Slump/Slide facies and biostratigraphy at the transition of the Cieszyn and Hradiště formations in the Cieszyn (Těšín) Section (Outer Flysch Carpathians)

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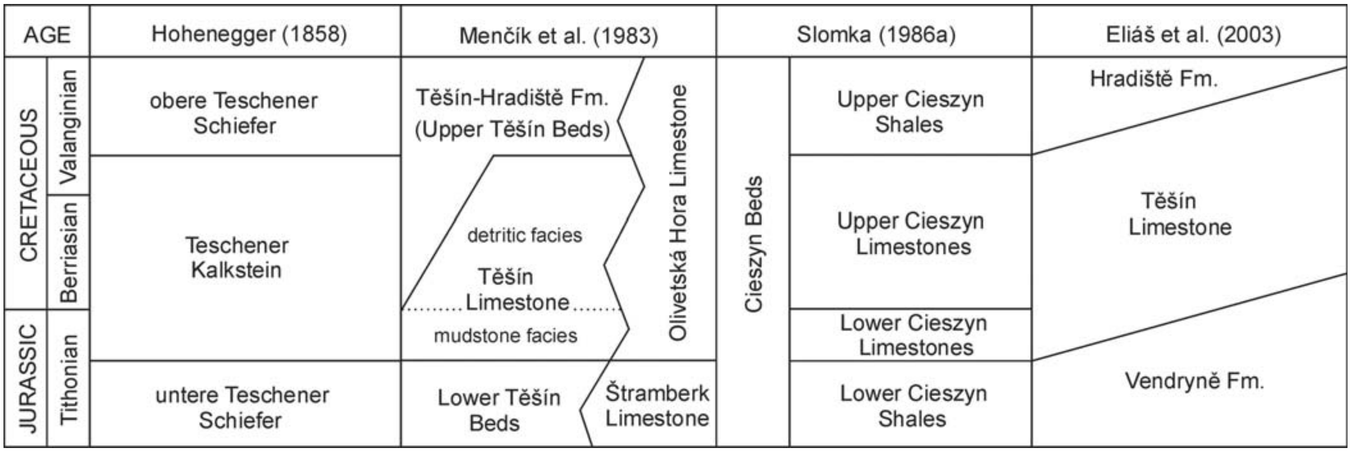
ABSTRACT: New sedimentological observations in the Lower Cretaceous of the Silesian Unit and integrated biostratigraphy based on calcareous nannofossils, dinoflagellate cysts, calpionellids and foraminifers have brought new insight to the stratigraphy of the Cieszyn section. The oldest exposed strata of the mudstone facies of the Cieszyn Limestone Formation are of early Berriasian age, based on calcareous nannofossil evidence. This work proposes that the Jurassic–Cretaceous boundary reported by previous authors was based on reworked microfossils. The detritic facies of the Cieszyn Limestone Formation, typically dominated by detritic-limestone turbidites, appears to be completely missing. Instead, a thick body with combined slump and slide features, of Berriasian–Valanginian age, forms the transition with the overlying lower Valanginian strata of the Hradiště Formation. The slump/slide body represents a local facies, deposited on a fault scarp related to fault-controlled extension of the Proto-Silesian Basin floor.

Keywords: Silesian Unit, Berriasian, Valanginian, biostratigraphy, calpionellids, calcareous nannofossils, foraminifera, dinoflagellates.

INTRODUCTION

Castle Hill in the town of Cieszyn (Teschen in German, Těšín in Czech) is a significant geological site. Outcrops of marlstones and limestones in its slope and adjacent riverbed provide evidence of the oldest recorded geological history of the Proto-Silesian Basin that started in the Late Jurassic period. These strata were documented by geologists in the first half of the 19th century when Oeynhausen (1822) reported the "Teschener Kalk-Gebirge", a regional unit including various strata of the Silesian and Subsilesian nappes. Pusch (1836, p. 17) introduced the name "Teschener Kalkstein (Kalk)" for the Cieszyn Limestone Formation, and assigned it to the Lias. He reported many localities, but none particularly in Cieszyn itself. Hohenegger (1852) distinguished the "Teschener Schiefer" and "Teschener Kalk" and assigned them to the upper Neocomian (Aptian). Later, he refined the subdivision of these strata (Hohenegger 1858) and defined the "untere Teschener Schiefer", "Teschener Kalkstain", and "obere Teschener Schiefer" (text-figure 1). At the same time, he assigned his Teschener Kalkstein to the lower part of the Hils Stage (Berriasian–Valanginian) based on macrofauna. Detailed descriptions of the units were given in the explanatory text of the 1:75000 scale geological map of the area (Hohenegger 1861). Thanks to this excellent study, Ludwig Hohenegger is referred to as the "Father of Carpathian Flysch geology".

Outcrops on the western slope of the Cieszyn Castle Hill and adjacent bed of the Olza River are often considered to be the type section of the Cieszyn Limestone Formation (e.g. Golonka et al. 2008; 2016). Hohenegger (1852) was the first who defined the formation but did not select the type section for it. In his map, Hohenegger (1861) assigned the area of Castle Hill and adjacent Olza River bed to the "untere Teschener Schiefer", which corresponds to the Vendryně Formation (see text-figure 1). Therefore the Cieszyn section cannot be the type section and this should be preferably chosen from the occurrences of the Cieszyn Limestone Formation recorded by Hohenegger himself. This fact does not decrease the importance of the Castle Hill section for stratigraphy and the section has attracted researchers for the Jurassic–Cretaceous boundary study.



TEXT-FIGURE 1
Lithostratigraphic division of Tithonian – Valanginian strata of the Silesian Unit by various authors.

For the last hundred years, the section has been the subject of many paleontological investigations focused on microfossils, biostratigraphy and paleoecology. A compilation of the geological map of the Silesian Carpathians prepared by Burtan et al. (1937) provided greater detail on the geological structure of the Cieszyn area. Preliminary results of calpionellid and stomiospherid biostratigraphy of Jurassic–Cretaceous transitional strata in the Cieszyn area were first published by Sujkowski (1932) and Nowak (1965). Nowak (1967) gave a detailed description of the 15 m thick section on the western slope of Castle Hill (Góra Zamkowa). Based on a bed-by-bed thin section study, he established a calpionellid biostratigraphy of the section and identified the Jurassic–Cretaceous (J–K) boundary. Furthermore, he reported on the exposures in the Olza riverbed: the dark marlstones intercalated with bituminous detritic limestones (Vendryně Fm.) and light-gray limestones intercalated with greenish and yellowish marls (Cieszyn Limestone Fm., which are approximately equivalent to the Castle Hill section). In his subsequent papers, he studied calcareous dinocysts (Nowak 1968) and the morphologic variability of *Calpionella* (Nowak 1971).

The calpionellid stratigraphy of the Cieszyn Limestone Formation was later studied by Ciborowski (2000) and results were included in his PhD thesis. Olszewska (2005) revised the biostratigraphy of the Castle Hill section based on thin section studies of calpionellids, calcareous dinocysts and foraminifers; she placed the J–K boundary in the basal part of the Cieszyn Limestone Formation. Olszewska (2005) assigned the main part of the section to the Berriasian and lower Valanginian and part of the outcrops in the Olza riverbed to the middle Berriasian. An updated integrated stratigraphy, including calcareous nannofossils, was published by Olszewska et al. (2008). Szydło (1997; 2004; 2005) dealt with foraminifers of the Cieszyn Limestone Formation from the Cieszyn section and wider area.

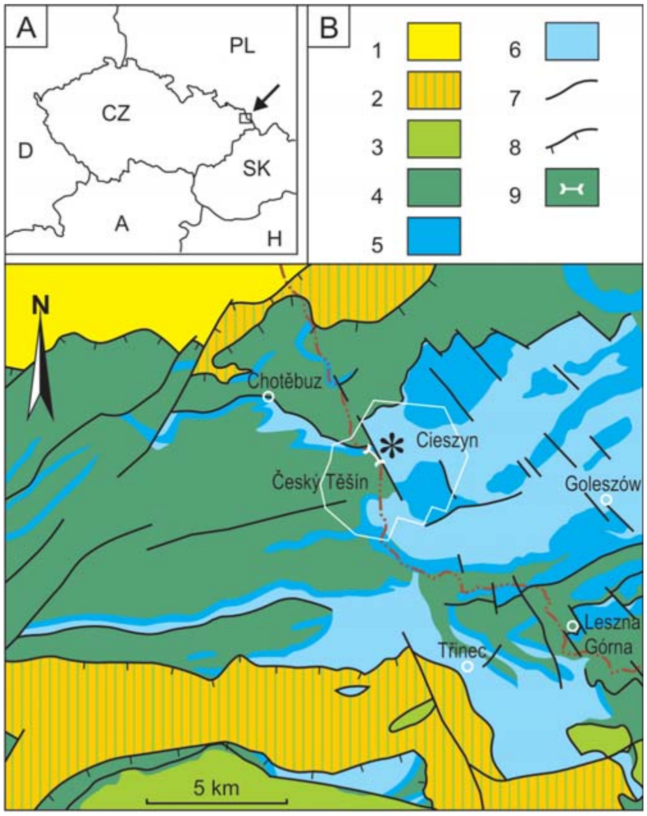
Currently, the classical Castle Hill section of Nowak (1967) is partly covered by slope debris and vegetation. The Cieszyn Limestone Formation can be observed in the extensive natural outcrops in the Olza riverbed below the castle. In the past, the Polish–Czech border demarcated in the Olza riverbed caused access issues to geologists. However, the Schengen Agreement now allows geologists to cross the border freely, across the river or through the Friendship Bridge and the riverbed is easily accessible from the Czech side.

