CALCAREOUS DINOFLAGELLATE AND CALPIONELLID BIOEVENTS VERSUS SEA-LEVEL FLUCTUATIONS RECORDED IN THE WEST-CARPATHIAN (LATE JURASSIC/EARLY CRETACEOUS) PELAGIC ENVIRONMENTS

DANIELA REHÁKOVÁ

Geological Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 842 26 Bratislava, Slovak Republic; geolreha@savba.savba.sk

Abstract: Recently established separate dinoflagellate cyst zonation combined with the successive calpionellid events contribute to the HIRES of the Upper Jurassic and Lower Cretaceous Tethyan pelagic carbonate sequences. Compositional changes in dinoflagellate and calpionellid assemblages are correlated with eustatic sea-level fluctuations. Thus, parallel calpionellid and cyst zonations give us more precise tools for the subdivision of deposits investigated as well as for better understanding and reconstruction of the paleoceanographical and paleoecological conditions of the ancient marine environments. The calcareous resting cyst distribution is shown to be influenced by the whole complex of environmental factors such as sea-level transgressive/regressive pulses, hydrological regime, nutrient content etc.

Key words: Upper Jurassic, Lower Cretaceous, Western Carpathians, calcareous dinoflagellates, calpionellids, integrated biochronology, paleoecology, sea-level changes.

Review of previous calcareous dinoflagellate studies

Plankton has an important role in the ecology of the ocean. Besides calpionellids, there were calcareous dinoflagellates which represented a further substantional planktonic element during the Late Jurassic and Early Cretaceous. Since Kaufmann's description (in Heer 1865) of *Lagena ovalis* and *Lagena sphaerica*, many notions of single chambered bodies of various shape and size (between 40–63 μm in diameter) appeared in the literature. They were attributed to newly defined genera *Stomiosphaera* Wanner 1940, *Cadosina* Wanner 1940, *Pithonella* Lorenz 1902, and *Calcisphaerula* Bonet 1956. The shape, size, gross structure and optical properties of the tests sectioned were the main taxonomical criteria for their classification. Contemporaneously, some authors (Colom 1955; Wanner 1940; Vogler 1941; Bonet 1956; Durand Delga 1957; Leischner 1959; Nagy 1966, 1971; Lineckaya 1974; etc.) pointed out that the vertical distribution of dinoflagellate associations may be used for time correlation of the pelagic sequences.

A new stage in these studies started after Bolli's (1974) publication including documentation of Jurassic and Cretaceous calcisphaeres isolated from soft Indian Ocean sediments in the framework of the Deep Sea Drilling Project. Scanning electron microscope (SEM) observations were used in investigation of specimens studied. Bolli (1974) described nineteen new species and four forms in open nomenclature of *Pithonella* Lorenz 1902 and included them in the "incertae sedis" family Calcisphaerulidae. However, he entirely omitted taxonomical diagnoses of the previously established above mentioned families. Bolli (l.c.) supposed that comparative studies of the topotypic material including optical and SEM methods might be realized in the future.

On the other hand, he hoped that his newly established species would not be synonymous with previously registered ones. However, the fact emerged, that several species successfully used in the biostratigraphic zonation during the last 40 years (Nowak 1966, 1968, 1976; Borza 1980a, 1984; Borza & Michalík 1986) were classified in the genus *Pithonella*. Later, (Řehánek 1992; Řehánek & Heliasz 1993; Vašíček et al. 1994; Lakova et al. 1999; Reháková 2000) solved some new problems of cyst biozonation.

Wall & Dale (1968) for the first time pointed out the possibility of the genetic interpretation of calcispheres as calcareous dinoflagellate cysts. Taking into consideration this fact, as well as the results of Fütterer (1976), Keupp (1981, 1987) showed the same nature for the Mesozoic calcisphaerulids. Keupp (1987) established the calcareous dinoflagellate system based on the orientation of the calcite crystals forming the outer calcareous wall layer. He subdivided all known cyst genera of the order Peridiniales Haeckel 1894 into three subfamilies: Orthopithonelloideae, Obliquipithonelloideae and Pithonelloideae. Thus, the taxonomy of calcareous dinoflagellate cysts became more approximate to the biological classification. This approach was dynamically followed by Keupp's group (Keupp & Mutterlose 1984; Keupp 1980, 1984, 1987, 1990, 1991, 1992; Fütterer 1990; Willems 1988, 1990, 1992, 1994; Keupp & Ilg 1989; Keupp & Versteegh 1989; Keupp & Kowalski 1992; Keupp et al. 1992; etc.).

In an accordance with Keup's division, Řehánek (in Řehánek & Cecca 1993) compared cadosinids and stomiosphaerids with dinoflagellate cysts on the basis of the optical character of their sections in polarized light. He included genera *Stomiosphaera* Wanner 1940, *Colomisphaera* Nowak 1968, *Committosphaera* Řehánek 1985, *Parastomiosphaera* Nowak 1968, *Carpistomiosphaera* Nowak 1968 and *Stomi-*

osphaerina Nowak 1974 into the subfamily Orthopitonelloideae Keupp 1987. On the other hand, genera *Cadosina* Wanner and *Crustocadosina* Řehánek 1985 belong to the subfamily Obliquipithonelloideae Keupp 1987. A different opinion was presented by Colom (1994) who summarized accessible knowledge on dinoflagellate cysts from the Balearic Islands area. He compared the small spherical, sporadically conical forms of the "incertae sedis" group with the recent genera *Gromia*, *Allogromia*, *Difflugia*, *Trigonopyris*. All forms presented were included by him in the Cadosinidae, Stomiosphaeridae and Calcisphaerulidae families.

A new contribution to systematic concepts was presented by Reháková & Michalík (1996), who used both the combined optical and SEM methods on Early Cretaceous cyst specimens. They proved that the wall structure of *Cadosina fusca* Wanner is identical to *Obliquipithonella multistrata* (Pflaumann & Krashenninikov 1978), the type species of the Obliquipithonelloideae Keupp 1987. They obtained the same results in *Stomiosphaera wanneri* Borza 1969 which ought to be identical with *Orthopithonella congruens* Fütterer 1990, a typical representative of the Orthopithonelloideae Keupp 1987. According to Hildebrand-Habel & Willems (1997), these investigations should be acceptable in a new approach to the systematics of calcareous dinoflagellates.

The main goal of this paper is to show the calcareous dinoflagellates distribution as a tool for more detailed biostratigraphy of carbonate pelagic sequences as well as for the interpretation of the paleoenvironmental conditions. This work also takes into account the tendency of the Committee of Stratigraphy and Paleontology of the Carpathian-Balkan Geological Association to create an integrated biostratigraphical scale, practically acceptable for the Upper Jurassic and Lower Cretaceous sedimentary records of the whole Tethyan area.

Dinoflagellate biozonation

The first calcareous cyst zonal scheme (including 6 Late Kimmeridgian to Hauterivian cyst zones) was proposed by Nowak (1968) who later on, (Nowak 1976) revised it. Further contributions to the biostratigraphy of calcisphaerids were made by Borza (1969, 1984), Borza & Michalík (1986), Řehánek (1992), Řehánek & Heliasz (1993), Řehánek & Cecca (1993), Vašíček et al. 1994. Lakova et al. (1999) not only confirmed all previously proposed dinocyst zones in the West Balkan and West Fore-Balkan area, but also recognized a further three Upper Berriasian to Valanginian dinocyst interval-zones.

The last detailed biostratigraphical contribution was made by Reháková (2000), who investigated the vertical distribution of the calcareous dinoflagellates in Late Oxfordian to Upper Albian sedimentary sequences of the Western Carpathians. On the basis of a series of successive first occurrences and acme accumulations of calcareous dinoflagellates she proposed a separate cyst biozonation. In this paper, recorded dinocyst events are directly correlated to the calpionellid ones (sensu Reháková & Michalík 1997a), to the ammonite zonation (Hoedemaeker et al. 1993; Cariou &

Hantzpergue 1997), to the stratigraphic time scale (Gradstein et al. 1995) as well as to the sea-level fluctuation (Haq et al. 1988, Fig. 1). This approach offers good arguments for establishing an integrated high-resolution event stratigraphic (HIRES) scale of the West-Carpathian Upper Jurassic and Lower Cretaceous pelagic sequences which will also be supported by radiolarian, planktonic foraminiferal and nannoplankton distribution in a short time. The sections and formations studied, their geological position in the framework of the West-Carpathian tectonic units are described in Vašíček et al. (1994), Reháková (1995).
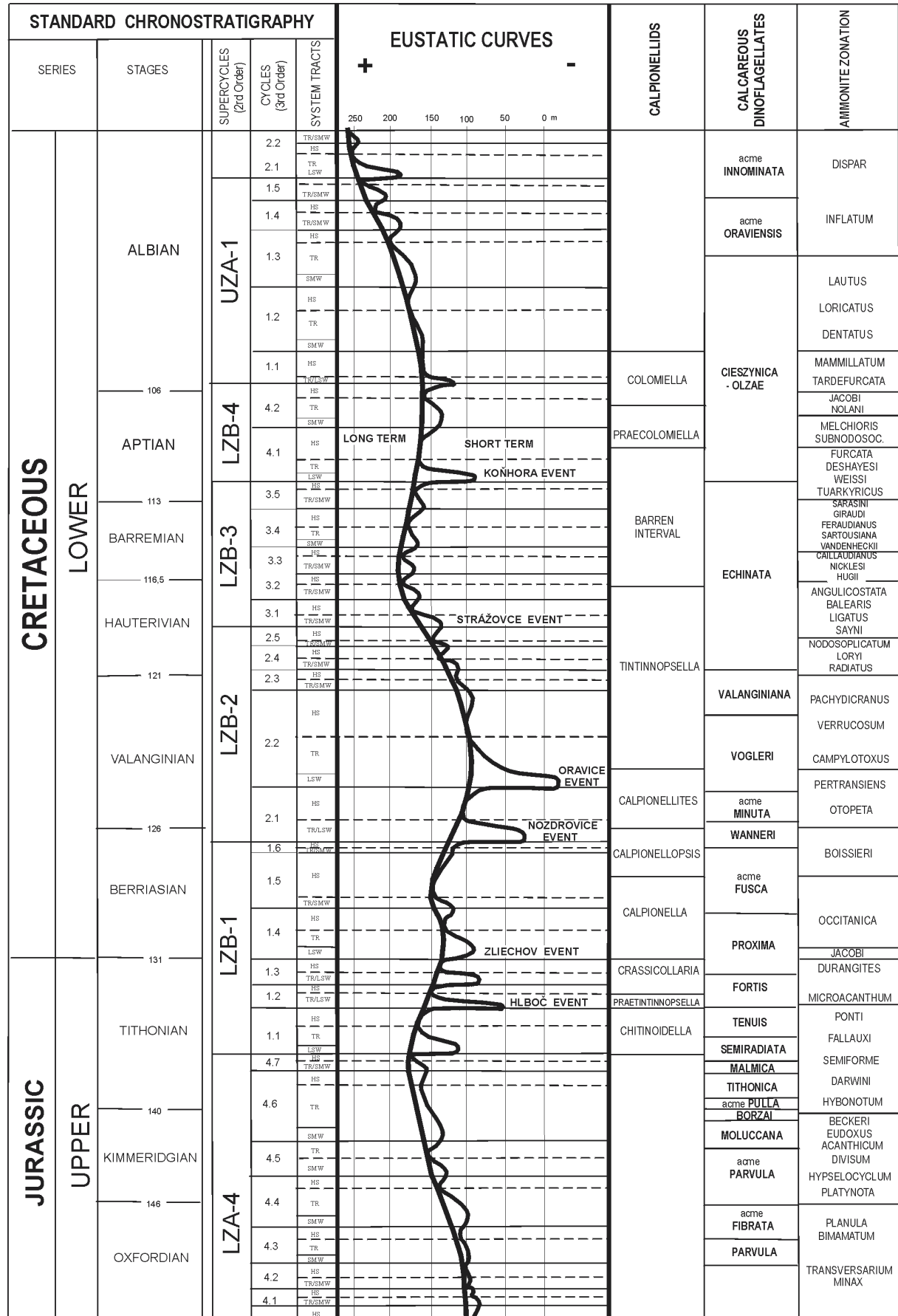
Oxfordian stage of the calcareous dinocyst evolution

