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MICROFOSSILS OF THE ALBIAN AND CENOMANIAN SHALES FROM THE ŠTRAMBERK AREA (SILESIAN UNIT, OUTER WESTERN CARPATHIANS, CZECH REPUBLIC)

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Abstract: Microbiostratigraphic study of sporomorphs, dinoflagellate cysts, foraminifers and calcareous nannofossils documented the age and paleoenvironmental features of black and grey-green, organic-rich sediments in the classical area of Štramberk (Baška Formation, Silesian Unit, Outer Western Carpathians). Age-assessments suggest Late Albian and Cenomanian age (foraminiferal Zones *Rotalipora appenninica*, *R. reicheli* and *R. cushmani*; nannoplankton Zones BC27/UC0-UC4). The character of dinoflagellate cyst assemblages (e.g. presence *Pterodinium*) reflects open-sea environment. The presence of calcareous foraminifers and nannofossils gives an evidence of depositional conditions above the carbonate compensation depth (CCD). The presence of some terrestrial and non-marine aquatic palynomorphs (e.g. *Tetraporina*, *Lecaniella*) documents the proximity of a continent and fluvio-lacustrine influences. The presence of microfossils tolerating low-oxygen bottom conditions such as foraminifers of genus *Lingulogavelinella* and jaws of polychateous annelids (scolecodonts) reflect a dysaerobic bottom environment. Co-occurrence of Boreal and Tethyan species encountered in foraminiferal and palynomorph assemblages documents the influences from the higher latitudes on the depositional area of northern Tethys. Moreover, Lower-?Middle Cenomanian sporomorphs (angiosperms) have similar character to others of the same age from the Blansko Graben, in the SE part of the Bohemian Cretaceous Basin, which is situated on the SE border of the West European plate.

Key words: Cretaceous, Outer Western Carpathians, palynomorphs, foraminifers, calcareous nannofossils, biostratigraphy, paleoecology.

Introduction

The Cretaceous sediments of the Silesian Unit have been studied by many authors since the 19th century and the great attention was paid to their biostratigraphic evaluation. However, no integrated microfossil study has been presented from the Štramberk area so far, and calcareous nannofossils from this area have not been studied at all. This study presents the results of an integrated biostratigraphic and paleoecological analysis of the Albian-Cenomanian deposits from the Štramberk vicinity. The Štramberk Limestone and associated Lower Cretaceous sediments in the vicinity of Oppel's and Zittel's classic Štramberk locality form isolated tectonic slices grouped within three complexes — Kotouč, Skalky and Trúba. The studied microfossils come from the deposits of the main quarry at Kotouč Hill near Štramberk (Moravskoslezské Beskydy Mts, NW Moravia, Czech Republic; Figs. 1, 2). The associations of marine and land-derived microfossils in the sediments of the Albian–Cenomanian age from the Kotouč Quarry near Štramberk provide an opportunity to compare marine and non-marine biostratigraphic schemes.

Geological setting

The Silesian Unit represents a middle nappe in the structure of the Outer Western Carpathians in Moravia, which was thrust over the Subsilesian Nappe, a part of Miocene fill of the Carpathian Foredeep and Variscides of the Bohemian Massif from East to West. The Silesian Unit is formed by Upper Jurassic to Oligocene-Miocene deposits. Three main developments were recognized in the structure of the Silesian Unit (Eliáš 1970): the Godula development (basinal setting), Baška development (frontal slope setting) and Kelč development (continental setting). The Godula development (Jurassic–Oligocene) consists of deep basinal sediments (maximum thickness up to 6000 m). The Baška development (Matějka & Roth 1949, 1955; Roth et al. 1962) is characterized by shallow marine deposits.

The Štramberk sequence, representing the Baška development (Menčík et al. 1983), is part of the tectonic megaslices (klippen) embedded within the front of the Silesian Unit. The klippen were probably detached from the autochthonous cover of the eastern slopes of the Bohemian Massif during overthrusting. The reef core, reef talus and reef breccia can be distinguished in the Štramberk Limestone representing a part of the original reef complex, which probably bordered the SE margin of the West European plate. Many clefts, open joints and cavities in the limestone are filled with different clayey limestones and claystones (Figs. 2, 3). Dark grey claystones with pyrite concretions described as the upper part of the Plaňava Formation (Houša 1976) and as the Kotouč facies (equivalent of the Baška Formation; Fig. 4; Pícha et al. in print) were the object of this study.

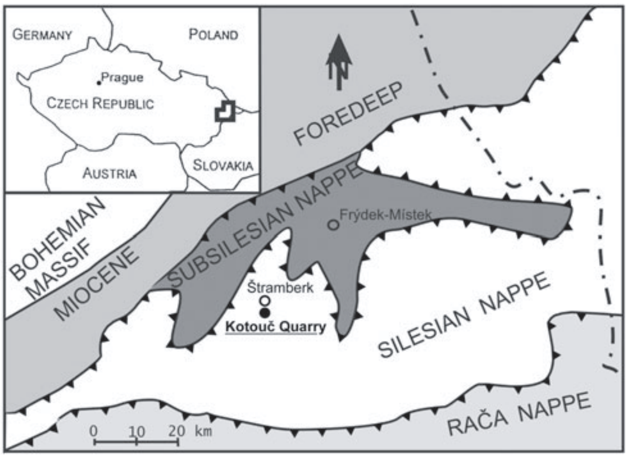

Fig. 1. A sketch map of the structural outline of the Silesian Unit with indicated locality.

Although the site has been intensively studied, the hypotheses concerning the origin of the limestone accumulation differ substantially. According to the first interpretation (Houša 1976; Houša in Menčík et al. 1983; Houša 1987), the bodies of the Štramberk Limestone represent a continuous stratigraphic section, though rotated, and Olivetská hora and Kopřivnice Limestones and clay-dominated sediments represent the Lower Cretaceous cover. According to the second interpretation (Eliáš & Stráník 1963; Eliáš & Eliášová 1965), the limestone bodies represent a huge oligostrome deposited during the Early and middle Cretaceous. The deposits are assigned to the Těšín-Hradiště and Baška Formations (Pícha et al. in print).

Previous studies

The origin of the lithologically variable fills of the fissures in the Štramberk Limestone is explained as a matrix of conglomerate composed of huge blocks and olistoliths of the Štramberk Limestone (Eliáš & Stráník 1963; Eliáš & Eliášová 1965). The sediments of the Kotouč Member are supposed to be of the Valanginian–Turonian age (Eliáš 1970, 1983). The sediments of the Plaňava Formation were dated to the Early Valangianian–Early Hauterivian (Houša & Vašíček 1996), and Hauterivian (Hanzlíková 1962; Hanzlíková & Roth 1962; Vavrdová 1964a,b, 1981). The age of the fills of fissures and depressions in the limestone was indicated as Hauterivian on the basis of macroflora by Hluštík (1979) and on the basis of microflora by Vavrdová (1964a,b). Hauterivian–Early Barremian fauna was found in the fills of fissures by Houša (Houša in Menčík et al. 1983; Houša 1987). The palynomorphs of the same age were described by Svobodová (1998). The dinoflagellate assemblages of the Cenomanian age from Štramberk (Silesian Unit) and from the Stráž Block of the Bohemian Cretaceous Basin (Peruc-Korycany Formation, boreholes of the Uranium Industry) were compared by Svobodová & Vavrdová (1987). Hanzlíková (1973) described the Cenomanian–Turonian foraminiferal assemblage from the Godula development. Most recently, dinocysts from the Godula development of the Silesian Unit were studied by Skupien (1997,1999a,b), Skupien et al. (2002) and Skupien & Vašíček (2003). Calcareous nannofossils of Early Barremian age were found in the Těšín-Hradiště Formation (Krejčí et al. 1999), and those of Turonian–Coniacian age were found in conglomerates near Starý Jičín (Stráník et al. 1997).

Material

All microfossil groups were studied from the same set of samples (sporomorphs were studied by Svobodová, dinocysts by Skupien, foraminifers by Hradecká, calcareous nannofossils by Švábenická). Material was obtained from the isolated fissure fillings and from the depressions of dark grey to black deposits in the tectonically deformed Štramberk Limestone of the Kotouč Quarry (Fig. 2). These deposits are mainly represented by dark grey and green-grey claystones and marlstones rich in organic matter (Fig. 3). They are known from isolated sites only (Fig. 3), no continuous exposures of these deposits have been found yet. Coding of the samples consists

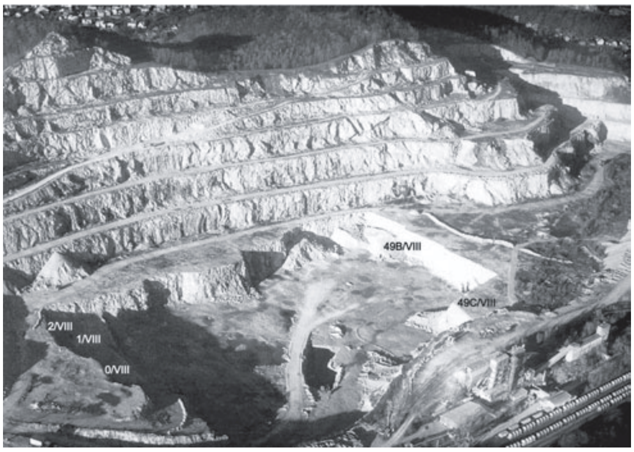

Fig. 2. Štramberk — Kotouč Quarry with some clayey fills (level VIII) in the Štramberk Limestone (state in 2002). Photo R. Kahánek.

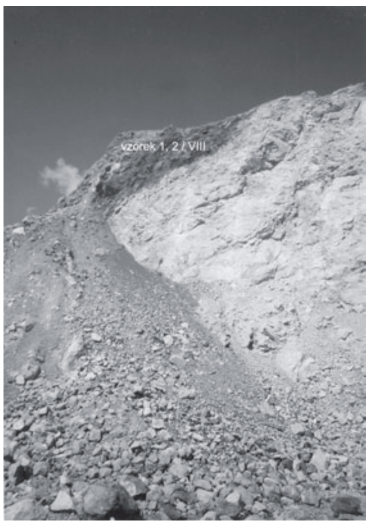

Fig. 3. Detail of fissure in the Kotouč Quarry, sample 2/VIII. Photo M. Svobodová.

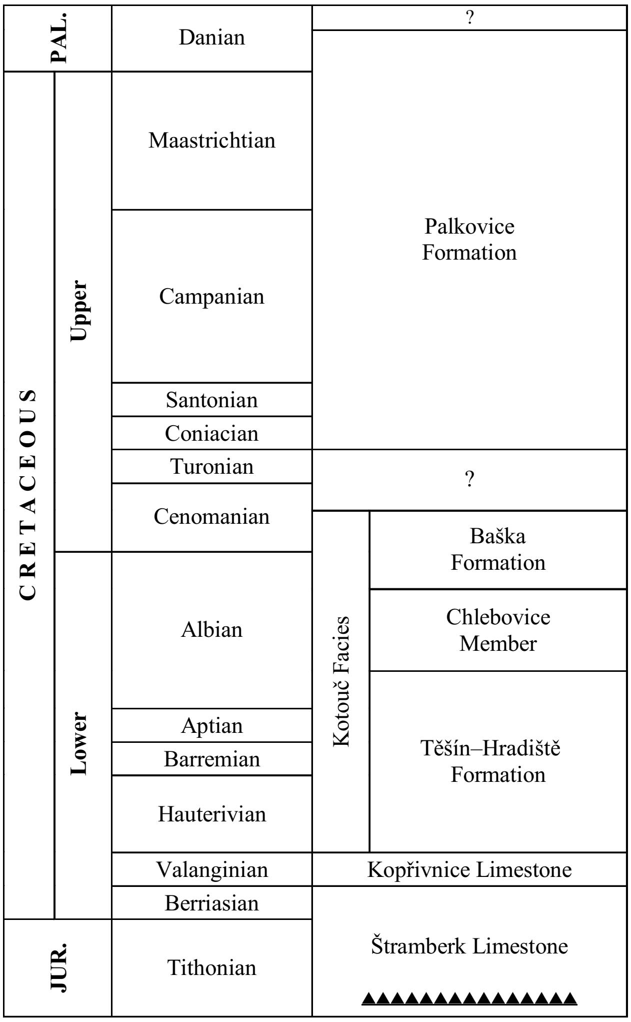

Fig. 4. Lithostratigraphy of the Silesian Unit, Baška development. From Pícha et al. (in print), modified. **Jur.** — Jurassic, **Pal.** — Paleogene, ▲▲▲▲ — tectonic detachment.