The aim of the present research was to verify the Jurassic–Cretaceous boundary at the Castle Hill section, as recorded by previous authors. We studied a relatively limited set of samples, but integrated biostratigraphic results from all available fossil groups for a combined interpretation.

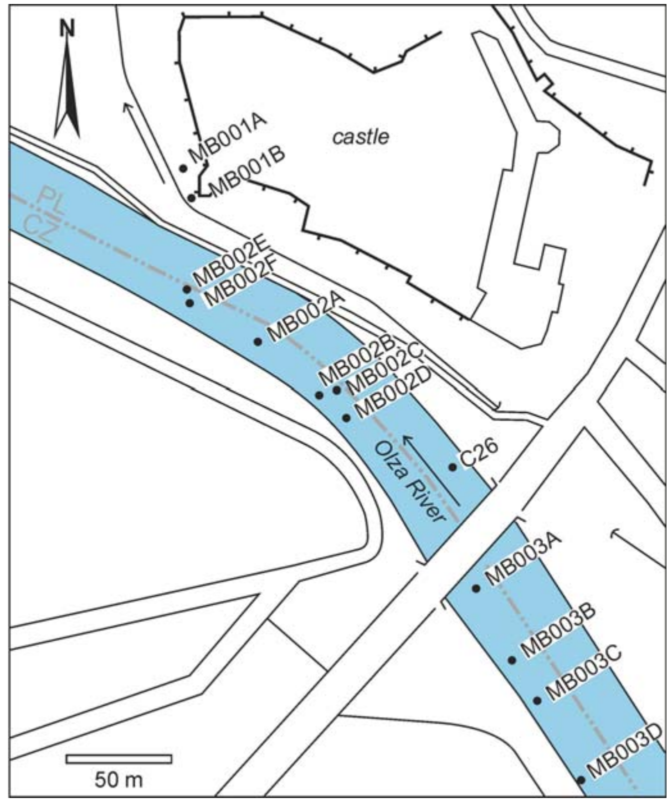
GEOLOGICAL SETTING

The Silesian Unit is part of the Flysch Belt of the Outer Western Carpathians representing a complex of allochthonous nappes (Ślączka et al. 2006). In its present form, the Outer Flysch Carpathians consist of the Outer Group of Nappes, divided from the lowest to the highest into the Subsilesian, Silesian, and Fore-Magura units, and the Magura Group of Nappes. The whole nappe complex is thrust over Miocene sediments of the Carpathian Foredeep at a distance of more than 60 km (Pícha et al. 2006).

During the Mesozoic, deep-sea deposits of the Outer Western Carpathians were deposited on the south-eastern margin of the North European Platform. The Upper Jurassic–Lower Cretaceous basinal facies of the Silesian Unit represent the infill of the early Proto-Silesian Basin (= the Severin-Moldavidic Basin). The basin opened within the North European Platform as a rift and/or back-arc basin that extended from the Bohemian Massif to Moesia. The Silesian Ridge and its Bucovina–Getic equivalent separated the Proto-Silesian Basin from the Magura Basin that belonged to the Alpine Tethys. The separation of these basins is expressed in their independent individual sedimentary record. The initial Kimmeridgian–early Berriasian stage of Proto-Silesian Basin evolution was characterized by slope facies with a significant amount of slump deposits known as the Vendryně Formation and previously termed the Lower Cieszyn Beds (Nowak 1964; Peszat 1967; Słomka 1986a; 1986b; Eliáš et al. 2003; Pícha et al. 2006 and references therein). The second stage of Proto-Silesian Basin evolution,



TEXT-FIGURE 2
Geologic map of wider Cieszyn surroundings after Roth (1964) and Burtan et al. (1937); modified: 1 – Carpathian Foredeep, 2 – Subsilesian Unit, 3–6 – Silesian Unit (3 – Upper Cretaceous, 4 – Hradiště Formation and other Lower Cretaceous formations, 5 – Cieszyn Limestone Formation, 6 – Vendryně Formation), 7 – normal faults, 8 – thrust faults, 9 – studied section (indicated by asterisk).



TEXT-FIGURE 3
Map of the Cieszyn section with sample positions and indicated state border (CZ – Czech Republic, PL – Poland).

during the Berriasian–Valanginian, was characterized by the formation of a deep-sea turbidite fan and deposition of carbonate turbidites, although deposition via turbidites is known to occur in the basin from the Tithonian (Eliáš 1970; Książkiewicz 1971; Słomka 1986b; Matyszkiewicz and Słomka 1994; Waśkowska–Oliwa et al. 2008 and references therein). These turbidites brought detritus from both the Silesian Ridge and the North European Platform. Deposition of the Cieszyn Limestone Formation started with marls and marly shales, intercalated with thin-bedded pelitic calciturbidites, and later passed to pelitic calciturbidites, and finally to medium- and thick-bedded detritic calciturbidites with abundant bioclasts and an admixture of quartz grains.

The middle Valanginian–Barremian phase of basin evolution is characterized by siliciclastic turbidite deposition of the Hradiště Formation (Burtan et al. 1937; Słomka 1986a; Matyszkiewicz and Słomka 1994; Golonka et al. 2008; 2013). Prevailing dark marly mudstones with thin intercalations of sandstone are classified as the Cisownica Member, formerly called the Upper Cieszyn Shales (Burtan et al. 1937; Słomka 1986a; Waśkowska-Oliwa et al. 2008; Golonka et al. 2008, 2013 and references therein).

The Upper Jurassic–Lower Cretaceous formations of the Proto-Silesian Basin correspond well with global sequence stratigraphy (Haq et al. 1988), as follows:

- the Vendryně Formation equates with the Lower Zuni II Supersequence,

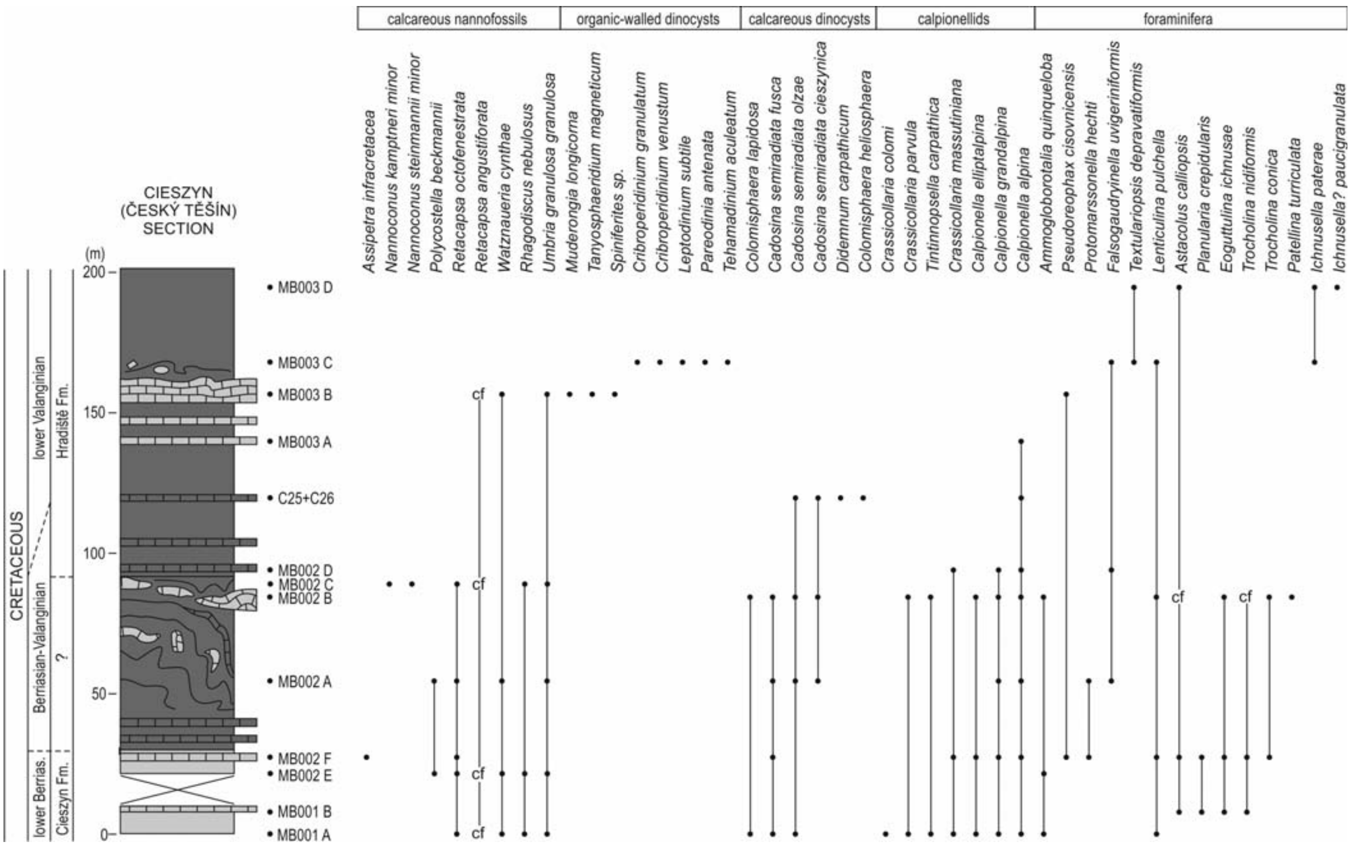
- the Cieszyn Limestone Formation equates with the Lower Zuni III Supersequence,

- the Hradiště Formation equates with the Upper Zuni I Supersequence.

