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Nannofossil record across the Cenomanian–Coniacian interval in the Bohemian Cretaceous Basin and Tethyan foreland basins (Outer Western Carpathians), Czech Republic

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Abstract: Nannofossil biostratigraphy and mutual correlation was worked out for the Cenomanian-Coniacian deposits of the Bohemian Cretaceous Basin (BCB) and Outer Western Carpathians (OWC) in the territory of the Czech Republic. Similar assemblages of the BCB and from sediments deposited on the SE slopes of West European Platform, Waschberg-Ždánice-Subsilesian Unit, OWC support the hypothesis that the two areas were connected by a sea way (nowadays the Blansko trough). The nannoflora of the Silesian Unit, OWC show more afinity to high latitudes as is documented by the presence of *Marthasterites furcatus* in the Lower Turonian, UC6b and UC7 Zones. Turonian and Coniacian deep-water flysch sediments of the Silesian Unit and Magura Group of Nappes provide nannofossils on rare occassions. Strongly atched nannofossils dominated by *W. barnesiae* from Cenomanian black shales of the BCB are comparable to those of the Silesian Unit and reflect a similar shallow nearshore sea. In the BCB, uppermost Cenomanian is marked by the last occurrence (LO) of *Axopodorhabdus albianus* and first occurrence (FO) of *Quadrum intermedium* (6 and 7 elements) and lowermost Turonian by a sudden quantitative rise in nannoflora and by the FO *Eprolithus octopetalus*. First *Eiffellithus eximius* and thus the base of the UC8 Zone was recorded in the upper part of ammonite Zone *Collignoniceras woollgari* in the lower Middle Turonian. *Lithastrinus grillii* is the stratigraphically youngest nannofossil species in this region and indicates the uppermost Coniacian. In the OWC, the Albian-Cenomanian boundary was recorded in the Silesian Unit and is marked by the LO *Crucicribrum anglicum* and FO *Prediscosphaera cretacea* and *Corollithion kennedyi* in the uppermost Albian. The Turonian-Coniacian boundary found both in the BCB and Waschberg-Ždánice-Subsilesian Unit, OWC is indicated by the FO *Broinsonia parca expansa* and by the base of the interval with common *Marthasterites furcatus.* In both areas, events were found closely below the FO inoceramid species *Cremnoceramus waltersdorfensis.* The Coniacian-Santonian boundary interval (Waschberg-Ždánice-Subsilesian and Foremagura Units, OWC) is indicated by *Lithastrinus grillii* occasionally accompanied by *Lucianorhabdus* ex gr. *cayeuxii*, *Hexalithus* sp. and *Arkhangelskiella specillata.*

Key words: Cenomanian-Coniacian, Outer Western Carpathians, Bohemian Cretaceous Basin, correlations, biostratigraphy, calcareous nannofossils.

Introduction

In the territory of the Czech Republic, both Upper Cretaceous marine epicontinental sediments of the West European Platform (Bohemian Cretaceous Basin) and deformed sediments of the Tethyan foreland basins (Outer Western Carpathians) occur (Fig. 1A). In this setting Tethyan and Boreal influences can be observed in closely spaced sections. A seaway between these two areas existed during the latest Cenomanian–Coniacian at the present Blansko trough (Uličný et al. 2009). In some cases, nannofossil stratigraphy has allowed higher resolution than macrofauna or foraminifers especially in the Western Carpathians (Stráník et al. 1996). The results of biostratigraphic and paleoenvironmental nannofossil research were published in partial works in English and Czech with English abstracts or they are mentioned in unpublished manuscripts.

The aim of this work is to give an overview of the biostratigraphic evaluation and mutual correlations of the Cenomanian-Coniacian sediments in the Bohemian Cretaceous Basin and in the individual units of the Outer Western Carpathians according to calcareous nannofossil biostratigraphy.

Previous studies

Bohemian Cretaceous Basin

The Upper Cenomanian marine ingression and Cenomanian-Turonian boundary interval and their correlations with nannofossils, foraminifers and macrofauna (inoceramids) were studied by Hradecká & Švábenická (1995) and Čech et al. (2005). Correlation of macrofauna and nannofossils was worked out for the Turonian and Coniacian deposits by Čech et al. (1987), Čech & Švábenická (1992) and Lees (1998). Attention was paid to the interval with common occurrence of *Braarudosphaera bigelowii* and to a short range of *Liliasterites angularis* and their correlation with global events (Švábenická 1999). Stratigraphic subdivision of the Upper Turonian sediments was suggested by Valečka & Švábenická (2009) and Švábenická (2009a) and for the Turonian-Coniacian boundary interval by Švábenická (2010) and Švábenická & Valečka (2011). Micro- and nannofossil content was analysed in the "rocky coast facies (zone)" of the south margin of the basin (Bubík & Švábenická 2001; Hradecká & Švábenická 2007).

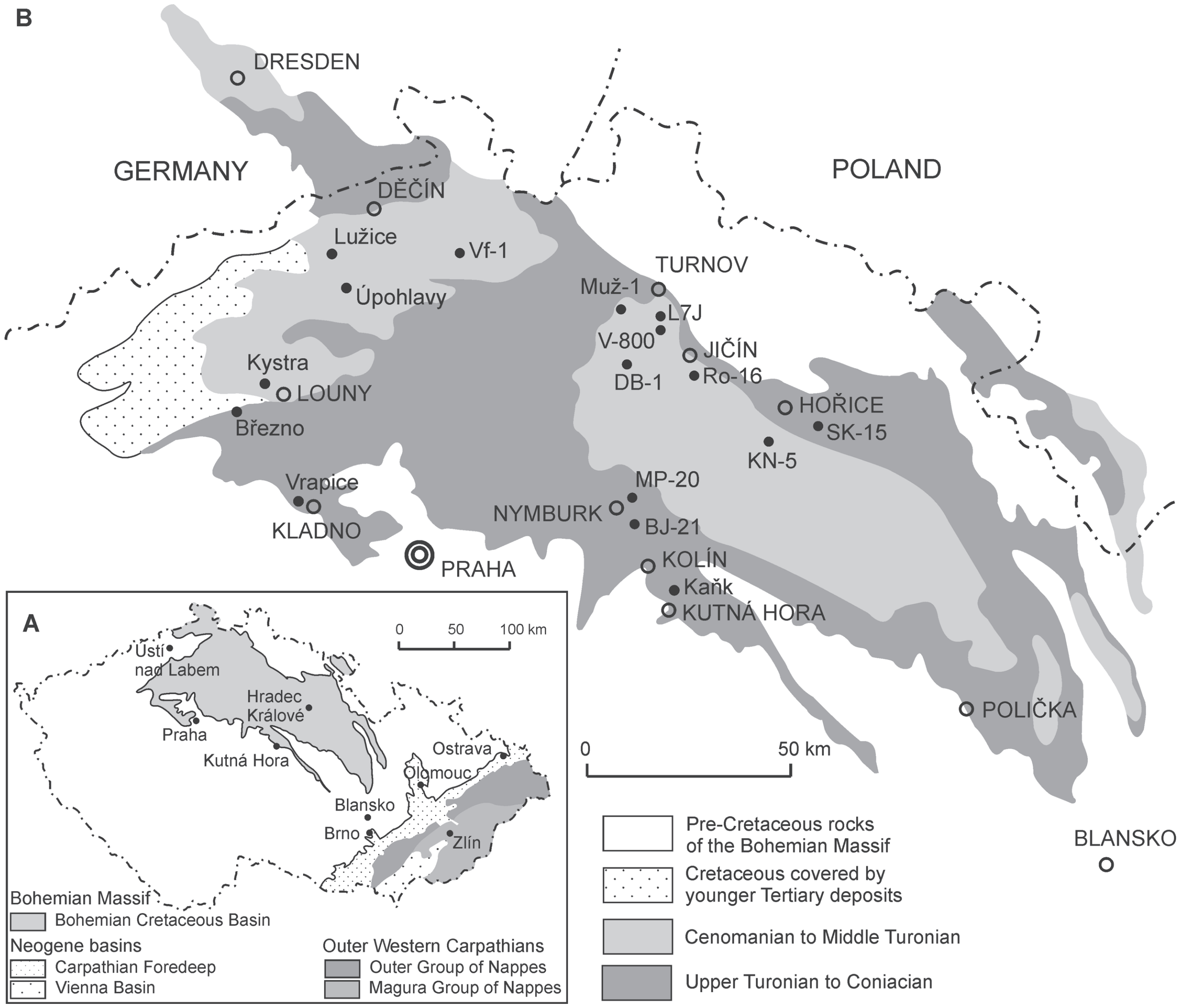

Fig. 1. A — Simplified geological map of the Bohemian Cretaceous Basin and Outer Western Carpathians in the territory of the Czech Republic. **B** — Simplified geological map of the Bohemian Cretaceous Basin and localities mentioned in the text. After Čech (1989), modified. Boreholes: BJ-21 Kouty, DB-1 Dolní Bousov, HP-20 Nymburk, KN-5 Sobčice, L7J Rokytnice, Muž-1 Mužský, Ro-16 Bystřice, SK-15 Benátky near Hořice, Vf-1 Volfartice, V-800 Střeleč.

Outer Western Carpathians

In the Outer Group of Nappes, the biostratigraphic evaluation of the Turonian–Coniacian interval was worked out for the Waschberg-Ždánice-Subsilesian Unit according to a study of macrofauna, foraminifers and nannofossils (Švábenická 1992; Stráník et al. 1996; Stráník & Švábenická 2000). The Upper Cretaceous sediments of the Zdounky Unit were biostratigraphically evaluated by foraminiferal microfauna and nannofossils (Bubík et al. 1995). Microfossils and palynomorphs were studied in anoxic dark pelites of Albian and Cenomanian age (Svobodová et al. 2004) and within the transition interval from dark anoxic to red oxic beds (Švábenická 2006; Skupien et al. 2009). In the Magura Group of Nappes, Rača Unit, nannofossils were mentioned from "black shales" of the Cenomanian age (Bubík et al. 1993) and from matrix of breccias deposited by repeated gravity flows in a continental rise within the Coniacian–Santonian interval (Švábenická et al. 1997). Comparison of the nannofossil record of the Bohemian Cretaceous Basin and Outer Western Carpathians with adjacent areas of Central Europe was published by Švábenická et al. (2002).

For stratigraphic evaluation of Upper Cretaceous sediments the following standard nannofossil zones were used: CC zones were used by Sissingh (1977) emended by Perch-Nielsen (1985), and UC zones by Burnett (1998). For the last two decades, the focus of attention has been the nannofossil record on stage boundaries. The Albian–Cenomanian interval was studied by Gale et al. (1996, 2011) and Kennedy & Gale (2006), the Cenomanian-Turonian boundary by Lamolda et al. (1994, 1997), Paul et al. (1999) and Luciani & Cobianchi (1999), the Turonian–Coniacian by Lees (2008) and Kedzierski (2008) and the Coniacian–Santonian by Melinte & Lamolda (2007) and Howe et al. (2007).

