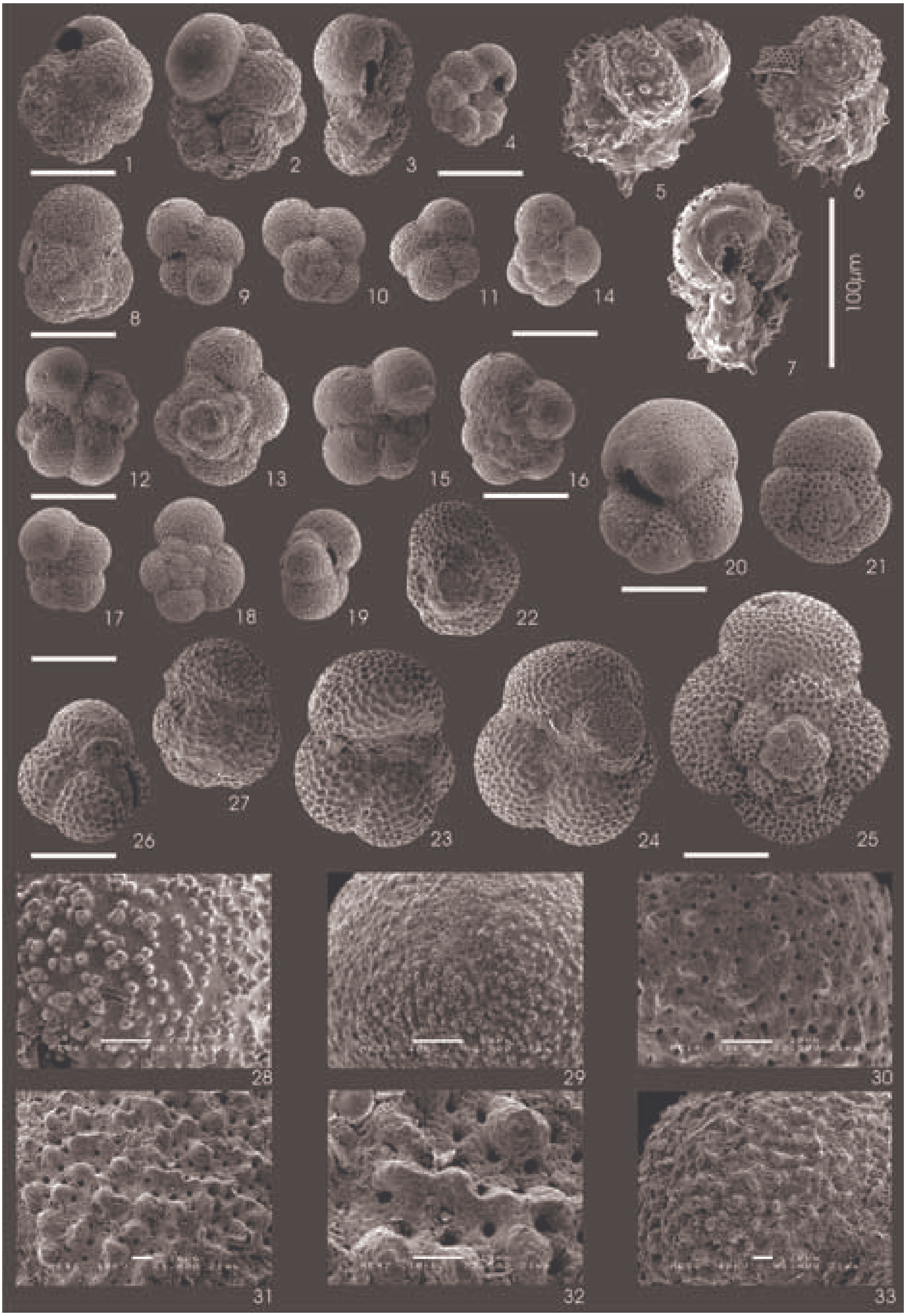
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Plate 3

Figs 1–2: *Globigerina ottnangiensis* Rögl. – Thin-walled specimens with flat initial trochospire of five chambers as in normal *G. ottnangiensis*, sometimes with bulla-like final chambers. – Ernstbrunn; sample E-14.

Figs 3–5: *Globigerina ottnangiensis* Rögl. – Specimens with normal thick walls, and in fig. 5 with a bulla-like final chamber. – Ernstbrunn; figs 3–4: sample E-4; fig. 5: sample E-18.

Fig. 6: *Globigerina dubia* Egger. – Spiral view of a high spired specimen. – Ernstbrunn; sample E-4.

Fig. 7: *Globigerina praebulloides* Blow. – Ernstbrunn; sample coll. P. Gottschling.

Fig. 8: *Globigerina* cf. *bulloides* d'Orbigny. – Ernstbrunn; sample coll. P. Gottschling.

Fig. 9: *Globigerina lentiana* Rögl. – In contrast to *G. praebulloides*, the final chamber of this species is reduced in size. – Ernstbrunn; sample E-18.