SampleNo./ level in quarry	Latitude N	Longitude E	Lithological description
Š 0/VIII	49°34′893′′	018°06′745′′	greenish marlstone
Š 1/VIII	49°34′902′′	018°06′747′′	greenish marlstone
Š 2/VIII	49°34′901′′	018°06′745′′	grey claystone
Š 11/VI	49°34′989′′	018°06′871′′	grey claystone
Š 15/V	49°34′985′′	018°06′858′′	sandy siltstone
Š 29/IV	49°34′998′′	018°06′779′′	green-grey sandy claystone
Š 30/IV	49°35′007′′	018°06′779′′	green-grey clayey siltstone
Š 49B/VIII	49°34′952′′	018°07′035′′	black claystone
Š 49C/VIII	49°34′792′′	018°07′051′′	dark grey claystone

Fig. 5. Localization and lithology of the Albian–Cenomanian samples. (Positions of samples were located using the GPS — General Position System. The error of the measurement was 5–7 meters.)

of three parts: the first denotes the sampling site (Štramberk — Š), the second denotes the sample number in Arabic numerals (e.g. 2), and the third part denotes the quarry level in Roman numerals (e.g. VIII). The location of the studied samples is given by the general position system GPS (Fig. 5).

Methods

Palynological preparations were obtained using a standard procedure involving mineral acid treatment (10% HCl, 40% HF, acetolysis, 30% HNO_3). One part of the residue was sieved using 10 µm mesh with ultrasonic vibration in order to dissolve and decompose amorphous organic matter. Qualitative analyses of palynomorph associations were based on counts of 200 sporomorphs and 200 dinoflagellate cysts per sample. The weight of collected samples for the study of foraminifers was about 0.75–1 kg. The samples were washed in the Laboratory of the Czech Geological Survey using standard washing methods and sieved at 0.063 mm sieve. Foraminifers were separated under a binocular microscope, and photographs of species were taken using a scanning electron microscope. Planktonic zonation of Robaszynski & Caron (1995) was used for the correlation of the studied assemblages. Suspension slides for calcareous nannofossil study were prepared using a decantation method, with a separated fraction of 3–30 µm. Slides were inspected with a Nikon light microscope at 1000× magnification. Quantitative data are based on ca. 300–500 specimens. Biostratigraphic data were correlated with the standard nannoplankton CC zones of Sissingh (1977), and with the Lower Cretaceous Boreal nannoplankton BC zones of Bown et al. (1998) and Upper Cretaceous nannofossil zones of Burnett (1998).

Results

Generally, light green-grey claystones and marlstones mostly contained foraminifers and calcareous nannofossils. In contrast, black and grey claystones contained rich dinocysts and sporomorphs, and usually provided poor foraminifers and calcareous nannofossil assemblages.

Sporomorphs

Spores and pollen grains were found in samples: Š2/VIII, Š15/V and Š49C/VIII (Figs. 6, 7, 8, 9). Dark grey claystones filling cavities in the limestone body of the Kotouč Quarry at Štramberk yielded mostly poorly preserved sporomorph assemblage characterized by the occurrence of angiosperm pollen grains. Angiosperm pollen grains are known to appear for the first time in the Barremian, but no angiosperm pollen grains have been found in either the Barremian or the Albian deposits at Štramberk (dated by calcareous nannofossils and foraminifers). Samples Š2/VIII, Š15/V and Š49C/VIII contain abundant trilete spores (18–35 %), gymnospermous pollen (6–12 %) and rare angiospermous pollen (2–5 %). The quality of sporomorph preservation in the investigated samples is variable. Poor preservation was observed in samples Š2/VIII and Š15/V, while sample Š49C/VIII provided excellent material probably as a result of caused by sampling of non-oxidized sediments due to rapidly advancing exploitation in the quarry. Samples Š2/VIII and Š15/V yielded mainly reticulate tricolpate pollen such as *Tricolpites variabilis*, *T. sagax*, psilate tricolpate and tricolporate pollen (*Psilatricolpites parvulus*, *Psilatricolporites* sp.). Monocotyledonous pollen *Liliacidites dividuus*, *L. variegatus*, *Clavatipollenites* spp. prevail in the angiosperm assemblage in sample Š49C/VIII. All three Štramberk samples consistently yielded abundant spore and gymnosperm pollen assemblages. Non-saccate forms such as *Cycadopites* spp., the monoporate striate type *Corollina torosa*, *Eucommiidites minor*, *Taxodiaceaepollenites hiatus*, and *T. vacuipites* are more common than bisaccate pollen grains. *Callialasporites dampieri* occurs rarely in samples Š15/V and Š49C/VIII. These pollen grains have not been found in coeval deposits of the Bohemian Cretaceous Basin (Svobodová et al. 1998; Svobodová & Brenner 1999). Some pteridophyte spores found in the Cenomanian deposits, that is, *Collarisporis fuscus*, *Corniculatisporites auritus* were described by Juhász (1983) from the Transdanubian mid-Cretaceous formations (Tethyan Realm, Hungary) while other sporomorphs are distributed worldwide. Nevertheless, this phenomenon supports the theory of mixing of Tethyan and Boreal elements in the depositional area of the Silesian Unit.

Dinocysts

Dinocyst preservation in the studied samples from the Kotouč Quarry at Štramberk is variable. The most conspicuous feature in the relative abundance diagrams (Fig. 7) is the prevalence of marine palynomorphs (mostly dinoflagellates and foraminiferal linings). Dinoflagellate cysts and acritarchs form 38–47 % and other marine faunal remains, foraminiferal linings represent 6–25 %. They were found in four samples: Š2/VIII, Š15/V, Š49B/VIII and Š49C/VIII (Figs. 10, 11). *Hystrichodinium pulchrum, Kiokansium unituberculatum, Litosphaeridium siphoniphorum, Oligosphaeridium complex, Spiniferites ramosus* and *Surculosphaeridium* sp. prevail in the dinocyst assemblages of samples Š2/VIII, Š49B/VIII and Š49C/VIII. The dinoflagellate assemblage of sample Š15/V differs markedly from previous one in the pronounced prevalence of representatives of genus *Ovoidinum*. Representatives of the genus *Achomosphaera* are common in all samples. Species *Pervosphaeridium pseudhystrichodinium,* which is typical for the Late Albian–Cenomanian deposits of the Silesian Unit, occurs only in sample 49C/VIII. This assemblage is comparable to that described from the uppermost part of the Lhoty Formation (Late Albian age) and the lower part of the variegated Godula Member (Early Cenomanian — Skupien 1999b; Skupien et al. 2002).

Foraminifers

The stratigraphically youngest assemblages of foraminifers were found in samples Š0/VIII,

SPORES, POLLEN, AQUATIC PALYNOMORPHS	**Early–?Middle CENOMANIAN**		
Sample No.	**Š2/VIII**	**Š15/V**	**Š49C/VIII**
sporomorph abundance in slide	L	M	M
sporomorph preservation	VP	M	M
Leiofusa jurassica Cookson et Eisenack		*	*
Lecaniella sp.		*	
Pterospermella australiensis (Deflandre et Cookson) Eisenack			*
Tetraporina sp.		*	
Veryhachium rhomboidium Downie			*
scolecodonts		*	*
foraminiferal linings		**	****
Appendicisporites sp.	*	*	*
Biretisporites sp.		*	
Camarozonosporites ambigens			*
Camarozonosporites insignis Norris	*	*	*
Cibotiumspora cf. *juncta* (Kara Murza) Zhang		*	
Cicatricosisporites cf. *proxiradiatus* Kemp	*		
Cicatricosisporites sp.	*	*	*
Clavifera triplex (Bolchovitina) Bolchovitina	*		*
Collarisporites fuscus Deák		*	
Corniculatisporites cf. *auritus* (Singh) Juhász	*		
Coronatispora perforata Dettmann			*
Cyathidites minor Couper		*	*
Dictyophyllidites sp.		*	
Echinatisporites varispinosus (Pocock) Srivastava	*	*	
Foveogleicheniidites confossus (Hedlund)	*	*	*
Foveosporites pseudoalveolatus (Couper) McKellar	*		
Gleicheniidites apilobatus Brenner			*
Gleicheniidites cf. *bolchovitinae* Döring	*		
Gleicheniidites carinatus (Bolchovitina) Bolchovitina			*
Gleicheniidites senonicus Ross emend. Skarby	***	**	**
Gleicheniidites spp.	**	*	*
Klukisporites sp.	*		
Laevigatosporites ovatus Wilson et Webster		*	*
Leptolepidites psarosus Norris		*	
Reticulosporites cretacius Pacltová et Krutzsch			*
Retitriletes austroclavatidites (Cookson) Döring et al. in W. Kr.	*	*	*
Retitriletes circolumenus (Cookson et Dettmann) Backhouse		*	
Stereisporites antiquasporites (Wilson et Webster) Kremp	*		
Retitriletes semimuris (Danzé-Corsin et Laveine) McKellar			*
Stereisporites psilatus (Ross) Pflug		*	
Vadaszisporites urkuticus Juhász		*	
Alisporites bilateralis Rouse	*		*
Alisporites cf. *grandis* (Cookson) Dettmann		*	*
Callialasporites dampieri (Balme) Sukh Dev		*	*
Corollina torosa (Reissinger) Klaus emend. Cornet et Traverse		**	*
Cycadopites cf. *follicularis* Wilson et Webster		*	
Cycadopites fragilis Singh	*		*
Cycadopites sp. A		*	
Eucommiidites minor Groot et Penny		*	*
Parvisaccites radiatus Couper	*	*	*
Parvisaccites rugulatus Brenner		*	
Phyllocladidites sp.		*	*
Podocarpidites sp.	*	**	**
Pristinuspollenites cf. *elongatu*s (Kemp) Singh		*	
Taxodiaceaepollenites hiatus (Potonié) Kremp		**	**
Taxodiaceaepollenites vacuipites (Woodhouse)			*
Vitreisporites pallidus (Reissinger) Nilsson	*	*	**
Asteropollis sp.			*
Brenneripollis peroreticulatus (Brenner) Juhász			*
Clavatipollenites sp.	*		***
Liliacidites dividuus (Pierce) Brenner			*
Liliacidites variegatus Couper			*
Psilatricolpites parvulus Norris		*	*
Psilatricolporites sp.		*	*
Retitricolporites sp.			*
Tricolpites sagax Norris	*		
Tricolpites variabilis Burger		*	*
Tricolporoidites sp.			*

Fig. 6. Distribution of sporomorph taxa and some aquatic palynomorphs in the Cenomanian deposits of Štramberk — Kotouč Quarry (Baška development), Silesian Unit. Sporomorph abundance: **L** — low, **M** — moderate , * — rare (1–3), ** — occurs (4–10), *** — common (11–20), **** — abundant (21–40 specimens). Sporomorph preservation: **VP** — very poor, **M** — moderate.

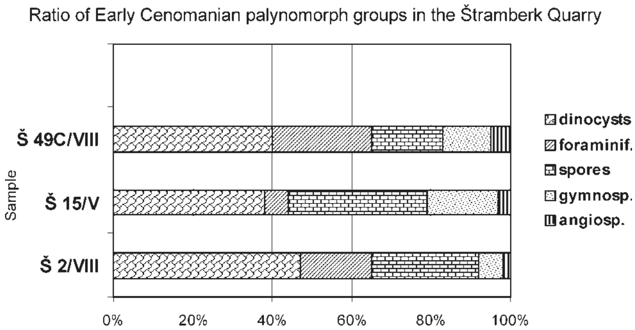

Fig. 7. Proportions of palynomorph groups of the Early Cenomanian age in the dark pelitic fillings in the limestone body of the Štramberk Member (Baška development).