Material

Sediments from the Bohemian Cretaceous Basin were obtained both from outcrops and boreholes. The biostratigraphic evaluation of the majority of boreholes is mentioned in the unpublished manuscripts stored in the Archive of the Czech Geological Survey.

The autochthonous Upper Cretaceous deposited on SE margin of the West European Platform was studied from boreholes drilled by Oil and Gas Company Hodonín in the 1960s and 1970s.

Sediments from the Outer Western Carpathian region were sampled mainly from isolated localities during geological research and mapping. Because of the soft flysch usually covered by Quaternary deposits and landslides, the best outcrops were available mainly in riverbeds after heavy rains and floods or in the grooves of newly built roads. Unfortunately, the majority of these outcrops were quickly covered again by mud and vegetation. No boreholes were drilled in recent years. The last one (Pavlov-5 borehole, Ždánice-Subsilesian Unit) was drilled in 1989. Considering the fact that nannofossils were investigated from isolated chip sampling, they provided important data about the relative age of strata and development of depositional areas in the Carpathian region.

Smear-slides are stored in the Department of Collections of the Czech Geological Survey, Prague.

Methods

Nannofossils were investigated in the fraction of 2–30 μm separated by decantation method using 7% solution of H_2O_2. The heavy-fraction was allowed to settle for 3 minutes in a 45 mm water column and removed, the fine-fraction was saved for slide preparation after 45 minutes. Simple smear-slides were mounted by Canada Balsam and inspected at 1000× magnification, using oil-immersion objective on a Nikon Microphot-FXA transmitting light microscope. Biostratigraphic data were interpreted applying Sissingh (1977) CC zones and Burnett (1998) UC zones. Nannofossil markers within the NC10 Zone were used from Bown (in Gale et al. 2011). Semiquantitative analyses were done according the method of Burnett & Whitham (1999). Lithostratigraphic units of the Bohemian Cretaceous Basin are mentioned after Čech et al. (1980), of Outer Western Carpathians after Picha et al. (2006).

The nannofossil record and its biostratigraphic evaluation

Bohemian Cretaceous Basin

Upper Cenomanian sediments are represented mostly by dark grey siltstones and claystones with admixture of organic matter and belong to the Peruc-Korycany Formation, Pecínov Member (Fig. 2). Marine ingression is marked by poor nannofossils. Their preservation is not particularly good and high percentage of *Watznaueria barnesiae* gives

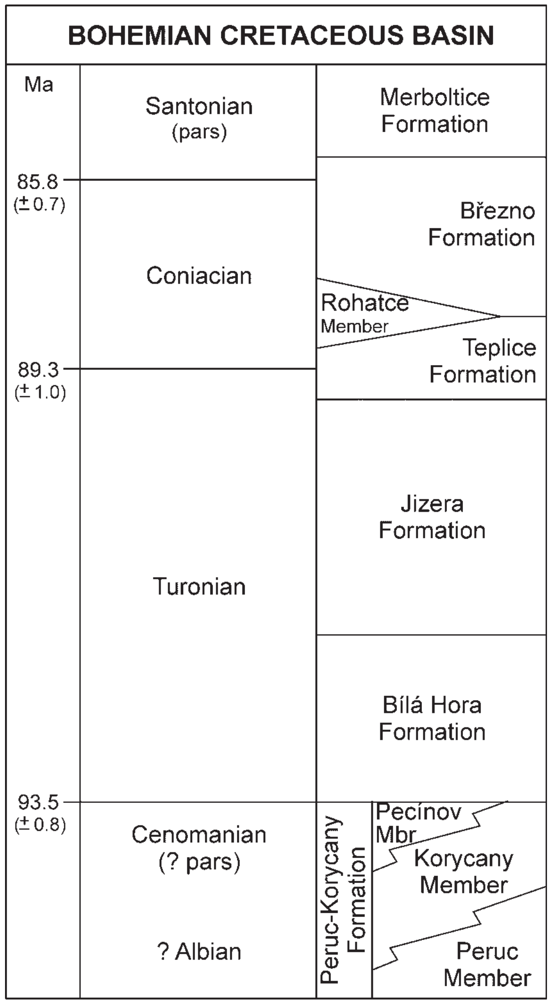

Fig. 2. Bohemian Cretaceous Basin, lithostratigraphic units after Čech et al. (1980, 2005). Age (Ma) after Ogg et al. (2004).

evidence for a higher degree of dissolution of nannoflora (Švábenická 2004; Čech et al. 2005).

The oldest deposits with nannofossil content were found in the Nymburk HP-20 borehole (117.0 m) and included *Corollithion kennedyi*, *Lithraphidites acutus* and *Axopodorhabdus albianus* (Čech et al. 2005), Fig. 1B. A similar association with *C. kennedyi* and *L. acutus* was recorded in the Bystřice Ro-16 borehole (527.0 m) and in the Benátky SK-15 borehole (279.0 m) near Hořice (Fig. 3–1,3,5,6). In the overlying strata, the gradual last occurrences (LO in the text) of *C. kennedyi*, *L. acutus* observed in Sobčice KN-5 borehole (168.0 m, Švábenická 2004), *Cretarhabdus striatus* and *A. albianus* (Čech et al. 2005) are stratigraphically important. The species *W. barnesiae* quantitatively prevails and species *Broinsonia signata* and *Prediscosphaera columnata* are relatively common. The broadly elliptical specimens of *Manivitella pemmatoidea* (8–13 μm in long axis) are typical features of the assemblages. In the uppermost part of the Cenomanian, scarce *Quadrum intermedium* (6–7 elements) appears. The uppermost part of the Cenomanian and/or the Cenomanian-Turonian boundary sediments of the Bystřice Ro-16 borehole (519.3 m) and Dolní Bousov DB-1 borehole (418.7–418.5 m) provided an assem-

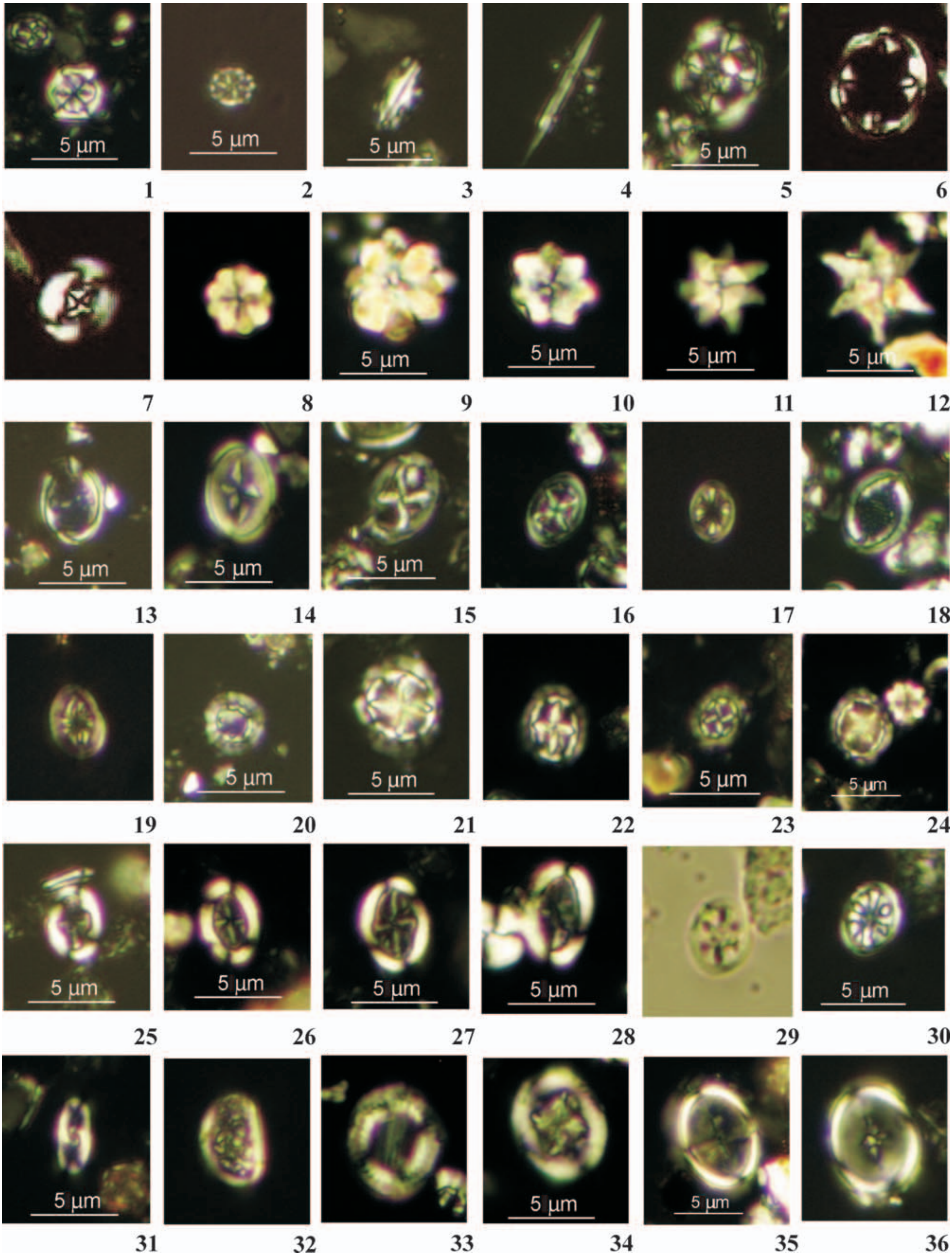
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Fig. 3.

blage with the first *Cribrosphaerella ehrenbergii* and last *Helenea chiastia* (Švábenická 2004).

Special attention was paid to the "rocky coast facies" of the rocky-shore zone exposed in south margin of basin, where the Upper Cretaceous transgression spread over the crystalline rocks of the Bohemian Massif. At the locality of Kaňk near Kutná Hora, matrix of basal conglomerates provided poor nannofossils with *Prediscosphaera cretacea*, *Lithraphidites* cf. *acutus* and relatively high numbers of specimens of the genus *Broinsonia*. According to the presence of the foraminifer species *Pseudotextulariella cretacea* in matrix, conglomerates are correlated with the Cenomanian-Turonian interval (Hradecká & Švábenická 2007). The overlying claystones contained Lower Turonian nannofossils with *Eprolithus moratus*. The next studies of this facies in the surroundings of Kolín (Švábenická 2004) and Kladno (locality Vrapice — Bubík & Švábenická 2001) showed a similarly poor nannofossil content. Absence of *A. albianus* and rare occurrences of *C. ehrenbergii*, *H. chiastia* and *Ahmuellerella octoradiata* indicated the Cenomanian-Turonian boundary interval. The lowermost Turonian is marked by the first occurrence (FO) of *Eprolithus octopetalus* (Fig. 3.9) and by the input of high numbers of medium-well preserved nannofossils.

