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New biostratigraphic evidence (calcareous nannofossils, ostracods, foraminifers, ammonites, inoceramids) on the Middle Coniacian in the eastern Bohemian Cretaceous Basin

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The classical locality of Svinary in the eastern Bohemian Cretaceous Basin is the site of new biostratigraphic investigations. Besides some scarce macrofossil evidence, bulk sediment samples were processed to retrieve micropalaeontological assemblages, and calcareous nannofossil smear slides were analysed. The studied material provided calcareous nannofossil assemblages including *Micula staurophora, Lithastrinus septenarius* and *Broinsonia parca expansa*, thus documenting the Middle Coniacian (upper part of UC10 Zone and lower part of UC11 Zone). The foraminifera assemblage is relatively rich, planktonic species show a wide stratigraphical range, while the benthic association represented by *Neoflabellina suturalis suturalis* and *Gaudryina carinata* is very similar to the Coniacian biozone of *Stensioeina granulata-Eponides whitei*, valid for the Bohemian Cretaceous Basin. Ostracods are represented by two common cytherellid species, and two rare ornamented species: *Imhotepia marssoni*? and *Pterygocythereis spinosa*. Inoceramid bivalves, namely *Platyceramus mantelli*, and a newly recorded ammonite, *Tridenticeras tridens*, support the late Middle Coniacian age of the Svinary outcrop. New biostratigraphic results are given along with palaeoecological interpretations of newly collected fossil material.

Key words: biostratigraphy, Coniacian, Late Cretaceous, Březno Formation, Bohemian Cretaceous Basin, Czech Republic

INTRODUCTION

The Upper Cretaceous strata of the Bohemian Cretaceous Basin (BCB) have been intensely studied by numerous authors (i.e. Krutský et al., 1975; Čech et al., 1980; Čech, 1989, 2011; Čech and Švábenická, 1992, 2017; Uličný et al., 1997, 2009, and others); the stratigraphy based on faunal assemblages of these sequences is the core of several papers (Čech and Švábenická, 1992, 2017; Košťák et al., 2004; Svobodová et al., 2014; Nádaskay et al., 2017). Although they provided important and relevant information on the Cretaceous System of the BCB, the Middle Coniacian deposits have been less thoroughly studied than older strata (e.g., Čech and Švábenická, 1992; Lees, 2008). In 2016 and 2017, field works were conducted on the Svinary outcrop where the Middle Coniacian succession is best exposed. The outcrop provided a continuous biotic record allowing a bed-by-bed collecting of numerous stratigraphically significant fossils, such as calcareous nannoplankton, foraminifers, inoceramid bivalves, and rare ammonites. Hereby, we introduce a new record of a tridenticerid heteromorph ammonite within the BCB. This paper presents new data to reconstruct the palaeoenvironment of these faunal assemblages, and subsequently to get a more precise age of the Svinary deposits. The new fossil record definitely contributes to a better knowledge of the Middle Coniacian succession in the eastern part of the BCB (Fig. 1).

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GEOLOGICAL AND GEOGRAPHICAL SETTINGS

The classical locality of Svinárky was first mentioned by Frič (1889). This locality is situated on the right bank of the Orlice River in the vicinity of Svinary, close to the house No. 19, east of Hradec Králové (Fig. 2A). The natural outcrop itself, showing soft grey calcareous claystones (Fig. 2B), exceeds 15 m in its overall thickness (Fig. 3). Frič (1889) assigned the locality to the Upper Turonian of the Teplice layers. Later, Zahálka (1949) dated this section as the Upper Turonian (zones Xa, b, c) Scaphites Zone, mentioning the following species: *Mesocrinus fischeri* (Geinitz), *Ostrea vesicularis* (Lamarck), *Leda semilunaris* (von Buch), *Inoceramus cuvieri* Sowerby (non Goldfuss), and *Inoceramus costellatus* Woods. Soukup (1962) was the first who attributed the Svinary deposits to the Coniacian upper series of Xeα with argillaceous pelosiderite concretions. He challenged Zahálka's (1949) identification of the inoceramid fauna, especially that of *Inoceramus costellatus* Woods.

Soukup (1962) mentioned in his guide (p. 90): "... From the wider area around Svinárky are known outcrops of the formation with pelosiderite concretions (Xeα), which belongs to the *Inoceramus koeneni* Zone; in a number of surrounding outcrops are also occurring small, irregularly spherical and cylindrical clay-phosphate concretions (with about 15% P_2O_5) in carbonate claystones, which are very characteristic of the same facies of the Březno layers in various regions of the Bohemian Cretaceous Basin...".

So far, the biostratigraphy of this locality has been based on macrofossils, especially inoceramid bivalves that were studied in detail for both taxonomic and stratigraphic purposes. Nevertheless, other biostratigraphic elements (micro- and nannofossils) have been put aside. Therefore, the present study aims to compile new fossil material from the Svinary outcrop to update the biostratigraphy of the studied section.

MATERIAL AND METHODS

CALCAREOUS NANNOFOSSILS

Calcareous nannofossils were analysed in smear slides prepared by the decantation method using a 7% solution of H_2O_2 (e.g., Švábenická, 2012) and mounted in Entellan. A total of 15 samples were examined under an *Olympus BX51* light microscope using an immersion objective with a 100× magnification. Digital images of nannofossil specimens were made using an *Olympus DP70* digital camera. In order to obtain the relative nannofossil abundances and semi-quantitative information about the respective calcareous nannofossil assemblages, 500 specimens were counted in each slide. Biostratigraphic data were then interpreted with reference to the UC zones of Burnett (1998). Smear slides are now stored in the palaeontological collections of the National Museum in Prague, under registration number NM-d27/2018.

OSTRACODS, FORAMINIFERS AND ASSOCIATED MACROFAUNA

For micropalaeontological purposes, bulk rock samples were collected every 1 m from the base of the profile up to its top on the right side of the natural outcrop. Samples were also taken from several levels: ~200 g sample for foraminifers, another one for ostracods. Bulk samples had been chemically processed with a 10% acetic acid solution for 24 hours and with a 10% hydrogene peroxide for 1 hour, and then washed and sieved through a 0.063 mm mesh-sized sieve. Subsequently, fossils from this fraction were sorted, hand-picked and identified under a Bresser binocular microscope (20× to 40× magnification).

Photos of microfossil material were taken using a scanning electron microscope (*SEM Hitachi S-3700N*) in low vacuum. Macrofossils were photographed under angled light using a

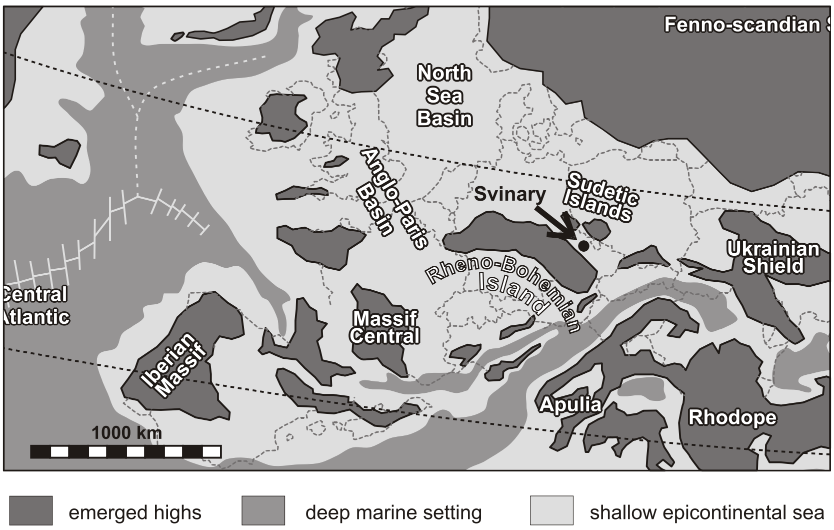


Fig. 1. Palaeogeographic position of the Bohemian Cretaceous Basin (Upper Cretaceous) and the Svinary locality (marked with arrow)

Modified after Košťák et al. (2018)