Š1/VIII, Š2/VIII, Š11/VI, Š15/V, Š29/IV, Š30/IV, Š49B,C/VIII. These foraminiferal assemblages are composed of tests of agglutinated, calcareous benthic and planktonic species (Fig. 12, 13). Benthos, especially calcareous benthos, prevails in all the studied samples. The species *Trocholina remesiana* (Chapman) and *Turrispirillina* sp. are frequent much like the representants of genera *Lingulogavelinella* and *Lenticulina.* The agglutinated species *Marssonella oxycona* (Reuss), *Arenobulimina macfadyeni* Cushman, *A. preslii* (Reuss) and *Ammodiscus gaultinus* Berthelin are common. Plankton is represented mostly by species of two genera — *Hedbergella*, and the stratigraphically important *Rotalipora* (Fig. 14, 15). Only a few specimens of *Globigerinelloides ultramicra* (Subbotina) were found in sample Š2/VIII. The character of the foramin-

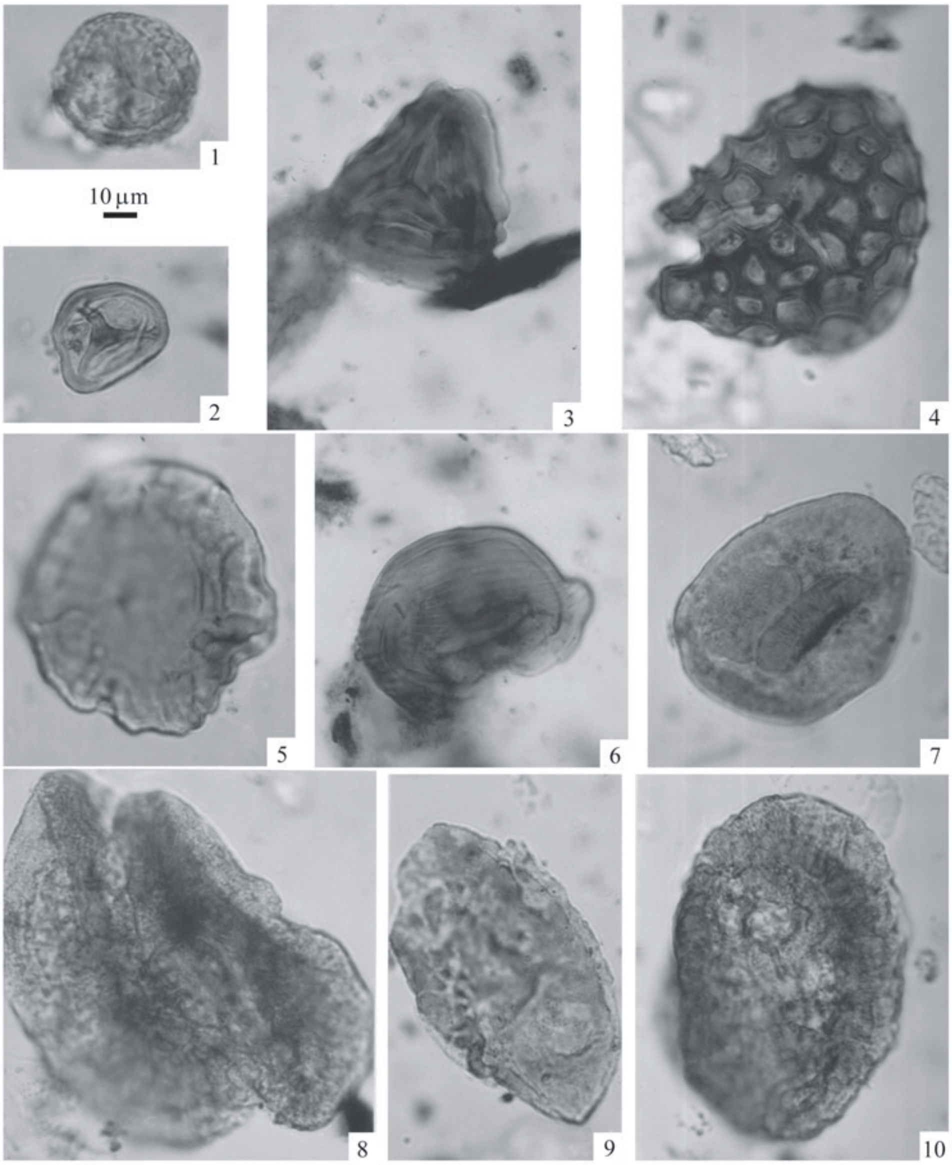

Fig. 8. Sporomorphs and some aquatic taxa from Štramberk — Kotouč Quarry. Locality name is followed by sample No. **1** — *Camarozonosporites insignis* Norris; Kotouč Quarry, 15/V. **2** — *Stereisporites psilatus* (Ross) Pflug, 1953; Kotouč Quarry, 2/VIII. **3** — *Gleicheniidites bolchovitinae* Döring, 1965; Kotouč Quarry, 15/V. **4** — *Retitriletes circolumenus* (Cookson et Dettmann) Backhouse, 1978; Kotouč Quarry, 15/V. **5** — *Callialasporites dampieri* (Balme) Sukh Dev, 1961; Kotouč Quarry, 15/V. **6** — *Corniculatisporites* cf. *auritus* (Singh) Juhász, 1977; Kotouč Quarry, 15/V. **7** — *Pristinuspollenites* cf. *elongatus* (Kemp) Singh, 1983; Kotouč Quarry, 15/V. **8** — *Alisporites* cf. *grandis* (Cookson) Dettmann, 1963; Kotouč Quarry, 15/V. **9** — *Cycadopites* sp. A; Kotouč Quarry, 15/V. **10** — *Parvisaccites rugulatus* Brenner, 1963; Kotouč Quarry, 15/V.

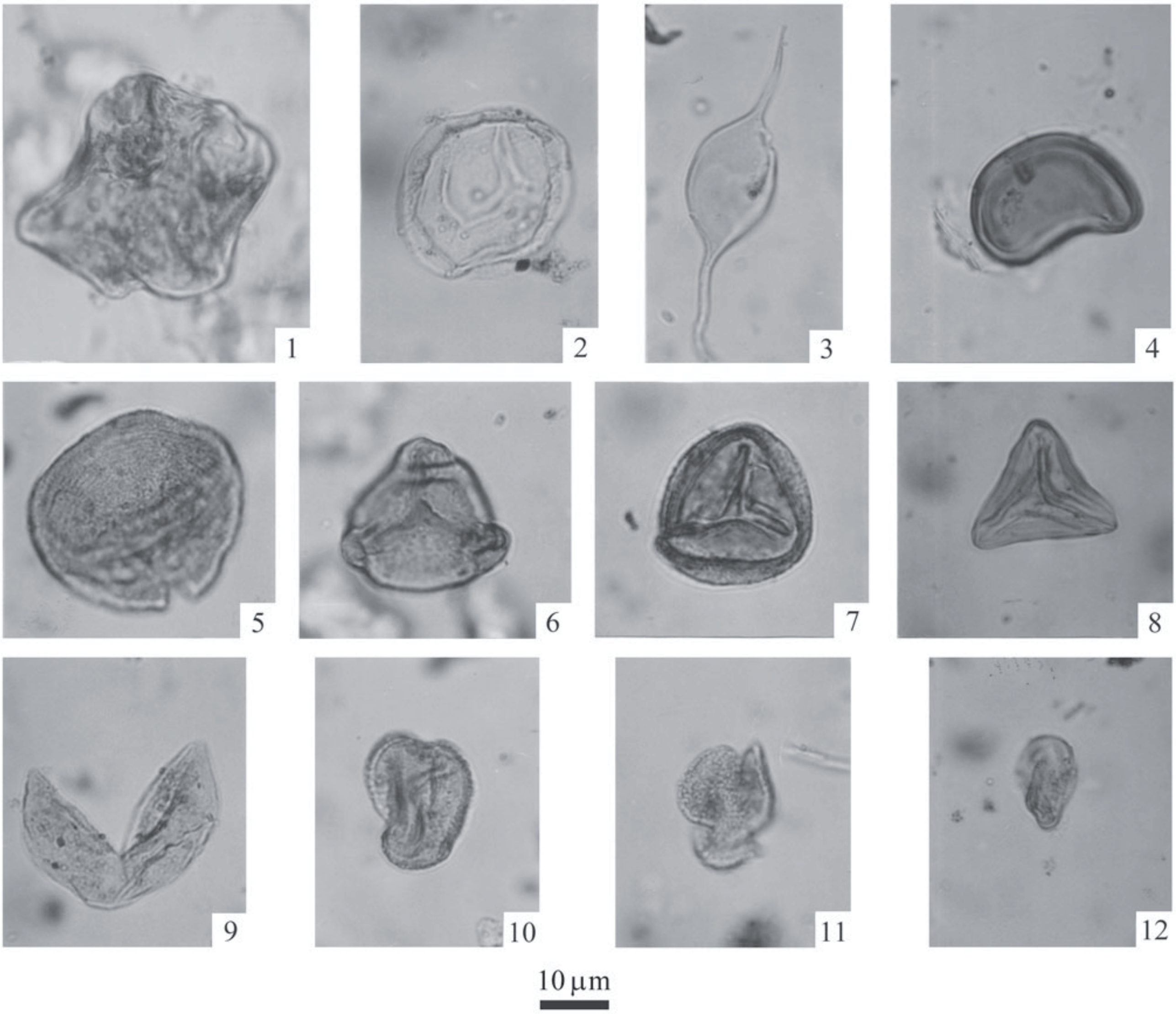

Fig. 9. 1 — *Tetraporina* sp.; Kotouč Quarry, 15/V. **2** — *Lecaniella* sp.; Kotouč Quarry, 15/V. **3** — *Leiofusa jurassica* Wall et al.; Kotouč Quarry, 15/V. **4** — *Laevigatosporites ovatus* Wilson et Webster, 1946; Kotouč Quarry, 15/V. **5** — *Corollina torosa* (Reissinger) Klaus emend. Cornet et Traverse; Kotouč Quarry, 49C/VIII. **6** — *Cibotiumspora* cf. *juncta* (Kara-Murza) Zhang, 1978; Kotouč Quarry, 15/V. **7** — *Coronatispora perforata* Dettmann; Kotouč Quarry, 49C/VIII. **8** — *Gleicheniidites senonicus* Ross emend. Skarby, 1964; Kotouč Quarry, 2/VIII. **9** — *Taxodiaceaepollenites hiatus* (Potonié) Kremp; Kotouč Quarry, 15/V. **10, 11** — *Tricolpites variabilis* Burger, 1970; Kotouč Quarry, 15/V. **12** — *Psilatricolpites parvulus* Norris, 1967; Kotouč Quarry, 2/VIII.

iferal assemblages is similar in all the studied samples (Fig. 10). Calcareous benthos prevails (42–70 %), agglutinated benthos constitutes 20–40 % of the assemblage and plankton constitutes only 10–25 %. Eighteen genera from nine families were recognized in the calcareous benthos, of which Vaginulinidae and Gavelinellidae (sensu Loeblich & Tappan 1988) are the most common. Genera *Lenticulina, Lingulogavelinella, Gavelinella* and *Trocholina* prevail in the calcareous benthos foraminiferal assemblage. The agglutinated species belong to 13 genera and 10 families, the most common of which are Ataxophragmidae, Ammodiscidae, and Spiroplectamminidae. The foraminiferal species *Rotalipora* is a typical single-keeled representative of the Tethyan Realm but Boreal elements are also present (*Gaudryina, Dorothia, Gyroidinoides* etc.).

Calcareous nannofossils

The deposits provided low- to medium-abundance, poorly preserved calcareous nannofossil assemblages. Specimens usually show strong dissolution and mechanical damage. The central areas of placoliths are mostly destroyed, which makes the identification of some species difficult (Fig. 16.10,11,21). The nannoplankton assemblages are characterized by abundant *Watznaueria barnesae*, by relatively high numbers of *Eiffellithus turriseiffelii, Eprolithus floralis* and *Prediscosphaera ponticula* (Fig. 17), and by the presence of large broadly elliptical specimens of *Manivitella pemmatoidea* (Fig. 16.25). Specimens of *Corrolithion kennedyi, Lithraphidites acutus* and *Gartnerago theta* occur rarely. High species diversity is displayed by the genera *Zeugrhabdotus* and *Watznaueria.*

DINOFLAGELLATE CYSTS	**Latest ALBIAN**			**Early CENOMANIAN**
Sample No.	**Š2/VIII**	**Š15/V**	**Š49B/VIII**	**Š49C/VIII**
Achomosphaera neptunii (Eisenack) Davey et Williams	x	x	x	x
Achomosphaera ramulifera (Deflandre) Evitt		x	x	x
Achomosphaera triangulata (Gerlach) Davey et Williams	x		x	x
Callaiosphaeridium asymmetricum (Deflandre et Courteville) Davey et Williams	x			
Circulodinium brevispinosum (Pocock) Jansonius			xx	
Circulodinium distinctum (Deflandre et Cookson) Jansonius	xx	xx	x	x
Cleistosphaeridium? *multispinosum* (C. Singh) Brideaux			x	
Cometodinium habibii Monteil	x			
Cometodinium? *whitei* (Deflandre et Courteville) Stover et Evitt	x		x	x
Coronifera oceanica Cookson et Eisenack				x
Cribroperidinium orthoceras (Eisenack) Davey		x	x	
Cymososphaeridium validum Davey	x			
Dapsilidinium multispinosum (Davey) Bujak et al.				x
Endoscrinium cf. *campanula* (Gocht) Vozzhennikova	x			x
Exochosphaeridium sp.	x	xx	x	x
Florentinia cooksoniae (C. Singh) Duxbury		x		
Florentinia laciniata Davey et Verdier		x		
Florentinia stellata (Maier) Below				x
Epelidosphaeridia spinosa Cookson et Hughes				x
Fromea amphora Cookson et Eisenack	x	x		
Gonyaulacysta cf. *cassidata* (Eisenack et Cookson) Sarjeant	x			
Gonyaulacysta sp.		x		
Heterosphaeridium sp.			xx	
Hystrichodinium pulchrum Deflandre	xx		x	xx
Hystrichosphaeridium sp.		x		
Hystrichostrongylon membraniphorum Agelopoulos				
Kiokansium unituberculatum (Tasch) Stover et Evitt	xx		xx	
Kiokansium sp.	xx		x	
Kleithriasphaeridium eoinodes (Eisenack) Davey	x	x	x	
Kleithriasphaeridium fasciatum Davey et Williams		x		
Leberidocysta chlamydata Cookson et Eisenack				
Litosphaeridium arundum (Eisenack et Cookson) Davey				x
Litosphaeridium siphoniphorum (Cookson et Eisenack) Davey et Williams	x	xx		xx
Odontochitina operculata (O. Wetzel) Deflandre et Cookson	xx	x	x	x
Oligosphaeridium? *asterigerum* (Gocht) Davey et Williams	x	x		xx
Oligosphaeridium complex (White) Davey et Williams	xx	xx	xx	xx
Ovoidinium scabrosum (Cookson et Hughes) Davey		xxx		
Ovoidinium verrucosum (Cookson et Hughes) Davey		xx		
Palaeohystrichophora infusorioides Deflandre	x		x	xx
Pervosphaeridium pseudhystrichodinium (Deflandre) Yun				xx
Pervosphaeridium truncatum (Davey) Below				x
Prolixosphaeridium sp.	x			
Protoellipsodinium spinocristatum Davey et Verdier		x		
Pterodinium cingulatum (O. Wetzel) Below	xx			x
Spiniferites ramosus (Ehrenberg) Mantell	xxx		x	xx
Spiniferites sp.		xx	x	
Surculosphaeridium? *longifurcatum* (Firtion) Davey et al.			x	x
Surculosphaeridium sp.	xx		x	
Systematophora diversispinosa (Davey et al.) Islam			xx	
Systematophora sp.		x	x	
Tanyosphaeridium sp.	x	x		
Xiphophoridium alatum (Cookson et Eisenack) Sarjeant				x
Wallodinium krutzschii (Alberti) Habib			x	x