The Early Turonian transgression is reflected not only by a change in lithology (to grey claystones of the Bílá Hora Formation — see Fig. 2), but also by a sudden quantitative rise in nannoflora and its high species diversity. This phenomenon was mentioned by Čech et al. (2005) and also observed in Kouty BJ-21 borehole (174.5–178.5) within the interval of macrofossil Zone *Watinoceras devonense*. The great number of medium-well preserved nannofossils (>>50 specimens/1 field of view of the microscope) included rare specimens of *E. octopetalus*, *C. ehrenbergii* and *Q. intermedium* (6 elements).

The succession of the first occurrence of marker species during the Turonian stage is following (Fig. 4): *Eprolithus octopetalus*, *E. moratus*, *Lucianorhabdus* sp., *Octolithus multiplus*, *Lucianorhabdus maleformis*, *Quadrum gartneri* (scarce), *Eiffellithus eximius*, *Kamptnerius magnificus*, *Helicolithus turonicus*, *Ottavianus giannus* (recorded only in the Upper Turonian), *Lithastrinus septenarius*, *Liliasterites angularis* (Fig. 5.13), *Marthasterites furcatus* (rare and not continual, Fig. 5.14), *Zeugrhabdothus biperforatus*, *Quadrum-Micula* (Fig. 6.22,23), *Broinsonia parca expansa*, *M. furcatus* (common and continual, acme) (Čech & Švábenická 1992; Švábenická 1999, 2010 and Švábenická in print a; Čech et al. 2010; Valečka & Švábenická in print). Placoliths of *Helenea chiastia* were found occasionally only in basal Turonian sediments (Bubík & Švábenická 2001; Čech et al. 2005).

The Coniacian stage is marked with the top of the interval with common *M. furcatus* (Švábenická & Valečka 2011) followed by the FO of *Micula adumbrata* (see Fig. 6.25,26, Švábenická in print b), *Micula staurophora* (Čech et al. 1987; Čech & Švábenická 1992; Lees 2008) and *Lithastrinus grillii* (Bubík et al. 2001). The species *H. turonicus* and *O. giannus* are already absent. The stratigraphically youngest nannofossils were found in the western part of basin at the locality of Lužice near Ústí nad Labem, the classical paleontological locality of Luschitz described by Reuss in 1844. The medium-well preserved and diversified assemblages comprise *L. grillii* in association with *M. staurophora* and *M. furcatus* and indicate the Upper Coniacian or possibly the Coniacian-Santonian boundary (Bubík et al. 2001).

On very rare occasions, reworked specimens from older Albian-Cenomanian (*Owenia* sp., *Crucibiscutum hayi*) and Jurassic (genus *Stephanollithion*) strata are to be found in the Turonian and Coniacian sediments.

Fig. 3. Calcareous nannofossils of the Cenomanian–Coniacian interval, Czech Republic. **BCB** — Bohemian Cretaceous Basin, **OWC** — Outer Western Carpathians. Photographs in cross-polarized light, **PPL** — plane-polarized light. For magnification see fig. 1. **1** — *Corrolithion kennedyi*, Upper Cenomanian, BCB, Nymburk HP-20 borehole, 117.0 m, Upper Cenomanian. **2** — *Corollithion exiguum*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **3** — *Lithraphidites acutus*, Upper Cenomanian, BCB, Běchary Bch-1 borehole, 402.8 m, Upper Turonian. **4** — *Lithraphidites carniolensis*, BCB, Rokytnice L7-J borehole, 406–407 m, Middle Turonian. **5, 6** — *Axopodorhabdus albianus*, 5 — BCB, Běchary Bch-1 borehole, 402.8 m, 6 — OWC, Štramberk Quarry Š0/VIII, Lower Cenomanian, etched specimen. **7** — *Helenea chiastia*, OWC, Štramberk Quarry Š49C/VIII, Lower–Middle Cenomanian. **8** — *Eprolithus floralis*, BCB, Kněžmost-Všeň CV24b, Upper Turonian. **9** — *Eprolithus octopetalus*, BCB, Běchary Bch-1 borehole, 401.2 m, Lower Turonian. **10** — *Eprolithus moratus*, BCB, Rokytnice L7-J borehole, 406–407 m, Middle Turonian. **11** — *Lithastrinus septenarius*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **12** — *Lithastrinus grillii*, BCB, Lužice 189/2000, Upper Coniacian. **13** — *Gartnerago theta*, BCB, Běchary Bch-1 borehole, 401.8 m, Upper Cenomanian. **14** — *Gartnerago obliquum*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **15** — *Tegumentum stradneri*, BCB, Rokytnice L7-J borehole, 76–77 m, Upper Turonian. **16** — *Chiastozygus litterarius*, BCB, Zbožíčko MP-7 borehole, 78 m, Lower Turonian. **17** — *Ahmuellerella octoradiata* Reinhardt, BCB, Střeleč V-800 borehole 19.9 m, Lower Coniacian. **18** — *Cribrosphaerella ehrenbergii*, BCB, Zbožíčko MP-7 borehole, 61 m, Lower Turonian. **19** — *Bukrylithus ambiguus*, BCB, Kněžmost CV24b, Upper Turonian. **20** — *Prediscosphaera columnata*, BCB, Nymburk HP-20 borehole, 117.0 m, Upper Cenomanian. **21** — *Prediscosphaera ponticula*, OWC, Foremagura Unit, Chomýž 252, Coniacian-Santonian boundary interval. **22** — *Prediscosphaera spinosa*, BCB, Střeleč V-800 borehole, 141.5 m, Upper Turonian. **23** — *Prediscosphaera cretacea*, Střeleč V-800 borehole, 141.5 m, Upper Turonian. **24** — *Prediscosphaera* cf. *grandis* and *Eprolithus floralis*, BCB, Kněžmost-Podolí, CV120, Upper Turonian. **25** — *Broinsonia signata*, BCB, Nymburk HP-20 borehole, 117.0 m, Upper Cenomanian. **26** — *Broinsonia enormis*, BCB, Kněžmost CV30, Upper Turonian. **27, 28** — *Broinsonia parca expansa*, BCB, Kněžmost CV01, Upper Turonian. **29, 30** — ?*Rhagodiscus plebeius*, BCB, Rokytnice L7-J 406–407 m, Lower Turonian; 29 — PPL. **31** — *Rhagodiscus angustus*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **32** — *Rhagodiscus asper*, BCB, Kněžmost CV24b, Upper Turonian. **33** — *Manivitella pemmatoidea*, Zbožíčko MP-7 borehole, 138.8–138.9 m, Lower Turonian. **34** — *Grantarhabdus coronadventis*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **35, 36** — *Kamptnerius magnificus*, BCB; 35 — Střeleč V-800 borehole, 55.3 m, Turonian-Coniacian boundary interval; 36 — Mužský Muž-1 borehole, 9.2 m, Lower Coniacian.

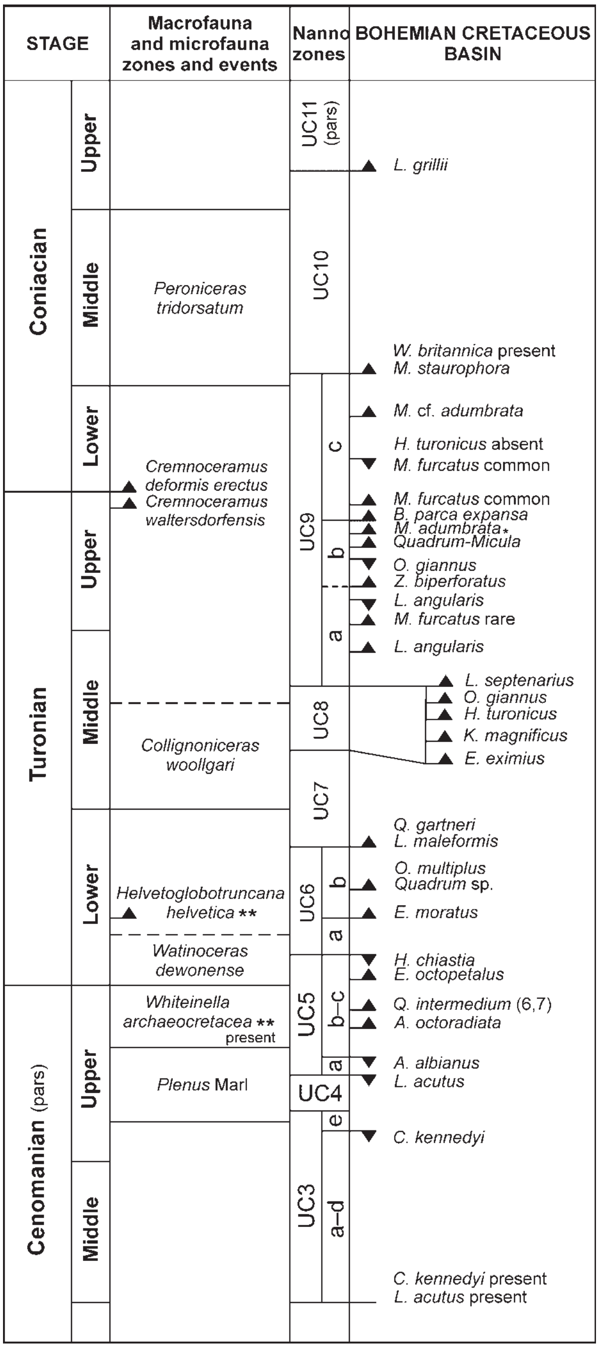

Fig. 4. Comparison of Cenomanian-Coniacian UC zones with data from the Bohemian Cretaceous Basin. Nannoplankton UC zones by Burnett (1998), selected macrofauna zones from Burnett (1998), macrofauna events by Čech (2009 and personal communication), * — Březno locality (Lees 2008), ** — foraminifers after Hradecká (in Čech et al. 2005).

Autochthonous Upper Cretaceous sediments deposited on the SE slopes of the West European Platform

Sediments of the Glauconitic Sand Formation (Picha et al. 2006) contain rare and badly preserved long-ranging nannofossils (Fig. 7). In poor assemblages, only the Turonian age is documented by *Quadrum gartneri* (Stráník et al. 1996). Sediments are not available in outcrops and data were obtained only from wells.

