FORAMINIFERA AND CALCAREOUS NANNOPLANKTON ASSEMBLAGES FROM THE CENOMANIAN-TURONIAN BOUNDARY INTERVAL OF THE KNOVÍZ SECTION, BOHEMIAN CRETACEOUS BASIN

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Abstract: Boreal foraminifers and calcareous nannofossils from the Cenomanian-Turonian boundary interval of the Bohemian Cretaceous Basin were studied. Detailed analyses of foraminiferal assemblages (benthonic diversity, diversity of species, ratio plankton/benthos) showed the important changes within this interval. The benthonic species are dominant within the foraminiferal assemblages, hence the representatives of genus *Gavelinella* were used for the biozonation. Effects of stressed life conditions on foraminiferal assemblages were recognized within this dysaerobic boundary interval. Similar effects are observed for calcareous nannofossils in the basal Turonian sediments.

Key words: Bohemian Cretaceous Basin, Cenomanian-Turonian boundary, *Foraminifera*, calcareous nannofossils.

Introduction

At present, sedimentologists, paleontologists and geochemists are concerned with study of the Cenomanian-Turonian boundary sediments (Jarvis et al. 1988; Leary & Peryt 1990; Leary et al. 1989; Corfield et al. 1990; Kennedy & Cobbau 1991; Peryt 1991; Peryt & Wyrwicka 1991; Ernst et al. 1984; Walaszczyk 1987). Foraminiferal assemblages show significant changes in abundance and diversity through the Cenomanian-Turonian boundary interval. It was mentioned in many biostratigraphical studies respective to this problematics (Grosheny et al. 1992; Kaiho & Hasegava 1994; Olesen 1991; Robaszynski et al. 1993; Salaj 1987).

Rather sporadic changes in nannofossil assemblages are observed in the Cenomanian-Turonian boundary sediments compared to macrofossils and foraminifers. There are some quite significant blooms of individual taxa around the boundary but their importance is not fully understood (Bralower 1988).

The nannofossil biostratigraphic subdivisions for the Cenomanian-Turonian boundary interval were reviewed by Bralower (1988) who notes that nannofossil events differ in their stratigraphic positions according to published zonations. Many authors (Sissingh 1977; Perch-Nielsen 1985; Peryt & Wyrwicka 1993; Gorostidi & Lamolda 1993; Lamolda et al. 1994 etc.) consider the first appearance of *Quadrum gartneri* Prins & Perch-Nielsen as an indicator for the base of the Turonian stage. Nevertheless, Bralower (1988) found this species already in the uppermost Cenomanian deposits within the Microstaurus chiastius Subzone that correlates with Neocardioceras juddii ammonite Zone, i.e. with the lower part of the Whiteinella archaeocretacea Zone. For the recognition of the Ce-Tu bound-

ary, Bralower (item) used the last occurrence of *Microstaurus chiastius* (Worsley) Grün.

Great attention has also been devoted to the Cenomanian-Turonian boundary interval in the Bohemian Cretaceous Basin (Čech & Váně 1989; Čech & Valečka 1991; Pražák 1989; Štemprokavá-Jírová 1991; Valečka & Skoček 1991; Uličný et al. 1993; Valečka et al. in press). This very important stratigraphical boundary-line is characterized by major changes in biostratigraphic, lithological and geochemical records in marine deposits.

The Cenomanian-Turonian boundary successions in the area of the Bohemian Cretaceous Basin are characterized by the Upper Cenomanian sediments of the Peruc-Korycany Formation (Metoicoceras geslinianum Zone) and the Lower Turonian sediments of the Bílá Hora Formation (Watinoceras coloradoense Zone). The Peruc-Korycany Formation is a transgressive succession of fluvial, lacustrine and lagoonal deposits (Peruc Member), passing into shallow-marine sandstones in the marginal parts and siltstones to calcareous siltstones in the deeper parts of the basin (Korycany Member).

The character of the Cenomanian-Turonian boundary varies in the Bohemian Cretaceous Basin mostly owing to variability of the Korycany Member facies. Siltstone facies is typically developed in the central part of the basin where it can be divided into two successive parts separated by a horizon rich in decalcified shell debris named "whitish broken fauna horizon" - WBF horizon sensu Pražák (1989). The Bílá Hora Formation is generally represented by marlstones and calcareous claystones.

The locality Knovíz is situated more in the western marginal part of the Bohemian Cretaceous Basin (Fig. 1), but the equivalent of siltstones facies is also developed here in the interval
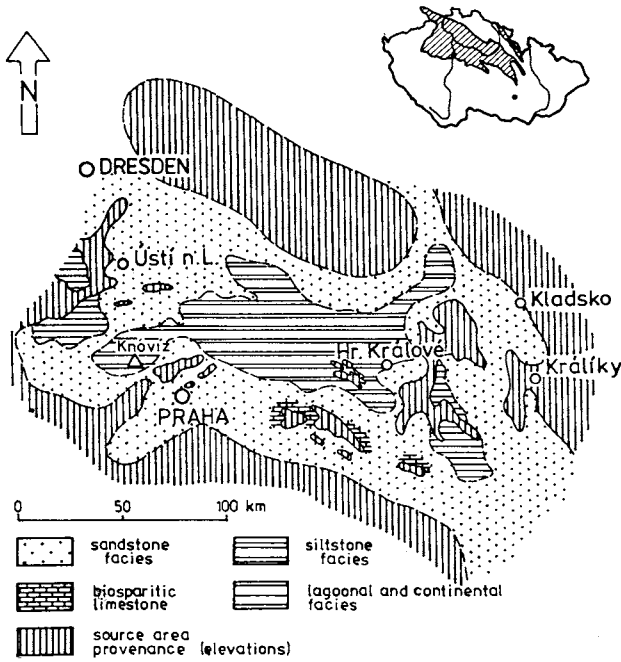
from 0 to 4 m (Fig. 2). The deposits are represented by silty claystones to claystones with sporadic glauconite content. These sediments are dark in color in the interval from 2 to 4 m (Valečka et al. in press).