Fig. 10. Distribution of dinoflagellate cysts in the Albian-Cenomanian deposits of Štramberk, Silesian Unit (**x** — less than 4 %, **xx** — 4–5%, **xxx** — 15–30%, **xxxx** — more than 30 %).

The quantity and diversity vary among the samples (Fig. 17). The most abundant assemblage with well preserved coccoliths was found in greenish marlstone (Š1/VIII) and dark grey claystone (Š49C/VIII) whereas the claystones of samples Š49B/VIII, Š2/VIII, Š30/IV and Š29/IV provided rare and poorly preserved nannofossil specimens. The sandy siltstone (Š15/V) contains no calcareous nannofossils.

Biostratigraphy

Age interpretation of the studied samples was determined on the basis of the presence of index microfossils. The selected specimens are plotted at Fig. 18.

Sample Š11/VI

The foraminiferal assemblage is characterized by the prevalence of genera *Lingulogavelinella* and *Lenticulina,* planktonic foraminifers are represented by genus *Hedbergella* sp. exclusively. This feature gives the evidence of the Late Albian–Cenomanian interval. The presence of the nannofossil species *Eiffellithus turriseiffelii* and the absence of the Cenomanian taxa indicate the latest Albian. No palynomorphs have been found.

Sample Š49B/VIII

Both foraminiferal and nannofossil assemblages have a similar character to the previous sample Š11/VI. The dinoflagellate cysts with *Palaeohystrichophora infusorioides*

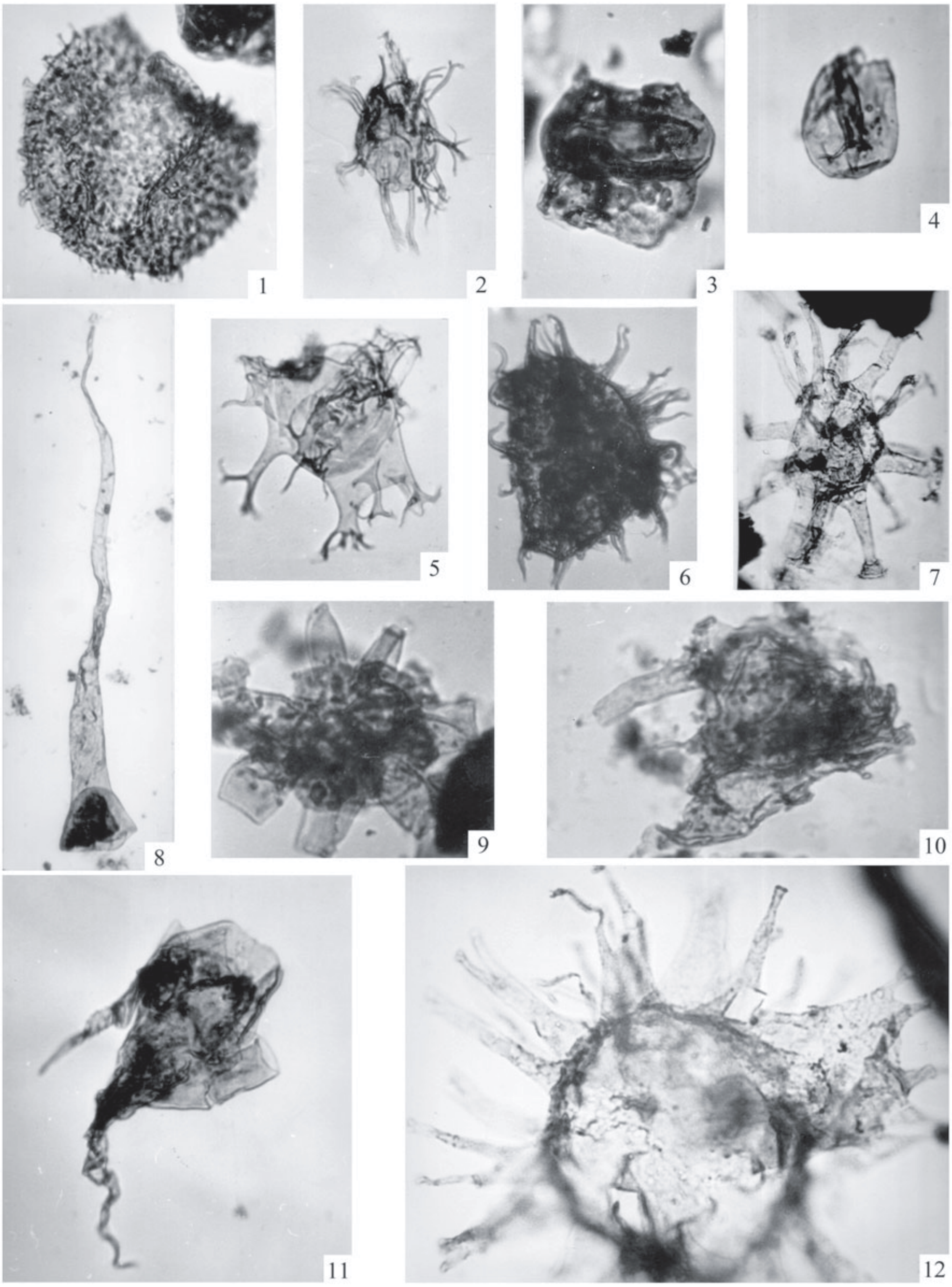

Fig. 11. Dinoflagellate cysts from Štramberk. The species name is followed by the size of the specimen, sample location and England Finder coordinates. **1** — *Circulodinium distinctum* (Deflandre et Cookson, 1955) Jansonius, 1986; body width 80 µm, 2/VIII-b, K27/28. **2** — *Surculosphaeridium* sp.; body diameter 60 µm, 2/VIII-g, W36/1. **3** — *Ovoidinium verrucosum* (Cookson et Hughes, 1964), Davey, 1970; length 60 µm, 15/V-a, N/O33. **4** — *Fromea amphora* Cookson et Eisenack, 1958; length 45 µm, 15/V-c, T36/1. **5** — *Achomosphaera ramulifera* (Deflandre, 1937) Evitt, 1963; length 62 µm, 15/V-c, P25. **6** — *Pervosphaeridium pseudhystrichodinium* (Deflandre, 1937) Yun, 1981; length 87 µm, 2/VIII-b, K28. **7** — *Kleithriasphaeridium eoinodes* (Eisenack, 1958) Davey, 1974; length 77 µm, 2/VIII-b, M18/19. **8, 11** — *Odontochitina operculata* (O. Wetzel, 1933) Deflandre et Cookson, 1955; 8. free operculum, length 114 µm, 2/VIII- h, B31/1; 11. length 105 µm, 2/VIII-f, S/T28. **9** — *Litosphaeridium siphoniphorum* (Cookson et Eisenack, 1958) Davey et Williams, 1966; diameter 43 µm, 15/V-a, T/U41. **10** — *Xenascus* sp.; length 63 µm, 2/VIII-f, J45/1. **12** — *Florentinia laciniata* Davey et Verdier, 1973; diameter 65 µm, 2/VIII-f, T28.

	FORAMINIFERA	**Late Albian - Cenomanian**				**Middle Cenomanian**				**M-L.C**
		***Rotalipora appenninica - R.cushmani* Zone**				***Rotalipora reicheli* Zone**				***R.cushmani* Zone**
	Sample No.	**Š11/VI**	**Š49B/VIII**	**Š0/VIII**	**Š15/V**	**Š49C/VIII**	**Š30/IV**	**29/IV**	**Š1/VIII**	**Š2/VIII**
agglutinated benthos	*Ammobaculites* sp.								xx	
	Ammobaculoides lepidus Hercogová								x	
	Ammodiscus gaultinus Berthelin			x				x	xx	
	Arenobulimina macfadyeni Cushman	x	x	x	x				x	
	Arenobulimina preslii (Reuss)						x	x	xx	
	Arenobulimina sp.							x		
	Ataxophragmium sp.	x		x						
	Dorothia filiformis (Berthelin)								x	
	Dorothia turris (d´Orbigny)			x						
	Gaudryina trochus (d´Orbigny)	x	x							
	Gaudryina dispanza Chapman								x	
	Glomospira irregularis (Grzybowski)								x	
	Haplophragmoides latidorsatus (Borne.)								x	
	Marssonella oxycona (Reuss)	x					xx	xx	x	
	Spiroplectammina scotti Cushm.-Alex.								x	
	Textularia foeda Reuss				x					
	Tritaxia plummerae Cushman						x			
	Trochammina sp.			x						
calcareous benthos	*Astacolus* sp.		x			x			x	
	Dentalina sp.			x		x	x		x	
	Gavelinella baltica Brotzen							x		
	Gavelinella cf. *cenomanica* (Brotzen)	x		x						
	Gavelinella sp.						x			
	Globorotalites sp.		x						x	
	Gyroidinoides infracretacea Morozova			x					x	x
	Hemirobulina linearis (Reuss)					x				
	Laevidentalina sororia (Reuss)		x							
	Lenticulina gaultina (Berthelin)	x								
	Lenticulina sp.	x			x	x			x	x
	Lingulogavelinella globosa (Brotzen)	x		xx				x		
	L.albiensis arachnoidea Gawor-Biedowa			x		x				
	Lingulogavelinella jarzevae Vasilenko	xx	xx		x		x			
	Lingulogavelinella pazdroae Gawor-B.			xx	x	xx				x
	Marginulina elongata d´Orbigny								x	
	Neobulimina minima Tappan			x	x					
	Pleurostomella reussi Berthelin								x	x
	Praebulimina avexa (Loeblich et Tappan)				x			x		
	Psilocitharella recta (Reuss)		x							
	Ramulina laevis Jones					x	x	x		
	Saracenaria triangularis (d‘Orbigny)								x	
	Trocholina remesiana (Chapman)							xxx		
	Trocholina solecensis Bielecka et Požar.							x		
	Turrispirillina sp.		x	x			x	x	x	x
plankton	*Globigerinelloides ultramicra* (Subbotina)					x				xx
	Hedbergella delrioensis (Carsey)	x			x	x	x		x	xx
	Hedbergella portsdownensis (Will.-Mit.)			x						
	Hedbergella planispira (Tappan)	x	x			x				x
	Hedbergella simplex (Morrow)					x			x	x
	Rotalipora appenninica (Renz)								x	
	Rotalipora brotzeni (Sigal)			x		x			x	
	Rotalipora cushmani (Morrow)									x
	Rotalipora greenhornensis (Morrow)					x	x		xx	
	Rotalipora reicheli Mornod						x	x	xx	
	Ticinella sp.	x	x							

Fig. 12. Distribution of foraminifers in the Albian-Cenomanian deposits of Štramberk, Silesian Unit.

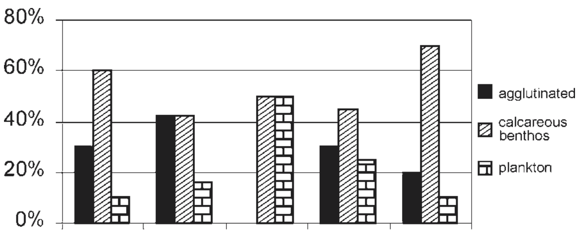

Fig. 13. Proportions of groups of foraminifers (in %) from the studied samples from the Kotouč Quarry.

and *Litosphaeridium siphoniphorum* indicate the latest Albian–Early Cenomanian. No sporomorphs have been found.