Lower Oxfordian passage beds are characterized by the first occurrence (FO) of *Cadosina parvula* Nagy (Pl. I: Figs.1–2) which indicates the base of the Parvula Zone (Reháková 2000). Fragments of dysaerobic bivalves (Oschmann 1995) form a persistent, substantional part of the Oxfordian microfacies (Pl. I: Fig. 8). Shortly after the FO of *Colomisphaera fibrata* (Nagy) — Pl. I: Figs. 3–4, the acme of this index species was documented in the uppermost Oxfordian deposits (Reháková 2000). The acme of *C. fibrata* coincides with the onset of a sea-level rise (Haq et al. 1988). The assemblage also contains rare *Colomisphaera pieniniensis* (Borza) — Pl. I: Fig. 5 and *Schizosphaerella minutissima* (Colom) — Pl. I: Fig. 6. A rich calcareous dinoflagellate association of the same age was documented by Keupp & Ilg (1989) from the shallower coastal parts of Normandy. At the end of the Oxfordian the abundance of bivalves was decreasing. In a well-oxygenated setting planktonic foraminifers became prevailing (Mutterlose & Böckel 1998). *Hauslerina helvetojurassica* (Hausler) — Pl. I: Fig. 7 and *Globuligerina bathoniana* (Pazdrowa) are present in the West-Carpathian pelagic sediments. In order to show their rock-forming role, pre-Kimmeridgian Protoglobigerinae Zone was distinguished by Dragastan et al. (1975) in the East-Carpathian region. The Favusellacea became holoplanktonic (fully planktonic) and according to Simmons et al. (in BouDagher-Fadel et al. 1997) their sudden appearance may have been related to a rising eustatic sea-level, which opened up new niches.

Kimmeridgian stage of cyst evolution

Cadosina parvula became most abundant at the beginning of the Kimmeridgian. On the basis of this event, the Parvula Acme Zone was distinguished (Reháková 2000). The index species is accompanied by common cysts of *Schizosphaerella minutissima* (Colom) and *Colomisphaera carpathica* (Borza) — Pl. I: Fig. 9. Planktonic foraminifers have been still dominating in microfacies of this time. Mass abundance of *Globo-*

Fig. 1. The most important calpionellid and cyst bioevents in the West-Carpathian area corelated with the combined ammonite zonation (Hoedemaeker et al. 1993; Gradstein et al. 1995) and eustatic sea-level fluctuations sensu Haq et al. (1988).
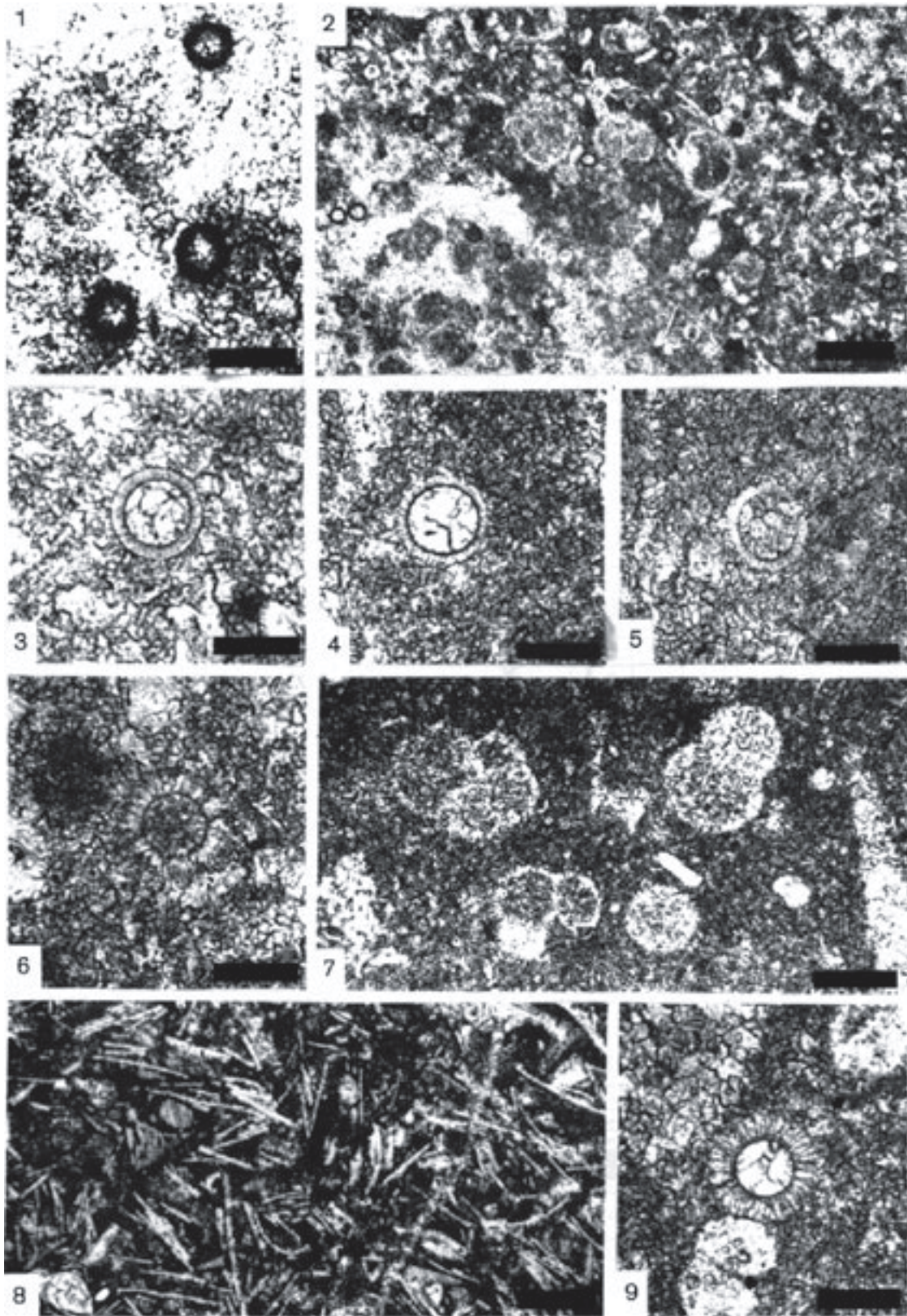
STANDARD CHRONOSTRATIGRAPHY					EUSTATIC CURVES	CALPIONELLIDS	CALCAREOUS DINOFLAGELLATES	AMMONITE ZONATION
SERIES	STAGES	SUPERCYCLES (2nd Order)	CYCLES (3rd Order)	SYSTEM TRACTS	+ 250 200 150 100 50 0 m −			
CRETACEOUS / LOWER	ALBIAN	UZA-1	2.2	TR/SMW			acme INNOMINATA	DISPAR
			2.1	HS / TR / LSW				
			1.5	TR/SMW			acme ORAVIENSIS	INFLATUM
			1.4	HS / TR/SMW				
			1.3	HS / TR / SMW			CIESZYNICA - OLZAE	LAUTUS
			1.2	HS / TR / SMW				LORICATUS
								DENTATUS
			1.1	HS / TR/LSW		COLOMIELLA		MAMMILLATUM / TARDEFURCATA
	APTIAN (106)	LZB-4	4.2	HS / TR / SMW		PRAECOLOMIELLA		JACOBI / NOLANI / MELCHIORIS / SUBNODOSOC.
			4.1	HS / TR / LSW	LONG TERM SHORT TERM KOŇHORA EVENT			FURCATA / DESHAYESI / WEISSI / TUARKYRICUS
	BARREMIAN (113)	LZB-3	3.5	HS / TR/SMW		BARREN INTERVAL	ECHINATA	SARASINI / GIRAUDI / FERAUDIANUS / SARTOUSIANA / VANDENHECKII
			3.4	HS / TR / SMW				CAILLAUDIANUS / NICKLESI / HUGII
			3.3	HS / TR/SMW				ANGULICOSTATA / BALEARIS / LIGATUS / SAYNI
			3.2	HS / TR/SMW				
	HAUTERIVIAN (116,5)		3.1	HS / TR/SMW	STRÁŽOVCE EVENT			NODOSOPLICATUM / LORYI / RADIATUS
		LZB-2	2.5	HS / TR/SMW		TINTINNOPSELLA	VALANGINIANA	
			2.4	HS / TR/SMW				
			2.3	HS / TR/SMW				PACHYDICRANUS
	VALANGINIAN (121)		2.2	HS / TR / LSW			VOGLERI	VERRUCOSUM / CAMPYLOTOXUS
			2.1	HS / TR/LSW	ORAVICE EVENT / NOZDROVICE EVENT	CALPIONELLITES	acme MINUTA	PERTRANSIENS / OTOPETA
						WANNERI		
	BERRIASIAN (126)	LZB-1	1.6	HS / TR/SMW		CALPIONELLOPSIS		BOISSIERI
			1.5	HS / TR/SMW			acme FUSCA	
			1.4	HS / TR / LSW	ZLIECHOV EVENT	CALPIONELLA	PROXIMA	OCCITANICA
			1.3	HS / TR/LSW		CRASSICOLLARIA	FORTIS	JACOBI / DURANGITES
	(131)		1.2	HS / TR/LSW	HLBOČ EVENT	PRAETINTINNOPSELLA		MICROACANTHUM
	TITHONIAN		1.1	HS / TR / LSW		CHITINOIDELLA	TENUIS	PONTI / FALLAUXI
JURASSIC / UPPER		LZA-4	4.7	HS / TR/SMW			SEMIRADIATA	SEMIFORME
			4.6	HS / TR			MALMICA	DARWINI
							TITHONICA	
	(140)						acme PULLA / BORZAI	HYBONOTUM
	KIMMERIDGIAN		4.5	SMW / TR / SMW			MOLUCCANA	BECKERI / EUDOXUS / ACANTHICUM
			4.4	HS / SMW			acme PARVULA	DIVISUM / HYPSELOCYCLUM / PLATYNOTA
	(146)		4.3	HS / TR / SMW			acme FIBRATA	PLANULA / BIMAMMATUM
	OXFORDIAN		4.2	HS / TR/SMW			PARVULA	TRANSVERSARIUM / MINAX
			4.1	HS / TR/SMW / HS				