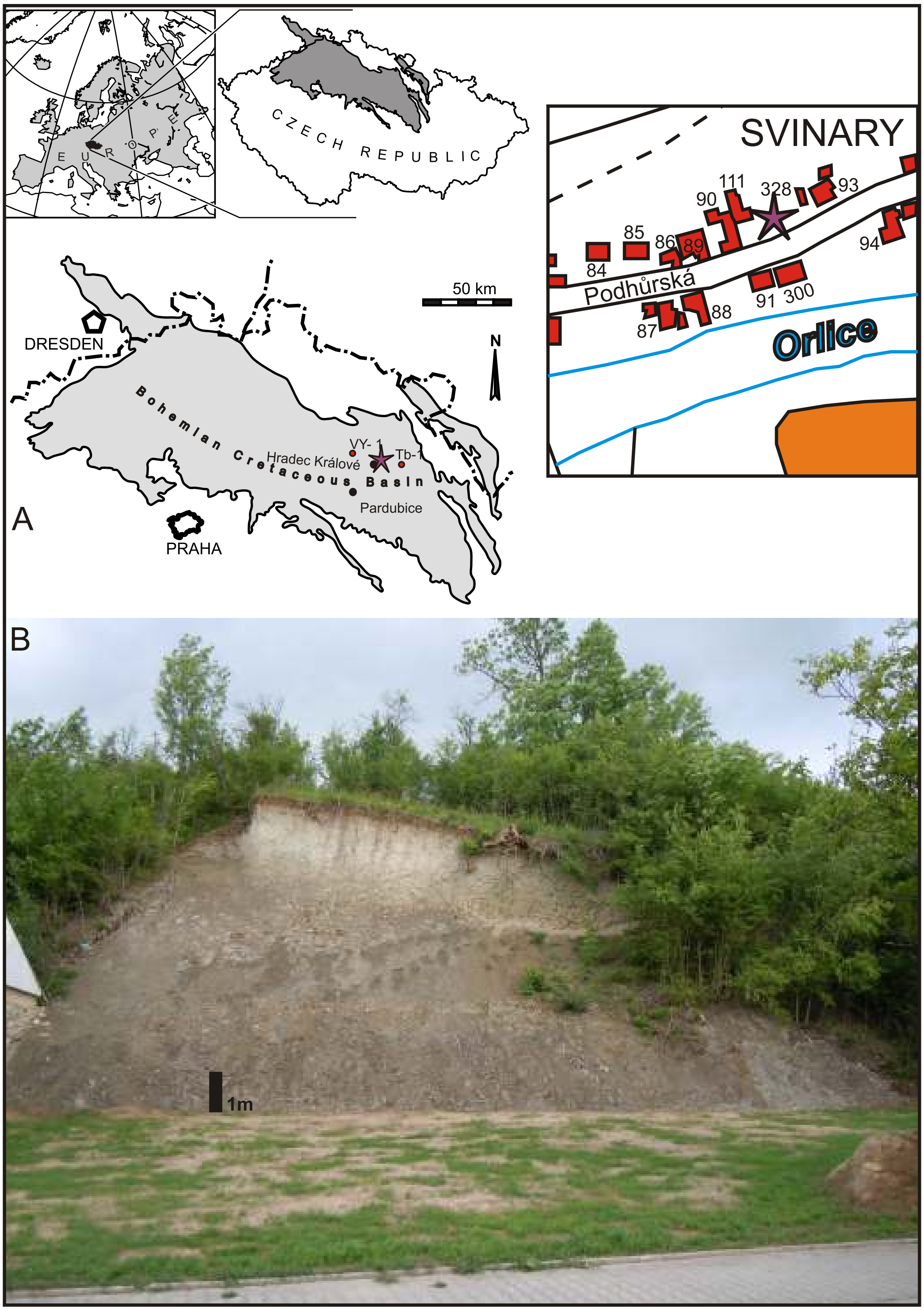


Fig. 2. Geographical location of the Middle Coniacian locality of Svinary within the Bohemian Cretaceous Basin and Europe (A); picture of the Svinary section (B)

Canon EOS 550D digital camera. In view of the clayey character of the sediment, coating of specimens with ammonium chloride for photography to enhance contrast deemed unfeasible. Specimens were measured using the microphotography setting of the *Olympus DP70*. Measurements are given in millimetres (mm). All micro- and macrofaunal material is deposited in the palaeontological collections of the National Museum in Prague, under registration numbers NM-O8455-62.

RESULTS

CALCAREOUS NANNOFOSSILS

The samples provide mostly moderately preserved and relatively abundant nannofossil assemblages. In total, 68 calcareous nannofossil taxa were identified. Detailed information about

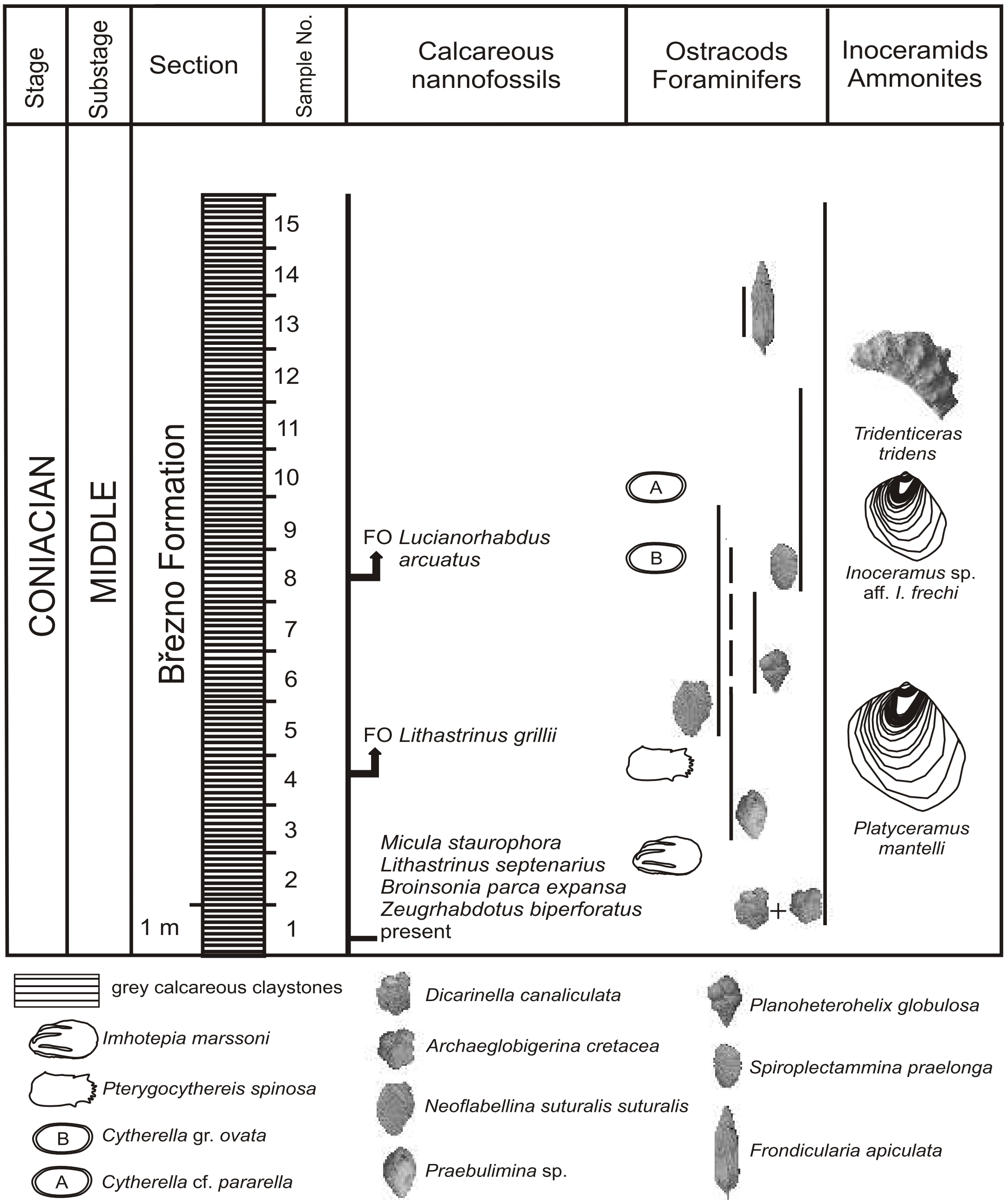


Fig. 3. Stratigraphic and lithologic profile of the Middle Coniacian locality of Svinary

nannofossil distribution and abundance is given in Table 1. The most significant components of the assemblage (20–30%) is *Watznaueria barnesiae* (Fig. 4S), followed by *Micula staurophora* and *Broinsonia parca expansa*. Other quantitatively significant taxa are *Eiffellithus turriseiffellii*, *Zeugrhabdotus scutula*, *Z. diplogrammus*, and *Helicolithus trabeculatus*. Less frequently, but continuously occurring species are *Marthasterites furcatus*, *Micula concava*, *Gartnerago obliquum*, *Kamptnerius magnificus*, *Prediscosphaera cretaceae*, *Lucianorhabdus maleformis*, *Eiffellithus eximius* and *Lithraphidites carniolensis*. Rare and irregular occurrences of stratigraphically significant taxa (e.g., *Lithastrinus septenarius*, *L. grillii*, *Lucianorhabdus arcuatus* and *Zeugrhabdotus biperforatus*) were also observed (Figs. 4 and 5). A list of calcareous nannofossil taxa in alphabetical order is given in Appendix 1*.

* Supplementary data associated with this article can be found, in the online version, at doi: 10.7306/gq.1489