Methods

Material from the Knovíz section was collected from a 10 m thick interval reaching from the equivalent of the siltstone facies (Fig. 2) to the overlying beds represented by foraminiferal marlstones and well-bedded spiculite marlstones. The section was sampled with an average of approximately three-four samples per meter.

Foraminifers were isolated from sediment samples of approximately 0.75 kg weight using the usual methods of sieving through 0.063 mm sieves and silk. Diversity was determined using the Simpson equation. The illustrated specimens are stored in the Czech Geological Institute, Prague.

Nannofossils were present in the calcareous sediments of the Bílá Hora Formation only. This fact hindered study of nannofossil assemblage changes in the whole Cenomanian-Turonian boundary interval, and investigation had to be restricted to the basal Turonian deposits.

Nannofossils were studied using a Nikon light microscope with 1,000× magnification. For quantitative analysis, 500 specimens per sample were counted. Nannofossil species observed in this study are listed in the distribution table (Fig. 4).

Fig. 1. Paleogeographical reconstruction of the Korycany Member (the Upper Cenomanian, Metoicoceras geslinianum Zone), modified after Čech & Valečka (1991).
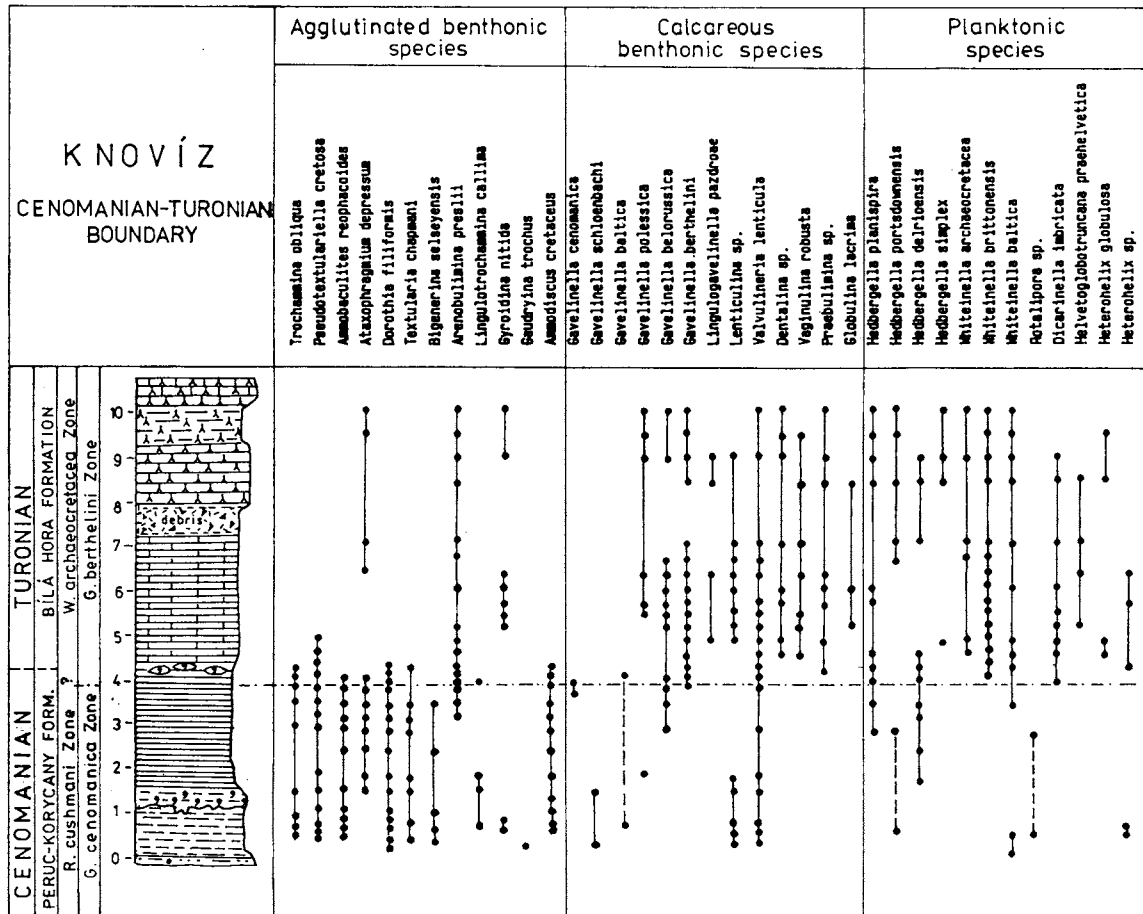

Fig. 2. Vertical distribution of the *Foraminifera* in the sediments of the Knovíz section.