Plate I: Fig. 1. *Cadosina parvula* Nagy. Oxfordian, Czorsztyn Unit, bar = 100 µm. **Fig. 2.** Abundant *Cadosina parvula* Nagy. Early Kimmeridgian, Czorsztyn Unit, bar = 200 µm. **Figs. 3–4.** *Colomisphaera fibrata* (Nagy). Late Oxfordian, Vysoká Unit, bars = 50 µm. **Fig. 5.** *Colomisphaera pieniniensis* (Borza). Late Oxfordian, Czorsztyn Unit, bar = 50 µm. **Fig. 6.** *Schizosphaerella minutissima* (Colom). Kimmeridgian, Vysoká Unit, bar = 50 µm. **Fig. 7.** *Hauslerina helvetojurassica* (Hausler). Late Oxfordian, Czorsztyn Unit, bar = 50 µm. **Fig. 8.** Microfacies with abundant juvenile bivalve fragments. Oxfordian, Manín Unit, bar = 200 µm. **Fig. 9.** *Colomisphaera carpathica* (Borza). Kimmeridgian, Pieniny Unit, bar = 50 µm.
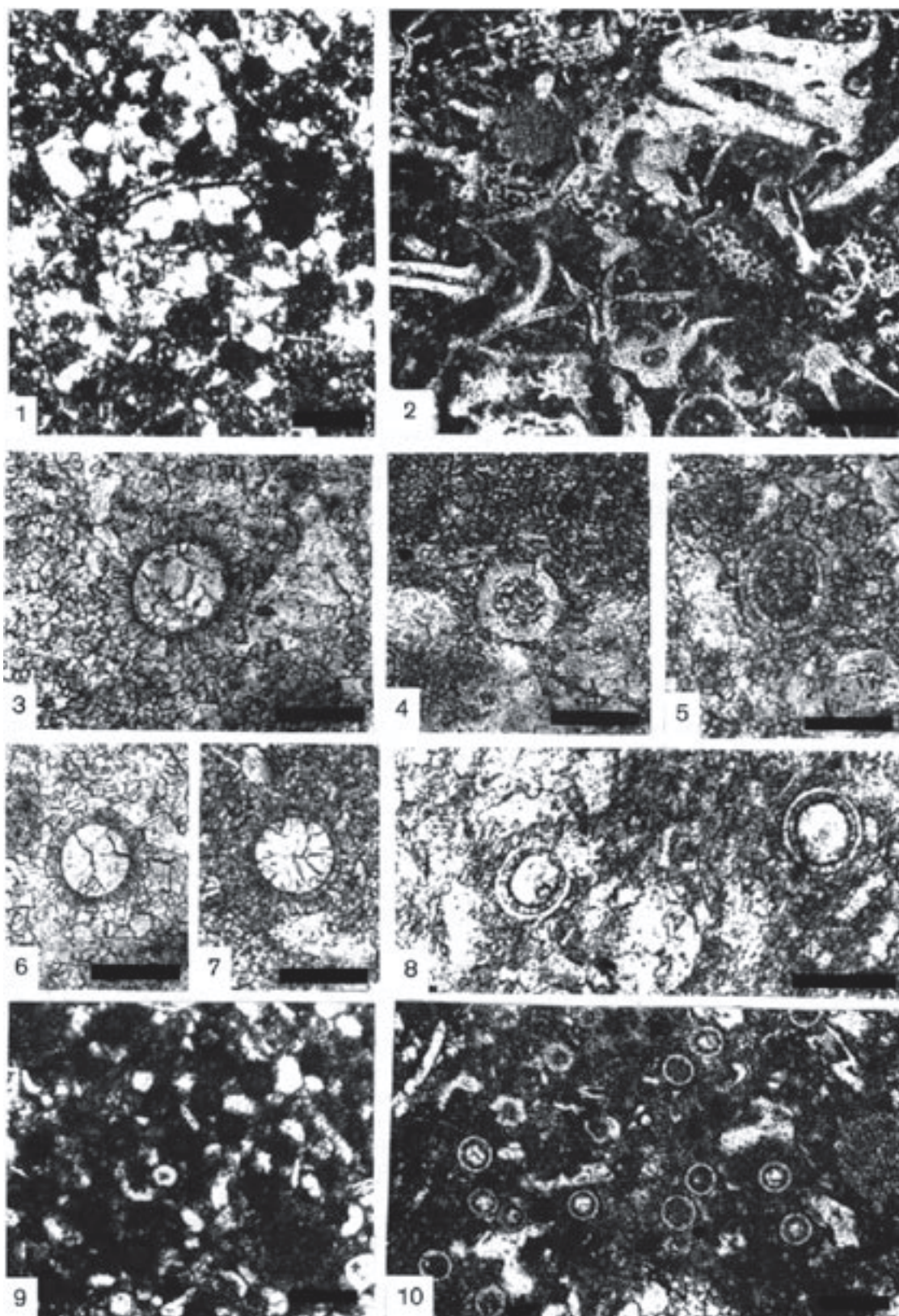
Plate II: Fig. 1. Microfacies with *Globochaete alpina* Lombard. Kimmeridgian, Manín Unit, bar = 100 μm. **Fig. 2.** Saccocoma packstone. Kimmeridgian, Czorsztyn Unit, bar = 200 μm. **Fig. 3.** *Colomisphaera nagyi* (Borza). Kimmeridgian, Czorsztyn Unit, bar = 50 μm. **Fig. 4.** *Stomiosphaera moluccana* Wanner. Kimmeridgian, Czorsztyn Unit, bar = 50 μm. **Fig. 5.** *Carpistomiosphaera borzai* (Nagy). Late Kimmeridgian, Vysoká Unit, bar = 50 μm. **Fig. 6.** *Colomisphaera pulla* (Borza). Early Tithonian, Vysoká Unit, bar = 50 μm. **Fig. 7.** *Carpistomiosphaera tithonica* Nowak. Early Tithonian, Vysoká Unit, bar = 50 μm. **Fig. 8.** *Parastomiosphaera malmica* (Borza). Early Tithonian, Czorsztyn Unit, bar = 100 μm. **Fig. 9.** Microfacies with acme *C. pulla*. Early Tithonian, Czorsztyn Unit, bar = 100 μm. **Fig. 10.** Microfacies with *Parastomiosphaera malmica* (Borza). Early Tithonian, Pruské Unit, bar = 100 μm.

chaete alpina Lombard (Pl. II: Fig. 1) proves favourable environmental conditions for the development of green algae. There was also the acme of *Saccocoma* Agassiz (Pl. II: Fig. 2). Planktonic crinoids became rock-forming organisms. This fact led Dragastan et al. (1975) to define the Saccocoma Zone. According to Matyszkiewicz (1997) and Keupp & Matyszkiewicz (1997) saccocomids are abundant in facies which prograded on the epicontinental platforms of the passive northern Tethyan shelf during the Late Oxfordian/?Earliest Kimmeridgian and Late Kimmeridgian/Early Tithonian and they marks the late transgressive systems tract as well as the presumed high stand deposits. Calcareous dinoflagellate associations were also abundant and diversified. Among them, groups with orthopitonellid type of wall structure reflecting pelagic conditions (Mutterlose & Böckel 1998) were dominant. *Colomisphaera nagyi* (Borza) — Pl. II: Fig. 3 occurs rarely in the higher part of the Kimmeridgian sequences together with *Stomiosphaera moluccana* Wanner (Pl. II: Fig. 4), an index species of the Moluccana Zone (sensu Nowak 1976). *Carpistomiosphaera borzai* (Nagy) — Pl. II: Fig. 5) appears in the uppermost Kimmeridgian deposits. Nowak (l.c.) defined the top Kimmeridgian–lowermost Tithonian Borzai Zone, later accepted by Borza (1984). According to Reháková (2000), the Borzai Zone is considered to be of Late Kimmeridgian age only.

Tithonian dinocyst stage

The dinocyst form *Colomisphaera pulla* (Borza) — Pl. II: Fig. 6 appeared at the beginning of the Early Tithonian. Nowak (1968) used the FO of this form for definition of the Pulla Zone, which he later abandoned. Borza (1984) pointed out a synchroneous FO event of *Colomisphaera pulla* and *Carpistomiosphaera tithonica* Nowak (Pl. II: Fig. 7) on the basis of which he proposed his Pulla-Tithonica Zone. Detailed studies of several sections indicated that the interval with abundant *C. pulla* (Pl. II: Fig. 9) precedes the FO of *C. tithonica*. This ecoevent was regarded as the Pulla Acme Zone (Reháková 2000). Environmental conditions dominating during the Early Tithonian were very favourable for development of calcareous dinocyst associations. Abundant *Parastomiosphaera malmica* (Borza) — Pl. II: Figs. 8, 10 appeared in the upper part of Lower Tithonian deposits. *Carpistomiosphaera tithonica* was also a distinct form of this interval. The FO of these two species was used for defining another two dinocyst Tithonica and Malmica zones. All the above mentioned Lower Tithonian cyst zones are characterized by high abundance and high diversity of dinoflagellate associations and they coincide with an elevated eustatic sea-level (Fig. 1).

The Middle Tithonian (sensu Gradstein et al. 1995) dinocyst zones Colomisphaera minutissima and C. carpathica were distinguished by Nowak (1968). Later, on the basis of the FO of *Colomisphaera cieszynica* Nowak, this interval was redefined as the "Cieszynica" Zone (Nowak 1976). Because, the first microgranular calpionellid forms of the genus *Chitinoidella* were shown to be a more reliable tool in stratification of pelagic deposits, these above mentioned cyst

zones were not accepted (Borza 1984). However, the recent tendency leading to utilization of the widest spectrum of elements suitable for detailed subdivision has forced the specialists to create separate dinoflagellate zonation. Correlating Kimmeridgian to Tithonian dinoflagellate and ammonite associations from the Monte Nerone pelagic limestone in Italy, Řehánek (in Řehánek & Cecca 1993) re-established the Cieszynica Zone. However, his conclusions have not been confirmed by Reháková (2000) who found out that the FO of *Cadosina semiradiata semiradiata* Wanner (Pl. III: Figs.1–2) precedes the FO of chitinoidellids belonging to the Dobeni Subzone. On the basis of these facts, the Semiradiata dinocyst zone has been distinguished (Reháková 2000).