Chronostratigraphy, nannofossil zonation and vertical distribution

Chronostratigraphy		Nannoplankton zones (Burnett 1998)		Sample	Nannofossil abundance (specimens per 1 field of view)	*Acuturris scotus*	*Ahmuellerella octoradiata*	*Biscutum constans*	*Biscutum ellipticum*	*Biscutum melaniae*	*Braarudosphaera bigelowii bigelowii*	*Braarudosphaera bigelowii parvula*	*Broinsonia enormis*	*Broinsonia parca expansa*	*Broinsonia signata*	*Calculites obscurus*	*Calculites ovalis*	*Chiastozygus litterarius*	*Cribrosphaerella ehrenbergii*	*Cyclagelosphaera margerelii*	*Cylindralithus biarcus*	*Eiffellithus eximius*	*Eiffellithus gorkae*	*Eiffellithus turriseiffelii*	*Eprolithus floralis*	*Eprolithus moratus*	*Gartnerago obliquum*	*Grantarhabdus coronadventis*	*Helicolithus trabeculatus*	*Kamptnerius magnificus*	*Lithastrinus grillii*	*Lithastrinus septenarius*	*Lithraphidites carniolensis*	*Lucianorhabdus arcuatus*	*Lucianorhabdus maleformis*
MIDDLE CONIACIAN	Upper part	UC11	UC 11 a-b subzones (part)	15	30-40	R	F		R		R		F	C	R		R	F	R		F	C	F	C	R	R	C	R	C	F		F	R	F	F
				14	30-40	R	R		R				R	C	R		R	F			R	C	F	C	F		C	R	C	F			R	R	F
				13	30-40				R				R	C	R		R	F	R		F	C	F	C	F		F	R	C	C		R	R	F	F
				12	30-40		R		F				R	C	F		R	F	R		R	C	F	C	R		C	R	C	C		R	F	F	F
				11	30-40	R	R		R				R	C	R		R	F	R		F	F	F	C	R		C	R	C	C		F	F	F	F
				10	30-40		R		F		R		R	C	R		F	F	R		F	F	F	C	F		C	R	C	C			R	F	F
				9	30-40	R	F						R	C	F	R	F	F	R		F	F	F	C	R	R	C	R	C	C	R	F	R	F	F
				8	30-40		F	R	R				R	C	R		F	F	R	R	F	C	F	C			C	R	C	F		R	R	F	C
				7	30-40	R	F		R				R	C	F		R	F	F		R	F	F	C	R	R	C	R	C	R		F	R		F
				6	30-40		F		R				R	C	R			F	R		F	F	F	C	R		C	R	C	F		F	F		F
				5	30-40		F		R				R	C	F			F	F		R	C	F	C			C	R	C	F		F	F		R
				4	20-30		F				R		R	C	F		R	F			R	C	C	C	R	R	C	R	C	C	R	R	R		F
	Lower part	UC10	(part)	3	20-30		R				R		F	C	R			F	R		F	C	C	C	F	R	F	R	C	F			R		F
				2	15-25	R	F			R	R		F	C	R	R		F			F	F	F	C	F	R	F	F	C	C			F		F
				1	15-25		F					R	F	C	F		R	F	F	R	R	C	F	C	F	R	F		C	C		F	R		F

A – abundant (more than 100 specimens per sample); C – common (11–100 specimens per sample);

OSTRACODS

The successive ostracod assemblages in this Middle Coniacian locality are generally poor in both specimens and species. Every ostracod sample contains a maximum of four species, namely *Cytherella* gr. *ovata* (Roemer, 1841), *Cytherella* cf. *parallela* (Reuss, 1846), *Imhotepia marssoni*? (Pokorný, 1984) and *Pterygocythereis spinosa* (Reuss, 1846) (see Fig. 6). Pokorný (1979) provided a schematic table of ostracod ranges for the Bohemian Cretaceous Basin and erected eight ostracod assemblage zones. His youngest ostracod zone Cd corresponds to the lower part of the *Inoceramus* (*Volviceramus*) *involutus* Zone.

The genus *Imphotepia*, with a special concern to *Imhotepia marssoni*?, ranges from the Upper Turonian to the Coniacian in the BCB (Damotte et al., 1981). The relatively poor state of preservation hampers any further subspecific identification (Fig. 6D).

FORAMINIFERS

Among all samples from the Svinary locality, 10 planktic and 24 benthic foraminifera species have been indentified. The foraminiferal assemblage consists of diverse benthic and planktonic specimens with some smaller, probably juvenile forms (Figs. 7 and 8A, B). Foraminifera shells are relatively poorly preserved, white to light grey, filled by micrite, in some cases by pyrite. Shell walls are often fragmentary or dissolved; some shells are flattened as a result of deformation caused probably by diagenetic alterations.

The foraminiferal assemblage includes benthic calcareous [e.g., *Globorotalites* gr. *micheliniana* (d'Orbigny, 1840), *Tritaxia* sp., *Praebulimina* sp., *Neoflabellina suturalis suturalis* (Cushman, 1935), *Frondicularia apiculata* Reuss, 1844], agglutinated [*Spiroplectammina praelonga* (Reuss, 1845), *Gaudryina carinata* Franke, 1914, see Appendix 2], and planktonic species [*Planoheterohelix globulosa* (Ehrenberg, 1840), *Whiteinella brittonensis* (Loeblich and Tappan, 1961), *W. baltica* Douglas and Rankin, 1969, *W. archaeocretacea* Pessagno 1967, *Dicarinella canaliculata* (Reuss, 1854), *D. imbricata* (Mornod, 1950), *Marginotruncana pseudolinneiana* Pessagno, 1967, and *Marginotruncana coronata* (Bolli, 1945)].

The planktonic foraminiferal assemblage is dominated by forms with globular chambers, represented by *Whiteinella* species. Among double-keeled foraminifera prevail genera *Marginotruncana* and *Dicarinella*, the only representative of biserial planktonic forms is *Planoheterohelix globulosa* (Ehrenberg, 1840).

Table 1

of calcareous nannofossils in studied samples

Lucianorhabdus quadrifidus	*Manivitella pemmatoidea*	*Marthasterites furcatus*	*Micula adumbrata*	*Micula concava*	*Micula cubiformis*	*Micula staurophora*	*Micula swastica*	*Octolithus multiplus*	*Prediscosphaera* sp. (side-view)	*Prediscosphaera cretacea*	*Prediscosphaera columnata*	*Prediscosphaera* cf. *grandis*	*Prediscosphaera ponticula*	*Prediscosphaera spinosa*	*Placozygus fibuliformis*	*Quadrum gartneri*	*Reinhardtites anthophorus*	*Retecapsa crenulata*	*Retecapsa octofenestrata*	*Rhagodiscus angustus*	*Staurolithites ellipticus*	*Tetrapodorhabdus decorus*	*Thoracosphaera operculata*	*Tranolithus orionatus*	*Uniplanarius gothicus*	*Watznaueria barnesiae*	*Watznaueria britannica*	*Watznaueria fossacincta*	*Watznaueria quadriradiata*	*Zeugrhabdotus bicrescenticus*	*Zeugrhabdotus biperforatus*	*Zeugrhabdotus diplogrammus*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus erectus*	*Zeugrhabdotus scutula*	*Zeugrhabdotus sigmoides*	*Zeugrhabdotus trivectis*
F	R		R	C	F	C	cf.		F	F	F	F	F	R			R	F	R	R	R		F	F		C				R	F	C		R	C		
R	F	F		F	R	C			F	F	R	R	R					C	R	F			F	F		A				R	R	C			C		
R	R	F		F	F	C			F	C	R	R	F				R	C		F			R	F		C	R			F	R	C			C		
R	R	F		C	F	C			F	F	R	R	R					C	F	F		R		F		A				F	F	C		R	C		
F	R	F	R	F	F	C			F	F		R	F				R	C		C	R		R	F		A				F	F	C	R	R	C		
F	R	F		F	F	C	R		F	F	F	R	R					C		C	R	R	F	F		A	R			F	R	C			C		
R	F	F		C	F	C	?		F	F		R	R	R				C	R	C	R		R	F		A	F			R	R	C	R		C		
F	R	F		F		C	R			F		R				F	R	C	R	F	R	R	R	R		A	R			F	F	C	R		C		
R	R	F		C	F	C			F	C		R	R		R	R		C		C	R		F	F		C	R	R		F	R	C		R	C		
R	F	C		F	R	C		R	F	F			F			R		C	R	C			F	F		A	R			F	R	C			C	?	?
	F	C		F		C			F	F		R	R	R			R	C	R	F	R		F	R		A	F			F	F	C	R	R	C		
F	F	F	R	F	F	C	R		F	F		R	R		R		R	C	R	C			F	R		A	R				R	C	R		C		
R	R	F	R	R		C	R		F	F		R	F					C	R	C	R	R	C	F		A			cf.	R		C	R	R	C		
		F	R	R		A	cf.		R	F		R	R				R	C		F			F	F	?	A	F			F		C	F	R	C		
		C		R	R	A			F	F		R		?		R		C	R	C			F	R	?	C		R		R	R	C	R		C		

F – few (3–10 specimens per sample); R – rare (1–2 specimens per sample); ? – questionable identification; cf. – confer

The benthic foraminiferal assemblage is more diverse than the planktonic one and includes stratigraphicaly important species of *Gaudryina carinata* Franke, 1914 and *Neoflabellina suturalis suturalis* (Cushman, 1935) for BCB (Hercogová, 1982; Hradecká, 2012).

Because of poor preservation of foraminifera shells (caused probably by diagenetic alterations) it was not always possible to determine all shells to the species rank; some species are identified to the generic level.

AMMONITES

Two fragments of the stratigraphically important heteromorph ammmonite *Tridenticeras tridens* (Schlüter, 1876) (Ancyloceratina; Nostoceratidae) have been collected. The larger one (specimen No. NM-O8455) is ~25 mm high and consists of eight (prorsiradiate) ribs, three rows of prominent tubercles (lateral to marginal; Fig. 9A) and one row of weakly developed umbilical tubercles (Fig. 9B, specimen No. NM-O8456). The second and third rows of tubercles are arranged in separated pairs (Fig. 9A). Main bifurcate ribs start at umbilical tubercles (Fig. 9B) and continue to marginal tubercles. Non-tuberculate single ribs (1–2) intercalate the tubercular ones; they are slightly concave and weakly developed. The sutures are not preserved. The FO of *Tridenticeras tridens* is documented in the middle/upper part of the *Gauthiericeras margae* Zone, i.e. the upper Middle Coniacian (see discussion below).

INOCERAMIDS

One specimen of the species *Platyceramus mantelli* (de Mercey, 1872) was found 3 m above the base of the Svinárky outcrop. The specimen has a slightly pointed beak, oval rugae and growth lines. This outline characterized the morphotype *beyenburgi* Seitz, 1965 (Fig. 9C). The second broken incomplete specimen with a *costellatus*-like ornament cannot be determined precisely, but it resembles *Inoceramus frechi* Flegel, 1905 (Fig. 9D).