MATERIAL AND METHODS

The Cieszyn section is a 350 m long composite section (text-figures 2 and 3) comprising more-or-less continuous outcrops in the Olza riverbed and isolated outcrops on the hillside of Castle Hill, identical to the Góra Zamkowa section of Nowak (1967). The position of the sampling points was recorded using a Garmin 60CSx GPS receiver (table 1). The whole composite section represents approximately 200 m of thickness (text-figure 4).

Marlstones for calcareous nannofossil analyses were crushed with a hammer to a powder and suspended in distilled water. A drop of this suspension was placed on a glass slide and dried and mounted using Canada Balsam. Slides were observed under a Nikon Microphot-FXA transmitting light microscope with an oil immersion objective of ×100 magnification. Taxonomic concepts



TEXT-FIGURE 4
Simplified lithology with microfossil range chart of the Cieszyn section.

follow Bown et al. (1998), Casellato (2010), and the Nannotax website (Young et al. 2018). Biostratigraphic data were interpreted with-reference to the nannofossil zonations of Bown and Cooper (1989), Bralower et al. (1989) and Casellato (2010).

Microfacies, calpionellids and calcareous dinocyst slides were analysed using a LEICA DM 2500 microscope under a magnification 200x, equipped with an Axiocam ERc 5s camera at the Department of Geology and Palaeontology, Comenius University in Bratislava. The standard calpionellid zonation of Remane et al. (1986) modified by Reháková and Michalík (1997) was applied.

Samples for foraminiferal study were processed at the Brno laboratory of the Czech Geological Survey. Marlstones were crushed, soaked in sodium bicarbonate solution and washed on 0.063 mm sieve. Solid limestones were dissolved in 80 % acetic acid using the method introduced by Lirer (2000) for recovering calcareous microfossils from limestone. Foraminifera were picked under a Zeiss binocular microscope. Foraminifera in thin sections were observed using a Nikon Eclipse ME600 microscope and documented using a Nikon DS-Fi2 digital camera. Foraminifera residues, rock pieces and slides from subsections MB001, MB002 and MB003 are deposited at the Czech Geological Survey in Brno. Thin sections from samples taken along the right bank of the Olza River are deposited at the AGH in Kraków.

Palynological samples were processed to concentrate the resistant palynological component using standard maceration techniques, including treatment with hydrochloric (HCl) and hydrofluoric (HF) acids to remove carbonates and silicates. The palynological residues were sieved using a 15 μm nylon mesh and were concentrated using a centrifuge. Oxidation was not used. Three slides for each sample were prepared. Photodocumentation was carried out using an Olympus BX60 optical microscope with a SW NIS-Elements 3.1 camera. The palynological slides are stored in the Department of Geological Engineering VŠB–Technical University Ostrava.

RESULTS

Sedimentology

At the lowest exposed levels in the section (text-figure 4, samples MB001A, MB001B, MB002E, MB001F), light-gray marlstone was observed, locally interbedded with fine-grained limestone (pl. 1, fig. 1); the marlstone contains dark bioturbation (*Chondrites–Planolites* ichnofabric). The limestone layers have sharp bases with hyporeliefs of fossil traces, and fine upwards. Based on thin-section analysis, the rocks are classified as bioclastic and peloid-bioclastic wackestones with layers of spiculite-radiolarian packstone (pl. 2, figs 1–3).

Higher up the section, an approximately 50 m thick submarine slump/slide body is exposed in the Olza River bed. Dark-gray claystones (mudstones) contain subordinate thin banks of limestones. The limestone microfacies are classified as lithoclastic and peloid-bioclastic-intraclastic grainstones with foraminifers, spiculite packstones and wackestones with an admixture of angular quartz grains (pl. 2, fig. 6). The claystones and limestones are locally deformed, with synsedimentary folds of variable geometry (pl. 1, fig. 2). Higher up, the claystones enclose limestone blocks exceeding 10 m in diameter (pl. 1, fig. 3). The limestone is thin-bedded and was intensively folded in a plastic state prior to lithification (pl. 1, fig. 4). The beds have sharp bases and fine upwards. The limestone is classified as peloid-bioclastic packstone of spiculite microfacies with some radiolarians, aptychi, ostracods, echinoid fragments and cysts, grading to bioturbated peloid wackestone (pl. 2, figs 4, 5). The whole body combines features of slump and slide. It contains limestone olistoliths in claystone matrix. Claystones are mostly coherent and well-bedded, not a chaotic mass.

Overlying undisturbed strata between the points MB002D and MB003B comprise dark claystones intercalated with limestone and marly limestone (pl. 1, fig. 5). Individual limestone layers rarely exceed 20 cm in thickness. Based on microscopic study, these rocks are classified mostly as fine-grained lithoclastic grainstones and laminated wackestones, locally bioturbated. Clastic laminae fine upwards. The matrix of the rocks frequently contains scattered pyrite; some bioclasts are phosphatized or silicified.

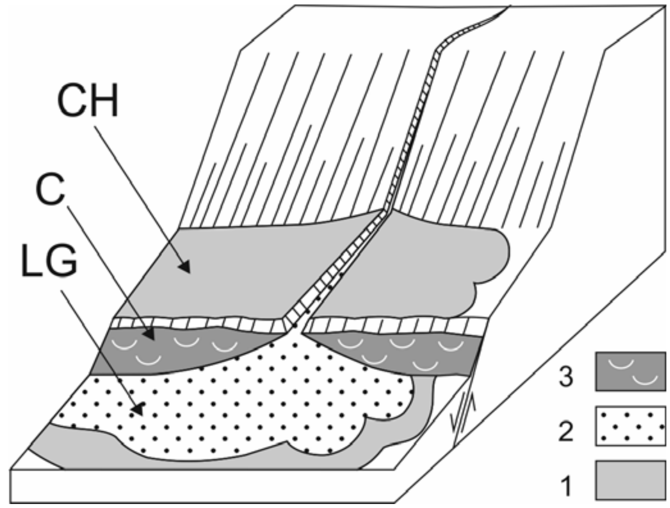
Between samples MB003B and MB003C a several meter thick bed consisting of folded thin-bedded marlstones and silty limestones was observed. Above this bed, a one meter thick pebbly claystone layer contains blocks of gray limestone in dark-gray claystone matrix (pl. 1, fig. 6).

The highest part of the section comprises dark-gray claystone intercalated with subordinate layers of fine-grained laminated sandstone. These strata represent distal turbidites with subordinate hemipelagic claystone horizons. They were deposited in a bathyal setting based on the presence of flysch-type agglutinated foraminifera together with calcareous taxa.

Calcareous nannofossils

Light-gray marlstones in the lower part of the section (sample MB001A2) contain abundant nannofossils comprising 20–30 specimens/FOV (= Field of View). However, they are mostly fragmented, making identification difficult. The species *Watznaueria barnesiae* constitutes 86% of the assemblage, specimens of *Rhagodiscus nebulosus* (pl. 3, figs 4–6), *Retacapsa octofenestrata*, *Retecapsa.* cf. *angustiforata, Zeugrhabdotus cooperi,* and *Crucibiscutum salebrosum* are very rare, and representatives of the genera *Nannoconu*s and *Conusphaera* are absent.

The marlstones and marly limestones in the Olza River bed, at approximately the same stratigraphic level or a little bit higher (samples MB002E and MB002F), contain poor nannofossil assemblages with abundances between 1–10 specimens/FOV. The assemblage is characterized by a preponderance of Ellipsagelosphaeraceae (89%), with *W. barnesiae* at 59–67%. Other nannofossils occur sporadically, including: *R.* cf. *angustiforata, Umbria granulosa granulosa* (pl. 3, fig. 7), *R. nebulosus, Watznaueria cynthae* (pl. 3, figs 1, 2) and *Assipetra infracretacea* (pl. 3, fig. 8). The genera *Nannoconus* and *Conusphaera* were not present.



TEXT-FIGURE 5
Model of the deep-sea fan system of the Cieszyn Limestone Formation in the Lower Valanginian: 1 – mudstone facies, 2 – detritic facies, 3 – slump/slide facies. Position of sections: C – Cieszyn, LG – Leszna Górna, CH – Chotěbuz.