Sample Š15/V

The foraminiferal assemblage is similar to that from samples Š11/VI and Š49B/VIII indicating the Late Albian–Cenomanian interval. The dinoflagellate cysts with *Ovoidinium scabrosum, Ovoidinium verrucosum* and *Protoellipsodinium spinocristatum* indicate an age not younger than Upper Albian. Both nannofossils with *Corrolithion kennedyi* (UC1-UC2 Zone) and the high number

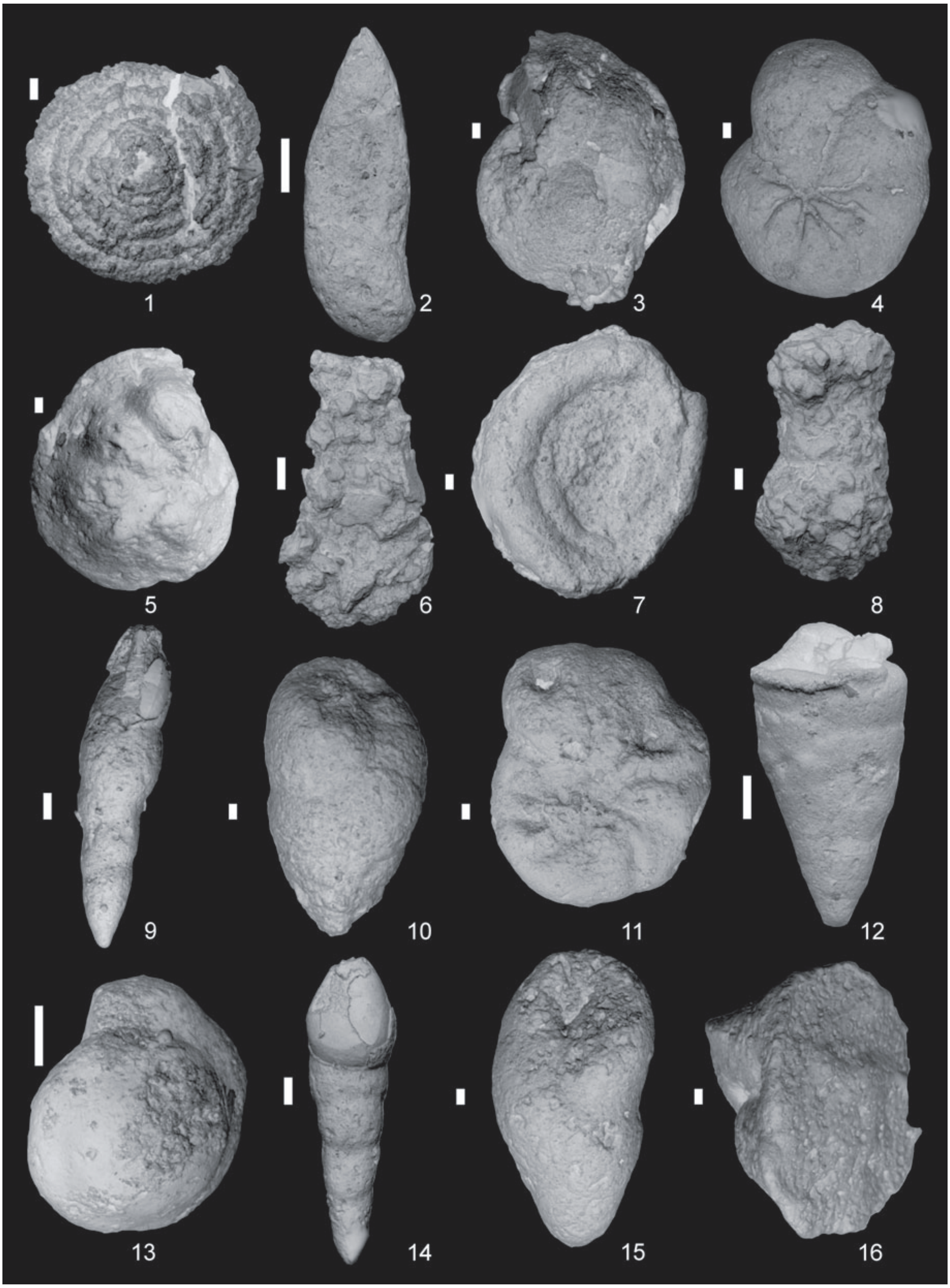

Fig. 14. Foraminifers from Štramberk — Kotouč Quarry. Species name is followed by sample No. **1** — *Turrispirillina* sp., Š0/VIII. **2** — *Astacolus* sp., Š1/VIII. **3** — *Lingulogavelinella pazdroae* Gawor-Biedowa, Š0/VIII. **4** — *Lingulogavelinella globosa* (Brotzen), Š0/VIII. **5** — *Lingulogavelinella jarzevae* Vasilenko, Š11/VI. **6** — *Ammobaculoides lepidus* Hercogová, Š1/VIII. **7** — *Ammodiscus gaultinus* Berthelin, Š1/VIII. **8** — *Ammobaculites* sp., Š1/VIII. **9** — *Pleurostomella reussi* Berthelin, Š1/VIII. **10** — *Arenobulimina preslii* (Reuss), Š1/VIII. **11** — *Lingulogavelinella albiensis arachnoidea* Gawor-Biedowa, Š0/VIII. **12** — *Dorothia turris* (d'Orbigny), Š0/VIII. **13** — *Gavelinella* cf. *cenomanica* (Brotzen), Š11/VI. **14** — *Dentalina* sp., Š1/VIII. **15** — *Neobulimina minima* Tappan, Š0/VIII. **16** — *Globorotalites* sp., Š1/VIII. Scale bars = 100 μm.

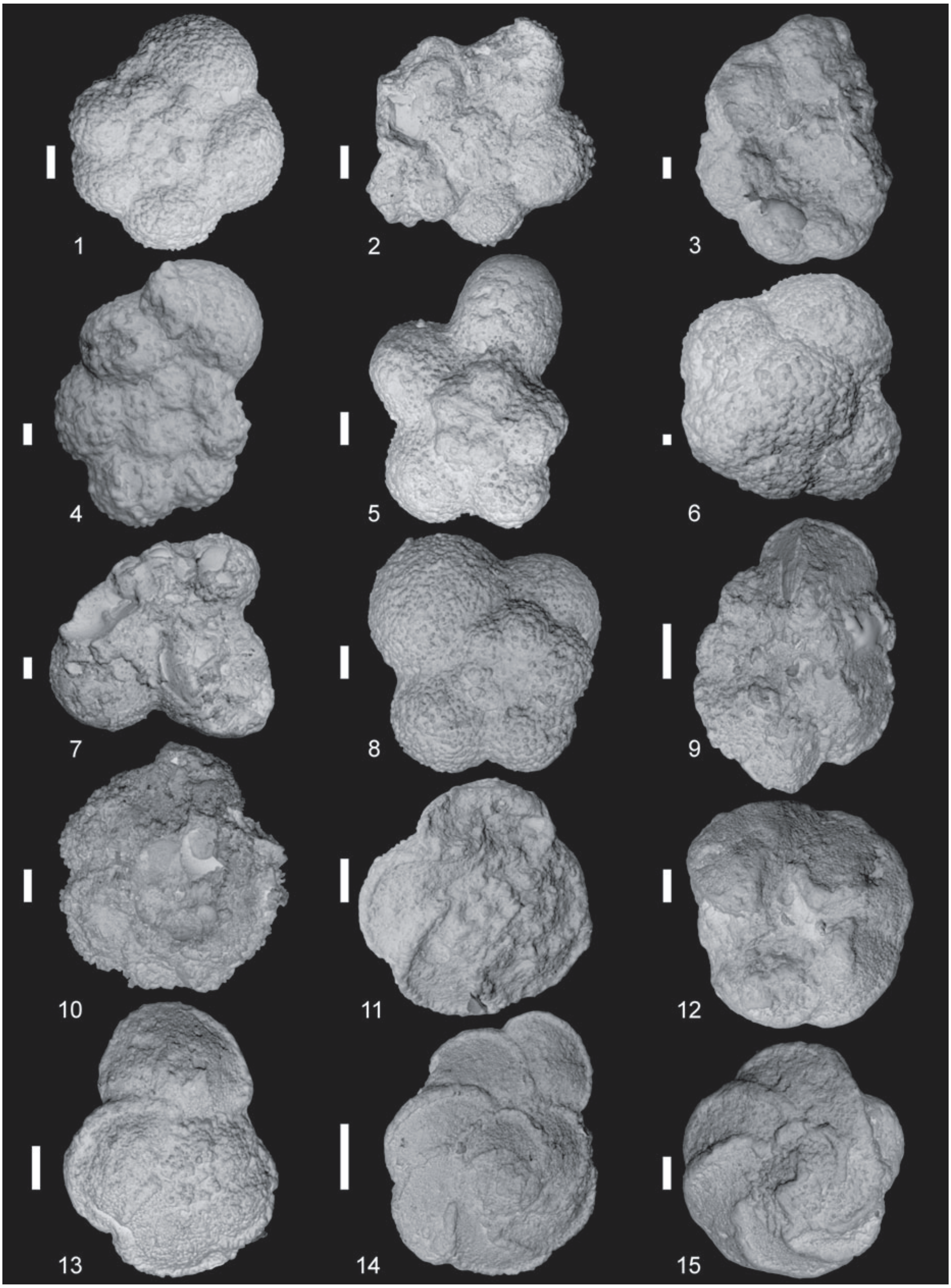

Fig. 15. **1** — *Ticinella* sp., Š11/VI. **2** — *Rotalipora*? sp., Š1/VIII. **3** — *Globigerinelloides ultramicra* (Subbotina), Š2/VIII. **4** — *Hedbergella planispira* (Tappan), Š2/VIII. **5** — *Hedbergella simplex* (Morrow), Š1/VIII. **6** — *Hedbergella portsdownensis* (Williams-Mitchell), Š0/VIII. **7** — *Hedbergella* cf. *simplex* (Morrow), Š1/VIII. **8** — *Hedbergella delrioensis* (Carsey), Š1/VIII. **9** — *Rotalipora reicheli* Mornod, Š1/VIII. **10** — *Rotalipora brotzeni* (Sigal), ventral view, Š1/VIII. **11** — *Rotalipora reicheli* Mornod, Š1/VIII. **12** — *Rotalipora appenninica* (Renz), ventral view, Š1/VIII. **13** — *Rotalipora cushmani* (Morrow), Š2/VIII. **14** — *Rotalipora greenhornensis* (Morrow), Š1/VIII. **15** — *Rotalipora appenninica* (Renz), dorsal view, Š0/VIII. Scale bars = 50 μm.