ASSOCIATED MACROFOSSILS

Infaunal bivalves are very scarce, only two specimens of deposit-feeding nuculids, *Nuculana (Jupiteria) semilunaris* (Buch) and *Nymphalucina laminosa* (Reuss, 1846), were found in the outcrop, representing the *Nucula* – *Nuculana* assemblage (Čech and Švábenická, 1992). Infaunal irregular echinoid tests of *Hemiaster* (*Leymeriaster*) cf. *regulusanus* (d'Orbigny, 1854) are more frequent but commonly squashed. This echinoid taxon became specialized to muddy substrates in rather deeper marine settings, pointing to offshore deeper waters (Fraaije et al., 2018).

The occurrence of araucarid gymnosperm plant leaves of *Pagiophyllum brachyphyllum* (Bayer) Kunzmann, 2007, constitutes an exceptional find and supports proximity to the land (Fig. 8I).

NANNOFOSSIL BIOSTRATIGRAPHY

The biostratigraphically significant species are as follows: *Lithastrinus septenarius*, *L. grillii*, *Zeugrhabdotus biperforatus*, *Marthasterites furcatus*, *Broinsonia parca expansa*, *Lucianorhabdus arcuatus*, *Micula staurophora* and *M. concava*. Rare occurrences of *Micula swastica*, *Quadrum gartneri* and *Octolithus multiplus* were also noticed. *Helicolithus turonicus* is absent.

Micula staurophora commonly occurs across the entire profile. The first occurrence (FO) of this species defines the base of the UC10 Nannofossil Zone in the lower Middle Coniacian (Burnett, 1998; Švábenická, 2012). The following UC11 Zone is defined by the FO of *Lithastrinus grillii*. Irregular records of this stratigraphically significant species were observed from sample No. 4 up the section (see Table 1). Based on the presence of *Micula staurophora*, *Lithastrinus septenarius* and *Broinsonia parca expansa*, samples Nos. 1–3 belong to the UC10 Zone. Co-occurrence of these taxa along with *Lithastrinus grillii* from sample No. 4 documents the UC11 Zone, more accurately the UC11a–b Subzones *sensu* Burnett (1998). The marker species for the base of the UC11c Nannofossil Subzone in the Upper Coniacian, *Lucianorhabdus cayeuxii*, has not been found.

DISCUSSION

Relatively numerous studies based on calcareous nannofossils focused on the Lower and Upper Coniacian, and specifically on the Turonian-Coniacian and Coniacian-Santonian boundaries (e.g., Melinte and Lamolda, 2007; Kędzierski, 2008; Lees, 2008; Blair and Watkins, 2009; Svobodová et al., 2014). The present study deals with Middle Coniacian material. As far as biostratigraphy is concerned, the studied samples range from the UC10 to UC11 zones. Burnett (1998) placed the base of the UC11 Zone, defined by the FO of *Lithastrinus grillii*, in the Upper Coniacian. Hampton et al. (2007) shifted this bioevent into the Middle Coniacian in the chalk facies of southern England. Such a position within the Middle Coniacian has also been accepted by Švábenická and Bubík (2014) for the Bohemian Cretaceous Basin and the Outer Western Carpathians. According to Švábenická et al. (2016) and Čech and Švábenická (2017), samples yielding *Lithastrinus grillii*, *Lucianorhabdus arcuatus* and *Marthasterites furcatus* are interpreted as the upper part of the Middle Coniacian. Moreover, the continuous presence of *Lithastrinus septenarius* excludes any overlap into the UC12 Zone (see Table 1).

The content of *Marthasterites furcatus* in the calcareous nannofossil assemblage does not exceed 2% in each sample, which also excludes the *Marthasterites furcatus* acme described across the Turonian-Coniacian boundary (e.g., Švábenická, 2009, 2010; Švábenická and Bubík, 2014; Švábenická and Havlíček, 2017).

During the deposition of the Middle Coniacian sediments of the Březno Formation (Xe: *sensu* Soukup, 1956), the most suitable conditions for a mixed (planktonic and benthic) foraminiferal assemblage prevailed. The occurrence of double-keeled planktonic foraminifers (*Dicarinella* and *Marginotruncana* genera) documents a well-oxygenated intermediate-to-deep water column (Štemproková-Jírová, 1978), while surface waters are inhabited by globular forms such as the genus *Whiteinella* (Keller et al., 2001). The mode of life strategies is neither fully understood yet, nor easy to summarize.

Nonetheless, Premoli Silva, Sliter (1999) and Petrizzo (2002) and other authors apply the ecological concept of K- and r-strategists for Cretaceous planktonic foraminifera.

While globotruncanids and marginotruncanids are described as K-strategists, *Archaeglobigerina cretacea* (d'Orbigny, 1840) and the genus *Whiteinella* are more r-selected intermediate strategists (Petrizzo, 2002), *Planoheterohelix globulosa* (Ehrenberg, 1840) is considered an opportunist and r-strategist (Petrizzo, 2002) with tolerance to lower oxygen levels (Keller at al., 2001). However, Abramovich et al. (2003) interpreted heterohelicids as inhabitants of subsurface layers, or water masses close to the thermocline. Furthermore, Premoli Silva, Sliter (1999) mentioned that heterohelicids represented the dominant element in the planktonic foraminiferal assemblage of the open ocean waters in the Early Cretaceous.

Among planktonic species, marginotruncanids (*Marginotruncana pseudolinneiana, Marginotruncana coronata*), *Archaeoglobigerina cretacea* and dicarinellids (*Dicarinella canaliculata, D. imbricata* and other species – see above) are characteristic for this locality. The planktonic foraminifera assemblage belongs to the *Dicarinella concavata* Biozone *sensu* Robaszynski and Caron (1995) and corresponds with work of Štemproková-Jírová (1969, 1978), valid for the BCB.

The large benthic species of *Neoflabellina suturalis suturalis* (Cushman, 1935) is typical for the upper part of the Lower Coniacian, and ranges into the Upper Coniacian in the BCB (Hercogová, 1982; Hradecká, 2012). The occurrence of *Neoflabellina suturalis suturalis* corresponds to its occurrence in the Lower Coniacian Buchletein Member of the Sandbach Formation of southeastern Germany (Schneider et al., 2011). These authors compared it with the standard chalk section of Lägerdorf (Schönfeld, 1990: 135) in northern Germany, where *Neoflabellina suturalis suturalis* has its FO in the Middle Coniacian. Likewise, the respective FO of *Neoflabellina suturalis* ssp. in the Münsterland Cretaceous Basin, northwestern Germany (Dölling et al., 2014: 528; Fig. 4), lies within the upper part of the UC10 nannofossil zone. Nonetheless, Niebuhr et al. (1999) report the FO of *Neoflabellina* (including the *Neoflabellina suturalis* group) from the Middle Coniacian in the extra-Alpine Cretaceous layers of Bavaria (Ohmert, 1969) and Austria (Wessely et al., 1981).

The benthic foraminifera assemblage shows similarity to the fauna structure of the *Stensioeina granulata-Eponides whitei* benthic foraminifera biozone, based on summary research from the Bohemian Cretaceous Basin (Hradecká, 2012). For this biozone, a diverse benthic assemblage with abundant agglutinated species of the genus *Gaudryina* (e.g., *G. carinata* Franke, 1914) and calcareous benthic species, such as *Neoflabellina suturalis suturalis* (Cushman, 1935), is characteristic. The *Stensioeina granulata-Eponides whitei* Biozone is classified as Lower to Upper Coniacian (Hradecká, 2012). *Gyrodinoides nitidus* (Reuss, 1844), widespread in Upper Cretaceous epicontinental deposits, seems not to be very useful as a palaeoenvironmental proxy; it is probably not a very sensitive species to environmental changes (Dubicka et al., 2014).

Pokorný (1979) and Damotte et al. (1981) did not mention *Cytherella* gr. *ovata*, *Cytherella* cf. *parallela* and *Pterygocythereis spinosa*. Following the revision of the genus *Pterygocythereis* from the BCB by Pokorný (1966, 1987), this genus