Dark-gray silty claystones in the slump/slide body (samples MB002A1 and MB002C) contained an impoverished assemblage of poorly preserved nannofossils with abundances at 1–8 specimens/FOV. Ellipsagelosphaeraceae constitute 79–84 % of the assemblage, including *W. barnesiae* (55–60 %). Fragmented placoliths of *R. octofenestrata*, *Helenea chiastia*, *Zeugrhabdotus* spp. and small specimens of the genus *Umbria* were observed in very low numbers. Nannoconids, represented by *N. globulus,* comprise less than 2 % of the assemblage. Specimens in the sample MB002A1 are classified as transitional forms between *N. globulus minor* and the larger *N. globulus globulus*, which is higher than 6 µm and wider than 8 µm (Casellato 2010; Young et al. 2013). Preservation of the studied specimens did not allow for accurate width and height measurements (pl. 3, fig. 12). The sample MB002C contained *Nannoconus kamptneri minor* (pl. 3, figs 13–14), *N. steinmannii minor* (pl. 3, figs 15–16), *Retacapsa* cf. *angustiforata* (pl. 3, fig. 3) and one specimen of *Conusphaera mexicana mexicana*.

Dark-gray claystones (sample MB003B) with intercalating marly limestones in a smaller slump/slide body south of the bridge contained abundant nannofossils (20–30 specimens/FOV), but most were fragmented. The assemblage is dominated by Ellipsagelosphaeraceae and small forms of *Watznaueria* prevail over large ones. One specimen of *W. cynthae* was recorded. Other coccoliths, such as *U. granulosa granulosa, R.* cf. *angustiforata, Zeugrhabdotus cooperi* and *Tubodiscus* sp. are rare. The genera *Nannoconus* and *Conusphaera* were not present.

Dark-gray silty claystones in the upper part of the section (samples MB003C and MB003D) contained mostly fragmented nannofossils 1–5 specimens/FOV. The assemblage is comprised almost exclusively of representatives of the genus *Watznaueria* (96%), with *W. britannica* at 40% (both small and large forms, pl. 3, figs 9 and 10). Rare specimens of *Lotharingius contractus* and *L. crucicentralis* (pl. 3, fig. 11) were identified in sample

TABLE 1
GPS coordinates of sampling points.

	Latitude	Longitude
MB001A	N49°45'03.8"	E18°37'29.7"
MB001B	N49°45'03.3"	E18°37'30.3"
MB002E	N49°45'02.0"	E18°37'30.2"
MB002F	N49°45'01.7"	E18°37'30.3"
MB002A	N49°45'01.2"	E18°37'32.0"
MB002B	N49°45'00.3"	E18°37'33.4"
MB002C	N49°45'00.4"	E18°37'33.8"
MB002D	N49°45'00.0"	E18°37'34.0"
C26	N49°44'59.2"	E18°37'36.3"
MB003A	N49°44'57.4"	E18°37'37.2"
MB003B	N49°44'56.3"	E18°37'37.9"
MB003C	N49°44'55.7"	E18°37'38.5"
MB003D	N49°44'54.5"	E18°37'39.5"

MB003G from an isolated outcrop 230 m upstream from sample MB003D.

Organic-walled dinocysts

Dinoflagellate cyst analyses were applied to dark-gray claystones in the upper part of the section. Sample MB003B contained a rich association of dinoflagellate cysts, accompanied by brown and black phytoclasts. The palynofacies is typical of littoral oxic conditions. The association consists of typical nearshore taxa, including *Circulodinium vermiculatum*, *Cometodinium habibii* (12% of the assemblage), *Cometodinium multispinosum* (20% of the assemblage), *Muderongia longicorna*, *M. neocomica*, *Systematophora daveyi* and *Systematophora penicillata*. The palynofacies in the sample MB003C was completely different. Amorphous organic matter (AOM) dominated over dinoflagellate cysts (20%), together with organic linings of foraminifera (5%). The enormous amounts of marine AOM are typical for dysoxic–anoxic marine conditions. Dinoflagellate cyst associations comprises the littoral taxa *Circulodinium distinctum*, *Cribroperidinium granulatum* (pl. 3, fig. 21), *C. globatum*, *C. venustum* (pl. 3, fig. 20), *Systematophora complicata*, *S. silyba*, *Prolixosphaeridium anassilum*, *Pareodinia antenata*, and *P. robusta* (pl. 3, fig 17). Sample MB003D contains amorphous organic matter; dinoflagellate cysts were degraded and poorly preserved.

Calcareous cysts

Calcareous dinoflagellate cysts and calcareous microproblematica are frequent in thin sections of the carbonate rocks from the Cieszyn section. Marlstones and limestones from the lower part of the section (samples MB001A1 and MB002F) contained calcareous dinocyst associations, including *Colomisphaera fortis*, *C. lapidosa*, *Cadosina semiradiata fusca*, *C. semiradiata olzae* and *Stomiosphaera moluccana*. Such associations can be assigned to the late Tithonian–early Berriasian interval, but contain also apparent older redepositons (*S. moluccana*). Different cyst associations occur in fine-grained grainstones, packstones and wackestones with intercalating dark-gray claystones higher in the slump/slide body and overlying strata up to the bridge. Cyst associations contain frequent *Cadosina semiradiata olzae* (pl. 3, fig. 29), *C. semiradiata fusca* (pl. 3, fig. 28), and *C. semiradiata cieszynica* (pl. 3, fig. 30). These taxa were abundant in the early Tithonian, and again in the late Berriasian–Valanginian. *Stomiosphaera alpina* occurs as rare specimens and indicates a middle Berriasian to early Valanginian age. At the same time, several cyst taxa with their first occurrence reported from the Valanginian are present throughout this part of the section. These are *Colomisphaera conferta* (pl. 3, fig. 26), *C. heliosphaera* (pl. 3, fig. 25), *C. vogleri* (pl. 3, fig. 24), *Carpistomiosphaera valanginiana* (pl. 3, fig. 27) and microproblematicum *Didemnum carpaticum* (pl. 3, fig. 23). Instead of characteristic successive appearances of *S. alpina* – *C. heliosphaera* – *C. conferta* – *C. vogleri*, as documented from numerous Tethyan sections (Lakova *et al.* 1999, Reháková 2000, Ivanova and Kietzmann 2017), all these taxa occur together. This may be explained by massive reworking and mixing of sediments.

Calpionellids

Bioclastic wackestones from the lower part of the section (sample MB001A1) contain an assemblage with *Crassicollaria parvula* (pl. 4, fig. 7), *C. massutiniana*, *C. colomi* (pl. 4, fig. 2), *Calpionella alpina* (pl. 4, fig. 5), *C. elliptalpina* and *Tintinnopsella carpathica* that can be assigned to the late Tithonian Colomi Subzone of the Crassicollaria Zone. A similar assemblage was also encountered in the radiolarian–spiculite wackestone from the Olza River bed (sample MB002F).

Thin layers of limestones (fine-grained grainstones, packstones, wackestones) within the slump/slide body contain mixed calpionellid associations composed of late Tithonian to middle Berriasian species. *Calpionella alpina* and *Crassicollaria parvula* are the most frequent, while *Crassicollaria massutiniana* (pl. 4, fig. 3), *Calpionella elliptalpina* (pl. 4, fig. 4), *C. grandalpina*, *C.* cf. *elliptica*, *Tintinnopsella carpathica* (pl. 4, fig. 1) and *Lorenziella hungarica* are rare.

A peloid–spiculite wackestone (sample MB002B) from the large sedimentary block incorporated within the slump/slide body contained a more abundant calpionellid association, with *Crassicollaria parvula*, *Calpionella alpina*, rare *C. grandalpina* (pl. 4, fig. 6) and *Tintinnopsella carpathica,* in which the spherical form of *C. alpina* dominates. The calpionellid association can be assigned to the late Tithonian Colomi Subzone of the Crassicollaria Zone, possibly the highest part of the subzone near the Jurassic–Cretaceous boundary.

Thin layers of grainstones higher in the section (samples MB002D and MB003A) contain scarce specimens of *Calpionella alpina* and *Crassicollaria parvula*, *C. massutiniana* and *C. grandalpina* enclosed solely in clasts of micritic limestone. These are interpreted as reworked and therefore not used biostratigraphically.

Foraminifera

The section is rich in both calcareous and agglutinated benthic foraminifers. Light-gray marlstones and limestones in the lower part of the section (samples MB001A1, MB001B, MB002E and MB002F) contain mostly long-ranging taxa, including *Rhizammina* sp., *Glomospira* spp., *Pseudoreophax cisovnicensis* (pl. 4, figs 13a, b, 14), *Ammogloborotalia quinqueloba*, *Pseudonodosinella troyeri*, *Astacolus calliopsis* (pl. 4, fig. 18), *Lenticulina pulchella* (pl. 4, fig. 19), and *Planularia crepidularis* (pl. 4, fig. 20). At the same time, co-occurrence of taxa restricted to the Jurassic and not older then Cretaceous was recorded. *Trocholina nidiformis* (pl. 4, fig. 16) and *T. conica* (pl. 4, fig. 17), considered as Jurassic according to Rigaud et al. (2013), occur together with *Eoguttulina ichnusae* (pl. 4, fig. 21) known from Valanginian and younger strata (e.g. Holbourn and Kaminski 1995). Exactly the same association was found in large allochthonous blocks of limestone enclosed in the slump/slide body (sample MB002B).