Results

Foraminifera

Generally, the foraminiferal associations from these boundary sediments have a typical boreal character. The assemblages are characterized: 1 - by a low abundance of planktonic foraminifers, with small specimens of the genera *Hedbergella* and *Whiteinella* predominating, 2 - by practical absence or very rare presence of keeled forms. In these assemblages, benthic foraminifers predominate, especially agglutinated species (Pl. I, II). In the Knovíz section, the index species *Rotalipora cushmani* is extremely rare, as in the central part of the Bohemian Cretaceous Basin. Only two poorly preserved specimens were found in the sample from 0.4 m and one badly preserved specimen from 2.8 m probably belongs to the genus *Rotalipora* (Fig. 2). On this account, benthic species of the group *Gavelinella* have been used for the foraminiferal zonation of the Upper Cenomanian to lowermost Turonian sediments.

The foraminiferal assemblage taken from the interval 0.4-1.0 m is represented mostly by benthic species. The lowermost part (0.10 m) of the section contained both calcareous and agglutinated species in the mutual ratio 1:1, although towards the top of the bed the agglutinated species prevail (Fig. 3). In the agglutinated association, the following foraminifers dominate: *Haplophragmoides*, *Trochammina obliqua* and *Dorothia filiformis*. Calcareous benthos was represented mainly by the genus *Lenticulina*, *Valvulineria lenticula* and the group of gavelinels. This part is thought to be an equivalent to the lower part of the siltstone facies of the central part of the Bohemian Cretaceous Basin where some calcareous species are present near the bottom of the siltstone facies, but upwards they become extinct and are replaced by agglutinated forms.

In the Knovíz section, the bed of silty glauconite claystone with phosphatic nodules (1.2-1.5 m) is an equivalent to the WBF horizon. This horizon contains extremely rare plankton and even in 1.2 m of thickness no planktonic tests have been found.

The upper part of the siltstone facies in the sense of Pražák (1989) may be equivalent to the claystone bed in the Knovíz

section (1.5-4.0 m). Agglutinated specimens such as *Dorothia filiformis*, *Ataxophragmium depressum*, *Trochammina obliqua*, *Haplophragmoides* etc. were abundant.

Calcareous benthos is rarely represented by occasional findings of *Valvulineria lenticula* and some gavelinels.

Further up calcareous species are more common and are represented mainly by *Gavelinella berthelini*. Planktonic species become a common component of the assemblages.

Geochemical analyses from the Knovíz section (Valečka et al. in press) as well as from the central part of the Bohemian Cretaceous Basin show rather high contents of organic carbon in the interval of the siltstone facies (Uličný et al. 1993). In the Knovíz section, the higher organic carbon content was observed in the range of 2-4 m thickness and may indicate worse life conditions due to oxygen depletion (Fig. 3). The evidence for these dysaerobic conditions is the following (Koutsoukos et al. 1990): 1 - low assemblage diversity, 2 - poorly-developed plankton, dwarfish and juvenile specimens with practically no keeled forms, 3 - extinction of some benthic species.

Some benthic species had an ability to adapt to the worse life conditions. Above all, they were calcareous-hyaline foraminifers mostly free-living deposit-feeding specimens e.g. of semi-epifaunal or shallow infaunal mode of life (partially buried and shallow burrowers in soft muddy substrata) sensu Koutsoukos et al. (1990). Species belonging to this group found in the area of the Bohemia Cretaceous Basin are *Gavelinella berthelini*, *Lingulogavelinella globosa*, *Valvulineria lenticula*, *Praebulimina*, *Lenticulina*, *Dentalina*, *Globulina lacrima* etc.

Agglutinated foraminifers indicating stressed life conditions are also representatives of an epifaunal or shallow infaunal habitat group (deposit feeders-detritivors or detrital/bacterial scavengers). They belong to the genera *Trochammina*, *Ammodiscus*, *Ammobaculites*, *Textularia* and *Tritaxia*.

Calcareous nannofossils

The first nannofossils - the rare specimens of *Eprolithus eptapetalus* - were found in the sample immediately below the 2nd horizon rich in glauconite (Figs. 4 and 5). For more precise

BENTHONIC DIVERSITY   DIVERSITY OF SPECIES   RATIO PLANKTON/ BENTHOS (SPECIES)   C org.%
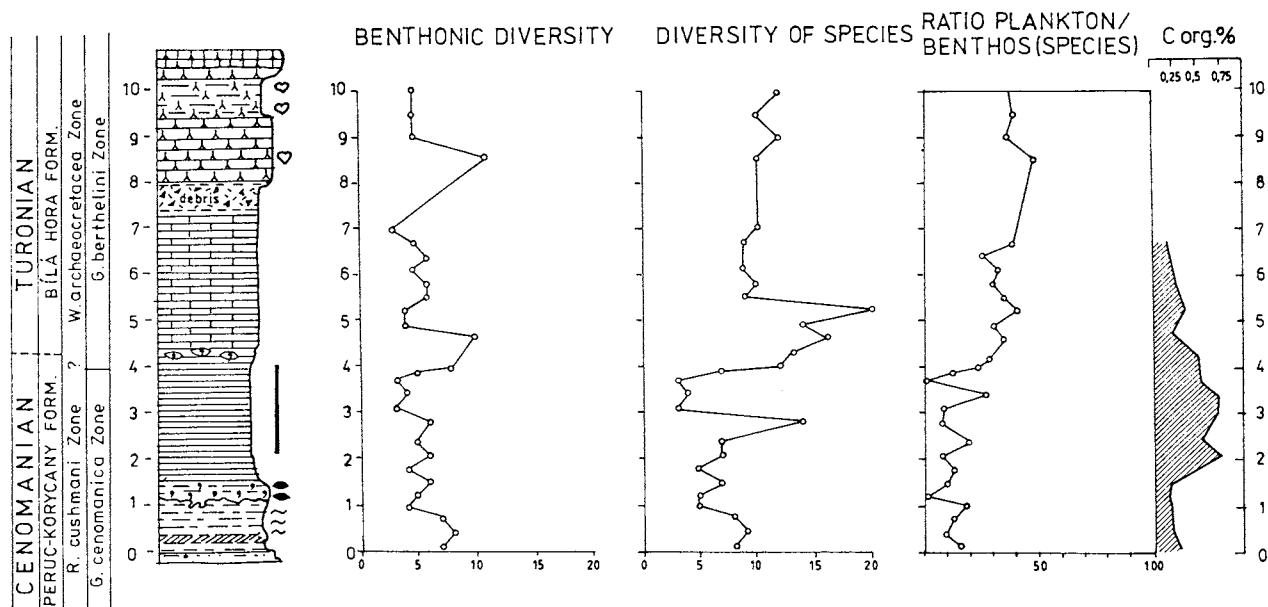
Fig. 3. The development of the foraminiferal assemblage across the Cenomanian-Turonian boundary and correlation with the total C_{org} content in the Knovíz section.