Fig. 10: *Globigerina gnaucki* Blow. – The aperture of this species extends umbilical-extraumbilical. – Michelstetten; sample M-5.

Figs 11–12: *Globoturborotalita connecta* (Jenkins) – The cancellate wall texture is difficult to observe in the corroded specimens. – Ernstbrunn; fig. 11: sample E-4; fig. 12: sample E-5.

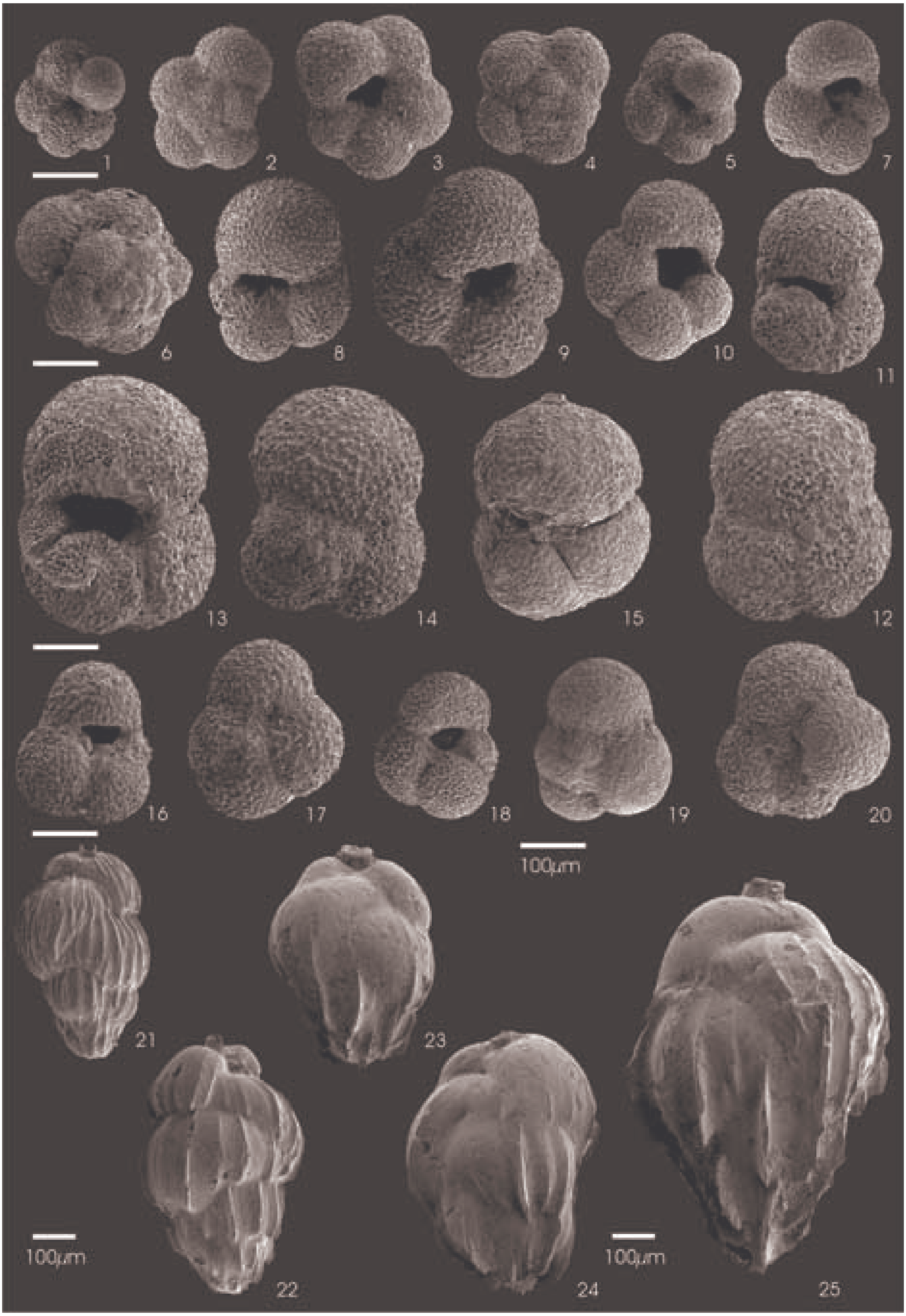
Figs 13–20: *Globigerina steiningeri* Rögl n. sp. – Ernstbrunn; fig. 13: sample E-4; figs 14, 16–17: sample E-5 (fig. 14: holotype); Michelstetten: fig. 15: sample M-3; figs 18–19: sample M-7; fig. 20: sample M-5.

Fig. 21: *Uvigerina* cf. *spinulosa* Hadley. – Ernstbrunn; sample E-18.

Fig. 22: *Uvigerina posthantkeni* Papp. – Ernstbrunn; sample E-18.

Figs 23–25: *Uvigerina popescui* Rögl. – Michelstetten; figs 23–24: sample M-15; fig. 25: sample Rö 8-90, from the northern cartroad to Pyhra.

Magnification: scale bar 100 µm (figs 21–25 are of same magnification)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