Outer Western Carpathians

Waschberg-Ždánice-Subsilesian Unit

In the Waschberg sector (sensu Picha et al. 2006 — see Fig. 7) of the Pavlovské vrchy Hills (Fig. 8), Upper Cretaceous sediments spread over the Ernstbrunn Limestone (Tithonian to ?Hauterivian). In the remnant of glauconitic sandstones and marlstones that are sandwiched within this limestone, Bubík et al. (2011) documented Lower Cenomanian by planktonic foraminifers assigned to the *Rotalipora globotruncanoides* Zone. However, the poor nannofossils with dominant speciments *Watznaueria barnesiae*, rare *Manivitella pemmatoidea* (fragments of the large broadly elliptical specimens), *Seribiscutum primitivum*, *Eprolithus floralis*, *Watznaueria biporta* and *Broinsonia signata* did not

Fig. 5. Calcareous nannofossils of the Cenomanian–Coniacian interval, Czech Republic. **BCB** — Bohemian Cretaceous Basin, **OWC** — Outer Western Carpathians. Photographs in cross-polarized light, **PPL** — plane-polarized light. For magnification see fig. 1. **1** — *Eiffellithus turriseiffelii*, BCB, Střeleč V-800 borehole, 55.3 m, Turonian-Coniacian boundary interval. **2** — *Eiffellithus gorkae*, BCB, Rokytnice L7-J borehole, 406–407 m, Middle Turonian. **3** — *Eiffellithus eximius*, BCB, Střeleč V-800 borehole, 55.3 m, Turonian-Coniacian boundary interval. **4** — *Stoverius achylosus*, BCB, Hořátev HO-19 borehole, 112.3 m, Upper Cenomanian. **5** — *Cylindralithus biarcus*, BCB, Mužský Muž-1 borehole, 8.32 m, Lower Coniacian. **6** — *Tetrapodorhabdus decorus*, BCB, Rokytnice L7-J borehole, 56–57 m, Upper Turonian. **7, 8** — *Helicolithus compactus*, specimen in 0° and 15°, BCB, Rokytnice L7-J borehole, 413–414 m, Middle Turonian. **9** — *Helicolithus trabeculatus*, BCB, Rokytnice L7-J borehole, 409–410 m, Middle Turonian. **10** — *Helicolithus turonicus*, BCB, Střeleč V-800 borehole, 141.5 m, Upper Turonian. **11** — *Rotelapillus crenulatus*, BCB, Rokytnice L7-J borehole, 406–407 m, Middle Turonian, PPL. **12** — *Amphizygus brooksii*, BCB, Rokytnice L7-J borehole, 56–57 m, Upper Turonian. **13** — *Liliasterites angularis*, BCB, Střeleč V-800 borehole, 123.5 m, Upper Turonian, PPL. **14** — *Marthasterites furcatus*, BCB, Kněžmost-Všeň CV024b, Upper Turonian, PPL. **15** — *Marthasterites inconspicuus*, BCB, Mužský Muž-1 borehole, 6.9 m, Lower Coniacian, PPL. **16** — *Tranolithus minimus*, BCB, Branžež borehole, 82–84 m, Upper Turonian. **17** — *Tranolithus gabalus*, BCB, Branžež borehole, 82–84 m, Upper Turonian. **18** — *Tranolithus orionatus*, BCB, Rokytnice L7-J borehole, 413–414 m, Middle Turonian. **19** — *Seribiscutum primitivum*, BCB, Střeleč V-800 borehole, 127.8 m, Upper Turonian. **20** — *Crucibiscutum hayi*, BCB, Střeleč V-800 borehole, 129.5 m; reworked specimen from older Cenomanian strata. **21** — *Biscutum ellipticum*, OWC, Štramberk Quarry Š29/IV, ?Middle–Upper Cenomanian. **22** — *Biscutum melaniae*, BCB, Střeleč V-800 borehole, 135.5 m, Upper Turonian. **23** — *Retacapsa angustiforata*, BCB, Branžež borehole, 70–72 m. **24** — *Retacapsa ficula*, BCB, Rokytnice L7-J borehole, 409–410 m, Middle Turonian. **25** — *Retacapsa crenulata*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **26, 27** — *Sollasites horticus*, BCB, Zbožíčko MP-7 borehole, 41 m, Lower Turonian. 26 — PPL. **28** — *Placozygus fibuliformis*, BCB, Kněžmost CV24b,

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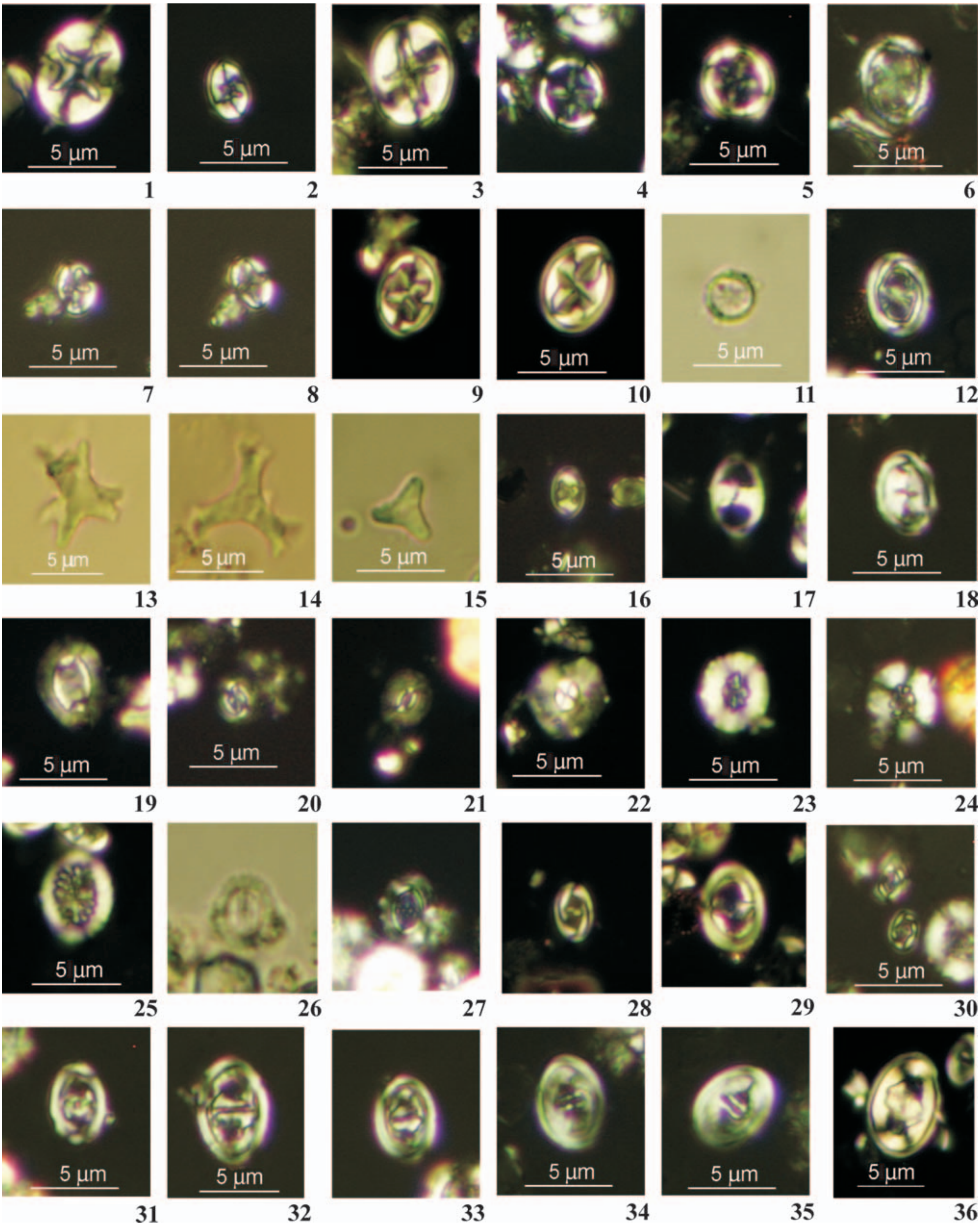

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Fig. 5. ... Upper Turonian. **29** — *Zeugrhabdothus* sp. cf. *Z. sigmoides*, BCB, Střeleč V-800 borehole, 123.5 m, Upper Turonian. **30** — *Zeugrhabdothus trivectis*, BCB, Rokytnice 413–414 m, Middle Turonian. **31** — *Zeugrhabdothus noeliae*, BCB, Zbožíčko MP-7 borehole, 67 m, Lower Turonian. **32** — *Zeugrhabdothus diplogrammus*, BCB, Rokytnice L7-J borehole, 409–410 m, Middle Turonian. **33** — *Zeugrhabdothus bicrescenticus*, BCB, Rokytnice L7-J borehole, 409–410 m, Middle Turonian. **34, 35** — *Zeugrhabdothus biperforatus*, specimen in 0° and 45°, BCB, Mužský Muž-1 borehole, 4.9 m, Lower Coniacian. **36** — *Zeugrhabdothus embergeri*, BCB, Kněžmost-Podolí CV120, Upper Turonian.