stratigraphical conclusions, this species is rather unsuitable because its occurrence is known from the Late Cenomanian to the Early Coniacian.

Within the 2nd horizon rich in glauconite (at 4.3 m) and in the overlying sediments, the content of $CaCO_3$ rapidly increases from 0 % and reaches its maximum value 3.95 m above the base of this layer. Simultaneously, an abundant and diverse nannoflora suddenly appears.

In the 2nd horizon rich in glauconite, coccolith preservation is relatively poor and the high percentage content of *Watznaueria barnesae* (more than 70 %) indicates strong nannofossil dissolution (Roth & Krumbach 1986). *Broinsonia enormis, Eprolithus floralis, Prediscosphaera cretacea, Eiffellithus turriseiffelii, Glaukolithus diplogrammus* etc. occur frequently, with values over 1 %. An essential component of the assemblage comprises specimens of the family *Polycyclolithaceae*, such as *Quadrum gartneri, Q. intermedium, Q.* sp. cf. *Q. giganteum, Eprolithus* div. spec. including *E. octopetalus* and *Radiolithus orbiculatus* (Pl. III).

The presence of *Quadrum gartneri* allows us to recognize the standard nannoplankton Zone CC11 sensu Sissingh (1977) and Perch-Nielsen (1985) which documents the Early Turonian age. The same age is also shown by the presence of *Quadrum intermedium* which was reported by Varol (1992) from the short interval within the Early and Middle Turonian. Gorostidi & Lamolda (1993) found *Q. intermedium* already in the basal Turonian sediments associated with the first appearance of *Quadrum gartneri*.

At 4.60 m and in the overlying sediments, the character of the assemblages is rather changing. Calcareous nannofossils are better preserved and species diversity/abundance increases. *Watznaueria barnesae* decreases in abundance to about 35–45 % and this value remains practically unchanged in the rest of the section. Specimens of the genus *Eprolithus* are still common but the quantitative value of *Broinsonia enormis* already drops below 1 %.

The nannofossil assemblages keep this character until 8.50 m, where the species quantity of the whole family *Polycyclolithaceae* rapidly decreases. At 10.00 m, *Eprolithus octopetalus* was already not found. Varol (1992) mentioned *Eprolithus octopetalus* only within the short interval from the Late Cenomanian to the basal Turonian, but Gorostidi & Lamolda (1993) found it only in the latest Cenomanian.

In agreement with Roth & Krumbach (1986) and Bralower (1988), the higher quantity of specimens of the genus *Broinsonia* in the 2nd horizon rich in glauconite (at 4.3 m) may indicate neritic environments and shallow epicontinental seaways. This taxon might be an indicator of numerous factors associated with these environments including shallow waters, reduced salinity, or high fertility. According to Roth & Krumbach (1986), *Eprolithus floralis* is characteristic of high latitudes. Enrichment in this species might, therefore, be indicative of colder and/or fresher water. This would be consistent with the concurrent enrichments in arenaceous foraminifers and ostracods (Diner in Bralower 1988). The idea that both floral anomalies may result from inputs of fresher water is particularly attractive because such influxes, by stabilizing the water column, may have led to the deposition of the black shales which correlate with these floral anomalies.

Biostratigraphy

The foraminiferal assemblages investigated from thirty samples from the Cenomanian-Turonian boundary interval of the Knovíz section belong to the Rotalipora cushmani Zone and to the lower part of the Whiteinella archaeocretacea Zone. Because the index species *Rotalipora cushmani* (Morrow) is extremely rare in the studied section, the upper limit of the Rotalipora cushmani total range Zone could be determined using the extinction level of *Gavelinella cenomanica* Brotzen as an additional criterion. This species disappears either earlier or in some areas together with *R. cushmani* (Jarvis et al. 1988; Peryt & Wyrwicka 1991; Uličný et al. 1993). The overlying planktonic Zone *W. archaeocretacea* can be substituted by other species of the genus *Gavelinella* namely by *G. berthelini* (Keller) (Fig. 5).

Gavelinella cenomanica Zone (R. cushmani Zone)

G. cenomanica, the index species for this zone becomes extinct within its upper limit. It occurs predominately in association with: *Gavelinella polessica, G. schloenbachi, Marginulina aequivoca, Trochammina obliqua, Dorothia filiformis, Haplophragmoides nonioninoides, Ataxophragmium depressum, Bigenerina selsyensis* and *Ammobaculites reophacoides*.