The FO of *Colomisphaera tenuis* (Nagy) — Pl. III: Figs. 3–4, an index species of the Tenuis Zone, was also documented in the Middle Tithonian part of the pelagic sequence. It coincides with the onset of more advanced and diversified chitinoidellids of the Boneti Subzone. In the uppermost part of the Middle Tithonian deposits *Colomisphaera fortis* Řehánek (Pl. III: Figs. 5–6) appeared. This index species was used for defining of the Fortis Zone by Řehánek (1992). This zone was later accepted by Lakova et al. (1999). It is also acceptable in the West-Carpathian sequence. It is worth mentioning, that the interval with *C. fortis* contains a dinoflagellate association poor in both, abundance and diversity. It coincides with an abrupt ecoevent in the calpionellid association: chitinoidellid exctinction. Later, an ecological change may have been triggered their substitution by hyaline calpionellid forms of the Praentintinnopsella and the Crassicollaria zones. Shortly before the first occurrence of hyaline calpionellids, marks of distinct erosion and redeposition with sedimentary breccia layers was observed in several of the sections studied. The overlying strata usually contain no chitinoidellids, but the first transitional calpionellids have an inner hyaline and an outer microgranular wall layer. Breccia layers from the *Chitinoidella* and *Praetintinnopsella* transition beds are known practically from the whole West-Carpathian area. Although they were studied in detail from the Vysoká Unit of the Krížna Nappe (Reháková & Michalík 1995), they were not named. It seems, that the global third-order sea-level fall, called here the **Hlboč Event** (Fig. 1), was also associated with a rapid turnover in calpionelid evolution. Afterwards, favourable environmental conditions for the development of calpionellids predominated. Among qualitatively new hyaline associations, several radiations, stagnant and extinction phases were documented. Shortly after the FO of *Tintinnopsella remanei* Borza, the index species of the Remanei Subzone, abundant crassicollarian forms of larger size (*Crassicollaria intermedia* (Durand Delga) and *Cr. massutiniana* (Colom)) appeared. This radiation coincides with the third-order sea-level rise as is shown in Fig. 1. The FO of abundant small crassicollarian forms (*Cr. brevis* Remane) characterize the Brevis Subzone of the Crassicollaria Zone. Shortly after their appearance, large crassicollarians disappeared. This stagnant calpionellid phase coincides with the third-order sea-level fall. *Calpionella grandalpina* Nagy, *C. alpina* Lorenz and *Crassicollaria parvula* Remane dominated in a new radiation phase. The occurrence of abundant *Schizosphaerella minutissima* is observed as a coeval di-
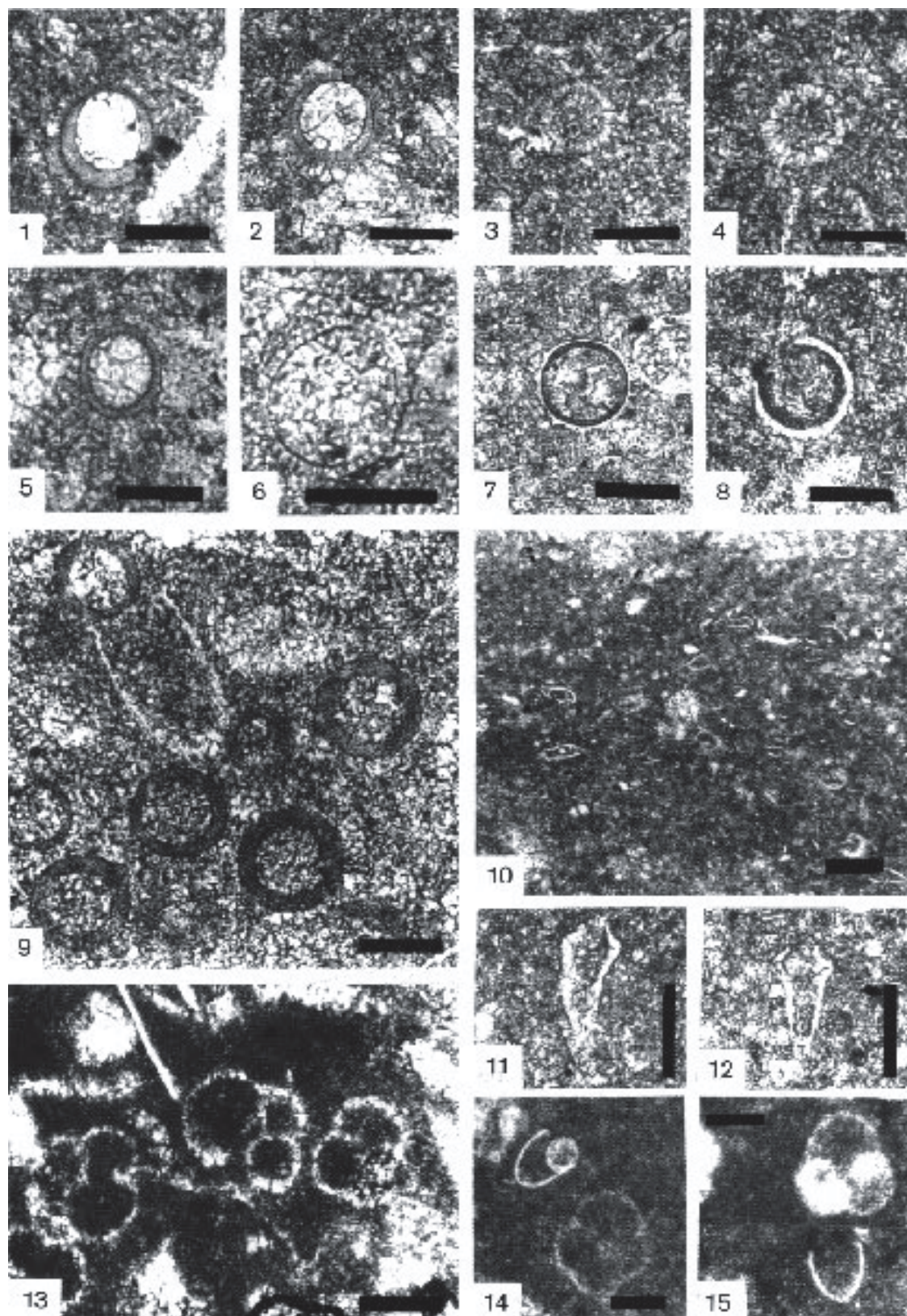
Plate III: Figs. 1–2. *Cadosina semiradiata semiradiata* Wanner. Middle Tithonian, Manín Unit, bars = 50 μm. **Figs. 3–4.** *Colomisphaera tenuis* (Nagy). Middle Tithonian, Czorsztyn Unit, bars = 50 μm. **Figs. 5–6.** *Colomisphaera fortis* Řehánek. Middle Tithonian, Vysoká Unit, bars = 50 μm. **Figs. 7–8.** *Stomiosphaerina proxima* Řehánek. Late Tithonian, Vysoká Unit, bars = 50 μm. **Fig. 9.** Microfacies with *Cadosina semiradiata fusca* Wanner and *Tintinnopsella carpathica* (Murg. & Filip.). Berriasian, Czorsztyn Unit, bar = 50 μm. **Figs. 10–12.** Deformed (?aberrant) crassicollarians. Late Tithonian, Zliechov Unit, bars = 100 μm. **Fig. 13.** *Favusella hoterivica* (Subbotina). Late Berriasian, Pruské Unit, bar = 100 μm. **Figs. 14–15.** *Gonoglobuligerina gulekhensis* (Gorbachik, Poroshina). Early Valanginian, Pruské Unit, bars = 100 μm.

nocyst event coinciding with an interval of calpionellid maximum diversity and it can be correlated with the sea-level transgression phase.

Decrease in the abundance of calcareous dinoflagellates is documented in the Upper Tithonian sequence. The FO of rare *Stomiosphaerina proxima* Řehánek (Pl. III: Figs. 7–8) was identified. The rare cadosinids (*Cadosina semiradiata fusca* (Wanner) and *C. semiradiata semiradiata* (Wanner)) are also present in microfacies of this time. According to Řehánek (1992), the FO of the index species *S. proxima* (defining the Proxima cyst zone) characterizes the Jurassic-Cretaceous boundary in the Western Carpathians. The Proxima Zone is accepted by Reháková (2000), although its age is regarded as Late Tithonian. The same result was arrived at by Lakova et al. (1999).

There is also an extinction of highly diversified crassicollarians which happened across the Tithonian-Berriasian boundary (Pl. III: Fig. 10). Compared with the interval of chitinoidellid disappearance, the same scenario of the environmental behaviour was also documented during the interval of crassicollarian retreat. Marks of erosion accompanied by siliclastic input and breccia accumulations were identified accross the whole West-Carpathian area (Pl. IV: Fig. 1). Huge, several metres thick breccia bodies observed in the Zliechov Unit of the Krížna Nappe (Michalík et al. 1995) can serve as a suitable example of environmental turnover. This abrupt change of the sedimentary conditions in the West-Carpathian area is defined as the **Zliechov Event**. It coincides with a global third-order sea-level fall (Fig. 1) interpreted as the so-called "Purbeckian regression" (Zakharov et al. in Rawson et al. 1996). Shortly afterwards, abundant "aberrant" crassicollarian forms (Pl. III: Figs. 11–12) occurred in environments influenced by a distinct siliclastic input. More turbiditic water masses and enhanced productivity could lead to diminishing penetration of sunlight into the photic zone (Gilbert & Clark 1982–1983). These conditions were not optimal for calcareous dinoflagellates and calpionellids.

On a global scale, the Jurassic Cretaceous Boundary Bio-Event is characterized as a second-order mass extinction interval. According to Barnes et al. (1996) it was spread through three short-term extinction events, or steps, at the base, middle and the end of the Tithonian Stage. Three distinct extinction steps are also documented among the planktonic associations of this time: saccocomid extinction during the Early Tithonian, chitinoidellid extinction during the Middle Tithonian and crassicollarian extinction during the Late Tithonian.

Berriasian–Valanginian dinocyst stage

Development of the calcareous dinoflagellates persisted in its stagnant phase from the Middle Berriasian. Rare *Schizosphaerella minutissima* and *Stomiosphaerina proxima* only were observed in sedimentary sequences of this time interval. Beside the dominant nannoconid associations, environmental conditions were favourable for calpionellid development. Free niches opened by the crassicollarian extinction were occupied by the expanding (r-strategist) spherical

Calpionella alpina Lorenz, an index species of the Alpina Subzone of the standard Calpionella Zone (Allemann et al. 1971; Remane et al. 1986). This form created a nearly monospecific association, which persisted from the appearence of the first remaniellids indicating the Ferasini Subzone. After a certain time following the innovation, strong calpionellid diversification is observable from the uppermost part of the Elliptica Subzone to the middle part of the standard Calpionellopsis Zone (the Oblonga Subzone). Abundant dinocyst (*Cadosina semiradiata fusca*, Pl. III: Fig. 9) with an obliquipithonelloid structure of calcite crystals forming a double-layered wall (Reháková & Michalík 1996) appeared in the interval of increasing calpionellid diversity. An interval with accumulation of this index species was considered as the Fusca Acme Zone (Reháková 2000). The abundance of these cysts varies from 35–50 % on pelagic elevations to 6–10 % of the planktonic remnants in basinal bottom sediments. After a longer break lasting from the end of Early Kimmeridgian, planktonic foraminifers represented by *Favusella hoterivica* (Subbotina) — Pl. III: Fig. 13 and *Gonoglobuligerina gulekhensis* (Gorbachik & Poroshina) — Pl. III: Figs. 14, 15 appeared in the planktonic assemblage. Enhanced calcareous dinoflagellate and calpionellid production, as well as the sudden onset of non-keeled, globular foraminifers, organisms typical of the Boreal bioprovince (Gasinski 1997), coincide with a second-order eustatic rise (Reháková & Michalík 1997b). It seems that a similar short communication between the biota of adjacent provinces as was documented during the Late Oxfordian, was repeatedly renewed during the Late Berriasian sea-level highstand.

An onset of more pelagic facies accompanied by both, distinct change in micro- and macrofaunal composition as well as changes recorded in stable isotopic values and clay minerals were discussed by Adatte et al. (1996). Sea-level rise influenced the atmospheric and consequently also the hydrodynamic oceanic regime. Near to the Calpionella and Calpionellopsis zonal boundary frequent intercalations of radiolaria rich horizons (Pl. IV: Fig. 2) appear in the hitherto rather monotonous calpionellid wackestones indicating more intensive aeration of deeper layers of oceanic water influenced by upwelling activity Reháková (1998).