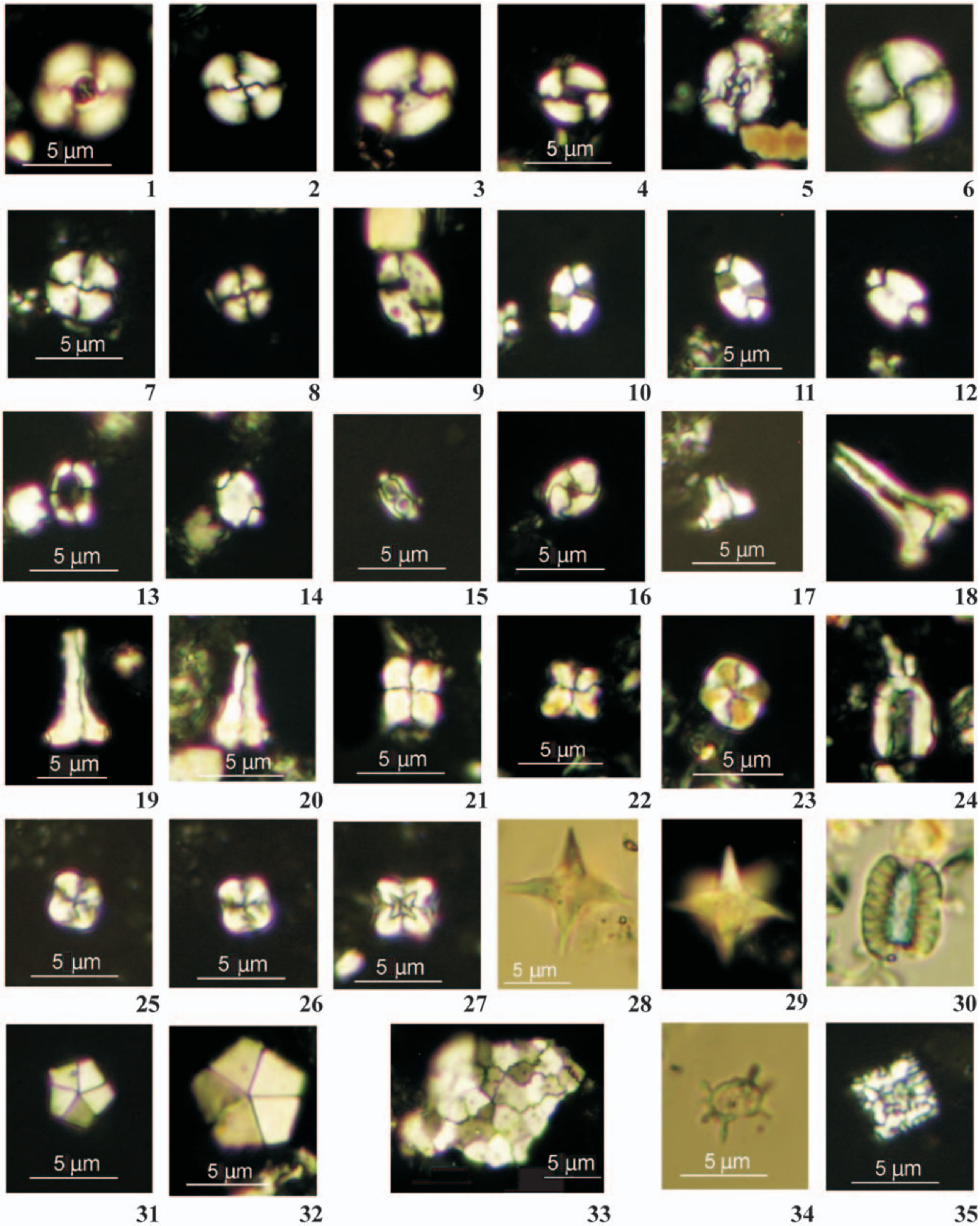

Fig. 6. Calcareous nannofossils of the Cenomanian–Coniacian interval, Czech Republic. **BCB** — Bohemian Cretaceous Basin, **WC** — Western Carpathians. Photographs in cross-polarized light, **PPL** — plane-polarized light. For magnification see fig. 1. **1** — *Watznaueria britannica*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **2** — *Watznaueria barnesiae*, BCB, Zbožíčko MP-7 borehole, 78 m, Lower Turonian. **3** — *Watznaueria biporta*, BCB, Střeleč V-800 borehole, 135.5 m, Upper Turonian. **4** — *Watznaueria ovata*, BCB, Střeleč V-800 borehole, 141.5 m, Upper Turonian. **5** — *Watznaueria quadriradiata*, BCB, Zbožíčko MP-7 borehole, 41 m, Lower Turonian. **6** — *Haqius circumradiatus*, BCB, Rokytnice L7-J borehole, 409–410 m, Middle Turonian. **7** — *Cyclagelosphaera margerelii*, BCB, Mužský Muž-1 borehole, 8.3 m,

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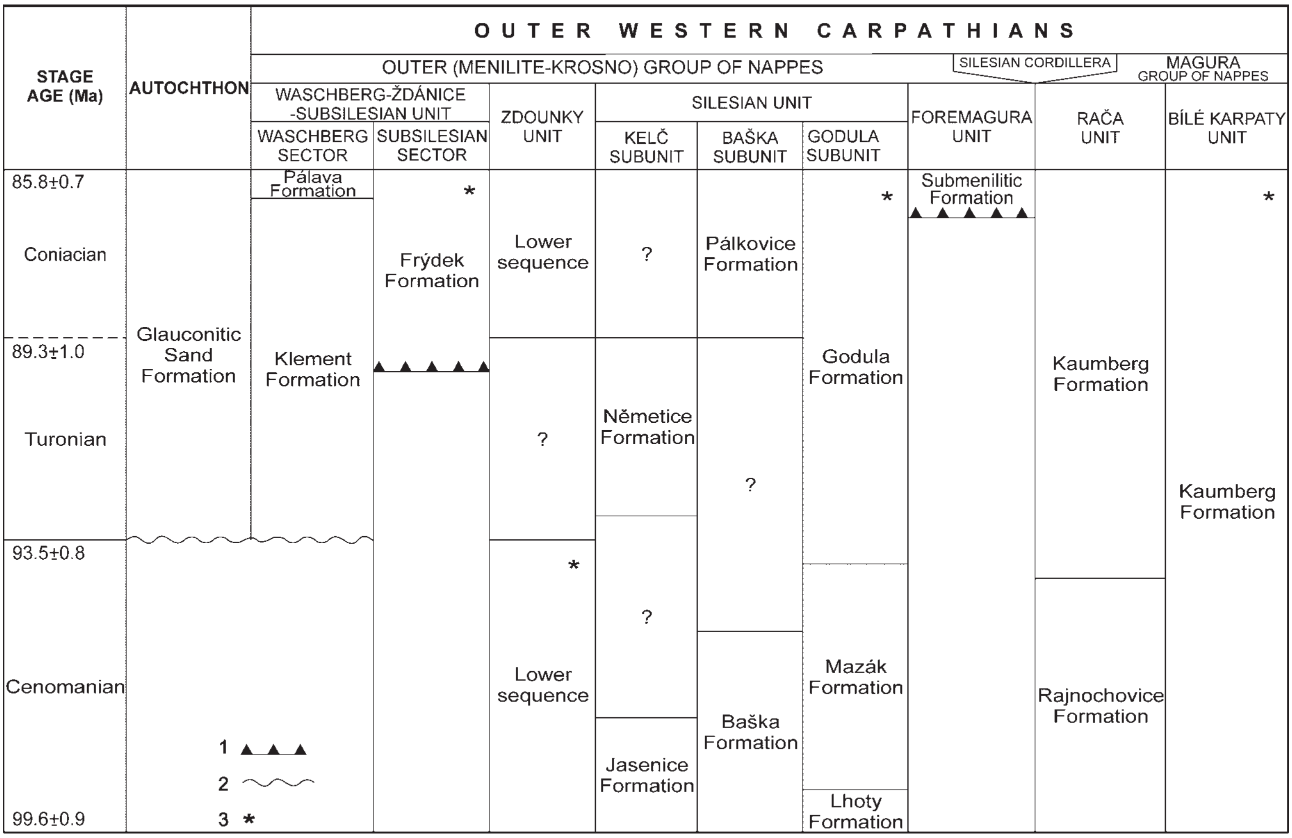

Fig. 7. Outer Western Carpathians, Cenomanian–Coniacian interval. Lithostratigraphic units after Picha et al. (2006), modified. Waschberg-Ždánice-Subsilesian Unit and Silesian units after Skupien et al. (2009). Age (Ma) after Ogg et al. (2004). **1** — tectonic detachment, **2** — transgression, * — sediments barren of calcareous nannofossils.

include any Cenomanian sensu stricto marker species. However, breccia filling the clastic dykes in limestones in the same area provided poor nannofossils of the Turonian age. Grey clayey-micritic matrix contained *Gartnerago obliquum* and problematic specimens of *Eprolithus* cf. *octopetalus*, and clayey glauconitic silt to sandstone provided *Eiffellithus eximius* and *Kamptnerius magnificus* (Stráník et al. 2006; Poul et al. 2010).

In the overlying Turonian and Coniacian deposits, Klement Formation, the nannofossil record shows similarity to that from the Bohemian Cretaceous Basin (Švábenická in Hamršmíd 1991; Švábenická 1992). The first *M. furcatus* was recorded together with the foraminifer species *Archaeoglobigerina cretacea* in the Upper Turonian and the first *K. magnificus* below the interval with common *M. furcatus* (Stráník et al. 1996), Fig. 9.

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Fig. 6. ... Lower Coniacian. **8** — *Cyclagelosphaera reinhardtii*, BCB, Kněžmost CV24, Upper Turonian. **9** — *Ottavianus giannus*, BCB, Střeleč V-800 borehole, 138.5 m, Upper Turonian. **10–12** — *Octolithus multiplus*, specimen in 0°, 15° and 45°, BCB, Rokytnice L7-J borehole, 52.7 m, Upper Turonian. **13, 14** — *Octolithus* sp., specimen in 0° and 15°, BCB, Rokytnice L7-J borehole, 52.7 m, Upper Turonian. **15** — *Owenia* sp. (basal plate of genus *Isocrystallithus*), BCB, Rokytnice L7-J borehole, 406–407 m, reworked specimen from older Cenomanian strata. **16** — *Calculites ovalis* (Stradner), BCB, Střeleč V-800 borehole, 141.5 m, Upper Turonian. **17** — *Lucianorhabdus* cf. *maleformis*, BCB, Rokytnice L7-J borehole, 406–407 m, Middle Turonian. **18** — *Lucianorhabdus* sp., BCB, Střeleč V-800 borehole, 141.5 m, Upper Turonian. **19** — *Lucianorhabdus maleformis,* BCB, Rokytnice L7-J borehole, 409–410 m, Middle Turonian. **20** — *Lucianorhabdus quadrificus*, BCB, Mužský Muž-1 borehole, 8.3 m, Lower Coniacian. **21** — *Quadrum gartneri*, BCB, Mužský Muž-1 borehole, 8.3 m, Lower Coniacian. **22, 23** — *Quadrum-Micula*, specimen in 0° and 30°, BCB, Mužský Muž-1 borehole, 4.9 m, Lower Coniacian. **24** — *Lapideacassis* sp. cf. *L. cornuta*, BCB, Zbožíčko MP-7 borehole, 78 m, Lower Turonian. **25, 26** — *Micula adumbrata*, specimen in 0° and 30°, BCB, Kněžmost-Mužský CE-051, Lower Coniacian. **27** — *Micula staurophora*, OWC, Foremagura Unit, Chomýž 252, Coniacian-Santonian boundary interval. **28, 29** — *Quadrum-Uniplanarius*, BCB, Mužský Muž-1 borehole, 4.9 m, Lower Coniacian; 28 — PPL. **30** — *Nannoconus elongatus*, BCB, Rokytnice L7-J borehole, 409–410 m, Middle Turonian, PPL. **31** — *Braarudosphaera bigelowii parvula*, BCB, Kněžmost-Podolí CV120, Upper Turonian. **32** — *Braarudosphaera bigelowii bigelowii*, BCB, Střeleč V-800 borehole, 55.3 m, Turonian-Coniacian boundary interval. **33** — *Thoracosphaera operculata*, BCB, Rokytnice L7-J borehole, 56–57 m, Upper Turonian. **34** — *Stephanolithion* sp., BCB, Střeleč V-800 borehole, 129.5 m, reworked specimen from older Jurassic strata. **35** — “Cube” of questionable origin. BCB, Rokytnice L7-J borehole, 29.1 m, Upper Turonian; occasionally, such cubes form a component of Turonian sediments in BCB.