Gavelinella berthelini Zone (W. archaeocretacea Zone)

G. berthelini is maximally extended during this zone. Among others, it is accompanied by *Gavelinella belorussica, Valvulineria lenticula, Lingulogavelinella globosa*.

According to the foraminiferal study, the precise determination of the Cenomanian-Turonian boundary was impossible. The significant and abrupt change in the foraminiferal assemblages in this profile could be traced for about 4 metres. This change probably indicates the boundary-line between two foraminiferal zones. Nevertheless the first appearance of *Dicarinella imbricata* (Mornod) and *Helvetoglobotruncana praehelvetica* (Drujilo) could be indicate the Lower Turonian below the supposed boundary. This change probably indicates the boundary-line between two foraminiferal zones. The first appearance of the nannofossil species *Quadrum gartneri* Prins & Perch-Nielsen was recorded in the sample from 4.3 m and may indicate the base of the Turonian. But this stratigraphical information is debased by nannofossil scarcity in the underlying non-calcareous sediments. A sample from 4.0 m yielded sporadic specimens only of *Eprolithus eptapetalus* which already is known from the Late Cenomanian. According to these data, the Cenomanian-Turonian boundary might be situated within the interval of the 2nd horizon rich in glauconite, i.e. in 4.3 m (Fig. 5).

Conclusion

The performed analyses may be correlated with the result of studies carried out in the Cenomanian-Turonian boundary sediments from the surrounding areas. Detailed analyses of foraminiferal assemblages showed the important changes within this interval. The indicated changes are probably closely related to the life conditions worsening as a result of oxygen shortage. For the foraminiferal zonation, representatives of genus *Gavelinella* were used (*G. cenomanica* and *G. berthelini*). They are abundant in the assemblages of the boreal bioprovinces.