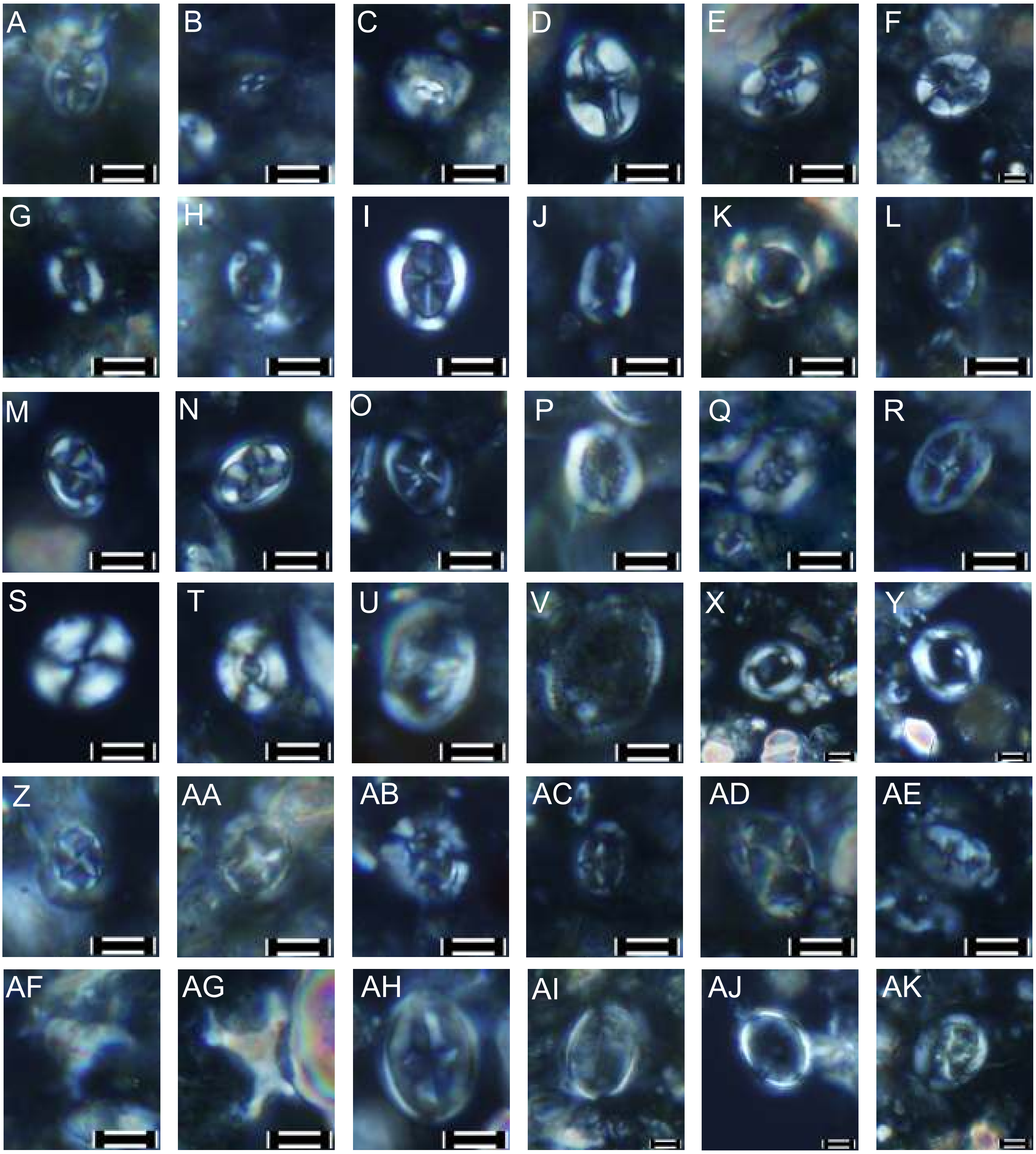


Fig. 4. Calcareous nannofossils of the Middle Coniacian locality of Svinary

A – *Ahmuellerella octoradiata*, sample 4; **B** – *Biscutum ellipticum*, sample 10; **C** – *Biscutum melaniae*, sample 2; **D** – *Eiffellithus eximius*, sample 1; **E** – *Eiffellithus gorkae*, sample 4; **F** – *Eiffellithus turriseiffelii*, sample 5; **G** – *Broinsonia enormis*, sample 1; **H** – *Broinsonia signata*, sample 10; **I** – *Broinsonia parca expansa*, sample 15; **J** – *Rhagodiscus angustus*, sample 15; **K** – *Cylindralithus biarcus*, sample 6; **L** – *Cribrosphaerella ehrenbergii*, sample 12; **M**, **N** – *Helicolithus trabeculatus*, samples 14 and 1; **O** – *Chiastozygus litterarius*, sample 9; **P** – *Retecapsa crenulata*, sample 6; **Q** – *Retecapsa octofenestrata*, sample 8; **R** – *Staurolithites ellipticus*, sample 5; **S** – *Watznaueria barnesiae*, sample 14; **T** – *Watznaueria britannica*, sample 5; **U** – *Reinhardtites anthophorus*, sample 13; **V** – *Tetrapodorhabdus decorus*, sample 3; **X**, **Y** – *Manivitella pemmatoidea*, samples 6 and 15; **Z** – *Prediscosphaera cretacea*, sample 10; **AA** – *Prediscosphaera ponticula*, sample 7; **AB** – *Prediscosphaera columnata*, sample 10; **AC** – *Prediscosphaera spinosa*, sample 9; **AD** – *Prediscosphaera* cf. *grandis* (*sensu* Burnett 1998), sample 4; **AE** – *Tranolithus orionatus*, sample 9; **AF**, **AG** – *Marthasterites furcatus*, samples 10 and 1; **AH** – *Gartnerago obliquum*, sample 13; **AI**, **AJ** – *Kamptnerius magnificus*, samples 4 and 15; **AK** – *Grantarhabdus coronadventis*, sample 2; cross-polarized light; scale bars – 5 µm

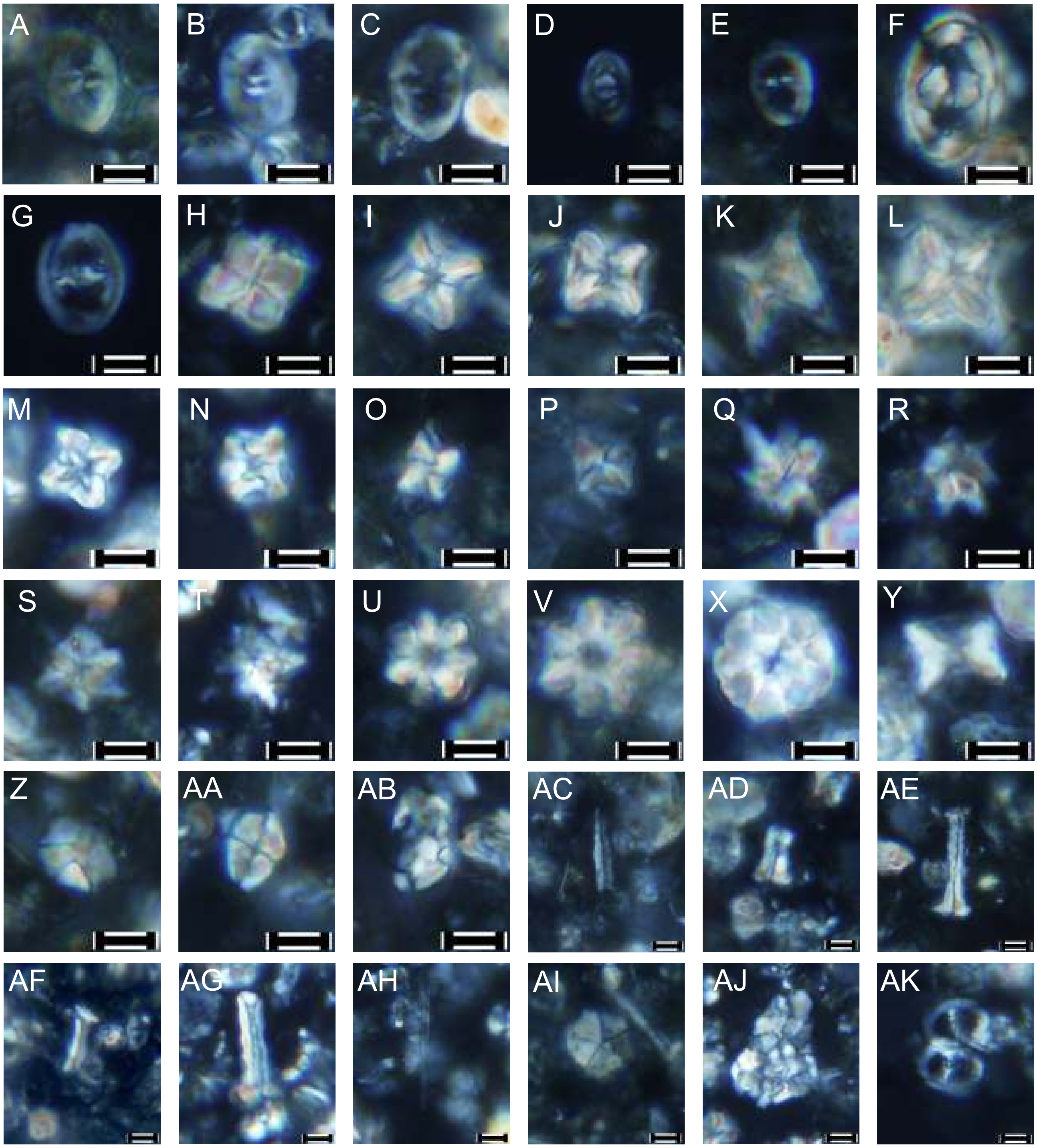


Fig. 5. Calcareous nannofossils of the Middle Coniacian locality of Svinary

A, **B** – *Zeugrhabdotus biperforatus*, samples 7 and 9; **C** – *Zeugrhabdotus diplogrammus*, sample 6; **D** – *Zeugrhabdotus bicrescenticus*, sample 11; **E** – *Zeugrhabdotus erectus*, sample 2; **F** – *Zeugrhabdotus embergeri*, sample 2; **G** – *Zeugrhabdotus scutula*, sample 11; **H** – *Quadrum gartneri*, sample 1; **I**, **J** – *Micula staurophora*, samples 3 and 6; **K**, **L** – *Micula concava*, samples 3 and 7; **M** – *Micula cubiformis*, sample 15; **N** – *Micula* cf. *swastica*, sample 15; **O**, **P** – *Micula adumbrata*, samples 4 and 11; **Q**, **R** – *Lithastrinus septenarius*, samples 5 and 13; **S**, **T** – *Lithastrinus grillii*, samples 4 and 9; **U**, **V** – *Eprolithus moratus*, samples 2 and 4; **X**, **Y** – *Eprolithus floralis*, sample 10 (Y – side view); **Z** – *Octolithus multiplus*, sample 6; **AA** – *Calculites ovalis*, sample 9; **AB** – *Calculites obscurus*, sample 2; **AC** – *Acuturris scotus*, sample 11; **AD** – *Lucianorhabdus maleformis*, sample 9; **AE** – *Lucianorhabdus quadrifidus*, sample 3; **AF**, **AG** – *Lucianorhabdus arcuatus*, samples 8 and 10; **AH** – *Lithraphidites carniolensis*, sample 10; **AI** – *Braarudosphaera bigelowii bigelowii*, sample 3; **AJ** – *Thoracosphaera operculata*, sample 9; **AK** – *Zeugrhabdotus scutula*, two specimens, sample 14; cross-polarized light; scale bars – 5 μm