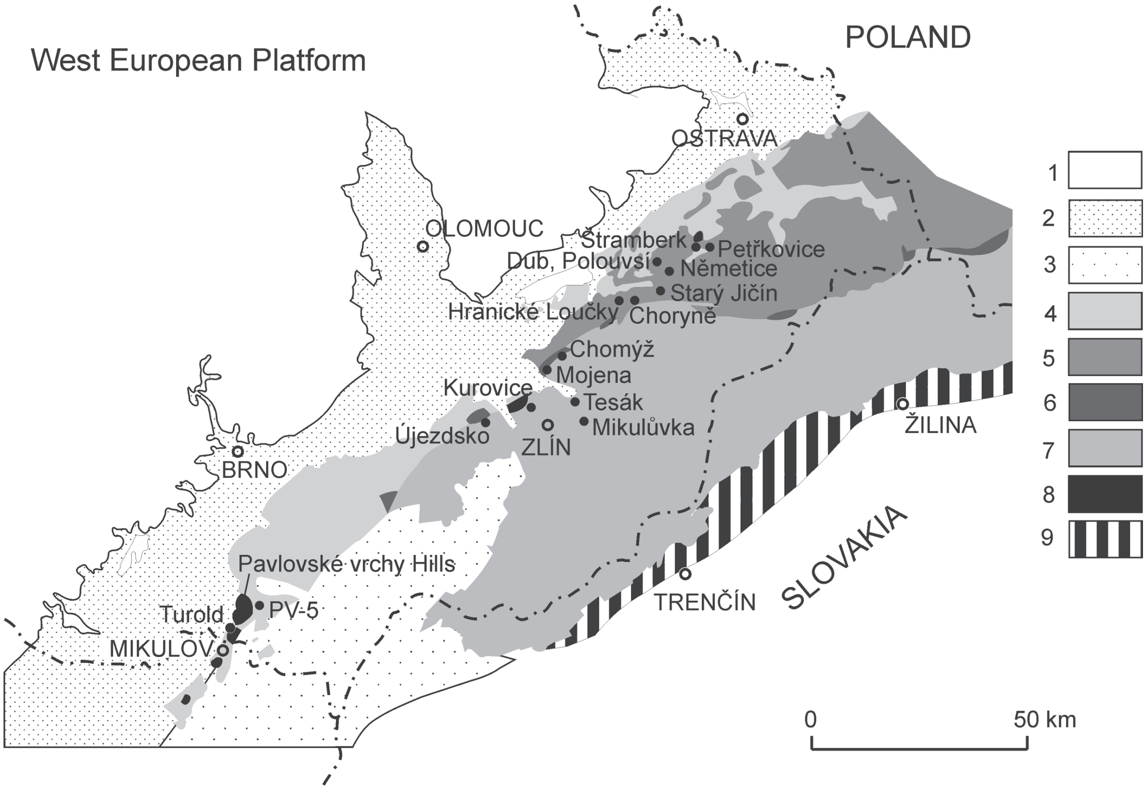

Fig. 8. Simplified geological map of the Outer Western Carpathians and localities mentioned in the text. Autochthonous Cretaceous deposits on the SE slopes of the Bohemian Massif are covered by the Neogene of the Carpathian Foredeep. **1** — Bohemian Massif, **2** — Neogene of the Carpathian Foredeep, **3** — Neogene of Vienna Basin, **4** — Waschberg-Ždánice-Subsilesian Unit and Pouzdřany Unit (unit without Cretaceous rocks), **5** — Silesian Unit, **6** — Foremagura and Zdounky Units, **7** — Magura Group of Nappes, **8** — Jurassic-Lower Cretaceous Limestone, **9** — Pienniny Klippen Belt. After Picha et al. (2006), simplified. PV-5 Pavlov borehole.

The Upper Coniacian and Coniacian-Santonian boundary interval, Pálava Formation is marked by the first *Lithastrinus grillii* followed by *Arkhangelskiella specillata* and *Lucianorhabdus* ex gr. *cayeuxii* (Švábenická 1992).

In the Subsilesian sector, nannofossils have not been found. Nevertheless, Hanzlíková (1969) mentioned planktonic foraminifers of the latest Turonian and Coniacian age from the Frýdek Formation. These foraminifers were examinated from wells drilled in the 1960s. Unfortunately, this rocky material was not available for nannofossil study and outcrops did not provide any calcareous strata.

Zdounky Unit

In the studied interval, nannofossils with *Micula staurophora*, *Lithastrinus septenarius* and relatively common *M. furcatus* proved the Coniacian age, UC10 Zone (locality Újezdsko 333), see Fig. 8. Cenomanian and Turonian nannofossil assemblages have not been found yet. Lithostratigraphically, the sediments go with the lower sequence of the unit (sensu Picha et al. 2006 — see Fig. 7).

Silesian Unit

Black organic carbon-enriched sediments of the Cenomanian age, the Baška Subunit (see Fig. 7), contain diminished assemblages. Nannofossil tests show signs of strong etching and dissolution (Figs. 3–6). The oldest assemblages contain *Prediscosphaera cretacea* and *Corollithion kennedyi*. Next come the first occurrences of *Gartnerago theta* and *Lithraphidites acutus*. The assemblages are complemented with rare specimens of *Helenea chiastia*, *Axopodorhabdus albianus* and *Manivitella pemmatoidea* (Svobodová et al. 2004). Similar nannofossils with *C. kennedyi* and *Cretarhabdus striatus* were found at the locality Dub (sample A35) near Hustopeče nad Bečvou, Kelč Subunit. The uppermost Cenomanian strata with *Gartnerago obliquum* and *Quadrum intermedium* (5 elements) were recorded in the same subunit at the locality of Němetice MB16F near Valašské Meziříčí (Skupien et al. 2009).

The Turonian and Coniacian deposits of the Kelč Subunit provided scarce nannofossils (see Fig. 9). The species *M. furcatus* was found in association with *Eprolithus moratus* in the Lower Turonian at the locality Choryně (Skupien et al. 2009; Švábenická 2009b). In the overlying strata, the following nannofossil markers were recognized: *Q. gartneri* (Němetice MB16A and Choryně MB25F), *L. septenarius* (Němetice MB16X2 and Starý Jičín 3A/96). Matrix from the conglomerates of Starý Jičín provided poor nannofossils with *M. furcatus* and *M. staurophora* of the Coniacian age (Stráník et al. 1997). Relatively common specimens of *M. staurophora* and *M. furcatus* accompanied by rare *L. grillii*

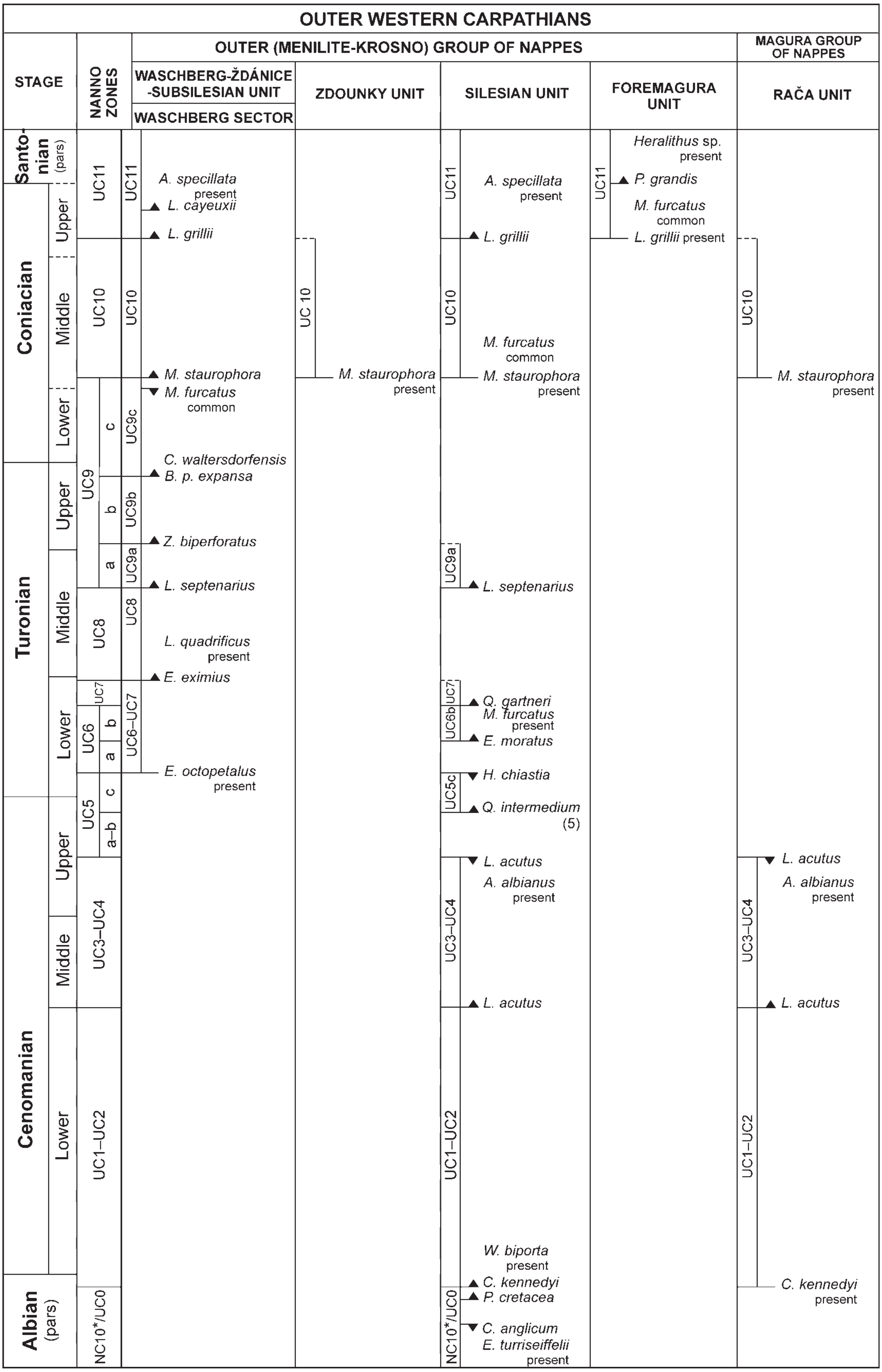

Fig. 9. Comparison of Cenomanian-Coniacian UC zones with data from the Outer Western Carpathians. Nannoplankton UC zones by Burnett (1998), macrofossil data by Čech (in Stráník & Švábenická 2000).

were found at the locality of Choryně (MB25B). Assemblages with *L. grillii* and *Arkhangelskiella* cf. *specillata* may document the Coniacian-Santonian boundary interval (Hranické Loučky A43).