The dark mudstones and grainstone layers within the slump/slide body (samples MB002A2, MB002C and MB002D) contain a rich foraminifer fauna, with deeper-water agglutinated and calcareous taxa including: *Rhizammina* sp., *Thalmannammina neocomiensis*, *Falsogaudryinella uvigeriniformis* (pl. 4, fig. 10), *Protomarssonella hechti* (pl. 4, fig. 9) and *Mohlerina basiliensis* (pl. 4, fig. 12). Miliolids typical of the inner part of carbonate platform (reef lagoon?) are also abundant. Taxa that would allow for a precise stratigraphic assignment are missing.

The dark mudstones higher in the section also contain mostly stratigraphically unimportant taxa, as with the older part of the section. The grainstone intercalation (sample MB003A) contained *Vinelloidea* sp., embedded into microbial nodules of *Crescentiella morronensis*, and *Coscinoconus alpinus* that are abundant components of the Štramberk Limestone (Vaňková et al. 2019). Starting with the sample MB003C upwards, the dark-gray claystones contained *Ichnusella paterae* and *I. paucigranulata;* these species have their lowest occurrence in the Valanginian according to Rigaud et al. (2018).

DISCUSSION

Nowak (1967) first documented a detailed bed-by-bed study of the "Góra Zamkowa" (Castle Hill) section and assigned it to the latest Tithonian – Berriasian, based on calpionellids. In the Berriasian part of the outcrop, he reported the presence of *Calpionellites darderi* – the index species of the Valanginian (Remane et al. 1986). Nowak documented this species as sketched illustrations only and figured specimens in fact may be poorly preserved representatives of *Tintinnopsella* or *Remaniella* lacking a collar. Moreover, Nowak's assemblages do not correspond with typical early Valanginian calpionellid assemblages and the later reinvestigation of his original slides by Olszewska (2005) did not confirm the presence of *C. darderi*. Olszewska (2005) distinguished the uppermost Tithonian, middle to upper Berriasian and lower Valanginian strata. It is necessary to note, that the "Góra Zamkowa" section exposes about 15 m of a thickness (cf. Nowak 1967) and represents just the lowermost part of our composite section with a thickness of approximately 200 m. The original section of Nowak can be identified with two isolated outcrops (MB001A and MB001B; text-figure 1), at thicknesses of 1.7 and 5 m, respectively. The rest of the section is covered by slope debris and vegetation at the present time. Olszewska (2005) also studied the samples from the section along the right bank of the Olza River. Based on calpionellids, she assigned part of the section to the middle Berriasian. She recorded the presence of the cyst *Colomisphaera heliosphaera,* which has its lowest occurrence in the Valanginian (Ivanova and Kietzman 2017).

Age Associations

Our new biostratigraphic study of the Cieszyn section, utilizing different microfossil groups (text-fig. 4), did not clarify the stratigraphy. There are serious discrepancies between stratigraphic interpretations based on different fossil groups and this may be, to some degree, related to the different reliability of the ranges of the stratigraphic marker taxa utilized. On the other hand, these discrepencies can also be explained by massive reworking, which is apparent from the documented sedimentological features and mixing of microfossils from various habitats. Under such conditions, integrated stratigraphy has to be based on the youngest elements of an association.

When starting from lowest outcrops at the Castle Hill section (MB001A and MB001B) we have the following biostratigraphic data:

- The calpionellid and calcareous cyst associations may be assigned to the late Tithonian – early Berriasian interval.

- Calcareous nannofossils can be assigned to the early Berriasian NK-1 zone (sensu Bralower et al. 1989) based upon the presence of marker species *Rhagodiscus nebulosus*. The presence of *Retacapsa* cf. *angustiforata* may suggest an even younger age, but we cannot distinguish it from the similar *R. octofenestrata* with any certainty. There is no consensus on the first occurrence of *R. octofenestrata*: early Berriasian (Casellato 2010), late Tithonian (Svobodová et al. 2019) or early Callovian (Young et al. 2017). Both taxa differ by width of central area; more than 1/3 of the distal shield width for *R. angustiforata* and less than 1/3 *for R. octofenestrata*. The morphological features of our specimens are hidden by diagenetic overgrowth of calcite.

- The foraminifera *Trocholina nidiformis* and *T. conica* do not range into the Cretaceous according to Rigaud et al. (2013). The lowest occurrence of *Eoguttulina ichnusae* is reported from the Valanginian to present by various authors (Dieni and Massari 1966; Kuznetsova and Seibold 1978; Holbourn and Kaminski 1995). The reliability of its stratigraphic range may be questioned by the fact that the oldest strata investigated in these papers were Valanginian. The Berriasian foraminiferal record is missing in many areas and Berriasian foraminifera fauna are generally understudied. On the other hand, *E. ichnusae* has never been reported from better-known Tithonian faunas (e.g. Kuznetsova and Seibold 1978), thus it is very probably a species restricted to the Cretaceous. Moreover, the characteristic morphology practically excludes misidentification of this species.

Thus, we conclude that this part of section is early Berriasian and stratigraphically older calcareous dinoflagellate cysts and foraminifers are reworked.

The light-gray marls and limestones in the Olza River bed were correlated with strata of the Castle Hill section by Nowak (1967). New biostratigraphic data from samples MB002E and MB002F confirm the Nowak correlation. The common occurrence of *Retecapsa* cf. *angustiforata*, *R.nebulosus* and *A. infracretacea* indicates placement in early Berriasian Zone NK-1 of Bralower et al. (1989). The samples also contain the foraminifers *Trocholina nidiformis*, *T. conica* and *Guttulina ichnusae*. This part of the section can be assigned to the early Berriasian.

A very similar fossil record was observed from an allochthonous limestone block enclosed in the overlying slump/slide body (sample MB002B). The calpionellids can be assigned to the late Tithonian – early Berriasian interval. Foraminiferal species include *T. nidiformis*, *T.* cf. *conica* and *Patellina turriculata* (pl. 4, fig. 15). The latter species ranges from the late Berriasian to the Barremian according to Ivanova and Kołodziej (2010) and recently was found also in the lower Berriasian Štramberk Limestone (Vaňková et al. 2019). The limestone block is interpreted to be Berriasian in age with partly reworked foraminifera.

The slump/slide body consists mainly of dark-gray silty claystones with intercalated layers of limestone (grainstone). The claystone in the lower part of the body (sample MB002A1) contains a nannofossil association with *N. globulus minor – N. globulus globulus* transitional forms and *R. octofenestrata*, suggesting a Tithonian age. Nannofossil assemblages with *A. infracretacea*, *N. kamptneri minor*, *N. streinmannii minor*, and *R. nebulosus* from claystones in the upper part of the slump/slide body (sample MB002C) indicates placement in Zones NKT to NK-1, early Berriasian (Bralower et al. 1989 and Casellato 2010). Rare *Polycostella beckmannii*, *Nannoconus compressus* and a single specimen of *C. mexicana mexicana* can be explained as reworking of Tithonian sediments. Thin layers of grainstone from the lower part of the slump/slide body (sample MB002A2) contained foraminifera without stratigraphic value, containing apparently reworked miliolids. Rare calpionellids did not help with stratigraphic interpretation. Calcareous cysts provided valuable additional stratigraphic information. They were obtained from samples from limestone intercalations collected along the right river bank – the same section studied by Olszewska (2005). Some of these samples are not localized precisely, but come approximately from the interval between samples MB002A and MB003B (text-figures 3 and 4), which cover the slump/slide body and the overlying undisturbed sequence of claystones interbedded with thin layers of limestone. Samples C15, C20 and C25 were taken between MB002A and C26 and contain the cysts *Colomisphaera conferta, C. heliosphaera, C. vogleri, Carpistomiosphaera valanginiana* and microproblematicum *Didemnum carpaticum* reported from the Valanginian or younger strata. It may be concluded that the slump/slide body and overlying sequence up to the bridge is of early Berriasian–early Valanginian age, with reworking from the Tithonian.

Upstream, the association of calcareous nannofossils with *Retacapsa* cf. *angustiforata* and *Watznaueria cynthae* from sample MB003B indicates placement in Zone NK-1, and is early Berriasian in age. The assemblage of organic-walled dinoflagellate cysts contained *Muderongia longicorna,* lowest occurrence reported from the early Berriasian (Monteil 1992; 1993), *Tanyosphaeridium magneticum* (pl. 3, fig. 18) lowest occurrence reported from the top of the early Berriasian (Boorová *et al.* 2000) and rare occurrences of *Spiniferites* sp. (pl. 3, fig. 22), which may indicate an early Valanginian age (Leereveld 1997). Thus, the assemblage corresponds to the latest Berriasian to late Valanginian dinocyst assemblage from Bruzovice and Skalice (Skupien and Smaržová 2011; Skupien and Doupovcová 2019).