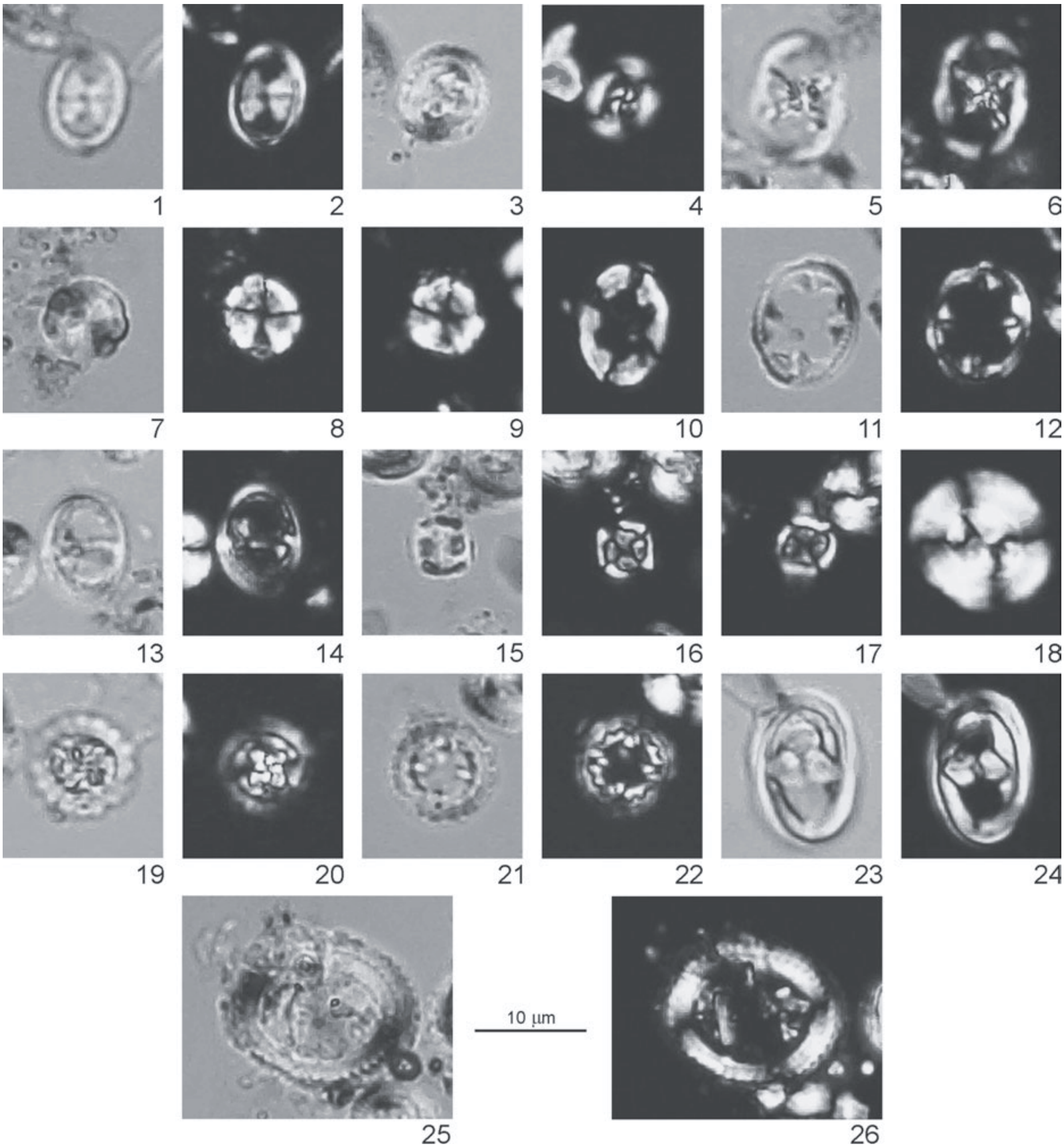

Fig. 16. Stratigraphically significant calcareous nannofossils from the Štramberk Quarry, Silesian Unit, Outer Western Carpathians. PPL — plane-polarized light; XPL — cross-polarized light. **1, 2** — *Tranolithus orionatus* (Reinhardt) Reinhardt; 1: PPL, 2: XPL. **3, 4** — *Helenea chiastia* Worsley; 3: PPL, 4: XPL. **5, 6** — *Chiastozygus litterarius* (Górka) Manivit; 5: PPL, 6: XPL. **7–9** — *Eprolithus floralis* (Stradner) Stover; 7: PPL, 8 and 9: XPL. **10** — *Eiffellithus turriseiffelii* Reinhardt; XPL. **11, 12** — *Axopodorhabdus albianus* (Black) Wind et Wise; 11: PPL, 12: XPL. **13, 14** — *Gartnerago theta* (Black) Jakubowski; 13: PPL, 14: XPL. **15–17** — *Corollithion kennedyi* Crux; 15: PPL, 16 and 17: XPL. **18** — *Watznaueria biporta* Bukry; XPL. **19, 20** — *Prediscosphaera cretacea* (Arkhangelsky) Gartner; 19: PPL, 20: XPL. **21, 22** — *Prediscosphaera ponticula* (Bukry) Perch-Nielsen; 21: PPL, 22: XPL. **23, 24** — *Zeugrhabdotus embergerii* (Noël) Perch-Nielsen; 23: PPL, 24: XPL. **25, 26** — *Manivitella pemmatoidea* (Deflandre) Thierstein; 25: PPL, 26: XPL.

of angiosperm pollen grains with *Psilatricolporites* sp., *Brenneripollis peroreticulatus, Liliacidites variegatus* and *Liliacidites dividuus* indicate the Early–?Middle Cenomanian age.

Sample Š30/IV

The presence of the foraminiferal species *Rotalipora reicheli* indicates the Middle Cenomanian age (*Rotalipora reicheli* Zone). The nannoplankton assemblage is similar to that one found in sample Š49C/VIII and gives evidence of an Early-?Middle Cenomanian age. No palynomorphs were found.

Samples Š29/IV and Š1/VIII

Both the foraminifers and nannofossils correspond to the Middle Cenomanian. The foraminiferal association has the same character as the assemblage from sample Š30/IV.

CALCAREOUS NANNOFOSSILS	**ALBIAN**		**C E N O M A N I A N**					
	Late		**Early**		**Early-Middle**		**?Middle-Late**	
Calcareous nannofossil zones	**BC27/UC0**				**UC1-?UC3a**		**?UC3-UC4**	
BC (Bown 1998); UC (Burnett 1998)	**a-b**	**b**	**c**					
Sissingh (1977)	**CC9a-b**				**CC9c**		**CC10a**	
Sample No.	**Š11/VI**	**Š49B/VIII**	**Š0/VIII**	**Š2/VIII**	**Š49C/VIII**	**Š30/IV**	**Š29/IV**	**Š1/VIII**
nannofossil abundance in sample	L	L	M	L	H	L	L	H
nannofossil preservation	P	VP	P	VP	M	VP	VP	M
Axopodorhabdus albianus (Black) Wind et Wise	R		F		F	R	R	F
Biscutum ellipticum (Górka) Grün	F			R	R	R		F
Broinsonia enormis (Shumenko) Manivit	R		R		R	R		R
Broinsonia signata (Noël) Noël	R	R		F	F		R	R
Chiastozygus litterarius (Górka) Manivit						R		R
Corollithion kennedyi Crux					F	R		
Cretarhabdus conicus Bramlette et Manivit		R	R					R
Cretarhabdus striatus (Stradner) Black	R						f	R
?*Cribrosphaerella* sp.								R
Cyclagelosphaera cf. *margerelii* Noël	R	R						
Cyclagelosphaera reinhardtii (Perch-Nielsen) Romein	R					R	R	
Discorhabdus ignotus (Górka) Perch-Nielsen	R							
Eiffellithus monechiae Crux		R						
Eiffellithus striatus (Black) Applegate et Bergen	R	R						
Eiffellithus turriseiffelii (Deflandre) Reinhardt	F	F	R	C	F	R		C
Eprolithus floralis (Stradner) Stover	R	R	C	F		F	C	F
Gartnerago theta (Black) Jakubowski				R	R	R		
Grantarhabdus coronadventis (Reinhardt) Grün								R
Haqius circumradiatus (Stover) Roth	R	R			R			
Helenea chiastia Worsley	R	F	F		F	R	R	R
Helicolithus trabeculatus (Górka) Verbeek	R					R		
Isocrystallithus sp.							?	
Lithraphidites acutus Thierstein							R	R
Lithraphidites carniolensis Deflandre	R	R	R		R			R
Manivitella pemmatoidea (Deflandre) Thierstein	F	F	C	F	F	F	C	F
Micrantholithus hoschulzii (Reinhardt) Thierstein		r						
Micrantholithus obtusus Stradner		r						
Nannoconus steinmanii Kamptner		r						
Perissocyclus fenestratus (Stover) Black								R
Prediscosphaera columnata (Stover) Perch-Nielsen	R		F	R	F	F	F	F
Prediscosphaera cretacea (Arkhangelsky) Gartner			R		F	R		
Prediscosphaera ponticula (Bukry) Perch-Nielsen			F		C	R	F	
Prediscosphaera spinosa (Bramlette et Martini) Gartner			R					
Prediscosphaera sp. (spines)	R		F					
Polypodorhabdus madingleyensis Black			R					
Radiolithus hollandicus Varol	F	F	F					R
Retacapsa angustiforata Black	R				R	R	F	
Retacapsa crenulata (Bramlette et Martini) Grün	R	R			R	R	R	
Retacapsa surrirela (Deflandre et Fert) Grün		R						
Retacapsa sp.			F					R
Rhagodiscus angustus (Stradner) Reinhardt	F	R	R	R				F
Rhagodiscus asper (Stradner) Reinhardt	R							
Rotelapillus crenulatus (Stover) Perch-Nielsen		R						
Seribiscutum primitivum (Thierstein) Filewicz et al.	F							
Speetonia colligata Black	r							
Staurolithites sp.		R						
Staurolithites crux (Deflandre et Fert) Caratini	R							
Stradneria sp.								R
Tegumentum stradneri Thierstein	R	R			R		R	
Tranolirthus gabalus Stover				R	C			
Tranolithus orionatus (Reinhardt) Reinhardt	R		R	R	C			
Tubodiscus sp.	r							
Watznaueria barnesae (Black) Perch-Nielsen	A	C	A	A	A	A	A	A
Watznaueria biporta Bukry	R	R	F	F	F			F
Watznaueria britannica (Stradner) Reinhardt	F	R	F		R	R	R	R
Watznaueria fossacincta (Black) Bown				R				
Zeugrhabdotus bicrescenticus (Stover) Burnett			R		R	R		F
Zeugrhabdotus diplogrammus (Deflandre) Burnett	F	F	F	C	F	F		C
Zeugrhabdotus embergerii (Noël) Perch-Nielsen	R	R		F	F	R	F	F
Zeugrhabdotus erectus (Deflandre) Reinhardt	F							
Zeugrhabdotus noeliae Rood et al.		F		C	F		R	C
Zeugrhabdotus scutula (Bergen) Rutledge et Bown	F		F					R
Zeugrhabdotus xenotus (Stover) Burnett	R							

Fig. 17. Distribution of nannofossil taxa in the Upper Albian and Cenomanian deposits of Štramberk Quarry, Silesian Unit, Outer Western Carpathians. Abundance of nannofossil taxa: **A** — abundant (>10%), **C** — common (5–10%), **F** — few (1–5 %), **R** — rare (<1%), **?** — questionable species, **r** — reworked species from older strata. Abundance of nannofossil specimens in sample: **H** — high (>30 specimens per field of view of microscope), **M** — moderate (10–30 specimens per field of view), **L** — low (<10 specimens per field of view). Preservation of nannofossils in sample: **M** — moderate (overgrowth and etching is apparent but the majority of specimens are easily identifiable), **P** — poor (overgrowth and etching is intensive making identification of some specimens difficult), **VP** — very poor (some specimens cannot be identified).

<table>
<tr><th rowspan="2">Sample No.</th><th rowspan="2">Lithology</th><th rowspan="2" colspan="2">Age</th><th colspan="4">Marine biostratigraphy</th><th>Non-marine biostratigraphy</th></tr>
<tr><th>Foraminiferal zones</th><th colspan="2">Nannoplankton zones</th><th>Dinoflagellate cysts</th><th>Angiosperm pollen grains</th></tr>
<tr><td>Š2/VIII</td><td>grey claystone</td><td rowspan="7">CENOMANIAN</td><td>Upper</td><td>Rotal. cushm.</td><td colspan="2"></td><td>Kiokansium unituberculatum, Litosphaeridium siphoniphorum</td><td>rare tricolpate pollen Tricolpites sagax</td></tr>
<tr><td>Š1/VIII</td><td>greenish marlstone</td><td rowspan="4">Middle</td><td rowspan="3">Rotalipora reicheli</td><td rowspan="2" colspan="2">UC3 – UC4</td><td rowspan="3">negative</td><td rowspan="3">negative</td></tr>
<tr><td>Š29/IV</td><td>green-grey sandy claystone</td></tr>
<tr><td>Š30/IV</td><td>green-grey clayey siltstone</td><td rowspan="2" colspan="2">UC1 – ?UC3</td></tr>
<tr><td>Š49C/VIII</td><td>dark grey claystone</td><td>? Rotal. reich.</td><td>Epelidosphaeridia spinosa, Litosphaeridium arundum, L. siphoniphorum</td><td>Psilatricolporites sp. Brenneripollis peroreticulatus Liliacidites dividuus</td></tr>
<tr><td>Š0/VIII</td><td>greenish marlstone</td><td rowspan="2">Lower</td><td rowspan="4"></td><td colspan="2">UC0c</td><td>negative</td><td>negative</td></tr>
<tr><td>Š15/V</td><td>sandy siltstone</td><td colspan="2">neg.</td><td rowspan="2">Ovoidinium verrucosum Protoellipsodinium spinocristatum Palaeohystrichophora infusorioides Litosphaeridium siphoniphorum</td><td>Tricolpites sagax, T. variabilis, Psilatricolporites sp.</td></tr>
<tr><td>Š49B/VIII</td><td>black claystone</td><td rowspan="2">ALBIAN</td><td rowspan="2">Upper</td><td rowspan="2">BC27/UC0</td><td>b</td><td rowspan="2">negative</td></tr>
<tr><td>Š11/VI</td><td>grey claystone</td><td>a – b</td><td>negative</td></tr>
</table>

Fig. 18. Distribution of selected index microfossil species from samples of Štramberk, Kotouč Quarry. Foraminiferal zones: ***Rotal. reich.*** — *Rotalipora reicheli*, ***Rotal. cushm.*** — *Rotalipora cushmani*.