Foremagura Unit

The green and grey clayey deposits of the Submenilitic Formation (Fig. 7) provided rich and medium-well preserved nannofossils of the Late Coniacian age. This is documented at the locality Chomýž 252 (north of Zlín) by the presence of *L. grillii* and *Hexalithus* sp. The sediments of the locality Mojena 32 provided assemblages with higher numbers of *M. staurophora* and *M. furcatus* and few *L. grillii* and *Prediscosphaera* cf. *grandis*, that may be correlated with the Coniacian-Santonian boundary interval.

Magura Group of Nappes

Nannofossils were recorded only in the flysch lithofacies zone of the Rača Unit, Rajnochovice Formation ("black shales", Gault flysch) (see Fig. 7). The Cenomanian is documented by *C. kennedyi* and *H. chiastia* at the locality of Mikulůvka No. 1/6 (Švábenická et al. 1997) and by *E. turriseiffelii* and *L. acutus* at the locality of Tesák (Bubík et al. 1993).

Red-brown non-calcareous clays of the Kaumberg Formation deposited below CCD in the abyssal zone span the Turonian–Coniacian interval. Naturally, these sediments are barren of calcareous nannofossils. The matrix of the sedimentary breccias of the Kurovice Klippe are an exception. Variegated clays provided poor nannofossil content with *Micula staurophora* and a few *Marthasterites furcatus* documenting the Coniacian age (Švábenická et al. 1997).

In the Bílé Karpaty Unit, deposits of Kaumberg Formation did not provide any calcareous nannofossils. The strata were deposited in the abyssal zone below CCD and offer only agglutinated foraminifers.

Nannofossil record across the stage boundary intervals

The uppermost Albian and/or Albian-Cenomanian boundary was recognized in black shales of the Outer Western Carpathians, Silesian Unit, at the locality of the Štramberk-Kotouč Quarry (Švábenická & Hradecká 2005). The Upper Albian is marked by the presence of *Eiffellithus turriseiffelii* and successive events, namely the LO *Crucicribrum anglicum* and FO *Corollithion kennedyi* (UC1a). The first *Prediscosphaera cretacea* (oval specimens with cross-bars aligned between the major axes) occasionally occurs with *C. kennedyi*. Signs of this interval were also found in the surroundings of Hranice na Moravě, localities Polouvsí A81, Dub MB3 and Petřkovice ZS27.

The Cenomanian-Turonian boundary interval was recorded in the central and southern part of the Bohemian Cretaceous Basin (Švábenická 2004; Čech et al. 2005). The Upper Cenomanian marine strata are subdivided into two distinct parts according to the LO *Axopodorhabdus albianus*. Above this event, the chain of FO *Gartnerago obliquum*, *Ahmuellerella octoradiata* and *Quadrum intermedium* (6 a 7 elements) is evident (Čech et al. 2005). The rocky coast facies spanning the Cenomanian–Turonian interval provided *A. octoradiata*, *Helenea chiastia* and *Cribrosphaerella ehrenbergii.* The lowermost Turonian is well marked by the FO *Eprolithus octopetalus.*

The Turonian-Coniacian boundary interval was documented both from the Bohemian Cretaceous Basin and Outer Western Carpathians, Waschberg-Ždánice-Subsilesian Unit. In the Bohemian Cretaceous Basin, the boundary was recognized in the Ohře River region (western part of the basin) at the type locality of the "Priesener Schichten" (Krejčí 1869) in Březno (Čech & Švábenická 1992; Lees 2008) and in the central part of the basin including the Střeleč V800 borehole (Švábenická 2010). The uppermost Turonian is marked by the FO *Broinsonia parca expansa* (BC9c Zone) and LO *Helicolithus turonicus* (Fig. 10). The base of acme *Marthasterites furcatus* (more than 6 % in assemblage) was recorded closely below the FO of inoceramid species *Cremnoceramus waltersdorfensis*. The acme of *M. furcatus* probably spans the interval with *Cremnoceramus deformis erectus*, that is supposed to be a marker species for the base of the Coniacian (Čech 2009), and continues up to the Lower Coniacian without regard to change in lithology (Švábenická 2010). The top of acme *M. furcatus* was found below the first occurrence of *Micula staurophora* (Švábenická & Valečka 2011). In the Waschberg-Ždánice-Subsilesian Unit, this boundary is accessible at the locality of Turold (Švábenická in Hamršmíd 1991; Stráník & Švábenická 2000). The base of acme *M. furcatus* in association with *B. parca expansa/Thiersteinia ecclesiastica* was recorded closely below the sandstone bed of lumachelle of *C. waltersdorfensis*.

Indications of the Coniacian-Santonian boundary interval were found in the Outer Western Carpathians in the Waschberg-Ždánice-Subsilesian and Foremagura Units, but only in individual samples. Nannofossil assemblages contain *Lithastrinus grillii* scarcely accompanied by *Arkhangelskiella specillata, Hexalithus* sp. and *Lucianorhabdus* ex gr. *cayeuxii.* In the Bohemian Cretaceous Basin, the species *L. grillii* of the Lužice locality may indicate the uppermost Coniacian. In both areas, no continuous cross-section spanning this boundary interval has been available for detailed study.

Discussion

Poor nannofossil preservation in black organic matter enriched shales of the Cenomanian age both in the Bohemian Cretaceous Basin and Outer Western Carpathians is caused by carbonate dissolution and etching that is documented by the dominance of *Watznaueria barnesiae* (±40 %, Čech et al. 2005) in assemblages (Roth & Krumbach 1986). This chemical process probably occurred during sediment burial as a result of liberation of organic acids during decomposition of organic matter enclosed in shallow water and nearshore sediments. Poor preservation or absence of nannofossils in some flysch deposits and red clays is probably caused by post mortem dissolution of nannofossil tests within or below the carbonate compensation depth (CCD) and indicates bathyal or abyssal paleoenvironment (Švábenická & Bubík 1992).

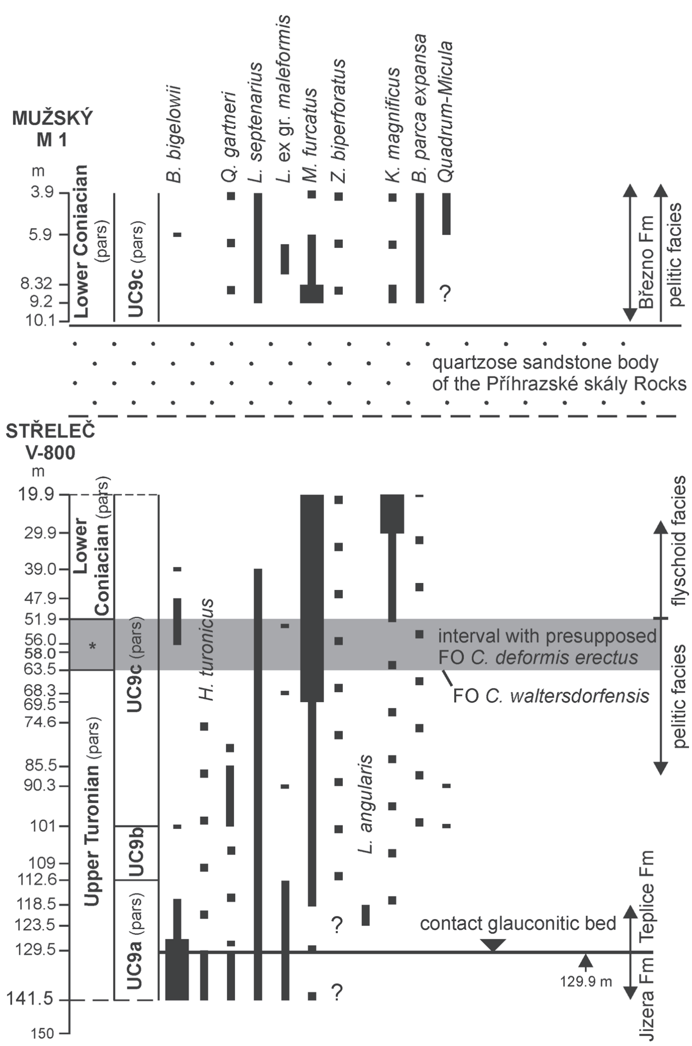

Fig. 10. Correlation between nannofossils and other important events across the Turonian-Coniacian boundary in Střeleč V-800 and Mužský Muž-1 boreholes, central part of the Bohemian Cretaceous Basin. Nannofossil UC zones by Burnett (1998), first occurrence of lamellibranch *Cremnoceramus waltersdorfensis* and interval with presupposed occurrence of *C. deformis erectus* and thus also presupposed base of Coniacian (*) by Čech (2009). Lithostratigraphic units by Čech et al. (1980). From Švábenická (2011), modified.

According to Čech et al. (2005), the Cenomanian-Turonian sequence of the Bohemian Cretaceous Basin is interrupted by major or prominent bounding surfaces associated with erosional surface and stratigraphic condensation of the uppermost Cenomanian strata. This hypothesis is also supported by nannofossils. The interval between LO *Axopodorhabdus albianus* and first *Eprolithus octopetalus* provides poor and poorly preserved nannofossils with abundant *W. barnesiae* (35–40 %) and without any other markers. Rare specimens of *Quadrum intermedium* (6 and 7 elements) and *Ahmuellerella octoradiata* that were recorded in boreholes Dolní Bousov DB-1 in 418.7–419.0 m and Bystřice Ro-16 in 519.3 m are exceptions (Švábenická 2004).

The first *Octolithus multiplus* (Fig. 6–10 to 12) occurs during the Early Turonian of the Bohemian Cretaceous Basin, close to the FO *Lucianorhabdus* sp.

In the Bohemian Cretaceous Basin, the first occurrence of *Eiffellithus eximius* was repeatedly recorded in the upper part of *Collignoniceras woollgari* Zone or pertinently in its overlying strata. The ammonite *Collignoniceras woollgari*, the FO of which is regarded as the marker for the base of Middle Turonian, was found in the Rokytnice L7J borehole in the interval of UC6b–UC7 nannoplankton Zones, and so without *E. eximius* (Švábenická in print a). Burnett (1998) mentioned the FO *E. eximius* and thus the base of the UC8 Zone in the uppermost part of the Lower Turonian, and so close below *Collignoniceras woollgari* Zone (sensu Hancock et al. 1993). For this reason, the FO *E. eximius* cannot be used as the marker for the uppermost Lower Turonian or the base of the Middle Turonian in the basin.