Dark-gray claystones from the uppermost part of the section (samples MB003C and MB003D) contained an association of

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PLATE 1

Outcrops at the Castle Hill (1) and Olza River bed (2–6).

1 Marlstone (Mst) interbedded with limestone (Lst), point MB001B, Cieszyn Limestone Formation.

2 Marlstone and grainstones with synsedimentary folds (slump/slide body), right riverbank.

3 Submarine slump/slide body with large blocks of pelagic limestone (LB), point MB002B.

4 Detail of synsedimentary fold within the limestone block, point MB002B.

5 Dark-gray grainstones on the right riverbank near the point MB002C (slump/slide body).

6 Dark-gray claystone (Cst) with paraconglomerate horizon (PCn), point MB003C, Hradiště Formation.


Lst
Mst
1
2
LB
3
4
Cst
PCn
Cst
5
6

calcareous nannofossils dominated by *Watznaueria britannica*. Further upstream in the isolated outcrop, representatives of the genus *Lotharingius* were documented. The whole of this interval is assigned to Zone NJ15a of Oxfordian age (Bown and Cooper 1989). An organic-walled dinoflagellate cyst assemblage containing *Cribroperidinium granulatum*, *C. venustum*, *Leptodinium subtitle* (pl. 3, fig. 19), *Pareodinia antenata* and *Tehamadinium aculeatum* from sample MB003C corresponds well with the late Tithonian assemblage from the Bruzovice section (Skupien and Doupovcová 2019). Foraminiferal assemblages, starting with the sample MB003C upwards, contain *Ichnusella paterae* and *I. paucigranulata* and are interpreted as Valanginian taxa by Rigaud et al. (2018). Based on the youngest fossil elements recorded, the uppermost part of this section is assigned to the Valanginian.

Integrated biostratigraphy reveals that the light marlstones and limestones at the base of the section are the lower Berriasian and overlying claystones with limestone intercalations and slump/slide bodies are the lower Berriasian-lower Valanginian. The Jurassic–Cretaceous boundary delimited by previous authors (Nowak 1967; Olszewska 2005) was not confirmed; their interpretation seems to be based on reworked microfossils.

Lithologic Associations

Light-gray, dark-mottled bioturbated marlstones and gray limestones in the lower part of the section are part of the Cieszyn Limestone Formation and not the Vendryně Formation (text-figure 1), as indicated by previous authors (Hohenegger 1861; Nowak 1967; Olszewska 2005). The marlstones show more similarity to marly intercalations within the mudstone facies of the Cieszyn Limestone Formation than to the marlstones of the Vendryně Formation at the type section in Vendryně and elsewhere.

The lithostratigraphy of overlying strata is questionable. The dark claystones with slump/slide bodies may be considered as a local facies within the Cieszyn Formation, replacing its detritic facies, or maybe the basal part of the Hradiště Fm., where subordinate intercalations of detritic limestone are common (Menčík et al. 1983).

In the context of the oldest depositional history of the Proto-Silesian Basin, the mudstone facies of the Cieszyn Limestone Formation (text-figure 1) is interpreted to be a deposit from distal diluted turbidites that brought carbonate mud downslope. This depositional phase locally persisted from the latest Tithonian to the late Berriasian. The second depositional phase, characterized by progradation of the more proximal turbidites and related to the destruction of the Štramberk reef complex, started in the late Berriasian and locally persisted to the late Valanginian; the detritic facies of the Cieszyn Limestone Formation is a product of this phase. In the Cieszyn section, there are no medium to thickly bedded, coarse grained, biodetritic limestones that are typical of this facies in the area of Goleszów, Leszna Górna and Třinec (Boorová et al. 2003; Waśkowska-Oliwa et al. 2008). Instead, this level comprises a thick slump/slide body and dark-gray claystones with thin intercalations of grainstones. The claystones are the result of repeated mudflows intercalated with turbidites (fining upward grainstones). The grainstone intercalations form more or less continuous layers, but are deformed by synsedimentary folds.

PLATE 2

Characteristic microfacies of the Cieszyn Limestone Formation and overlying strata, scale bars: 500 μm.

1 Bioclastic wackestone with silt admixture and bioturbation (Ch – *Chondrites*), Cieszyn Limestone Formation, sample MB001A1

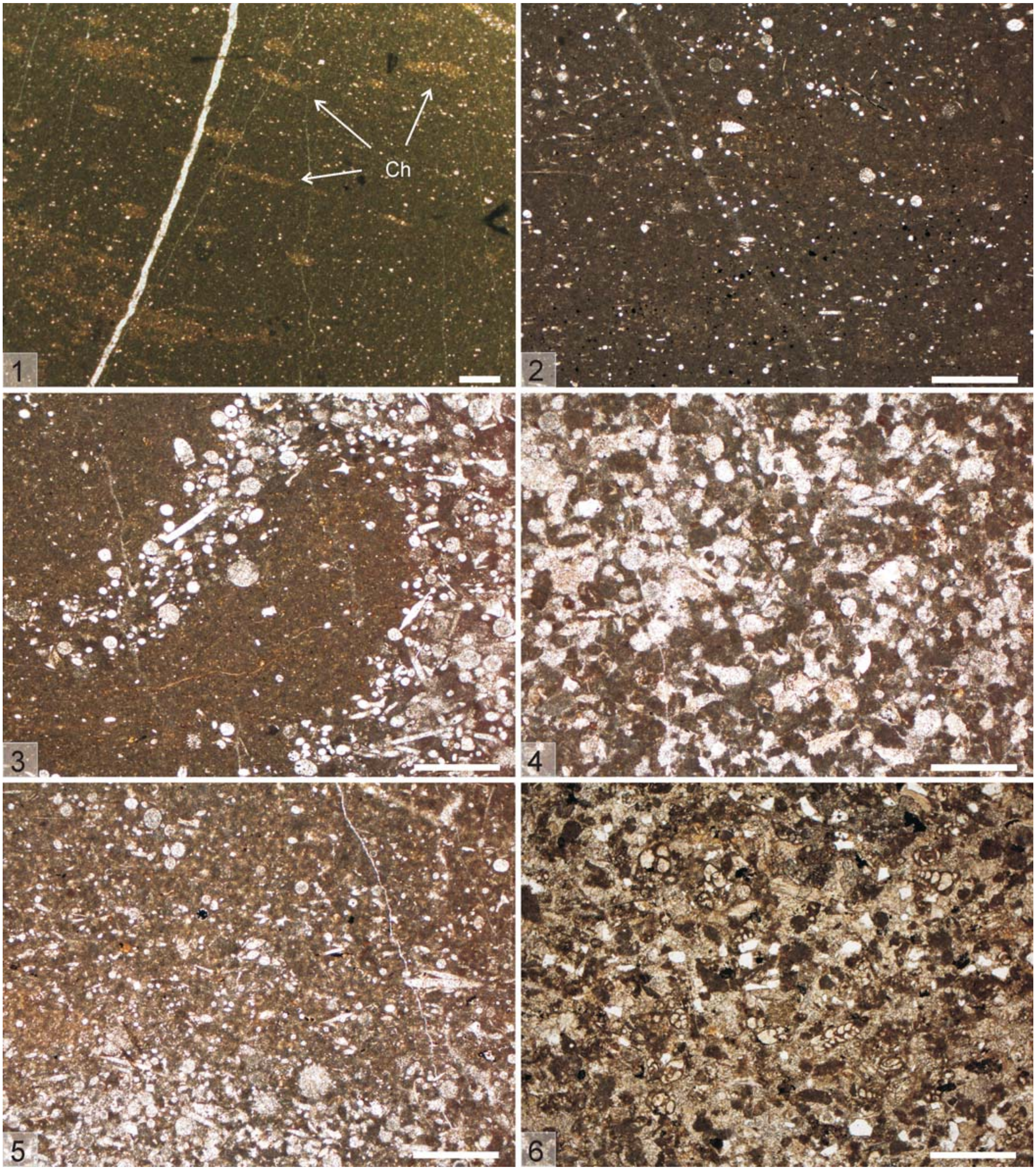
2 Radiolarian-spiculite wackestone, Cieszyn Limestone Formation, sample MB002F

3 Bioturbated bioclastic wackestone and peloid-bioclastic packstone, Cieszyn Limestone Formation, sample MB002F

4 Peloid-bioclastic packstone, block of the Cieszyn Limestone Formation in the slump/slide body, sample MB002B

5 Graded peloid-bioclastic packstone (distal turbidite), block of the Cieszyn Limestone Formation in the slump/slide body, sample MB002B

6 Peloid-foraminiferal-intraclastic grainstone with clastic quartz admixture, slump/slide body, sample MB002A2


Ch
1
2
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4
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6

The micritic limestone blocks enclosed within the mudstones were generated by sliding of weakly consolidated lime mud, as apparent from plastically folded internal structures (pl. 1, fig. 4). Such deposition can be expected on a relatively steep unstable basin slope. The frequent layers of packstones within the micritic limestone represent thin-bedded distal turbidites that were originally part of a turbidite fan. Blocks of such rock within the typical slope facies may be related to faults on the sea floor. A fault scarp exposing the deposits of a former submarine fan may produce typical slope deposits, enclosing blocks of turbidite limestones sliding from the crest of the fault scarp (text-figure 7). The subsidence of the Proto-Silesian Basin floor was very probably connected with the existence of such faults. Faulting was perhaps also responsible for drowning and destruction of the Štramberk reef complex during the Valanginian.