A tiny dinocyst form, *Stomiosphaera wanneri* Borza (Pl. IV: Figs. 3–4) with typical orthopithonelloid wall structure (Reháková & Michalík 1996) was identified in the uppermost part of the Upper Berriasian. The FO of this index species is considered to be the base of the Wanneri cyst zone which was established by Lakova et al. (1999). Their results have also been confirmed by Reháková (1999). The Wanneri Zone corresponds to the Late Berriasian calpionellid Oblonga and Murgeanui subzones of the Calpionellopsis Zone. At the end of this zone a distinct breccia accumulation known as the Nozdrovice Breccia (Borza et al. 1980b; Pl. IV: Fig. 5) was identified in several sections. The third-order eustatic curve shows a rapid fall of the sea-level (Fig. 1). Shortly afterwards, sudden siliclastic input disturbing previously monotonous basinal carbonate sedimentation was observed. This broadly identified environmental change (similar to those shown in Late Tithonian) negatively influenced the amount of microplankton components. Calcareous dinoflagellates de-
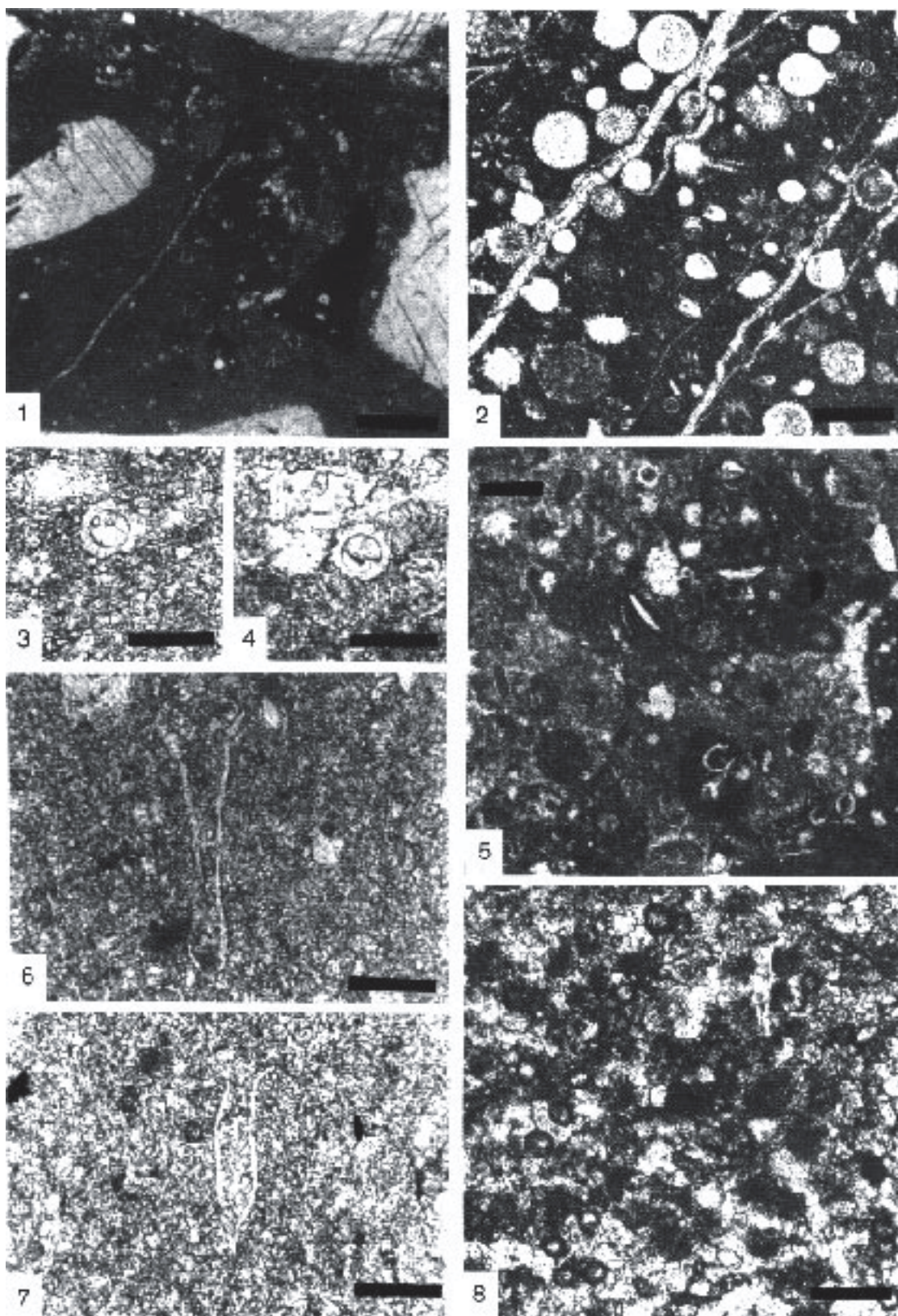
Plate IV: Fig. 1. Brecciated limestone from the Jurassic-Cretaceous boundary interval representing the global sea-level fall (named as the Zliechov Event). Tatric Superunit, bar = 200 µm. **Fig. 2.** Radiolarian wackestone reflecting the Late Berriasian current regime change. Kysuca Unit, bar = 200 µm. **Figs. 3–4.** *Stomiosphaera wanneri* Borza. Late Berriasian, Vysoká Unit, bars = 50 µm. **Fig. 5.** Nozdrovice Breccia with *Calpionella alpina* Lorenz. Late Berriasian, Zliechov Unit, bar = 100 µm. **Figs. 6–7.** "Aberrant" calpionellid forms documented in the end of standard Calpionellopsis Zone. Late Berriasian, Zliechov Unit, bars = 50 µm. **Fig. 8.** Acme Minuta (microfacies with abundant *Cadosina minuta* Borza). Early Valanginian, Czorsztyn Unit, bar = 100 µm.

creased in abundance. Previously highly diversified calpionel-lid associations rapidly decreased in diversity and abundance, too. Abundant "aberrant" calpionellid forms were observed in many of the studied sections (Pl. IV: Figs. 6, 7). This regressive pre-phase, leading later to calpionellid extinction, ultimately caused an increase in the evolutionary rate of nannoplankton associations.

From the topmost part of the Lower Valanginian deposits the FO of the cyst form of *Cadosina minuta* Borza (Pl. IV: Fig. 8) was confirmed. On the basis of the abundant monoassociation of the index species, this distinct short interval was defined as the Minuta Acme Zone (Reháková 2000). Among a nannoconid blooming the calpionellids tried to survive. Only several large forms of the standard Calpionellites Zone (Darderi and Major subzones) successfully asserted themselves in a strong selection stress. A very brief new radiation calpionellid phase coincides with a small third-order sea-level rise on a broad second-order sea-level fall. The Upper Valanginian sequence contains the dinocyst form *Colomisphaera vogleri* (Borza) — Pl. V: Figs. 1–2. A little later, the FO of *Carpistomiosphaera valanginiana* Borza (Pl. V: Figs. 3–4) was observed. The appearance of these two index species were used for establishing the Vogleri and Valanginiana cyst zones. Different results were obtained by Ivanova (in Lakova et al. 1999) who stated that the FO of the above mentioned index species are synchronous and they together characterize the onset of the Carpistomiosphaera valanginiana Zone.

A new, stronger siliciclastic input (Pl. V: Fig. 5) represented by the **Oravice Event** coinciding with the rapid third-order sea-level fall (Fig. 1). This abrupt change in environmental conditions led to total calpionellid decimation in almost the whole Tethyan region. It seems that this was the reason why calpionellids have never been observed in the Boreal Realm. On the other hand, rapid evolution and spreading of nannoconid communities is documented as a coeval event to the "calpionellid crisis" (Pl. V: Fig. 6). Only rare *Tintinnopsella carpathica* (Murgeanu & Filipescu) survived in the huge nannoconid blooms until the Late Valanginian, where marly limestones show a short interval of nannoconid depletion. From that point, overlying thin turbiditic intercalations contain rich accumulations of bivalve fragments (Pl. V: Fig. 7) recording coeval low oxygenate conditions in the adjacent areas. The marks of widespread-levels Late Valanginian transgression (Mutterlose 1992) controlled by further environmental factors were recorded from the Outer West-Carpathian area (Michalík et al. 1995). According to their interpretation, a positive excursion of the δ^{13}C corresponded to a short warm and humid climate interval preceding the mid-Cretaceous greenhouse state. Locally graded intercalations, rich in radiolaria and sponges (Pl. V: Fig. 8) could have been linked with the periodically active contour currents persisting until the Early Hauterivian.

Hauterivian Barremian dinocyst stage

The cyst form *Stomiosphaera echinata* Nowak (Pl. V: Figs. 9–10) was documented in the Upper Valanginian–Late Barremian passage beds. The FO of this rare form was stated as the base of the Echinata Zone. This interval contains a low abundance, but a highly diversified dinocyst association. A coeval more diversified cyst association from the NW part of the German Basin was described by Keupp (1979, 1981). The maximum diversity of calcareous dinoflagellates coincides with the trangressive phase recorded by the second-order eustatic curve (Fig. 1). An ongoing transgression influenced a turbiditic regime documented practically throughout the whole West-Carpathian area. The huge Strážovce turbidite complex (Pl. V: Fig. 11) deposited in the Zliechov Basin of the Fatric Unit was described by Borza et al. (1980b). The factor responsible for its accumulation is regarded here as the **Strážovce Event**. The evident depletion in dinoflagellate diversification is observed in Lower Barremian deposits. Nevertheless, the nannofloral speciation and development have still continued.

Aptian dinocyst stage

The disappearance of the index species forms of *Colomisphaera vogleri* and *Stomiosphaera echinata* at the beginning of the Early Aptian was considered as the base of the Cieszynica-Olzae cyst zone (Reháková 2000), in which cadosinids became dominant in the dinocyst association. The zone was named according to synchronously appearing obliquipithonelloid indexes: *Cadosina semiradiata cieszynica* (Nowak) — Pl. VI. Fig. 1 and *C. semiradiata olzae* (Nowak) — Pl. VI: Fig. 2. Only one orthopithonelloid dinoform *Colomisphaera heliosphaera* (Vogler) survived. The Early Aptian global climatic change (Arthur et al. 1991; Weissert & Lini 1991) is mirrored in the basinal Carpathian environments (Michalík et al. 1999), too. An onset of the black shale deposition was documented in several of the studied sections. The most spectacular occurrence from the Kysuca Basin was described as the **Koňhora Event** which was correlated with the known **"Selli Event"** of Erba (1994). Halásová in (Michalík et al. 1999) parallelized a dramatic decrease in abundance of the *Nannoconus* with the event known as the "nannoconid crisis" (Erba 1994). Planktonic foraminifers became dominant components of planktonic communities. Marly limestone with rich accumulations of radiolarians and sponges, periodically intercalated by black shale sequence, point to a renewed contourite current activity.