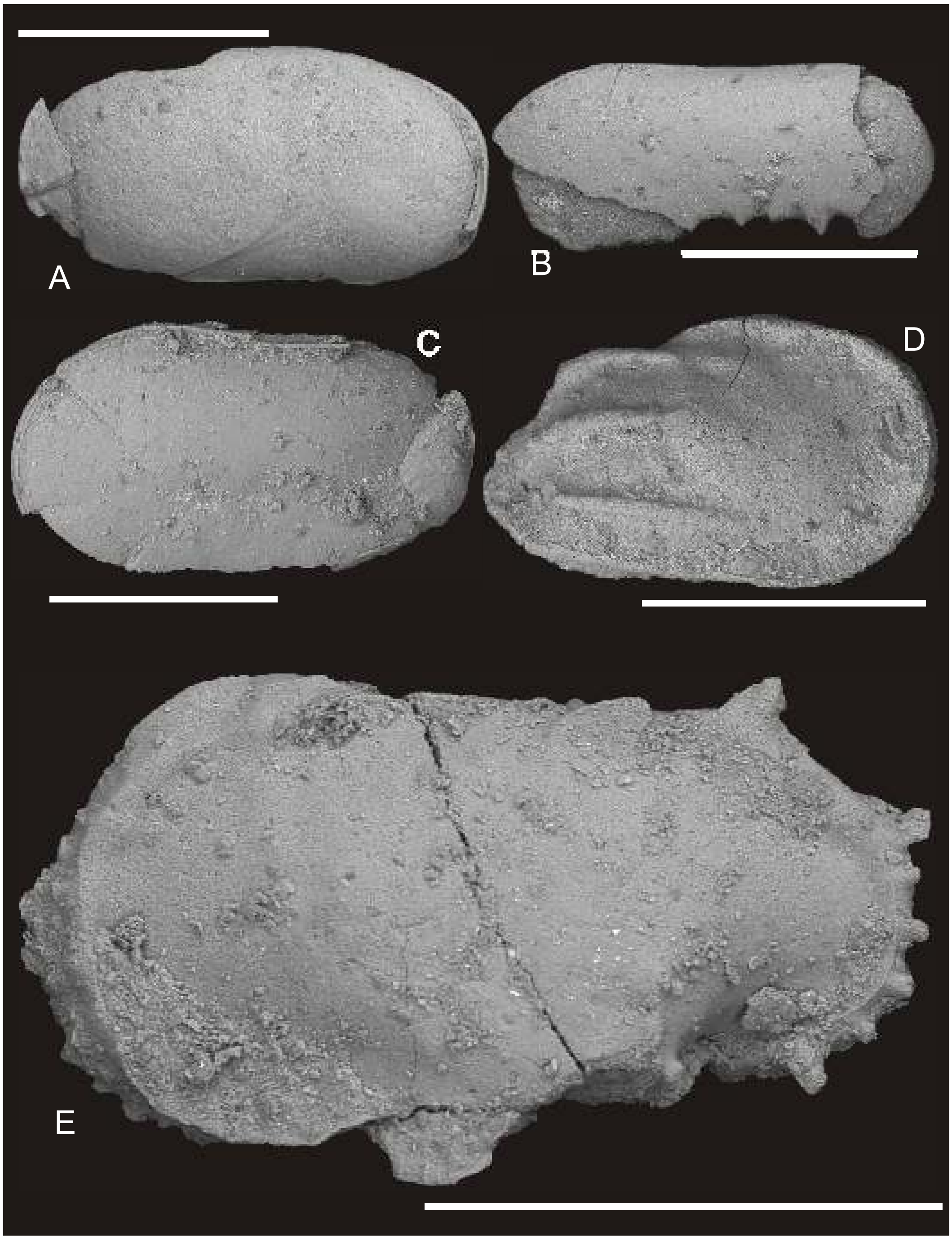
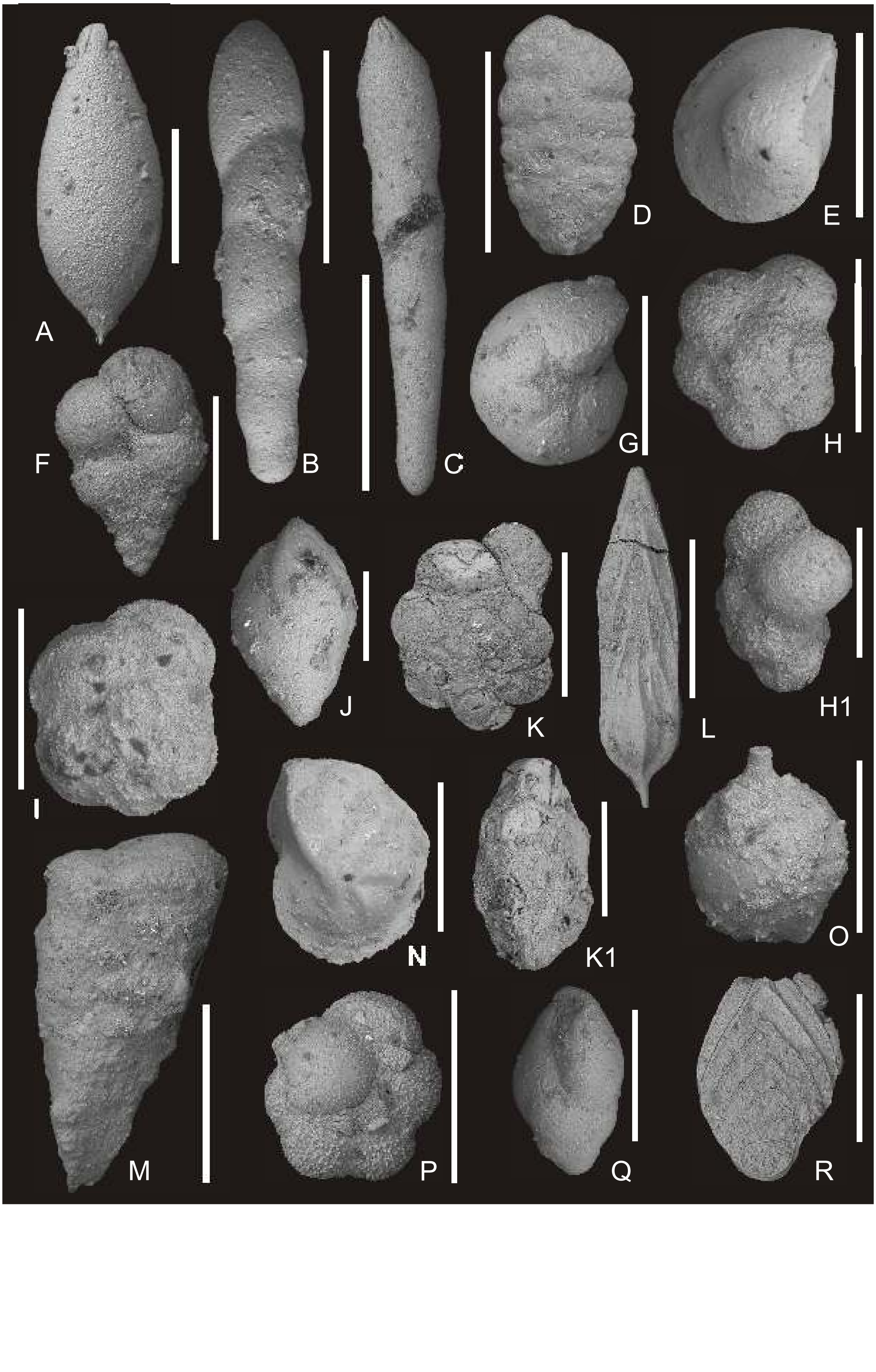


Fig. 6. Ostracods from the Middle Coniacian locality of Svinary

A, **C** – *Cytherella* gr. *ovata* (Roemer, 1841), scale bar – 500 µm; **B** – *Cytherella* cf. *parallela* (Reuss, 1846), scale bar – 300 µm; squashed valves; **D** – *Imhotepia marssoni*? (Pokorný, 1984), scale bar – 300 µm; **E** – *Pterygocythereis spinosa* (Reuss, 1846), scale bar – 300 µm