The described structural and depositional model is in compliance with the distribution of the facies from a regional perspective (text-figure 7). Single tectonic slices of the Silesian Nappe in the Cieszyn surroundings display a logical arrangement of facies. The Cieszyn section represents slope deposition below a fault scarp. The isochronous strata of a tectonic slice in the Chotěbuz area, northwest of Cieszyn, are claystone–siltstone turbidites of the Hradiště Formation (see Menčík et al. 1983, text-figure 4) directly overlying the mudstone facies of the Cieszyn Limestone Fm. A tectonic slice in the Třinec area southeast of Cieszyn is characterized by detritic facies at the same stratigraphic level (Boorová et al. 2003).

CONCLUSIONS

The Cieszyn section, including the historical Góra Zamkowa section, is documented and its precise location is specified for the first time. Integrated biostratigraphic research, originally focused on verification of the Jurassic–Cretaceous boundary in the Cieszyn section, reveals the following unexpected results:

1. The oldest exposed part of the Cieszyn section (= Góra Zamkowa section) is of early Berriasian age. The Jurassic–Cretaceous boundary reported by previous authors was probably delimited using reworked microfossils.

2. The 350 m long composite Cieszyn section, representing 200 m of thickness, comprises the mudstone facies of the Cieszyn Limestone Formation (lower Berriasian), a slump/slide body and dark claystones intercalated with grainstones (lower Berriasian–lower Valanginian) and dark claystones with subordinate sandstones of the Hradiště Formation (lower Valanginian).

3. Integrated biostratigraphy based on calcareous nannofossils, dinoflagellates, calpionellids and foraminifera, provides evidence for reworking of older microfossils; Jurassic foraminifera and calcareous dinocysts were reworked into to Berriasian sediments, Jurassic and Berriasian dinocysts, calpionellids, nannofossils and foraminifera were reworked into to the Valanginian sediments.

PLATE 3

Calcareous nannofossils and dinocysts, scale bars: 5 µm (1–16), 50 µm (17–22, 24–30), 100 µm (23).

1 *Watznaueria cynthae*, sample MB002E

2 *Watznaueria cynthae*, sample MB001A1

3 *Retacapsa* cf. *angustiforata*, sample MB002C

4–6 *Rhagodiscus nebulosus*, sample MB001A2

7 *Umbria granulosa granulosa*, sample MB002E

8 *Assipetra infracretaceea*, sample MB002F

9 *Watznaueria britannica*, sample MB003B

10 *Watznaueria britannica* large, sample MB003C

11 *Lotharingius* cf. *L. crucicentralis*, sample MB003G

12 *Nannoconus globulus*, sample MB002A1

13–14 *Nannoconus kamptneri minor*, sample MB002C

15–16 *Nannoconus steinmannii minor*, sample MB002C

17 *Pareodinia robusta*, sample MB003C

18 *Tanyosphaeridium magneticum*, sample MB003B

19 *Leptodinium subtile*, sample MB003C

20 *Cribroperidinium venustum*, sample MB003C

21 *Cribroperidinium granulatum*, sample MB003C

22 *Spiniferites* sp., sample MB003B

23 *Didemnum carpaticum*, sample C26

24 *Colomisphaera vogleri*, right riverbank

25 *Colomisphaera heliosphaera*, right riverbank

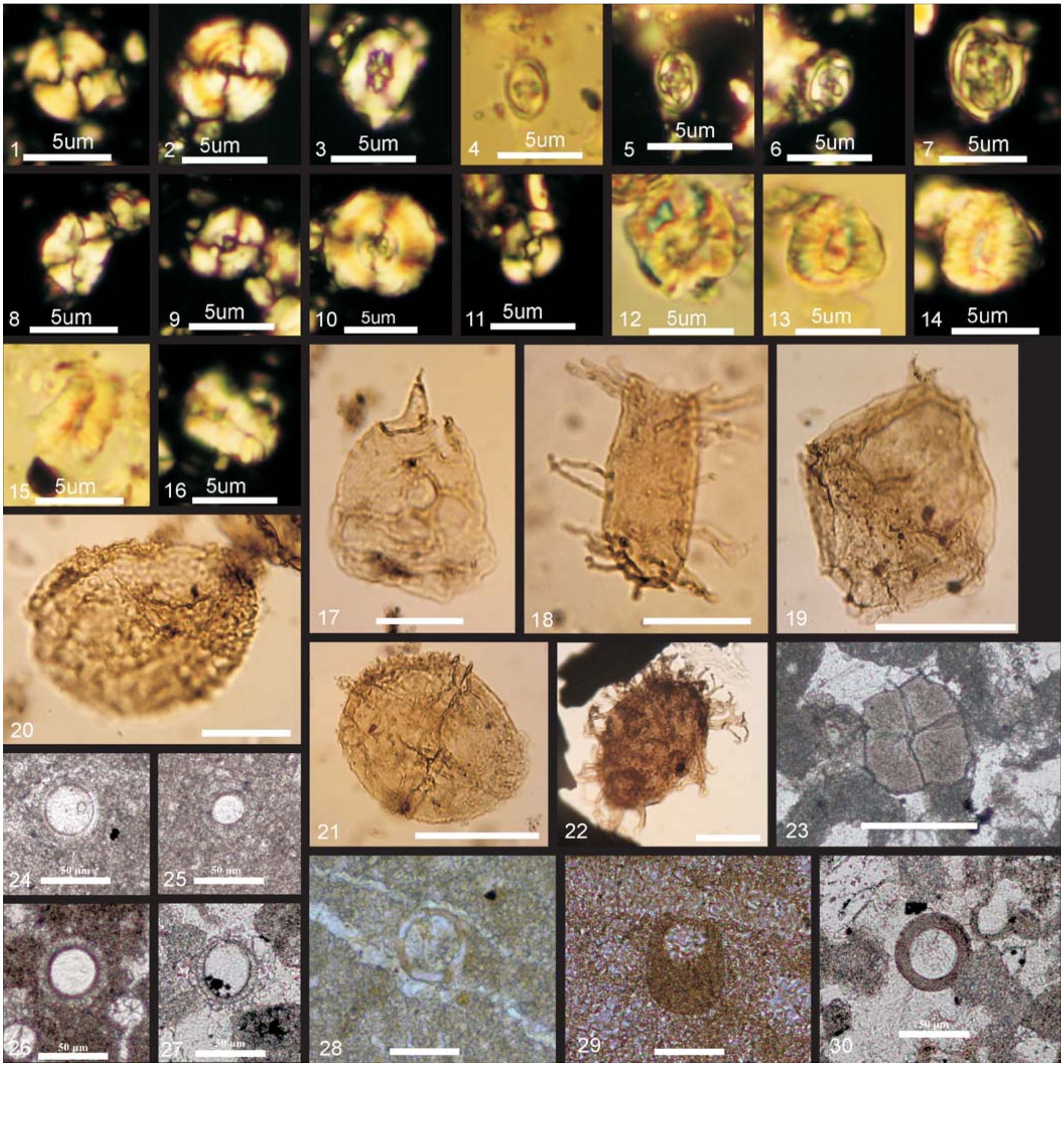
26 *Colomisphaera conferta*, right riverbank

27 *Carpistomiosphaera valanginiana*, right riverbank

28 *Cadosina semiradiata fusca*, silicified specimen, sample MB001A1

29 *Cadosina semiradiata olzae*, sample MB002B

30 *Cadosina semiradiata cieszynica*, right riverbank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24 50 µm
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30 50 µm

4. The slump/slide body, enclosing large blocks of the micritic Cieszyn Limestone, is a local slope facies, laterally replacing the detritic facies of the Cieszyn Limestone Formation.

5. The slump/slide body very probably represents deposition on a fault scarp created due to fault-controlled basin floor subsidence of the Proto-Silesian Basin.

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PLATE 4

Calpionellids and foraminifera, scale bars: 50 µm (1–7), 100 µm (9–11, 13–21), 500 µm (8, 12).