At the beginning of the Middle Aptian new forms of microgranular calpionellids appeared in foraminiferal wackestones to packstones. The vertical span of the calpionellid genera *Praecolomiella* Borza, *Deflandronella* Trejo, and *Parachitinoidella* Trejo was defined as the Praecolomiella Zone. Microgranular praecolomiellids are less frequent, but, on the other hand, their loricas are twice or several times larger than those of Middle Tithonian chitinoidellids. The nomismogenesis of planktonic foraminifers lowered the selectional stress among the calpionellids and this competitive environment led to a growth of their loricas. The revival of microgranular calpionellids at this time level allows us to speculate about a similar climatic and paleoceanographic conditions as were previously described in the Middle Tithonian (see position of the eustatic curve on Fig. 1).
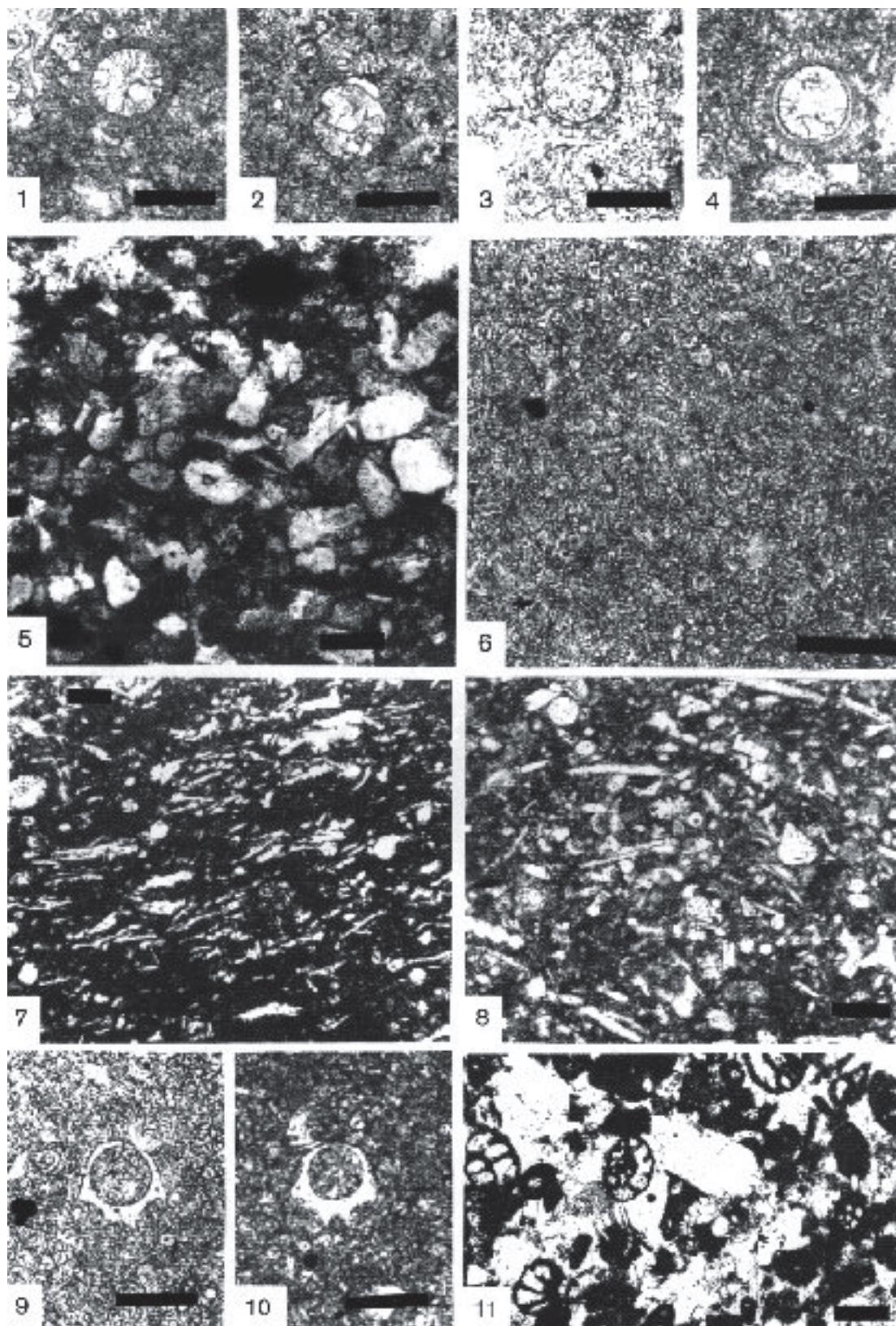
Plate V: Figs. 1–2. *Colomisphaera vogleri* (Borza). Late Valanginian, Vysoká Unit, bars = 50 μm. **Figs. 3–4.** *Carpistomiosphaera valanginiana* Borza. Late Valanginian, Manín Unit, bars = 50 μm. **Fig. 5.** Sandy limestone deposited during the Oravice Event. Early Valanginian, Zliechov Unit, bar = 100 μm. **Fig. 6.** Nannoconid packstone. Late Valanginian, Czorsztyn Unit, bar = 100 μm. **Fig. 7.** Calcareous turbidite limestone with bivalve fragments. Late Valanginian, Pruské Unit, bar = 100 μm. **Fig. 8.** Sponge packstone documented in the Lower Hauterivian part of Pruské Unit, bar = 100 μm. **Figs. 9–10.** *Stomiosphaera echinata* Nowak. Early Hauterivian, Czorsztyn Unit, bars = 50 μm. **Fig. 11.** Pelbiodetritic limestone with benthonic foraminiferal remnants sedimented in turbidite regime during the Strážovce Event. Hauterivian, Zliechov Unit, bar = 100 μm.
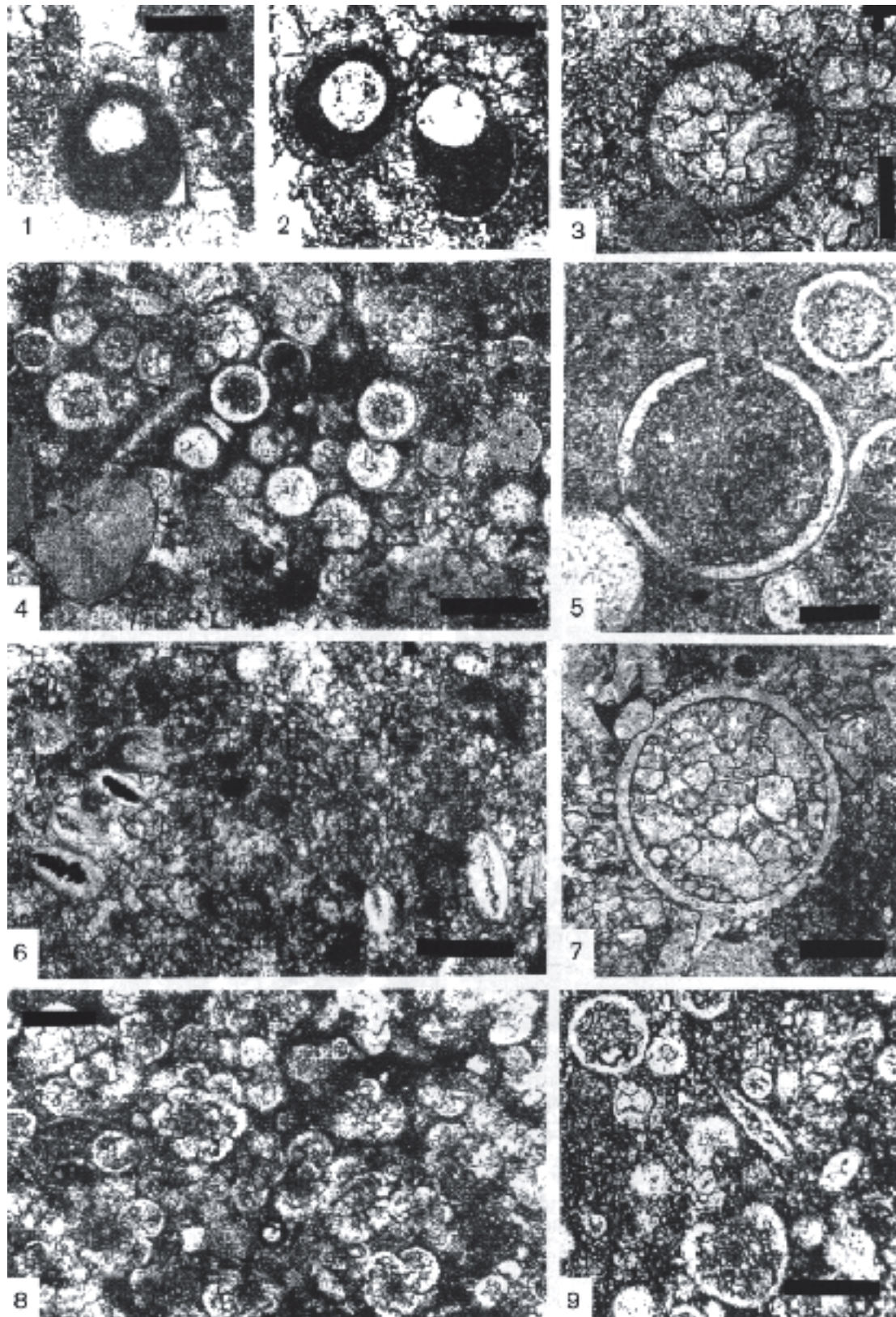
Plate VI: **Fig. 1.** *Cadosina semiradiata cieszynica* (Nowak). Early Aptian, Manín Unit, bar=50 µm. **Fig. 2.** *Cadosina semiradiata olzae* (Nowak). Early Aptian, Manín Unit, bar=50 µm. **Fig. 3.** *Cadosina oraviensis* Borza. Late Albian, Tatric Superunit, bar=50 µm. **Fig. 4.** Microfacies with *Calcisphaerula innominata* Bonet. Late Albian, Campanian congl. from the Pieniny Klippen Belt (PKB) area, bar=100 µm. **Fig. 5.** *Stomiosphaera sphaerica* Bonet. Late Albian, Tatric Superunit, bar=50 µm. **Fig. 6.** Microfacies with *Pithonella ovalis* (Kaufmann). Late Albian, Manín Unit, bar=100 µm. **Fig. 7.** *Colomisphaera gigantea* (Borza). Late Albian, Tatric Superunit, bar=50 µm. **Fig. 8.** Microfacies with abundant planktonic foraminifers. Albian, Kysuca Unit, bar=100 µm. **Fig. 9.** Microfacies with *Pithonella trejoi* Bonet, *Bonetocardiella conoidea* (Bonet), *Calcisphaerula innominata* Bonet and *Stomiosphaera sphaerica* Bonet. Late Albian, Ilerdian congl. of the PKB, bar=100 µm.

Albian dinocyst stage

Something like a restriction phase of calcareous dinocyst production is observable at the beginning of the Albian. On the other hand, there was a new explosive phase of nannoconid evolution documented by Erba & Quadrio (1987). Microgranular calpionellid forms disappeared. They were substituted by a new group with hyaline loricas. The FO of these hyaline calpionellids is used for definition of the last Early Cretaceous calpionellid Colomiella Zone which includes all species of the *Colomiella* Bonet and *Calpionellopsella* Trejo. It seems that microgranular calpionellid forms gave rise to hyaline ones several times independently. The change of the lorica composition was synchroneous with the Early Albian peak in nannoconid abundance (Erba & Quadrio 1987) similarly, as during the previously described Late Tithonian change of a chitinoidellid microgranular structure (Reháková & Michalík 1997a). The development of the last two mentioned calpionellid associations coincided with the elevated rate of the third-order sea-level rise (Fig. 1).