ranged from the Middle Turonian to the Coniacian. *Pterygocythereis spinosa* (Reuss, 1846) is mentioned from the Upper Turonian deposits of Úpohlavy (Houdková, 2016). Based on the sculpture and shape of carapace for palaeoecological comparison, the specimens at hand of the genus *Pterygocythereis* may well compare with extant *Pterygocythereis* species: e.g. *Pterygocythereis* (*Pterygocythereis*) *jonesii* (Baird, 1850) and *Pterygocythereis ceratoptera* (Bosquet, 1852). *P. jonesii* occurs in the Mediterranean between 20 to 300 m (Puri et al., 1965; Breman, 1976; Peypouquet and Nachite, 1984), and in the Adriatic Sea between 40 and 100 m (Breman, 1976) and between 80 and 170 m (Bonaduce et al., 1975). *Pterygocythereis jonesii* is a common sublittoral marine species found at all depths down to 200 m. It is essentially a warm-water form living in the Mediterranean (e.g., Zakynthos: Tsourou et al., 2012; Aegean Sea and Black Sea: Perçin-Paçal et al., 2015; Özuluğ et al., 2018; Sea of Marmara: Tunoglu, 1996, Özuluğ et al., 2018; and the Atlantic continental shelf of Spain: Pascual et al., 2008). Its most septentrional record lies in the Kattegat and Skagerrak (Wilkinson, 2007). *Pterygocythereis ceratoptera* is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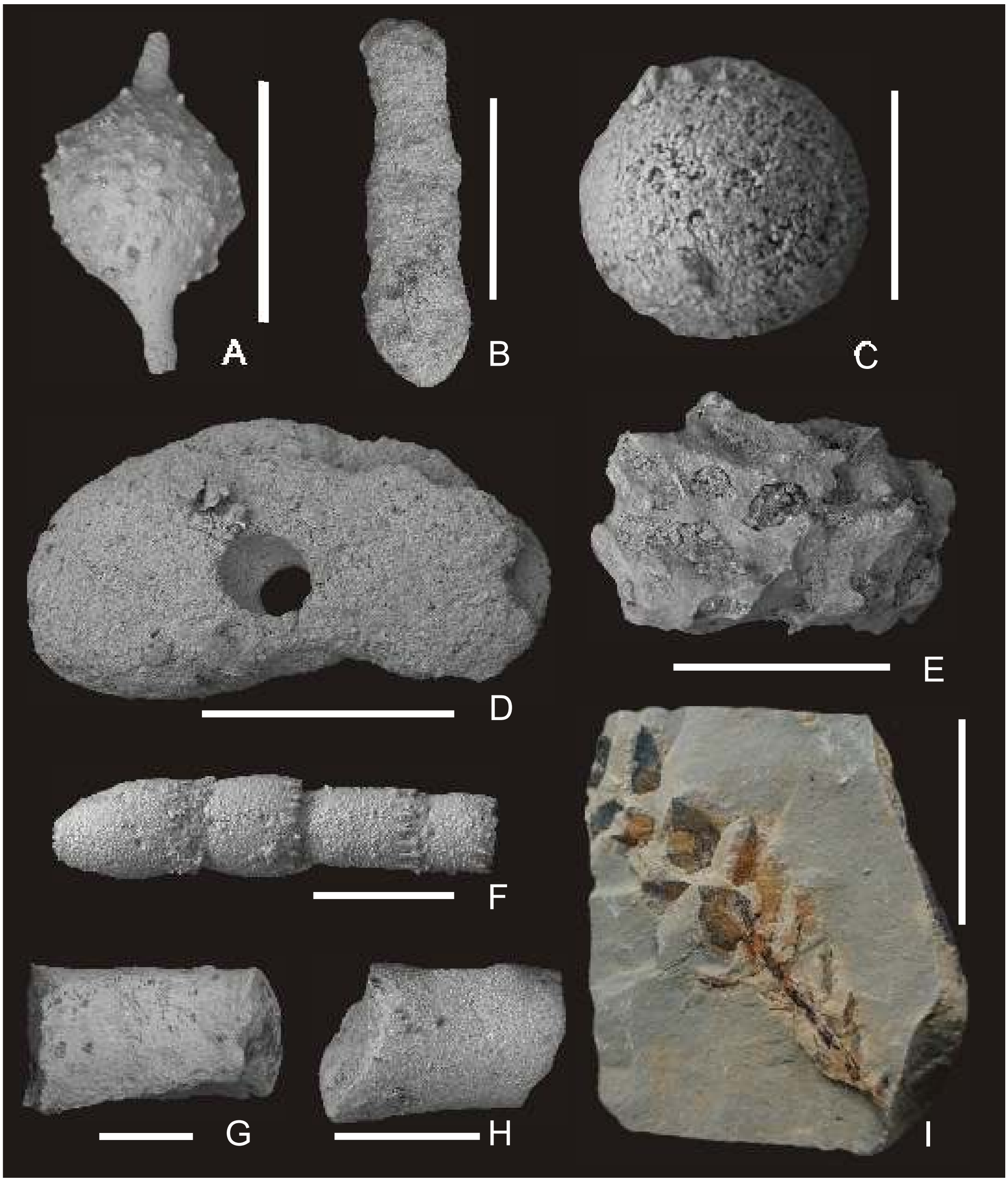

Fig. 8. Selected microfossils and macrofossils from the Svinary locality

A – *Ramulina aculeata* d'Orbigny, 1840, scale bar – 400 µm; **B** – *Dorothia filiformis* (Berthelin), scale bar – 500 µm; **C** – Calcisphere (Calcareous dinocysts) species *Calcisphaerula innominata* Bonet, 1986, scale bar – 50 µm; **D** – borehole in an ostracoda test, scale bar – 500 µm; **E** – Porifera gen. et sp. indet., scale bar – 500 µm; **F** – fragment of ophiuroid arm, scale bar – 100 µm; **G** – bourgueticrinid brachial plate, scale bar – 500 µm; **H** – bourgueticrinid brachial plate, scale bar – 500 µm; **I** – Araucarid gymnosperm plant leaves *Pagiophyllum brachyphyllum* (Bayer) Kunzmann, 2007, scale bar – 1 cm

Fig. 7. Foraminiferal assemblage from the Middle Coniacian locality of Svinary

Benthic calcareous foraminifera: A – *Lagena* cf. *apiculata* (Reuss, 1850), scale bar – 100 µm; **B** – *Dentalina gracilis* (d'Orbigny, 1840), scale bar – 200 µm; **C** – *Nodosaria oligostegia* (Reuss, 1845), scale bar – 400 µm; **E** – *Lenticulina lobata* (Reuss, 1845), scale bar – 300 µm; **G** – *Gyrodinoides globulosa* (Hagenow, 1842), scale bar – 1 mm; **J** – *Praebulimina* sp., scale bar – 100 µm; **L** – *Frondicularia apiculata* Reuss, 1844; scale bar – 400 µm; **N** – ?*Eggerellina* sp., scale bar – 500 µm; **O** – *Lagena hispida* (Reuss, 1858), scale bar – 300 µm; **Q** – *Praebulimina reussi* (Morrow, 1931), scale bar – 200 µm; **R** – *Neoflabellina suturalis suturalis* (Cushman, 1935), scale bar – 400 µm. **Benthic agglutinated foraminifera**: **D** – *Spiroplectammina praelonga* (Reuss, 1845), scale bar – 400 µm; **M** – *Gaudryina carinata* Franke, 1914, scale bar – 500 µm. **Planktic foraminifera**: **F** – *Planoheterohelix globulosa* (Ehrenberg, 1840), scale bar – 200 µm; **H** – *Archaeglobigerina cretacea* (d'Orbigny, 1840), scale bar – 400 µm; **H1** – *Archaeglobigerina cretacea* (d'Orbigny, 1840), scale bar – 300 µm; **I** – *Marginotruncana marginata* (Reuss, 1845), scale bar – 400 µm; **K** – *Dicarinella canaliculata* (Reuss, 1854), scale bar – 500 µm; **K1** – *Dicarinella canaliculata* (Reuss, 1854), lateral view, scale bar – 300 µm; **P** – *Whiteinella brittonensis* (Loeblich and Tappan, 1961), scale bar – 400 µm