The Zone *Liliasterites angularis* was defined by Stradner & Steinmetz (1985) as the interval from the first occurrence of the nominate species to the first *Marthasterites furcatus* below the Turonian-Coniacian boundary in the Angola Basin, Atlantic Ocean. In the Bohemian Cretaceous Basin, common *L. angularis* was recorded before the first *M. furcatus* in the Middle to Upper Turonian at the locality Kystra, SW Bohemia (Ohře river region) in the uppermost part of the Jizera Formation immediately below the "coprolite bed" (Švábenická in Hamršmíd 1991; Stradner et al. 2010). The next discoveries of this species were sporadic, in low numbers and already associated with *M. furcatus* in the Upper Turonian: in the lowermost part of the Teplice Formation of the Úpohlavy Quarry, NW Bohemia (Švábenická 1999) and in the Střeleč V-800 and Rokytnice L7J boreholes (Švábenická 2010 and Švábenická in print a). In the Outer Western Carpathians, rare badly preserved specimens of *L. angularis* accompanied by higher numbers of *M. furcatus* were found in the Waschberg-Ždánice-Subsilesian Unit, Waschberg sector, Pavlov Pv-5 borehole (135.0–140.6 m). This species has no significance for biostratigraphic correlations because of its only occasional occurrence. If present in association with *M. furcatus*, it can indicate overlying strata of a regionally important horizon of "contact glauconitic bed" in the Bohemian Cretaceous Basin (see Fig. 10).

The interval with common occurrence of *M. furcatus* across the Turonian-Coniacian boundary interval may reflect sea-level changes in this region. It may correspond to the acme event of *Braarudosphaera* and *Nannoconus* of the same age described by Wyton et al. (2007) from SE England that may represent a response to shallowing during this boundary interval.

In the Bohemian Cretaceous Basin, the Early Santonian age was mentioned apart from other things in the Volfartice Vf-1 borehole by study of benthic foraminifers (Hercogová in Čech et al. 1987). Nevertheless, sediments provided only poor nannofossils with *Micula staurophora*, *M. furcatus*, *Lithastrinus septenarius* and *Broinsonia parca expansa* without any Upper Coniacian or Santonian nannofossil markers. Nannofossil scarcity may be explained here by flyschoid facies with sandy intercalations that is not favourable for their preservation.

Watznaueria quadriradiata was rarely recorded in the Upper Turonian of the Střeleč V-800 borehole and in the Upper Coniacian in association with *Lithastrinus grillii* at the locality of Lužice (Bubík et al. 2001). Burnett (1998) mentioned first *W. quadriradiata* from the Santonian.

Conclusions

— Nannofossil assemblages of the Bohemian Cretaceous Basin and from sediments deposited on the SE side of the North European Platform, Waschberg-Ždánice-Subsilesian Unit, show similar character and support the hypothesis that the two areas were connected by a sea way (the present Blansko trough);

— Some differences of regional character were recorded in the nannoplankton assemblages. An example is the diachronic occurrence of *Marthasterites furcatus* in the Lower Turonian, UC6b Zone of the Outer Western Carpathians, Silesian Unit, and in the Upper Turonian, UC9 Zone of the Bohemian Cretaceous Basin and Outer Western Carpathians, Waschberg-Ždánice-Subsilesian Unit;

— Nannofossils are absent in some stratigraphic intervals of the Silesian and Foremagura Units and Magura Group of Nappes because sediments (flysch and red beds) were deposited within fluctuating CCD or below CCD in bathyal or abyssal environments and calcareous nannofossils were dissolved after death;

— The Albian-Cenomanian boundary interval was found in the Outer Western Carpathians, Silesian Unit. The uppermost Albian is marked by the LO *Crucicribrum anglicum* and FO *Corollithion kennedyi*;

— The Cenomanian nannofossils from the black shales of the Bohemian Cretaceous Basin are comparable to those of the Outer Western Carpathians, Silesian Unit. They are represented by diminished assemblages dominated by *Watznaueria barnesiae*, higher number of *Broinsonia specimens* and fragments of large broadly elliptical *Manivitella pemmatoidea*. Nannofossils show signs of strong etching and dissolution and document shallow nearshore waters;

— The Cenomanian-Turonian boundary, Bohemian Cretaceous Basin: the Upper Cenomanian is marked by a chain of events — LO *Corollithion kennedyi*, LO *Lithraphidites acutus*, LO *Axopodorhabdus albianus* (important event in the area) and rare irregular occurrence of *Quadrum intermedium* (6 and 7 elements). The Lower Turonian is well identified by first *Eprolithus octopetalus*. The poor nannofossil record after the LO *A. albianus* is explained by interrupted sequence associated with erosional surface and stratigraphic condensation;

— Turonian and Coniacian nannofossils are usually medium-well preserved and highly diversified both in the Bohemian Cretaceous Basin and Outer Western Carpathians, Waschberg-Ždánice-Subsilesian Unit. In the Silesian and Foremagura Units and Magura Group of Nappes, nannofossils occur on rare occasions exclusively in calcareous intercalations within the flysch deposits.

— The first occurrence of *Eiffellithus eximius* (and base of UC8 Zone) was recorded in the upper part of ammonite Zone *Collignoniceras woollgari*, and so in the lower Middle Turonian of the Bohemian Cretaceous Basin;

— The Turonian-Coniacian boundary was recorded both in the Bohemian Cretaceous Basin and Outer Western Carpathians, Ždánice-Subsilesian Unit. The uppermost Turonian is marked by the first *Broinsonia parca expansa* and by the base of the interval with common *Marthasterites furcatus*. In both areas, events were found closely below the first occurrence of the inoceramid species *Cremnoceramus waltersdorfensis*;

— The Upper Coniacian was identified in the western part of the Bohemian Cretaceous Basin by *Lithastrinus grillii*. This species is the youngest nannofossil marker found in this area. In the Outer Western Carpathians, the Upper Coniacian or Coniacian-Santonian boundary interval was observed in the Waschberg-Ždánice-Subsilesian and Foremagura Units. In addition to *L. grillii*, the species *Lucianorhabdus* ex gr. *cayeuxii*, *Hexalithus* sp. and *Arkhangelskiella specillata* are occasional constituents of assemblages.

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Appendix 1

List of calcareous nannofossils mentioned in the text, in alphabetical order of genera epithets.

Ahmuellerella octoradiata Reinhardt
Amphizygus brooksii Bukry
Arkhangelskiella specillata Vekshina
Axopodorhabdus albianus (Black) Wind & Wise
Biscutum ellipticum (Górka) Grün
Biscutum melaniae (Górka) Burnett
Braarudosphaera bigelowii parvula Stradner
Braarudosphaera bigelowii bigelowii (Gran & Braarud) Deflandre
Broinsonia enormis (Shumenko) Manivit
Broinsonia signata (Noël) Noël
Broinsonia parca expansa Wise & Watkins
Bukrylithus ambiguus Black
Calculites ovalis (Stradner) Prins & Sissingh
Chiastozygus litterarius (Górka) Manivit
Corollithion exiguum Stradner
Corollithion kennedyi Crux
Cretarhabdus striatus (Stradner) Black
Cribrosphaerella ehrenbergii (Arkhangelsky) Deflandre
Crucibiscutum hayi (Black) Jakubowski
Crucicribrum anglicum Black
Cyclagelosphaera margerelii Noël
Cyclagelosphaera reinhardtii (Perch-Nielsen) Romein
Cylindralithus biarcus Bukry
Eiffellithus eximius (Stover) Perch-Nielsen
Eiffellithus gorkae Reinhardt
Eiffellithus turriseiffelii (Deflandre) Reinhardt
Eprolithus floralis (Stradner) Stover
Eprolithus moratus (Stover) Burnett
Eprolithus octopetalus Varol
Gartnerago obliquum (Stradner) Noël
Gartnerago theta (Black) Jakubowski
Grantarhabdus coronadventis (Reinhardt) Grün
Haqius circumradiatus (Stover) Roth
Helenea chiastia Worsley
Helicolithus compactus (Bukry) Varol & Girgis
Helicolithus trabeculatus (Górka) Verbeek
Helicolithus turonicus Varol & Girgis
Hexalithus gardetae Bukry
Kamptnerius magnificus Deflandre
Lapideacassis cornuta (Forchheimer & Stradner) Wind & Wise
Liliasterites angularis Švábenická & Stradner
Lithastrinus septenarius Forchheimer
Lithastrinus grillii Stradner
Lithraphidites acutus Verbeek & Manivit
Lithraphidites carniolensis Deflandre
Lucianorhabdus cayeuxii Deflandre
Lucianorhabdus maleformis Reinhardt
Lucianorhabdus quadrificus Forchheimer
Manivitella pemmatoidea (Deflandre) Thierstein
Marthasterites furcatus (Deflandre) Deflandre
Marthasterites inconspicuus Deflandre
Micula adumbrata Burnett
Micula staurophora (Gardet) Stradner
Nannoconus elongatus Brönnimann
Octolithus multiplus (Perch-Nielsen) Romein
Ottavianus giannus Risatti
Placozygus fibuliformis (Reinhardt) Hoffmann
Prediscosphaera columnata (Stover) Perch-Nielsen
Prediscosphaera cretacea (Arkhangelsky) Gartner
Prediscosphaera cf. *grandis* Perch-Nielsen
Prediscosphaera ponticula (Bukry) Perch-Nielsen
Prediscosphaera spinosa (Bramlette & Martini) Gartner
Quadrum gartneri Prins & Perch-Nielsen
Quadrum intermedium Varol
Reinhardtites anthophorus (Deflandre) Perch-Nielsen
Retacapsa angustiforata Black
Retacapsa ficula (Stover) Burnett
Retacapsa crenulata (Bramlette & Martini) Grün
Rhagodiscus angustus (Stradner) Reinhardt
Rhagodiscus asper (Stradner) Reinhardt
Rhagodiscus plebeius Perch-Nielsen
Rotelapillus crenulatus (Stover) Perch-Nielsen
Seribiscutum primitivum (Thierstein) Filewicz et al.
Sollasites horticus (Stradner) Čepek & Hay
Stoverius achylosus (Stover) Perch-Nielsen
Tegumentum stradneri Thierstein
Tetrapodorhabdus decorus (Deflandre) Wind & Wise
Thiersteinia ecclesiastica Wise & Watkins
Thorascosphaera operculata Bramlette & Martini
Tranolithus gabalus Stover
Tranolithus minimus (Bukry) Perch-Nielsen, BCB,
Tranolithus orionatus (Reinhardt) Reinhardt
Watznaueria barnesiae (Black) Perch-Nielsen
Watznaueria biporta Bukry
Watznaueria britannica (Stradner) Reinhardt
Watznaueria ovata Bukry
Watznaueria quadriradiata Bukry
Zeugrhabdothus bicrescenticus (Stover) Burnett
Zeugrhabdothus biperforatus (Gartner) Burnett
Zeugrhabdothus diplogrammus (Deflandre) Burnett
Zeugrhabdothus embergeri (Noël) Perch-Nielsen
Zeugrhabdothus noeliae Rood et al.
Zeugrhabdothus sigmoides (Bramlette & Sullivan) Bown & Young
Zeugrhabdothus trivectis Bergen