1 *Tintinnopsella carpathica*, right riverbank

2 *Crassicollaria colomi*, right riverbank

3 *Crassicollaria massutiniana*, right riverbank

4 *Calpionella elliptalpina*, right riverbank

5 *Calpionella alpina*, sample MB002B

6 *Calpionella grandalpina*, sample MB002B

7 *Crassicollaria parvula*, sample MB001A1

8 *Everticyclammina praekelleri*, 8 m downstream from sample C26

9 *Protomarssonella hechti*, sample MB002A2

10 *Falsogaudryinella uvigeriniformis*, sample MB002A2

11 *Meandrospira favrei*, sample MB002A2

12 *Mohlerina basiliensis* (Mb) 8 m downstream from sample C26

13a, b, 14 *Pseudoreophax cisovnicensis*, sample MB002F

15 *Patellina turriculata*, sample MB001B

16 *Trocholina nidiformis*, sample MB001B

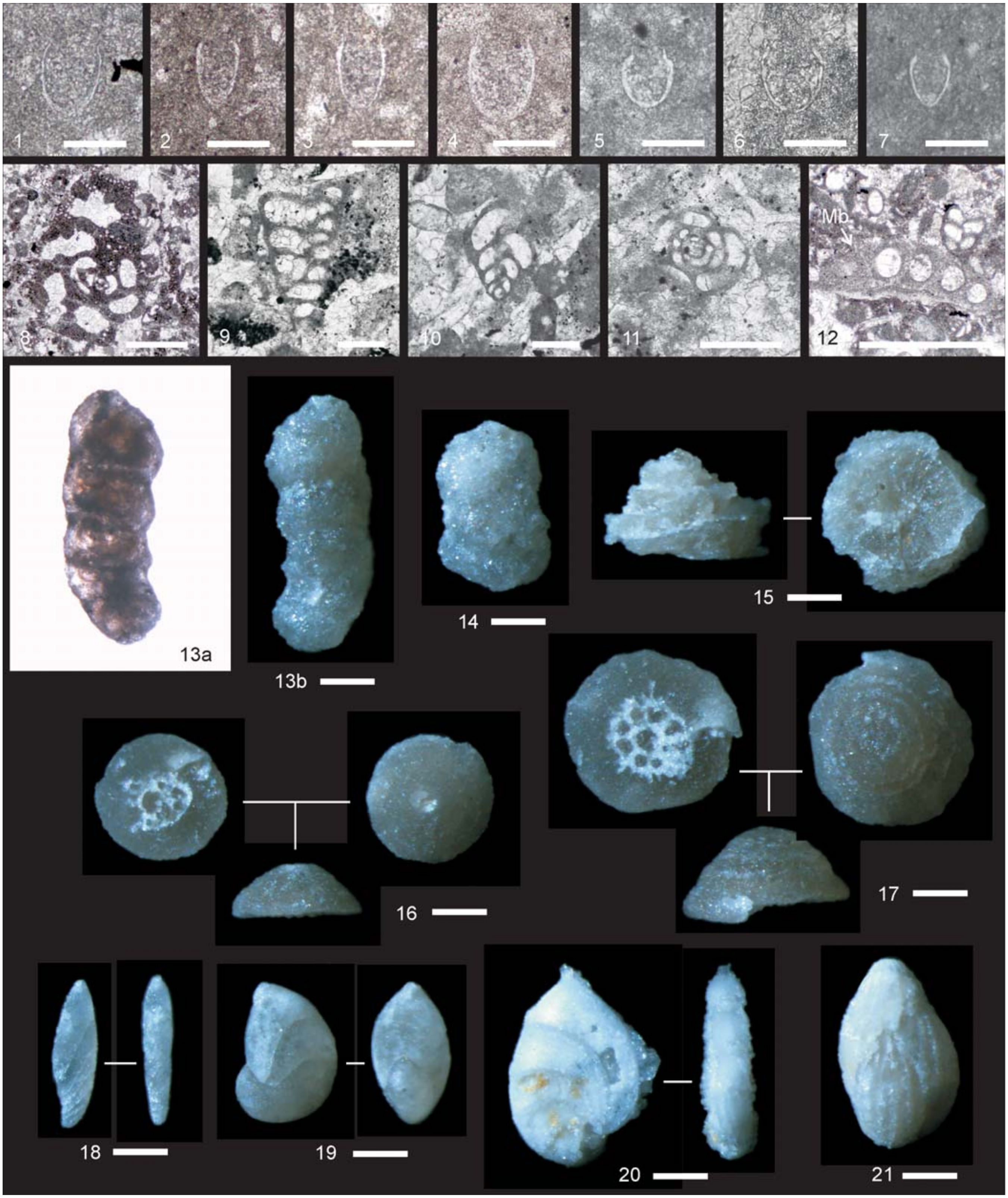
17 *Trocholina conica*, sample MB002F

18 *Astacolus calliopsis*, sample MB002F

19 *Lenticulina pulchella*, sample MB002F

20 *Planularia crepidularis*, sample MB001B

21 *Eoguttulina ichnusae*, sample MB001B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APPENDIX 1
Full names of taxa mentioned in the text.

Calcareous nannofossils:
Assipetra infracretacea (Thierstein 1973) Roth 1973
Conusphaera mexicana mexicana Trejo 1969
Crucibiscutum salebrosum (Black 1971) Jakubowski 1986
Eiffellithus primus Applegate and Bergen 1988
Helenea chiastia Worsley 1971
Lotharingius contractus Bown and Cooper 1989
Lotharingius crucicentralis (Medd 1971) Grün and Zweili 1980
Nannoconus compressus Bralower et Thierstein *in* Bralower et al. 1989
Nannoconus globulus globulus (Brönnimann 1955) Bralower *in* Bralower et al. 1989
Nannoconus globulus minor (Brönnimann 1955) Bralower *in* Bralower et al. 1989
Nannoconus kamptneri minor Bralower *in* Bralower et al. 1989
Nannoconus steinmannii minor Deres and Achéritéguy 1980
Polycostella beckmannii Thierstein 1971
Retacapsa angustiforata Black 1971
Retacapsa octofenestrata (Bralower *in* Bralower et al. 1989) Bown *in* Bown et Cooper 1998
Rhagodiscus nebulosus Bralower et al. 1989
Umbria granulosa granulosa Bralower and Thierstein *in* Bralower et al. 1989
Watznaueria barnesiae (Black *in* Black and Barnes 1959) Perch–Nielsen 1968
Watznaueria britannica (Stradner 1963) Reinhardt 1964
Watznaueria cynthae Worsley 1971
Zeugrhabdotus cooperi Bown 1992

Organic-walled cysts:
Circulodinium distinctum (Deflandre and Cookson,1955) Jansonius 1986
Circulodinium vermiculatum Stover and Helby 1987
Cometodinium habibii Monteil 1991
Cometodinium multispinosum (Singh 1964) Masure in Fauconnier and Masure 1004
Cribroperidinium globatum (Gitmez and Sarjeant 1972) Helenes 1984
Cribroperidinium granulatum (Klement 1960) Stover and Evitt 1978
Cribroperidinium venustum (Klement 1960) Poulsen 1996
Leptodinium subtile Klement 1960
Muderongia longicorna Monteil 1991
Muderongia neocomica (Gocht 1957) Lentin and Williams 1993
Pareodinia antenata (Gitmez and Sarjeant 1972) Wiggins 1975
Pareodinia robusta Wiggins 1975
Prolixosphaeridium anassilum Erkmen and Sarjeant 1980
Systematophora complicata Neale, J. W. and Sarjeant, W. A. S. 1962
Systematophora daveyi Riding and Thomas 1988
Systematophora penicillata (Ehrenberg 1843) Sarjeant 1980
Systematophora silybum Davey 1979
Tanyosphaeridium magneticum Davies 1983
Tehamadinium aculeatum (Klement 1960) Thomas and Cox 1988

Calcareous cysts:
Cadosina semiradiata cieszynica (Nowak 1966)
Cadosina semiradiata fusca (Wanner 1940)
Cadosina semiradiata olzae (Nowak 1966)
Carpistomiosphaera valanginiana Borza 1986
Colomisphaera conferta Řehánek 1985
Colomisphaera fortis Řehánek 1992
Colomisphaera heliosphaera (Vogler 1941)
Colomisphaera lapidosa (Colom 1935)
Colomisphaera vogleri (Borza 1969)
Stomiosphaera alpina Leischner 1959
Stomiosphaera moluccana Wanner 1940

Calpionellids:
Calpionella alpina Lorenz 1902
Calpionella elliptalpina Nagy 1986
Calpionella grandalpina Nagy 1986
Calpionellites darderi (Colom 1934)
Crassicollaria colomi Doben 1963
Crassicollaria massutiniana (Colom 1948)
Crassicollaria parvula Remane 1962
Lorenziella hungarica Knauer and Nagy 1964
Tintinnopsella carpathica (Murgeanu and Filipescu 1933)

Foraminifera:
Ammogloborotalia quinqueloba (Geroch 1966)
Astacolus calliopsis (Reuss 1863)
Coscinoconus alpinus Leupold 1936
Everticyclammina praekelleri Banner and Highton 1990
Falsogaudryinella uvigeriniformis (Seibold and Seibold 1960)
Eoguttulina ichnusae Dieni et Massari 1966
Ichnusella paterae Neagu 1995
Ichnusella paucigranulata (Moullade 1960)
Lenticulina pulchella (Reuss 1863)
Meandrospira favrei (Charollais et al. 1966)
Mohlerina basiliensis (Mohler 1938)
Planularia crepidularis Roemer 1842
Protomarssonella hechti (Dieni and Massari 1966)
Pseudonodosinella troyeri (Tappan 1960)
Pseudoreophax cisovnicensis Geroch 1961
Thalmannammina neocomiensis Geroch 1962
Trocholina conica (Schlumberger 1898)
Trocholina nidiformis (Brueckmann 1904)

Other:
Crescentiella morronensis (Crescenti 1969) – foraminiferal-microbial fossil
Didemnum carpaticum Borza et Misik 1978 – microproblematicum