From the Middle to the Late Albian, there were very favourable environmental conditions for calcareous dinoflagellate development in the West-Carpathian area. Their innovation and radiation phases can be correlated with a broad second-order eustatic rise (Fig. 1). Two dinocyst zones, "Cadosina oraviensis" and Calcisphaerula were previously distinguished by Borza in (Borza & Michalík 1986). According to Reháková (2000), the interval with abundant *Cadosina oraviensis* Borza (Pl. VI: Fig. 3) is considered as the Oraviensis Acme Zone. The index species is further accompanied by abundant *Cadosina callosa* Knauer usually occurring in sediments characterized by foraminiferal and crinoidal microfacies (Pl. VI: Fig. 8). The Late Albian interval with abundant *Calcisphaerula innominata* Bonet (Pl. VI: Fig. 4) was considered as the Innominata Acme Zone (Reháková 2000). Shortly above the FO of the index species, *Stomiosphaera sphaerica* (Kaufman) — Pl. VI: Fig. 5, *Pithonella ovalis* (Kaufmann) — Pl. VI: Fig. 6, *Colomisphaera gigantea* (Borza) — Pl. VI: Fig. 7, *Bonetocardiella conoidea* (Bonet) and *Pithonella trejoi* Bonet (Pl. VI: Fig. 9) appear in the glauconitic limestone and marly sequence.

Conclusions

Dinoflagellates formed a significant element of the Jurassic and Cretaceous marine phytoplankton throughout the world in open shelf, slope and basinal environments. Due to very favourable conditions for the development of planktonic associations, a rich and structured ecosystems could originate in the photic zone of the Tethyan Realm during that time. Certain dinoflagellate taxa formed a resistant calcareous/or sporopollenin cyst which was the only potentially fossilizable stage of their life cycle. The focus of this study was precisely calcareous dinocyst associations. The investigation of their vertical distribution allowed us:

 a) to show that the independent dinocyst zonation can serve as one of the important tools of the integrated biostratigraphy of the Upper Jurassic and Lower Cretaceous carbonate deposits of the Western Carpathians;

b) to correlate this zonation with dinocyst zonations established recently in the East-Carpathian area, in order to show its interregional availability;

 c) to distinguish several diversification and diversity reduction events among the cyst associations studied and to utilize them for paleoenvironmental reconstruction.

d) to correlate the dinocyst zonation with the calpionellid events and zonation and thus to contribute to the HIRES of the Upper Jurassic and Lower Cretaceous Tethyan pelagic carbonate sequences.

It seems that not only calpionellids but also calcareous dinoflagellates belonged to the planktonic elements sensitively recording the whole complex of environmental changes such as climate perturbations, sea-level fluctuations, nutrient distribution. It was shown that the sea-level transgressive stages were favourable for dinocyst development and all distinguished acme concentrations of cyst taxa studied were controlled by sea-level highstand phases. On the other hand, cyst diversity reduction events coincided with sea-level regressive stages.

References

Adatte T., Stinnesbeck W., Remane J. & Hubberten H. 1996: Paleoceanographic changes at the Jurassic-Cretaceous boundary in the Western Tethys, northeastern Mexico. *Cretaceous Research* 17, 671–689.

Allemann F., Catalano R., Fares F. & Remane J. 1971: Standard calpionellid zonation (Upper Tithonian–Valanginian) of the western Mediterranean Province. *Proc. II Plankt. Conf. Roma 1970,* 1337–1340.

Arthur M.A., Kump L.R., Dean W.E. & Larson R.L. 1991: Superplume, supergreenhouse? *Eos Trans. AGU* 72, 17, *Spring Meeting Suppl.*, 301.

Barnes Ch., Hallam A., Kaljo D., Kauffman E.G. & Walliser O.H. 1996: Global event stratigraphy. In: Walliser O.H. (Ed.): Global events and event stratigraphy. *Springer,* 1–319.

Bolli H.M. 1974: Jurassic and Cretaceous Calcisphaerulidae from DSDP Leg 27, eastern Indian Ocean. In: Veevers J.J. & Heirtzler J.R. et al. (Eds.): Init. Repts. DSDP, 27. *U.S. Govt. Printing Office,* Washington, 843–907.

Bonet F. 1956: Zonificación microfaunística de las calizas cretácicas del Este de México. *Bol. Asoc. Mex. Geol. Petrol.* 7, 7–8, 389–488.

Borza K. 1969: Die Mikrofazies und Mikrofossilien des Oberjuras und der Unterkreide der Klippenzone der Westkarpaten. *Editory House of the Slovak Academy of Sci.*, Bratislava, 5–301.

Borza K. 1980a: Relationships of Inner Carpathians to the Klippen Belt, microfacies and microfossils of Upper Jurassic and Lower Cretaceous. *Manuscript, Archive of Geol. Inst. of Slovak Acad. of Sci.,* Bratislava, 1–392 (in Slovak).

Borza K. 1984: The Upper Jurassic-Lower Cretaceous parabios-

tratigraphic scale on the basis of Tintinninae, Cadosinidae, Stomiosphaeridae, Calcisphaerulidae and other microfossils from the West Carpathians. *Geol. Zbor. Geol. Carpath.* 35, 5, 539–550.

Borza K., Gašparíková V., Michalík J. & Vašíček Z. 1980b: Upper Jurassic-Lower Cretaceous sequence of the Krížna-nappe (Fatric) in the Strážovce section, Strážovské vrchy Mts. (Western Carpathians). *Geol. Zbor. Geol. Carpath.* 31, 541–562.

Borza K. & Michalík J. 1986: Problems with delimitation of the Jurassic/Cretaceous boundary in the Western Carpathians. *Acta Geol. Hung.* 29, 1–2, 133–149.

Cariou E. & Hantzpergue P. 1997: Biostratigraphie du Jurassique uoest — Européen et Méditerranéen. *Bull. Centre Rech. Elf. Explor. Prod., Mém.* 17, 1–422.

Colom G. 1955: Jurassic-Cretaceous pelagic sediments of the western Mediterranean zone and the Atlantic area. *Micropaleontology* 1, 109–124.

Colom G. 1994: Sobre la presencia de organismos esferoidales ”incertae sedis” en el Jurásico–Cretácico de las Baleares. *Rev. Cuatrimestral Micropaleont.* 16, 3, 5–25.

Dragastan O., Mutiu R. & Vinogradov C. 1975: Les zones micropaléontologiques et la limite Jurassique–Crétacé dans les Carpates orientales (Monts de Haghimas) et dans la plateforme moesienne. *Mém. Bur. Rech. Géol. Min.* 86, 188–203.

Durand Delga M. 1957: Quelques remarques sur les fibrosphàres. *Publ. Serv. Carte Géol. l'Algérie. Nouv. Sér., Bull.* 13, *Trav. Collab.,* 153–164.

Erba E. 1994: Nannofossils and superplumes: the early Aptian nannoconid crisis. *Paleoceanography* 9, 483–501.

Erba E. & Quadrio B. 1987: Biostratigrafia a nannofossili calcarei, calpionellidi e foraminiferi della Maiolica (Titoniano superiore–Aptiano) nelle Prealpi Bresciane (Italia settentrionale). *Riv. Ital. Paleont. Stratig.* 93, 3–108.

Fütterer D.K. 1976: Kalkige Dinoflagellaten (“Calciodinelloideae”) und die systematische Stellung der Thoracosphaeroideae. *Neu. Jb. Geol. Paläont. Abh.* 151, 119–141.

Fütterer D.K. 1990: Distribution of calcareous dinoflagellates at the Cretaceous-Tertiary boundary of Queen Maud Rise, eastern Weddell Sea Antarctica (ODP Leg 113). In: Barker P.F. & Kennet J.P. et al. (Eds.): Proc. ODP, Sci. Results, 113. *College Station, TX (Ocean Drilling Program),* 533–538.

Gasinski W.A. 1997: Tethys and Boreal connection: influence on the evolution of mid-Cretaceous planktonic foraminiferids. *Cretaceous Research* 18, 505–514.

Gilbert M.W. & Clark D.L. 1982–1983: Central arctic ocean paleoceanographic interpretation based on Late Cenozoic calcareous dinoflagellates. *Mar. Micropaleontol.* 7, 385–401.

Gradstein F.M., Agterberg F.P., Ogg J.G., Hardenbol J., VanVeen P., Thierry J. & Huang Z. 1995: A Triassic, Jurassic and Cretaceous time scale. In: Berggren W.A., Kent D.V., Aubry M.P. & Hardenbol J. (Eds.): Geochronology, time scales and global stratigraphic correlation. *SEPM Spec. Publ.* 54, 95–126.

Haeckel E. 1894: Entwurf eines natürlichen Systems der Organismen auf Grund ihrer Stammesgeschichte, erster Teil: Systematische Phylogenie der Protisten und Pflanzen. 1–400.

Haq B.U., Hardenbol J. & Vail P.R. 1988: Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In: Wilgus C.K., Hastings B.S., Kendall C.G.St C., Posamentier H.W., Ross C.A. & van Wagoner J.C. (Eds.): Sea-level changes — an integrated approach. *Soc. Econ. Paleont. Miner. Spec. Publ.* 42, 26–108.

Heer O. 1865: Urwelt der Schweiz. *Friedrich Schulthess,* Zürich, 1–622.

Hildebrand-Habel T. & Willems H. 1997: Calcareous dinoflagellate cysts from the Middle Coniacian to Upper Santonian chalk facies of Lägerdorf (N Germany). *Cour. Forsch. Inst.*

Senckenberg 201, 177–199.

Hoedemaeker Ph.J., Company M., Aguirre-Urretta B., Avrame, Bogdanova T.N., Bulot L., Cecca F., Delannoy G., Ettachfini M., Memmil, Owen H.G., Rawson A.F., Sandoval J., Tavera J.M., Thieuloy J.P., Tovbina S.Z. & Vašíček Z. 1993: Ammonite zonation for the Lower Cretaceous of the Mediterranean region, basis for stratigraphic correlations within IGCP Project 262. *Rev. Esp. Paleontol.* 8, 117–120.

Keupp H. 1979: Lower Cretaceous Calcisphaerulidae and their relationship to calcareous dinoflagellate cysts. *Bull. Cent. Rech. Explor. Prod. Elf-Aquit.* 3, 2, 651–663.

Keupp H. 1980: *Pithonella patriciacreeleyae* Bolli 1974, eine kalkige Dinoflagellaten-Zyste mit innerer Paratabulation (Unter-Kreide, Speeton/SE-England). *Neu. Jb. Geol. Paläontol. Monatsh. 1980* 9, 513–524.

Keupp H. 1981: Die kalkigen Dinoflagellaten-Zysten der borealen Unter-Kreide (Unter-Hauterivium bis unter-Albium). *Facies* 5, 1–90.

Keupp H. 1984: Revision der kalkigen Dinoglagellaten-Zysten G. Deflandres, 1948. *Paläont. Z.* 58, 1/2., 9–31.

Keupp H. 1987: Die kalkigen Dinoflagellaten Zysten des Mittelalb bis Untercenoman von Escalles/Boulonnais (N-Frankreich). *Facies* 16, 37–88.

Keupp H. 1990: Fossil calcareous dinoflagellate cysts. In: Riding R. (Ed.): Calcareous Algae and Stromatolites. *Springer Editory House,* Berlin, 267–286.

Keupp H. 1991: Kalkige Dinoflagellaten-Zysten aus dem Eibrunner Mergel (Cenoman–Turon–Grenzbereich) bei Bad Abbach/Süddeutschland. *Berliner Geowiss. Abh.* 134, 127–145.