Rotalipora reicheli corresponds to the Middle Cenomanian interval. The nannofossils are characterized by joint occurrence of *Corrolithion kennedyi* and *Lithraphidites acutus* and it is correlated with the UC3-UC4 Zone of the Middle–?Upper Cenomanian.

Sample Š2/VIII

The occurrence of the species *Rotalipora cushmani* (*Rotalipora cushmani* Zone) corresponds to the upper part of the Middle Cenomanian to Upper Cenomanian. The poor assemblage of angiosperm pollen grains (mainly *Tricolpites sagax* and the absence of the Upper Cenomanian angiosperm pollen from the Normapolles group) corresponds to Lower–Middle Cenomanian.

Note: The dinoflagellate cysts are interpreted as the uppermost Albian. The poor nannofossil assemblage is characterized by *Prediscosphaera cretacea* and *Gartnerago theta* and by the absence of "younger" Cenomanian species and so it can be correlated with the lowermost Cenomanian.

Paleoenvironmental interpretation

The spore and pollen assemblages of samples Š15/V and Š49C/VIII are also characterized by the presence of non-marine aquatic palynomorphs — *Lecaniella* sp. and *Tetraporina* sp., which are found in the fluvio-lacustrine environment. Some prasinophytes such as *Pterospermella australiensis*, acritarchs — *Veryhachium rhomboidium*, and faunal remains — chitinous foraminiferal linings (planispiral, trochospiral, biserial types) were found especially in sample Š49C/VIII. Scolecodonts were recorded in sample Š15/V and Š49C/VIII. Some palynologists such as Jarvis et al. (1988) and Courtinat et al. (1990) agree that co-occurrence of chitinous foraminifers and scolecodonts may indicate environments with low oxygen content. The presence of gymnosperm taxa *Taxodiaceaepollenites*, *Corollina/Classopollis* and some thick-walled spores from *Camarozonosporites, Cicatricosisporites, Appendicisporites, Corniculatisporites*, or *Gleicheniidites carinatus* indicates the xerophytic character of the flora.

The dinoflagellate cyst assemblages are dominated by dinocysts characterizing deep neritic sea (e.g. *Oligosphaeridium, Spiniferites*), but oceanic types (*Pterodinium cingulatum,* Lister & Batten 1988, Leereveld 1995) are also frequent in sample Š2/VIII and Š49C/VIII. A part of the assemblage is formed by dinocysts redeposited from shallow marginal parts of the sedimentary space (presence of brackish *Odontochitina* and littoral *Circulodinium* species). The dinoflagellate assemblage in sample 15/V differs markedly in the prevalence of representatives of the genus *Ovoidinum*. The composition of the dinoflagellate assemblages of_samples 15/V and 49B/VIII corresponds to shallow neritic sea. No oceanic dinocyst types appear. Littoral (*Circulodinium*, *Systematophora*) and inner neritic (*Cribroperidinum*) specimens are frequent.

The character of foraminiferal assemblages of the studied samples and their basic characteristics suggest marine sedimentation within neritic to inner shelf environments. Poor foraminiferal assemblages were found in samples Š15/V and Š2/VIII. Only eight species were found in sample Š15/V and no agglutinated foraminifers were present in sample Š2/VIII. In these two samples, each species was represented only by one or two specimens with the exception of planktonic *Globigerinelloides ultramicra* (Subbotina) and *Hedbergella delrioensis* (Carsey) in sample Š2/VIII. A few species of calcareous benthos (genera *Lingulogavelinella, Lenticulina, Neobulimina* and *Praebulimina*), which represent epifaunal to shallow infaunal deposit feeders (Koutsoukos & Hart 1990), were found in these samples. Agglutinated *Textularia foeda* Reuss was found only in sample Š15/V and was absent in other studied samples. It is possible to speculate on the basis of the poor assemblage with sporadic presence of genus *Lingulogavelinella,* which tolerates low-oxygen conditions, that the foraminifers were probably living in a dysaerobic environment. Representatives of the gavelinellids (*L. globosa, L. jarzevae, L. pazdroae)* were frequent in samples Š0/VIII and Š11/VI. Their assemblages are representative for inner shelf associations. A similar foraminiferal assemblage has been also found in the Cenomanian sediments of the Bohemian Cretaceous Basin (Uličný et al. 1993; Hradecká 1996). Foraminiferal assemblages from rather deeper neritic biotopes were found in samples Š29/IV and Š30/IV (Middle Cenomanian). Representatives of low to high conical morphotypes of genera *Trocholina* and *Turrispirillina* prevail, together with *Marssonella oxycona* (Reuss). Plankton is represented by rare occurrences of *Hedbergella delrioensis* (Carsey), *Rotalipora greenhornensis* (Morrow) and *Rotalipora reicheli* Mornod. Fragments of echinoderm spines, cyclostomate bryozoans and fish teeth were also found in both samples. *Rotalipora* is frequent in sample Š1/VIII. The relatively rich foraminiferal assemblage of this sample represents a deeper-water environment (middle to outer neritic and maybe deeper). The deepest

Sample No.	Lithology	Age		Paleoenvironmental interpretation	
Š2/VIII	grey claystone	CENOMANIAN	Upper	deep neritic sea	prevalence of calcareous foraminifers planktonic foraminifers with keeled tests deep neritic and oceanic dinocyst types
Š1/VIII	greenish marlstone		Middle		abundance of calcareous nannofossils
Š29/IV	green-grey sandy claystone				keeled planktonic foraminifers; agglutinated and calcareous conical morphotypes of benthos
Š30/IV	green-grey claeye siltstone				
Š49C/VIII	dark grey claystone				deep neritic and oœanic dinocyst types abundance of calcareous nannofossils
Š0/VIII	greenish marlstone		Lower	shallow	group of gavelinellids frequent
Š15/V	sandy siltstone			dysaerob. conditions	foraminifers toleranting low oxygen conditions (*Lingulogavelinella*) and scolecodonts; absence of calcareous nannofossils
Š49B/VIII	black claystone	ALBIAN	Upper	neritic sea	group of gavelinellids frequent
Š11/VI	grey claystone				

Fig. 19. Paleoenvironmental interpretation of main changes in marine environment during the Albian–Cenomanian in Kotouč Quarry based on foraminifers, dinocysts and scolecodonts.

biotope is also represented by agglutinated genera *Ammobaculites, Ammodiscus* and *Arenobulimina*. Specimens of the genus *Lingulogavelinella* were not found here.

Both the poor state of preservation and the low quantity of calcareous foraminifers and nannofossils reflect the paleoenvironmental, depositional and post-depositional conditions. The presence of calcareous nannofossils and microfauna indicates sea of normal salinity and depositional conditions above the carbonate compensation depth (CCD). Strong carbonate dissolution of probably post-mortem tests is supported by the following calcareous nannofossil phenomena: 1. high numbers of the genus *Watznaueria*, 2. destroyed central areas of placoliths (such as in genera *Axopodorhabdus, Eiffellithus* or *Prediscosphaera*), 3. a very low number or absence of nannofossils formed by "subtle" specimens, such as genera *Corrolithion* or *Rotelapillus*. According to Roth & Krumbach (1986), the positive correlation of organic carbon content of sediment and the relative abundance of *W. barnesae* are indicative of the carbonate dissolution caused by the release of carbon dioxide during the oxidation of organic matter.

A brief overview of the main phenomena and their paleoenvironmental interpretations were compiled into a table (Fig. 19). A shallow neritic environment with a short interval of low-salinity and dysoxic conditions is documented in the uppermost Albian and Lower Cenomanian deposition. Deepening of the sedimentary basin is evident during the Cenomanian. These data correspond to the paleogeographical reconstruction of the Outer Group of nappes of the Western Carpathians. According to Stráník et al. (1996), the Silesian Unit is the external sedimentary area of the northern part of Tethys, which was probably situated on the southeastern passive margin of the European Platform.

Note: An interesting feature was observed during the study of palynomorph residue (sample Š49C/VIII) using the scanning electron microscope — a relatively high number of calcareous nannofossils was found in the palynomorph residue after strong maceration techniques. This surprising phenomenon can be explained by the fact that calcareous nannofossils were probably mineralized by other elements which protected them from aggressive acids during the laboratory maceration

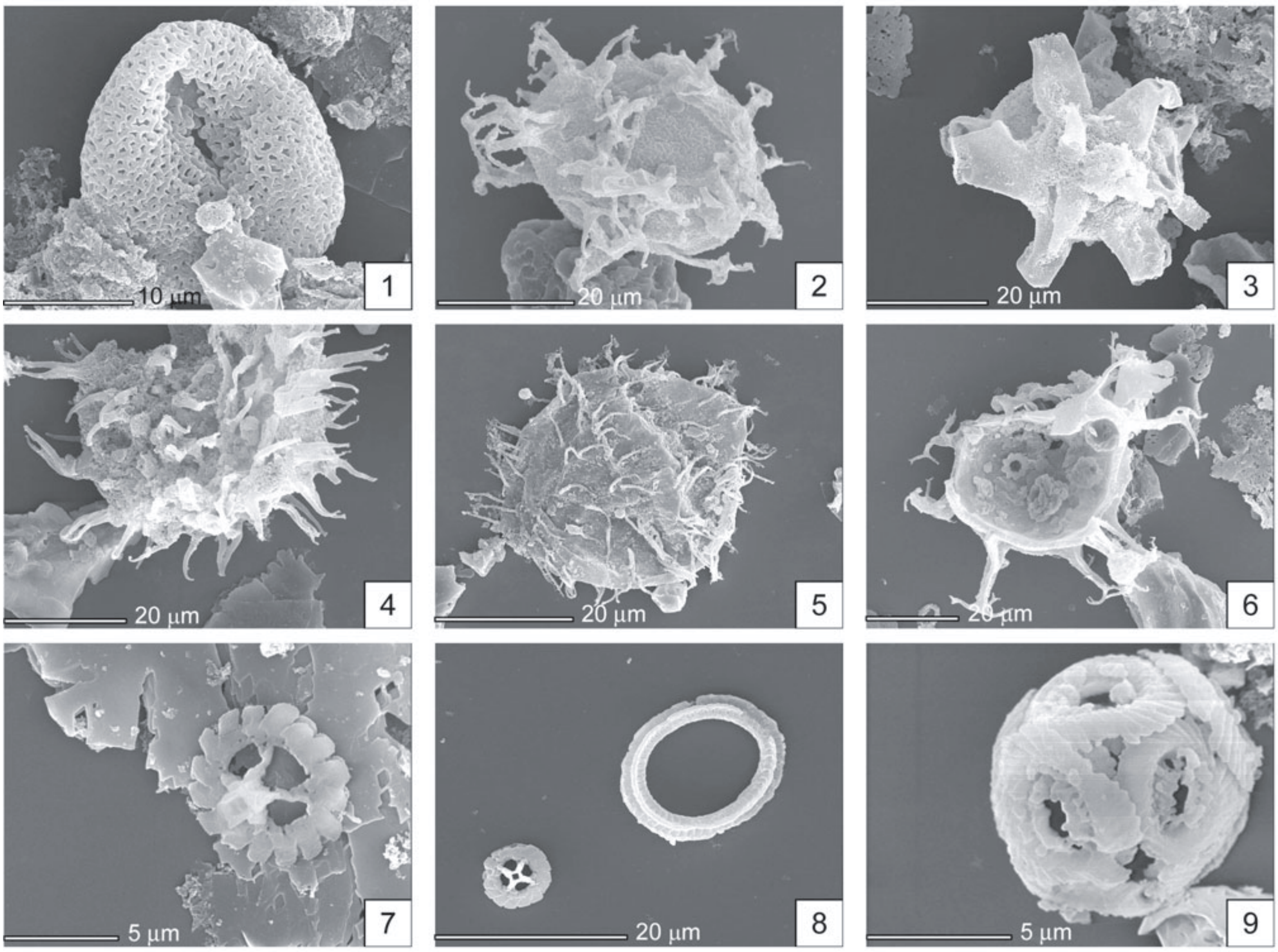

Fig. 20. Pollen grains, dinoflagellate cysts, and calcareous nannofossils. Figs. 1–9 — Štramberk sample Š49C/VIII (SEM micrographs). **1** — *Clavatipollenites* sp. **2** — *Achomosphaera neptuni* (Eisenack, 1958) Davey et Williams, 1966. **3** — *Litosphaeridium siphoniphorum* (Cookson et Eisenack, 1958) Davey et Williams, 1966. **4** — *Pervosphaeridium pseudhystrichodinium* (Deflandre, 1937) Yun, 1981. **5** — *Palaeohystrichophora infusorioides* Deflandre, 1935. **6** — dinoflagellate cyst *Spiniferites* sp. and inside nannofossil *Eprolithus floralis* (Stradner) Stover. **7** — *Prediscosphaera columnata* (Stover) Perch-Nielsen. **8** — left: *Prediscosphaera cretacea* (Archangelsky) Gartner; right: *Manivitella pemmatoidea* (Deflandre) Thierstein. **9** — *Watznaueria* sp. (coccosphere).

techniques (see Methods and Fig. 20. 6-9). Alternatively, they could have been covered by organic matter secondarily lining calcareous plates of coccoliths.