An abundant and diverse nannoplankton occurs at the Knovíz section only in the calcareous sediments of the Bílá Hora Formation and allows us to recognize the Quadrum gartneri Zone
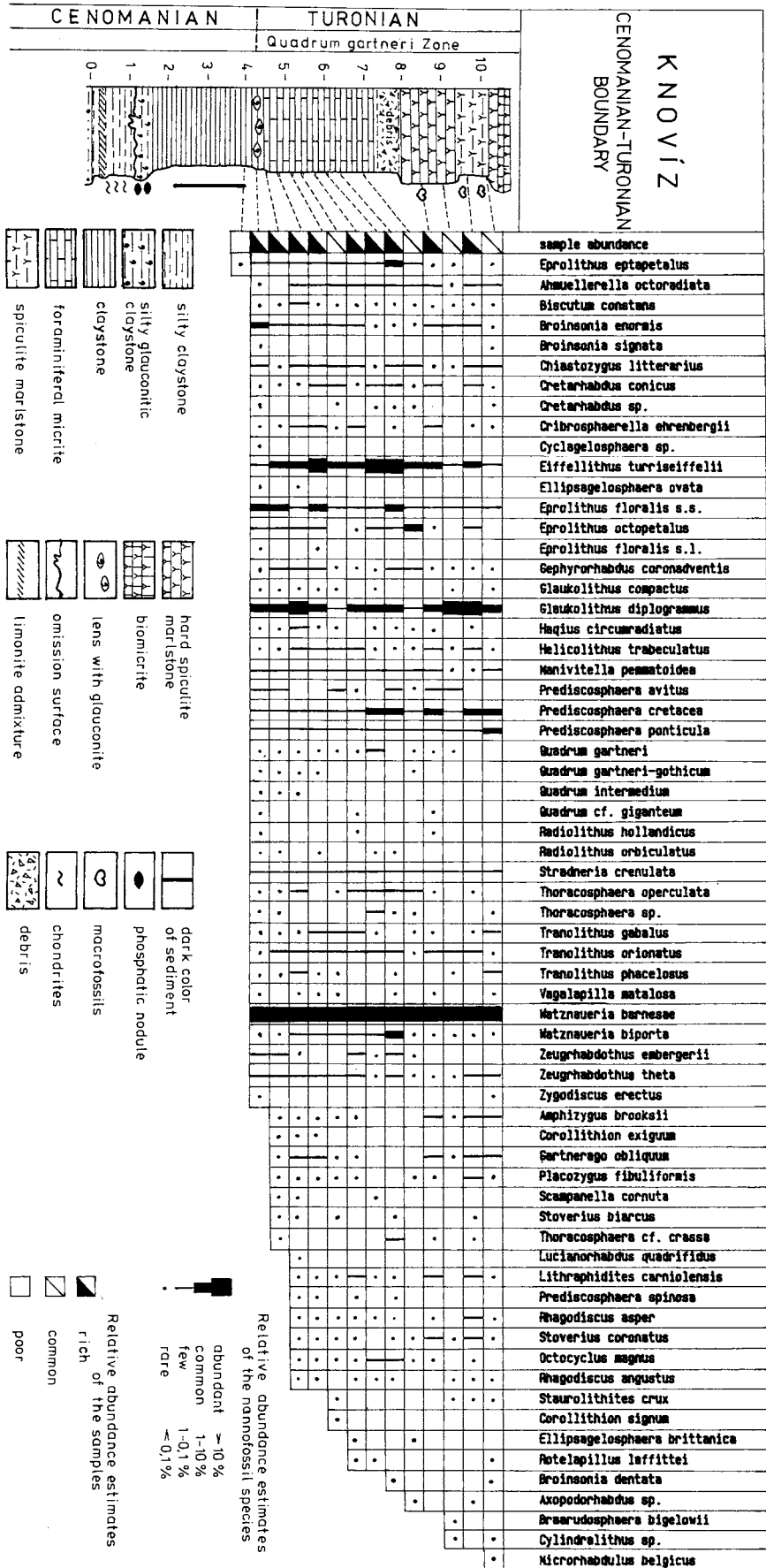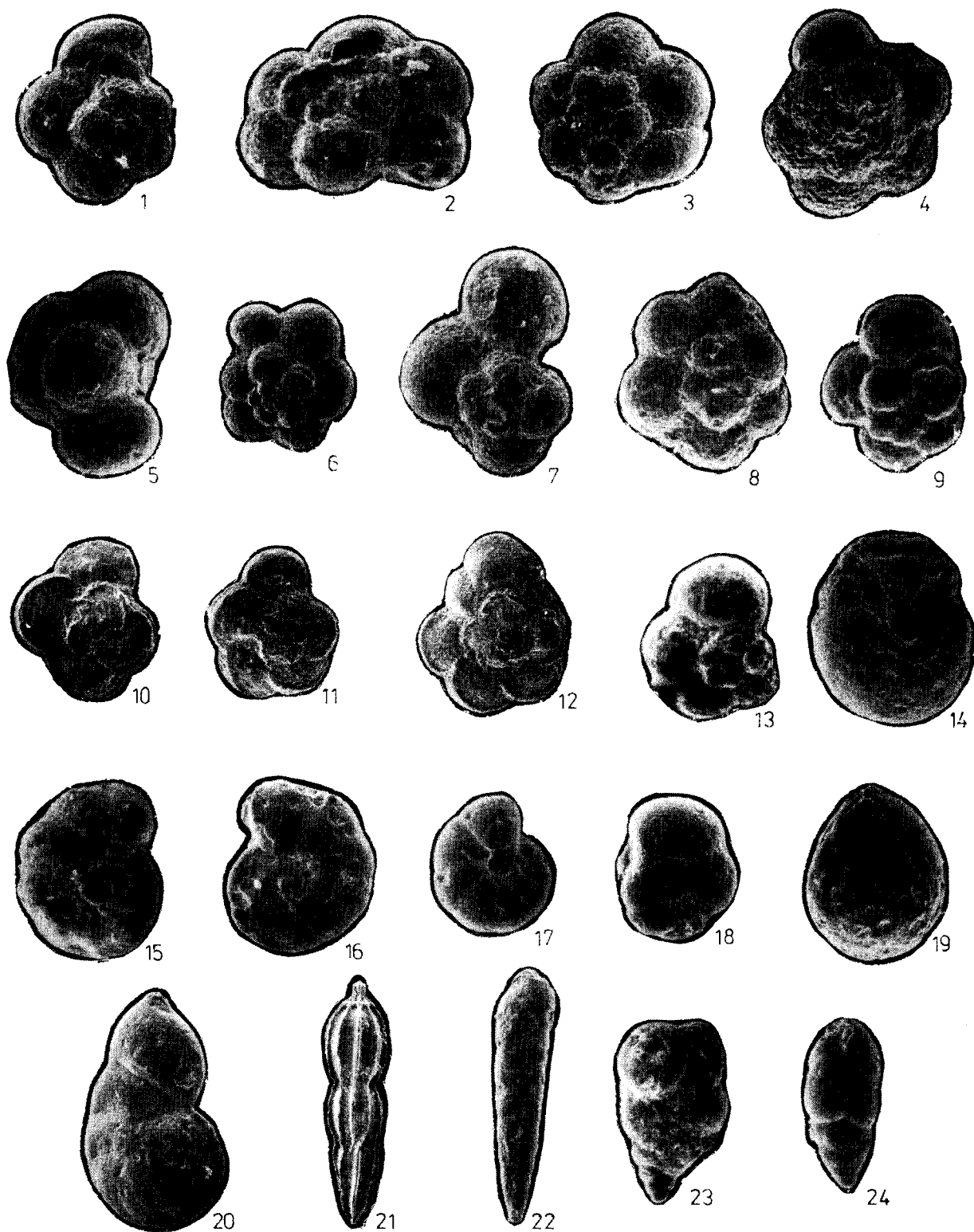
Fig. 4. Vertical distribution of calcareous nannofossils in the sediments of the Knovíz section.