Keupp H. 1992: Calcareous dinoflagellate cysts from the Lower Cretaceous of hole 761 C, Wombat Plateau, Eastern Indian ocean. In: Rad U. & Haq B.U. et al. (Eds.): Proceedings of the Ocean Drilling Program, Scient. Res. 122. 497–509.

Keupp H. & Ilg A. 1989: Die kalkigen Dinoflagellaten im Ober-Callovium und Oxfordium der Normandie/Frankreich. *Berliner Geowiss. Abh. A* 106, 165–205.

Keupp H., Kohring R. & Kowalski F.U. 1992: Neue Arten der Gattung *Ruegenia* Willems 1992 (kalkige Dinoflagellaten-Zysten) aus Kreide und Tertiär. *Berliner Geowiss. Abh.* 3, 191–209.

Keupp H. & Kowalski F.U. 1992: Die kalkigen Dinoflagellaten — Zysten aus dem Alb von Folkestone/SE — England. *Berliner Geowiss. Abh.* 3, 211–251.

Keupp H. & Matyszkiewicz J. 1997: Zur Faziesrelevanz von Saccocoma — Resten (Schwebcrinoiden) in Oberjura — Kalken des nördlichen Tethys-Schelfs. *Geol. Bl. NO-Bayern* 47, 1–4, 53–70.

Keupp H. & Mutterlose J. 1984: Organismenverteilung in den D-Beds von Speeton (Unterkreide, England) unter besonderer Berücksichtigung der kalkigen Dinoflagellaten-Zysten. *Facies* 10, 153–178.

Keupp H. & Versteegh G. 1989: Ein neues systematisches Konzept für kalkige Dinoflagellaten-Zysten der Subfamilie Orthopithonelloideae Keupp 1987. *Berliner Geowiss. Abh. A* 106, 207–219.

Lakova I., Stoykova K. & Ivanova D. 1999: Calpionellid, nannofossils and calcareous dinocyst bioevents and integrated biochronology of the Tithonian to Valanginian in the West Balkan Mountains, Bulgaria. *Geol. Carpathica* 50, 2, 151–168.

Leischner W. 1959: Zur Mikrofazies kalkalpiner Gesteine. *Sitz. Ber. Österr. Akad. Wiss.* I, 839–882.

Lineckaya L.V. 1974: Stratigraphy of limestone beds of Upper Jurassic and Lower Cretaceous of Tethys USSR (Carpathians, Crimea, Big Balchan, Kopet-Dag, south-west spur Gissarian Mountain-Range) in the light of study little known group of Nannoplankton (Tintinnoidea, Stomiosphaera, Cadosina and Globochaete). *Sect. Stratigraphy and Paleont. Proceed. Xth Congress CBGA, 1973,* Bratislava, 108–115.

Lorenz T. 1902: Geologische Studien im Grenzgebiet zwischen

helvetischer und ostalpiner Fazies. II. Der südliche Rhaetikon. *Berl. Naturforsch. Gesell. Freiburg i. Br.*, 12, 34–62.

Matyszkiewicz J. 1997: Microfacies, sedimentation and some aspects of diagenesis of Upper Jurassic sediments from the elevated part of the Northern peri-Tethyan Shelf: a comparative study on the Lochen area (Schwäbische Alb) and the Cracow area (Cracow — Wielun Upland, Polen). *Berliner Geowiss. Abh.* E 21, 1–111.

Michalík J., Reháková D., Lintnerová O., Boorová D., Halásová E., Kotulová J., Soták J., Peterčáková M., Hladíková J. & Skupien P. 1999: Sedimentary, biological and isotopical record of an Early Aptian paleoclimatic event in the Pieniny Klippen Belt, Slovak Western Carpathians. *Geol. Carpathica* 50, 169–191.

Michalík J., Reháková D. & Vašíček Z. 1995: Early Cretaceous sedimentary changes in the West Carpathian area. *Geol. Carpathica* 46, 5, 285–296.

Mutterlose J. 1992: Migration and evolution patterns of floras and faunas in marine Early Cretaceous sediments of N-W-Europe. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 94, 261–282.

Mutterlose J. & Böckel B. 1998: The Barremian–Aptian interval in NW Germany: a review. *Cretaceous Research* 19, 539–568.

Nagy I. 1966: Sur le rôle stratigraphique des genres Stomiosphaera et Cadosina dans le Jurassique supérieure de la Montagne Mecsek. *Földt. Közl.* 96, 1, 86–104.

Nagy I. 1971: Dissection of Upper Jurassic sediments of the Mecsek Mts. on the basis of fossils. *Ann. Inst. Geol. Publ. Hung.* 54, 319–332 (in Russian).

Nowak W. 1966: Cadosina Wanner, 1940 (incertae sedis) from the Polish part of flysh Carpathians. *Spraw. Posiedz. Kom. Oddz.* 468–470 (in Polish).

Nowak W. 1968: Stomiosphaerids of the Cieszyn Beds (Kimmeridgian–Hauterivian) in the Polish Cieszyn Silesia and their stratigraphic value. *Roczn. Pol. Tow. Geol.* 38, 2–3, 275–327 (in Polish).

Nowak W. 1974: Stomiosphaerina nov.gen. (incertae sedis) of the Upper Cretaceous in the Polish Flysch Carpathians. *Roczn. Pol. Tow. Geol.* 44, 1, 51–63.

Nowak W. 1976: Parastomiosphaera malmica (Borza) from the Polish Carpathians and their stratigraphical value for Lower Tithonian deposits. *Roczn. Pol. Tow. Geol.* 46, 1–2, 89–134.

Oschmann W. 1995: Black shales models: an actualistic approach. *Europal* 8, 26–35.

Pflaumann U. & Krasheninnikov V.A. 1978. Cretaceous calcisphaerulids from DSDP Leg 41, E North Atlantic. In: Lancelot Y. & Seibold E. et al. (Eds.): Init. Repts. DSDP 41. *U.S. Govt. Printing Office,* Washington, 817–839.

Reháková D. & Michalík J. 1995: Sedimentary record of Early Cretaceous tectonic activity in the Alpine-Carpathian region. *Slov. Geol. Mag.* 2, 159–164.

Reháková D. & Michalík J. 1996: Stomiosphaera or Orthopitonella? Cadosina or Obliquipithonella? notes to ultrastructure and systematic position of some Jurassic-Cretaceous calcareous dinoflagellates from Western Carpathians. *Miner. Slovaca* 28, 92–98.

Reháková D. & Michalík J. 1997a: Evolution and distribution of calpionellids — the most characteristic constituent of Lower Cretaceous Tethyan microplankton. *Cretaceous Research* 18, 493–504.

Reháková D. & Michalík J. 1997b: Calpionellid association versus Late Jurassic and Early Cretaceous sea level fluctuations. *Miner. Slovaca* 29, 4–5, 306–307.

Reháková D. 1995: Upper Jurassic/Lower Cretaceous carbonate microfacies and environmental models from Western Carpathians and adjacent paleogeographic units. *Cretaceous Re-*

search 16, 283–297.

Reháková D. 1998: Calpionellid genus *Remaniella* Catalano 1956 in Lower Cretaceous pelagic deposits of Western Carpathians. *Miner. Slovaca* 30, 443–452.

Reháková D. 2000: Evolution and distribution of the Late Jurassic and Early Cretaceous calcareous dinoflagellates recorded in the Western Carpathian pelagic carbonate facies. *Miner. Slovaca,* 32, 79–88.

Řehánek J. 1985: Cadosinidae Wanner and Stomiosphaeridae Wanner (incertae sedis) from the Mesozoic limestones of Southern Moravia. *Čas. Mineral. Geol.* 30, 4, 367–380.

Řehánek J. 1992: Valuable species of cadosinids and stomiosphaerids for determination of the Jurassic–Cretaceous boundary (vertical distribution, biozonation). *Scripta* 22, 117–122.

Řehánek J. & Cecca F. 1993: Calcareous dinoflagellate cysts biostratigraphy in Upper Kimmeridgian–Lower Tithonian pelagic limestones of Marches Apennines. *Rev. Micropaléont.* 36, 2, 143–163.

Řehánek J. & Heliasz Z. 1993: Microfacies and microbiostratigraphy of the Oxfordian–Lower Kimmeridgian on the basis of Cadosinids and Stomiosphaerids in the Czestochowa region of Poland. *Geol. Carpathica* 44, 2, 81–93.

Remane J., Bakalova-Ivanova D., Borza K., Knauer J., Nagy I., Pop G. & Tardi-Filacz E. 1986: Agreement on the subdivision of the standard calpionellid zones defined at the IInd Planktonic Conference, Roma 1970. *Acta Geol. Hung.* 29, 5–14.

Simmons M.D., BouDagher-Fadel M.K., Banner F.T. & Whittaker J.E. 1997: The Jurassic Favusellacea, the earliest Globigerinina. In: BouDagher-Fadel M.K., Banner F.T. & Whittaker J.E. with a contribution from Simmons M.D. (Eds.): The Early Evolutionary History of Planktonic Foraminifera. *Chapman & Hall*, London, 1–265.

Vašíček Z., Michalík J. & Reháková D. 1994: Early Cretaceous stratigraphy, paleogeography and life in Western Carpathians. *Beringeria* 10, 1–170.

Vogler J. 1941: Oberer Jura und Kreide von Misol (Niederländisch — Ostindien). *Paleontographica Suppl.* B., 4, 246–293.

Wanner J. 1940: Gesteinbildende Foraminiferen aus Malm und Unterkreide des östlichen Ostindischen Archipels nebst Bemer kungen über Orbulinaria Rhumbler und andere verwandte Foraminiferen. *Paläont. Z.* 22, 2, 75–79.

Wall D. & Dale B. 1968: Quaternary calcareous dinoflagellates (Calciodinellideae) and their natural affinities. *J. Paleontology* 42, 1395–1408.

Weissert H. & Lini A. 1991: Ice Age interludes during the time of Cretaceous greenhouse climate? In: Müller D.W., McKenzie J.A. & Weissert H. (Eds.): Controversies in Modern Geology. *Academic Press*, London, 173–191.

Willems H. 1988: Kalkige Dinoflagellaten-Zysten aus der oberkretazischen Schreibkreide-Fazies N-Deutschlands (Coniac bis Maastricht). *Senckenberg. Lethaea* 68, 433–477.

Willems H. 1990: Tetratropis, eine neue Kalkdinoflagellaten-Gattung (Pithonelloideae) aus der Ober-Kreide von Lägerdorf (N-Deutschland). *Senckenberg. Lethaea* 70, 1–3, 239–257.

Willems H. 1992: Kalk-Dinoflagellaten aus dem Unter-Maastricht der Insel Rügen. *Z. Geol. Wiss.* 20, 1–2, 155–178.

Willems H. 1994: New calcareous dinoflagellates from the Upper Cretaceous white chalk of northern Germany. *Rev. Paleobot. Palynol.* 84, 57–72.

Zakharov V.A., Bown P. & Rawson P.F. 1996: The Berriasian stage and the Jurassic-Cretaceous boundary. In: Rawson P.F., Dhondt A.V., Hancock J.M. & Kennedy W.J. (Eds.): Proceedings "Second International Symposium on Cretaceous Stage Boundaries". *Sci. Terre* 66, *Supp.* 7–10.