Conclusions

— The sporomorphs, dinoflagellate cysts, foraminifers and calcareous nannofossils recovered from dark grey and light greenish pelitic fills in the limestone body of the Štramberk Member allowed their assignment to the Upper Albian–Upper Cenomanian.

— Dark organic-rich sediments contain mainly palynomorphs, while light greenish highly calcareous sediments provided higher numbers of foraminifers and calcareous nannofossils.

— Mixing of Boreal and Tethyan elements in sporomorph and foraminifera assemblages was identified in the Štramberk area during the Early Cenomanian (the foraminiferal genus *Rotalipora* represents the Tethyan Realm, the Boreal elements are *Gaudryina, Dorothia, Gyroidinoides*, the sporomorphs characteristic for Tethyan realm are pteridophyte spores, *Collarisporis fuscus* and *Corniculatisporites auritus).*

— The dinoflagellate cyst assemblages from the Štramberk area confirmed the latest Albian–Cenomanian age of the pelitic fills and are correlable with the other parts of the Silesian Unit. The quantitative composition of dinocysts reflects open-sea conditions.

— Two planktonic zones were determined: *Rotalipora reicheli* Zone (Middle Cenomanian) (samples Š1/VIII, Š29/IV, Š30/IV, Š49C/VIII) and *Rotalipora cushmani* Zone (Upper Cenomanian) (sample Š2/VIII). The foraminiferal assemblages from samples Š0/VIII, Š11/VI, Š15/V, Š49B/VIII belong to zones with the stratigraphical range from *Rotalipora appenninica* to *Rotalipora cushmani* (Upper Albian–Cenomanian). Calcareous benthos prevails, agglutinated benthos is less frequent and plankton occurs occasionally.

— The presence of calcareous nannofossils and calcareous microfauna indicates the depositional conditions above the CCD. Strong post-mortem carbonate dissolution is documented by high numbers of genus *Watznaueria*, and by the low numbers or absence of nannofossils formed by "subtle" specimens.

— Gavelinellids, dinocysts and poor nannofossil assemblages document inner shelf and shallow neritic sea in the Upper Albian. A short interval of dysaerobic conditions is marked by the occurrence of foraminifers tolerating low oxygen conditions and by scolecodonts. The deepening of the sedimentary basin during the Cenomanian is supported by higher numbers of calcareous foraminifers and nannofossils.

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References

Bown P.R., Rutledge D.C., Crux J.A. & Gallagher L.T. 1998: Lower Cretaceous. In: Bown P.R. (Ed.): Calcareous nannofossil biostratigraphy. *University Press*, Cambridge, 86–131.

Burnett J.A. 1998: Upper Cretaceous. In: Bown P.R. (Ed.): Calcareous nannofossil biostratigraphy. *University Press*, Cambridge, 132–199.

Courtinat B., Crumiére J. & Méon H. 1990: Les organoclastes du Cénomanien supérieur du bassin Vocontien (France): les scolecodontes. *Geobios* 23, 4, 387–397.

Eliáš M. 1970: Lithology and sedimentology of the Silesian Unit in the Moravskoslezské Beskydy Mts. *Sbor. Geol. Věd* G, 18, 7–99 (in Czech).

Eliáš M. 1983: Notes to the origin of the Štramberk Limestones. *Věst. Ústř. Úst. Geol.* 58, 4, 235–239 (in Czech).

Eliáš M. & Eliášová H. 1965: Sedimentology and paleoecology of Štramberk limestones (Moravia-Silesian Beskid in ČSSR). *Rep. Carpatho-Balkan Geol. Assoc.*, VII Congr. Sofia II, 1, 257–259.

Eliáš M. & Stráník Z. 1963: To the origin of the Štramberk limestones. *Věst. Ústř. Úst. Geol.* 38, 2, 133–136 (in Czech).

Eliáš M., Vašíček Z. & Skupien P. 2003: A proposal to the modificatiation of the lithostratigraphical division of the lower part of the Silesian Unit in the Bohemian territory (Outer Western Carpathians). *Sbor. Věd. Prací Vys. Šk. Báň. (TU Ostrava) Ř. Horn.-Geol.—Monografie* 8, 7–13 (in Czech).

Hanzlíková E. 1962: Microbiostratigrafical evaluation of the Štramberk boreholes No. 18, 21, 23, 24, 25, 26, 27, 28, 29, 30. *MS Archiv Ústř. Úst. Geol.* (in Czech).

Hanzlíková E. 1973: Foraminifera of the variegated Godula member in Moravia (Cenomanian-Turonian). *Sbor. Geol. Věd*, Ř. P. 15, 119–184.

Hanzlíková E. & Roth Z. 1963: Review of the Cretaceous stratigraphy of the flysch zone in West Carpathians. *Geol. Sbor. Slov. Akad. Vied* 14, 1, 37–81.

Hluštík A. 1979: Fossil gymnosperms from the Plaňava Formation (Hauterivian), Štramberk (Moravia). *Čas. Morav. Muz., Vědy Přír.* 64, 25-36 (in Czech).

Houša V. 1976: Lower Cretaceous sequences accompanying the Tithonian Štramberk Limestones at Štramberk. *Čas. Slez. Muz., Sér. A* 25, 65–85, 119–131 (in Czech).

Houša V. 1987: Stratigraphy and calpionellid zonation of the Stramberg Limestone and associated Lower Cretaceous beds. *Atti II Conv. Int. F.E.A. Pergola* 87, 365–370.

Houša V. & Vašíček Z. 1996: Lower Cretaceous ammonites from the envelope formation of the Štramberk limestone bodies. *Zpr. Geol. Výzk. v Roce 1995*, 95–96.

Hradecká L. 1996: *Gavelinella* Brotzen, 1942 and *Lingulogavelinella* Malapris, 1969 (Foraminifera) from the Bohemian Cretaceous Basin. *Sbor. Geol. Věd*, *Ř. P.* 33, 79–96.

Jarvis J., Carson G.H., Cooper M.K.E., Hart M.B., Leary P.N., Tocher B.A., Horne D. & Rosenfeld A. 1988: Microfossil assemblages and the Cenomanian-Turonian (late Cretaceous) oceanic anoxic event. *Cretaceous Research* 9, 3–103.

Juhász M. 1983: Palynostratigraphic zonation of the Transdanubian Middle Cretaceous. *Acta Geol. Hung.* 26, 1–2, 41–68.

Koutsoukos E.A.M. & Hart M.B. 1990: Cretaceous foraminiferal morphogroup distribution patterns, palaeocommunities and trophic structures: a case study from the Sergipe basin, Brazil. *Trans. Roy. Soc. Edinburg, Earth Sci.* 81, 221–246, Part 3.

Krejčí O., Adamová M., Bubík M., Fojt B., Přichystal A. & Švábenická L. 1999: Geological structure of the Silesian and Subsilesian units in the Bečva riverbed after outcrop. *Geol. Výzk. Mor. Slez. v Roce 1998,* 56–65 (in Czech).

Leereveld H. 1995: Dinoflagellate cysts from the Lower Cretaceous Río Argos succession (SE Spain). *LPP Contribution Series 2*, 1–175.

Lister J.K. & Batten D.J. 1988: Stratigraphic and palaeoenvironmental distribution of Early Cretaceous dinoflagellate cysts in the Hurlands Farm Borehole, west Sussex, England. *Palaeontographica*, *Abt. B* 210, 8–89.

Loeblich A.R. Jr. & Tappan H. 1988: Foraminiferal genera and their classifications. *Van Nostrand Reinhold,* New York, 1–1127.

Matějka A. & Roth Z. 1949: Preliminary notes to the geology of the Moravskoslezské Beskydy Mts. *Sbor. Stát. Geol. Úst*. 293–328 (in Czech).

Matějka A. & Roth Z. 1955: Preliminary report to the geological mapping of the Štramberk area. *Zpr. Geol. Výzk. v Roce 1954,* 110–113 (in Czech).

Menčík E., Adamová M., Dvořák J., Dudek A., Jetel J., Jurková A., Hanzlíková E., Houša V., Peslová H., Rybářová L., Šmíd B., Šebesta J., Tyráček J. & Vašíček Z. 1983: Geology of the Moravskoslezské Beskydy Mts. and Podbeskydy hills. *Rozpr. Ústř. Úst. Geol., ČSAV* 1–304 (in Czech).

Pícha F., Stráník Z. & Krejčí O. (in print): Geology and hydrocarbon resources of the Outer West Carpathians and their foreland, Czech Republic. *AAPG Memoirs.*

Robaszynski F. & Caron M. 1995: Foraminiféres planctoniques du Crétacé: commentaire de la zonation Europe-Méditerranée. *Bull. Soc. Geol. France* 166, 681–692.

Roth Z. et al. 1962: Explanations to the geological map of the ČSSR 1 : 200,000 M-34-XIX Ostrava. *Geofond*, Praha, 1–292.

Roth P.H. & Krumbach K.P. 1986: Middle Cretaceous calcareous nannofossil biogeography and preservation in the Atlantic and Indian Oceans: Implications for paleoceanography. *Marine Micropaleont.* 10, 235–266.

Sissingh W. 1977: Biostratigraphy of Cretaceous calcareous nannoplankton. *Geol. en Mijnb.* 56, 37–65.

Skupien P. 1997: Iventory of Barremian-Albian dinoflagellate cysts of the Silesian Unit in the Outer Western Carpathians (Czech Republic). *Sbor. Věd. Prací Vys. Šk. Báň. (TU Ostrava)*, *Ř. Horn.-Geol.* Spec. Issue, 34–42.

Skupien P. 1999a: Dinoflagellate cysts distribution of Albian–Cenomanian sections from the Outer Western Carpathians. *Věst. Čes. Geol. Úst.* 74, 1, 1–10.

Skupien P. 1999b: Non-calcareous dinoflagellate cysts of the Lower Cretaceous deposits of the Godula development in the Silesian Unit. *PhD Thesis*, *VŠB- TU*, Ostrava, 1–202 (in Czech).

Skupien P. & Vašíček Z. 2003: Lithostratigrafical and biostratigrafical knowledge from the Bystrý potok near Frenštát p. R. profile (Upper Cretaceous, Silesian Unit of the Outer Western Carpathians). *Sbor. Věd. Prací Vys. Šk. Báň. (TU Ostrava)*, *Ř. Horn.-Geol.—Monografie* 8, 65–93 (in Czech).

Stráník Z., Bubík M., Čech S. & Švábenická L. 1996: The Upper Cretaceous in South Moravia. *Věst. Čes. Geol. Úst.* 71, 1, 1–30.

Stráník Z., Bubík M. & Švábenická L. 1997: Upper Cretaceous age of the conglomerates from Starý Jičín. *Geol. Výzk. Mor. Slez. v Roce 1996,* 43–44 (in Czech).

Svobodová M. 1998: Preliminary results of the palynological investigation of dark pelitic sediments accompanying the Štramberk Limestone body. *Zpr. Geol. Výzk. v Roce 1997*, 71–72 (in Czech).

Svobodová M. & Brenner 1999: Correlation of mid-Cretaceous plant microfossils from the Raritan Formation of the Atlantic Coastal Plain with the Peruc-Korycany Formation of the Blansko Graben. *Acta Palaeobot.* Suppl. 2*,* 199–210.

Svobodová M. & Vavrdová M. 1987: Some fossil microplankton from the Bohemian Cretaceous. *Věst. Ústř. Úst. Geol.* 62, 165–178.

Svobodová M., Méon H. & Pacltová B. 1998: Characteristics of palynospectra of the Upper Cenomanian-Lower Turonian (anoxic facies) of the Bohemian and Vocontian Basins. *Věst. Ústř. Úst. Geol.* 73, 3, 229–251.

Uličný D., Hladíková J. & Hradecká L. 1993: Record of sea-level changes, oxygen depletion and the δ^{13} C anomaly across the Cenomanian-Turonian boundary, Bohemian Cretaceous Basin. *Cretaceous Research* 14, 211–234.

Vavrdová M. 1964a: *Trubasporites* n.g. and some other sporomorphs of the Carpathian Lower Cretaceous. *Čas. Nár. Muz., Odd. Přírodověd.* 133, 1, 37–40 (in Czech).

Vavrdová M. 1964b: Fossil microplankton from the Těšín-Hradiště Series (Lower Cretaceous). Part 1. Dinoflagellates. *Sbor. Geol. Věd*, *Ř. P.* 4, 91–104.

Vavrdová M. 1981: Plant microfossils from the Lower Cretaceous of Štramberk, Czechoslovakia. *Čas. Mineral. Geol.* 26, 4, 421–426.