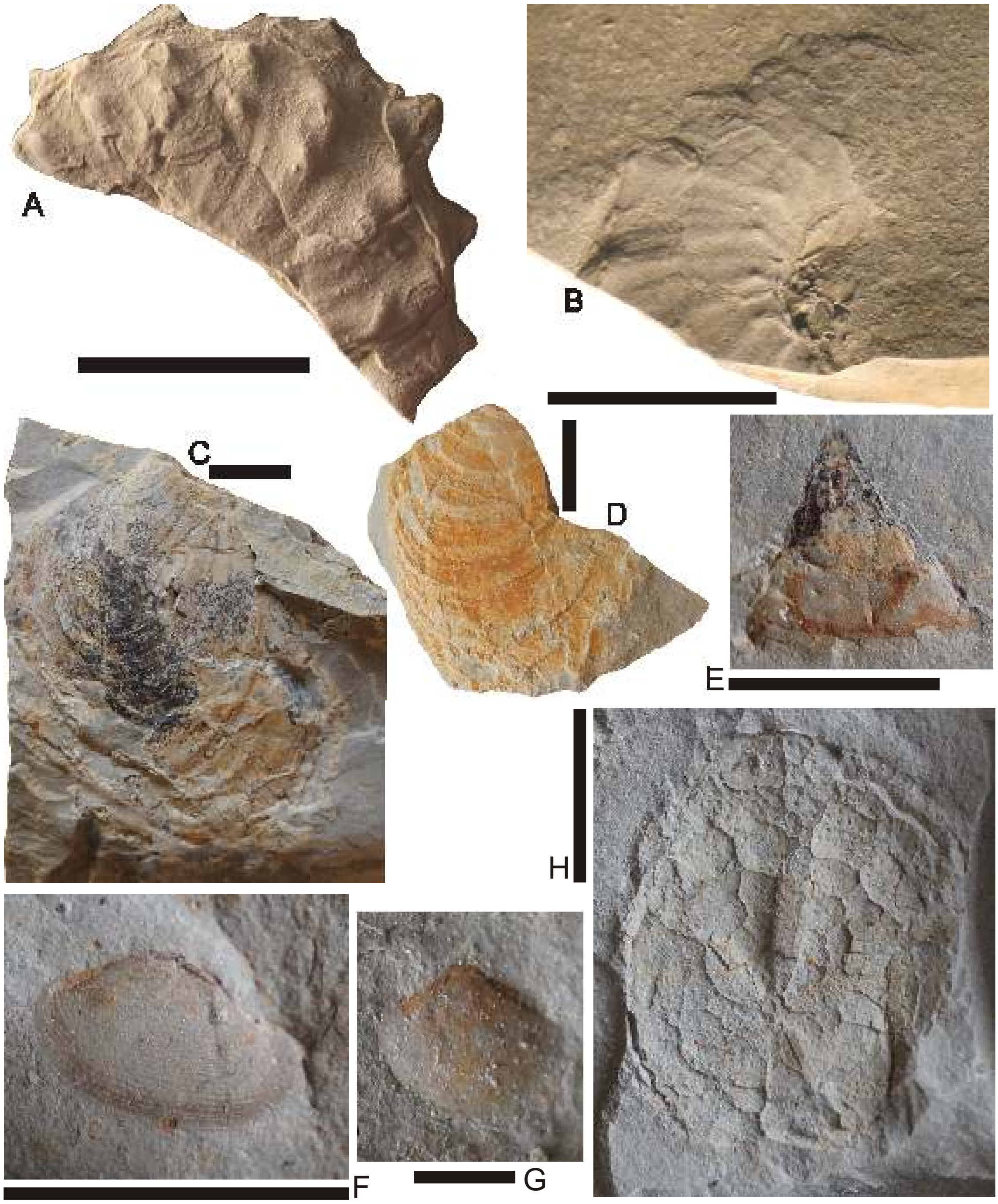

Fig. 9. Selected macrofossils from the Svinary locality

A – *Tridenticeras tridens* (Schlüter, 1876), compressed part of turriliticone whorl (adult); **B** – *Tridenticeras tridens* (Schlüter, 1876), compressed part of turriliticone whorl (juvenile, adolescent); **C** – *Platyceramus mantelli* (de Mercey, 1872), morphotype *beyenburgi* Seitz, 1965. Lateral view of the right valve; **D** – *Inoceramus* sp. aff. *Inoceramus frechi* Flegel, 1904; **E** – "*Trochus*" sp.; **F** – *Nuculana* (*Jupiteria*) *semilunaris* (Buch). Lateral view of the left valve; **G** – *Nucula* sp.; **H** – *Hemiaster* (*Leymeriaster*) cf. *regulusanus* (d'Obirgny, 1854); all scale bars – 1 cm, except G – 0.5 cm

reported from the Aegean Sea and the Sea of Marmara (Tunoglu, 1996; Özuluğ et al., 2018). Its upper bathymetric limit varies in different regions, oscillating between 2 m in some lagoons to 115 m in the Gulf of Biscay (Pokorný, 1987). This is related mainly to the actual depth of the wave base or, more precisely, the storm wave base (Liebau, 1984). *Pterygocythereis* has not been found living above this level. Liebau (1984) designated a pterygocline – upper level of the bathymetric range of waves-avoiding organisms. This conclusion by Lieabau (1984) is supported by the fact that *Pterygocythereis* species are generally not found in strand-line material, and that worn species do not occur in autochthonous material.

The ornamented specimens in this ostracod assemblage are rather small and devoid of any ocular tubercle, thus indicating a limited oxygen shortage within the first centimetres of mud-supported bottom sediments (infaunal habits).

Palaeoecologic conditions of coccolithophorids are typically constrained by the photic zone. The continued presence of *Lucianorhabdus* with increasing occurrences starting at sample 8 indicates continuous shallowing in the upper part of the profile. This is in accordance with the co-occurrences of the *Braarudosphaera* and *Thoracosphaera* nannofossil genera, both documenting a potential input of terrigenous material (e.g., Wyton and Bown, 2007; Švábenická, 2010). Simultaneously, joint occurrences of the conifer *Frenelopsis alata* and araucarid gymnosperm plant leaves of *Pagiophyllum brachyphyllum* in sample 13 support the proximity to the land as well.

The FO of the ammonite *Tridenticeras tridens* is reported from the upper part of the *Prionocycloceras iberiense* Zone in Spain and is correlatable to the FO in Germany (Westphalia: Kaplan and Kennedy, 1994; Küchler, 1998). Kaplan and Kennedy (1994) reported its stratigraphic range from the upper Middle Coniacian (*Gauthiericeras margae* ammonite Zone, *Volviceramus koeneni* and *Volviceramus involutus* inoceramid Zones) through the *Paratexanites serratomarginatus* Zone in Germany. In Spain, the stratigraphic range is reported from the middle/upper part of the *Gauthiericeras margae* Zone, upper part of the *Prionocycloceras iberiense* Zone, including the Tridenticeras II Event (Küchler, 1998). *Tridenticeras tridens* occurs above the FO of *Tridenticeras varians* (Schlüter, 1876), and the LO is reported from the *Hemitissotia turzoi* Zone (upper *Paratexanites serratomarginatus* Zone through the lowermost Santonian: Santamaría-Zabala, 1992; Santamaría-Zabala and Ricardo, 1993; Küchler, 1998).

Vašíček (1992) established a new tridenticerid taxon (*Tridenticeras soukupi* Vašíček, 1992) based on well-preserved material from the Middle Coniacian of Štíty (eastern part of the BCB, *Peroniceras tridorsatum* = *P. subtricarinatum* and *Gauthiericeras margae* Zones). The new taxon is characterized by the presence of four rows of tubercles (in contrast to the similar species of *T. varians* with three tubercle rows). However, the closely related species *Tridenticeras tridens* has also four rows of similarly developed tubercles. Thus, the differences between *T. soukupi* and *Tridenticeras tridens* are slight; both species may be conspecific. In such a context, *Tridenticeras soukupi* requires revision and needs to be compared in more detail to *Tridenticeras tridens*. The accompanying ammonite fauna reported by Vašíček (1992) is almost identical to those of *Tridenticeras tridens* from Spain and Germany (Santamaría-Zabala, 1992; Kaplan and Kennedy, 1994; Küchler, 1998 and references therein). The inoceramid species *Platyceramus mantelli* and *Volviceramus koeneni* co-occur and both are commonly accepted as markers for the base of the Middle Coniacian (Walaszczyk and Wood, 2018). *Platyceramus mantelli* ranges up into the Upper Coniacian. Up to now, no study deals with the stratigraphic value of the subspecies or morphotypes of *Platyceramus mantelli*. In the adjacent boreholes (VY-1 Všestary and Tb-1 Třebechovice – recent revision of SČ), the FO of the genera *Volviceramus* – *Platyceramus* appears 75–100 m below the present surface, approximately 50–60 m above the top of the Rohatce Member (lowermost Coniacian). Thus, the surface outcrop in Svinary falls in the younger part of the Middle Coniacian.

CONCLUSIONS

The classical locality of Svinary in the eastern Bohemian Cretaceous Basin has been reinvestigated within the scope of acquiring new palaeontological data, improving its biostratigraphic assignment, and providing firm palaeoenvironmental evidence.

Moderately preserved and abundant calcareous nannofossil assemblages provided evidence for the Middle Coniacian age, namely the upper part of the Middle Coniacian. From the co-occurences of *Micula staurophora*, *Broinsonia parca expansa*, *Lithastrinus septenarius*, and *L. grillii*, the upper part of the UC10 Zone and lower part of the UC11 Zone *sensu* Burnett (1998) are confirmed.

Based on its original record in Svinary, the stratigraphic occurrence of ammonite *Tridenticeras tridens* is in accordance with its occurrences in northern Spain and Westphalia (i.e. the upper part of the *Gauthiericeras margae* Zone). The Middle Coniacian age of the Svinary outcrop is also supported by the occurence of the inoceramid species *Platyceramus mantelli* as a Euramerican Boreal element.

The ecological groups and morphotypes in planktonic foraminifera recorded in the Svinary locality permit speculations about the depositional environment, but the palaeoecology of Upper Cretaceous foraminifera is not entirely clear from available literature. Nonetheless, the double-keeled planktonic dicarinellids and marginotruncanids inhabited probably a well-oxygenated intermediate-to-deep water column, whereas the globular planktonic whiteinellids inhabited surface waters in this locality. The abundance of double-keeled dicarinellids and marginotruncanids is similar through the geological profile (see Fig. 4). Heterohelicids inhabited subsurface layers or waters close to the thermocline, with their increasing abundance in the middle part of the profile in the Svinary outcrop (see Fig. 4).

Ostracods are represented mostly by the genus *Cytherella* (*C.* gr. *ovata*, *C.* cf. *parallela*), as well as by *Imhotepia marssoni*?, *Bairdia* gr. *cretacea* and *Pterygocythereis spinosa*. Calcareous dinocysts include *Calcisphaerula innominata*. The macrofossil material consists of ammonites (*Tridenticeras tridens*), bivalves (*Platyceramus mantelli*), echinoids [*Hemiaster* (*Leymeriaster*) cf. *regulusanus*], ophiuroids and trochiid gastropods, as well as by representatives of the *Nucula* – *Nuculana* bivalve level-bottom assemblage. Fossil plant remains were also found (*Pagiophyllum brachyphillum*, *Frenelopsis alata*). The inoceramid and ammonite faunas clearly indicate a Middle Coniacian age for the entire exposure at Svinary and document the youngest preserved deposits of the muddy facies of the central part of the BCB.

The faunal assemblages and the sedimentary facies indicate a relatively low-energy hydrodynamic regime below the storm wave base (*Pterygocythereis* ostracod), soft pelitic ground (suitable for, e.g., irregular echinoids), warm temperature, and a water depth not exceeding 200 m. The foraminiferal and nannoplankton communities also document rising temperatures. Abundant plant remains recorded in the upper part of the section may indicate a shallowing process and/or a higher terrestrial input to the basin.

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