Plate II: SEM photomicrographs of Cenomanian and Turonian *Foraminifera* from Knoviz section **Figs. 1, 2.** *Haplophragmoides nonioninoides* (Reuss),1.0 m, 80×; **Fig. 3.** *Trochammina obliqua* Tappan, 2.8 m, 50×; **Fig. 4.** *Haplophragmoides sp.*, 1.0 m, 70×; **Fig. 5.** *Lingulotrochammina callima* (Loeblich & Tappan), 1.8 m, 50×; **Fig. 6.** *Ammobaculoides lepidus* Hercogova, 1.8 m, 70×; **Fig. 7.** *Ammobaculites reophacoides* Bartenstein,1.8 m, 50×; **Fig. 8.** *Ammobaculites reophacoides* Bartenstein, 2.4 m, 70×; **Figs. 9, 10.** *Spiroplectammina scotti* Cushman-Alexander, 1.2 m, 70×; **Fig. 11.** *Bigenerina selseyensis* Heron-Allen-Earland, 3.4 m, 70×; **Fig. 12.** *Gaudryina praepyramidata* Hercogova, 1.5 m, 50×; **Fig. 13.** *Tritaxia compressa* Egger, 1.0 m, 50×; **Fig. 14.** *Textularia foeda* Reuss, 3.4 m, 50×; **Fig. 15.** *Dorothia sp.*, 1.8 m, 70×; **Fig. 16.** *Dorothia filiformis* (Berthelin), 1.8 m, 70×; **Fig. 17.** *Pseudotextularia cretosa* (Cushman), 1.8 m, 70×; **Fig. 18.** *Arenobulimina preslii* (Reuss), 3.9 m, 50×; **Fig. 19.** *Ataxophragmium depressum* (Perner), 3.9 m, 50×; **Fig. 20.** *Glomospirella gaultina* (Berthelin), 1.0 m, 50×; **Fig. 21.** *Ammodiscus cretaceus* (Reuss), 1.0 m, 50×; **Fig. 22.** *Arenobulimina brevicona* (Perner), 3.9 m, 90×; **Fig. 23.** *Lituotuba incerta* Franke, 3.1 m, 50×; **Fig. 24.** *Lituotuba sp.*, 3.4 m, 50×. Photomicrographs by Ananda Gabašová, Czech Geological Survey Prague.
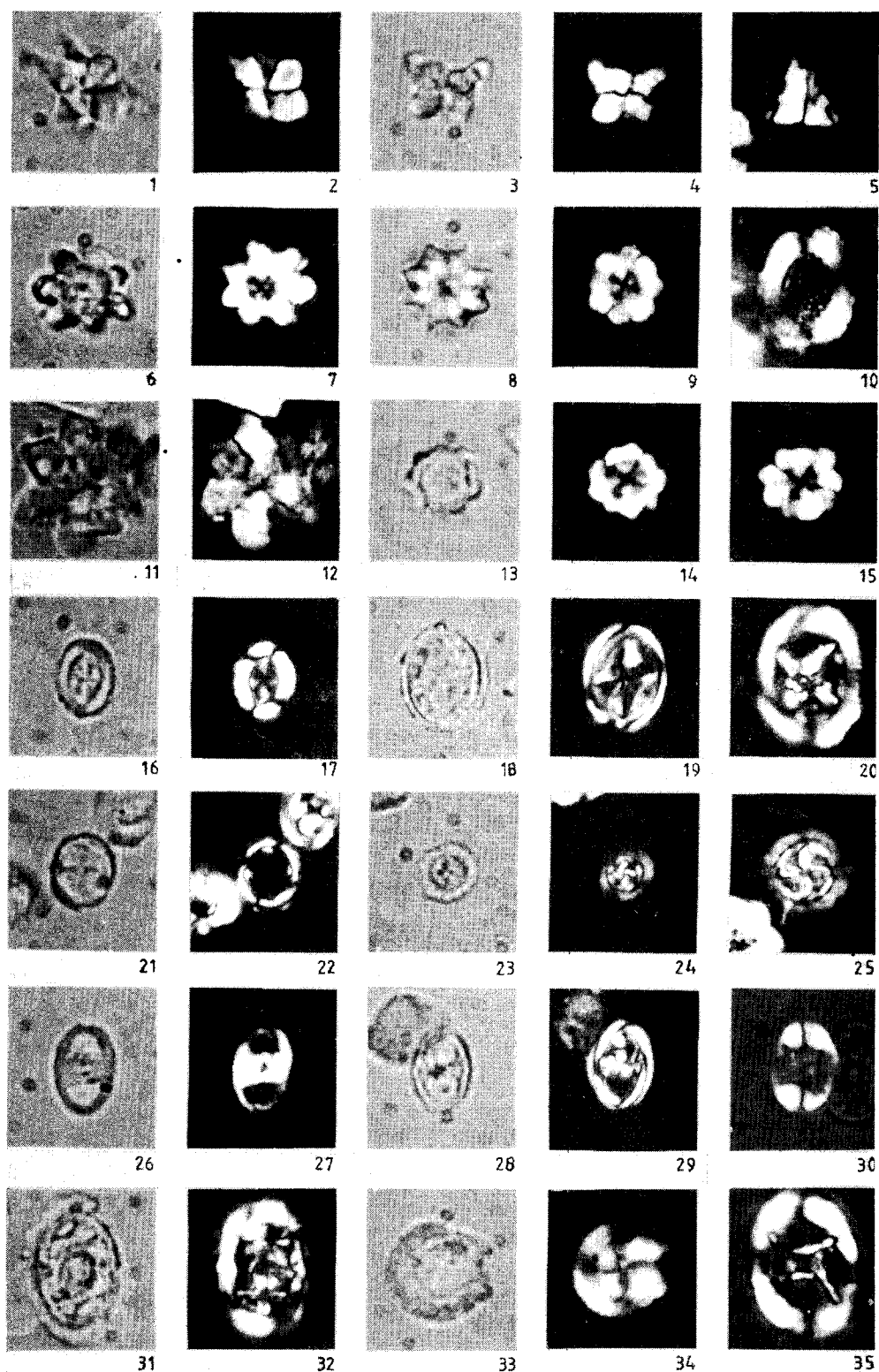
Plate III: Knovíz section, sample taken from 4.60 m (with the exception of *Quadrum* cf. *giganteum* that comes from 8.50 m); Figs. 1, 2. *Quadrum intermedium* Varol; Figs. 3, 4. *Quadrum gartneri-gothicum*; Fig. 5. *Lucianorhabdus quadrifidus* Forchheimer; Figs. 6, 7. *Eprolithus eptapetalus* Varol; Figs. 8, 9. *Eprolithus octopetalus* Varol; Fig. 10. *Cretarhabdus sp.*; Figs. 11, 12. *Quadrum cf. giganteum* Varol; Figs. 13, 14. *Radiolithus orbiculatus* (Forchheimer) Varol; Fig. 15. *Eprolithus floralis* Stradner; Figs. 16, 17. *Broinsonia enormis* (Shumenko) Manivit; Figs. 18, 19. *Gartnerago obliquum* (Stradner) Noel; Fig. 20. *Gephyrorhabdus coronadventis* (Reinhardt) Hill; Figs. 21, 22. *Stoverius coronatus* (Bukry) Perch-Nielsen; Figs. 23, 24. *Prediscosphaera avitus* (Black) Perch-Nielsen; Fig. 25. *Prediscosphaera ponticula* (Bukry) Perch-Nielsen; Figs. 26, 27. *Tranolithus gabalus* Stover; Figs. 28, 29. *Placozygus fibuliformis* (Reinhardt) Hoffmann; Figs. 30, 35. *Eiffellithus turriseiffelii* (Deflandre) Reinhardt; Figs. 31, 32. *Octocyclus magnus* Black; Figs. 33, 34. *Haqius circumradiatus* (Stover) Roth Magnification: 2,000×. Photomicrographs by Lilian Švábenická.
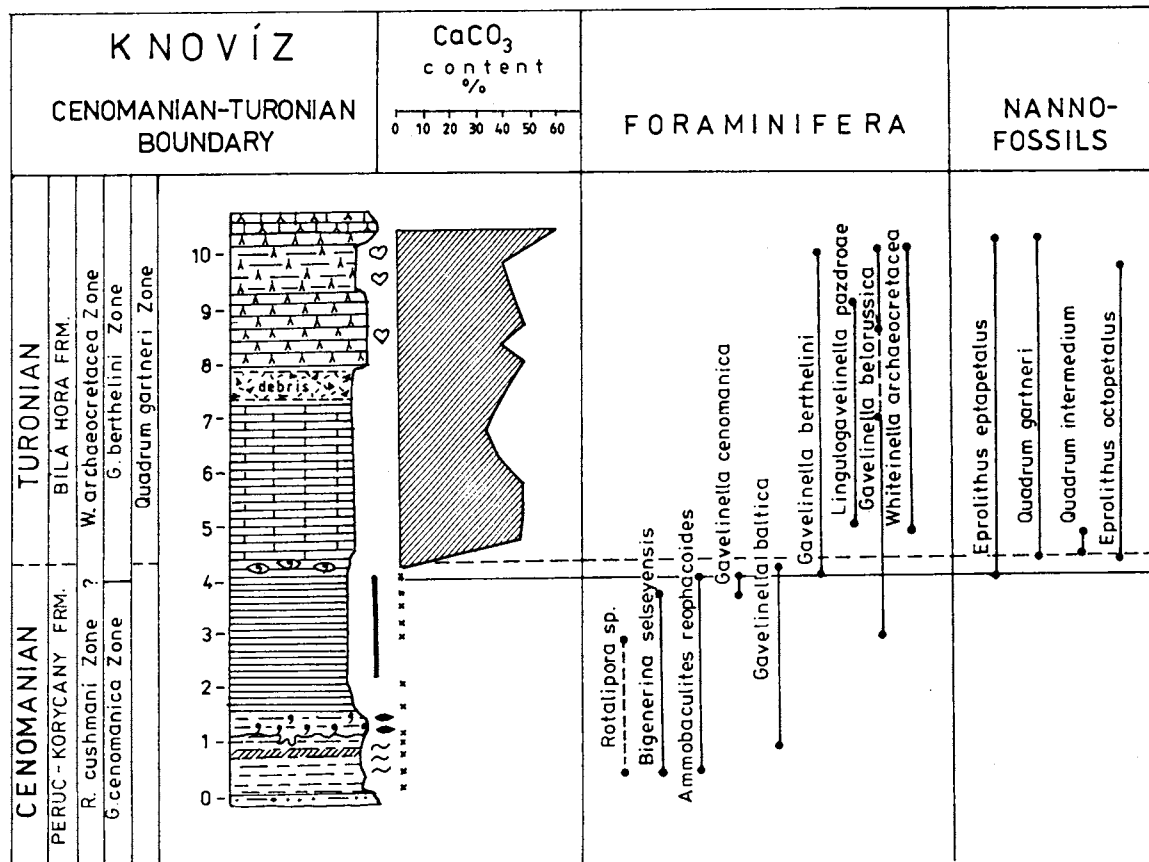
Fig. 5. Knovíz section - distribution of the stratigraphical important *Foraminifera* and calcareous nannofossils and its correlation with the $CaCO_3$ content.

(sensu Sissingh 1977 and Perch-Nielsen 1985) from the base of the 2nd horizon rich in glauconite (from 4.30 m) upwards.

The percentage of *Watznaueria barnesae* indicates a decreasing dissolution of coccoliths in an upward direction aross the basal Turonian sediments. *Eprolithus floralis* and *Broinsonia enormis* become abundant in the assemblage in the sample taken from the 2nd horizon rich in glauconite. This fact may indicate colder water and shallow epicontinental seaways.

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