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Microfacies and calcareous dinoflagellates documentation of the Early Kimmeridgian hiatus in the Oxfordian–lower Tithonian strata of the Central Balkan Mts, Bulgaria

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Abstract: An Oxfordian–lower Tithonian pelagic sedimentary succession from the Central Balkan Mts (Bulgaria) is revisited here in terms of its microfacies and calcareous dinocyst distribution. The eight successive microfacies that are recognized include: (1) bioclastic to bio-lithoclastic packstone to grainstone (MFT 1, in the underlying Bathonian); (2) filamentous wackestone to packstone (MFT 2, upper Oxfordian–upper Kimmeridgian); (3) *Globuligerina* wackestone (MFT 3, upper Oxfordian–upper Kimmeridgian); (4) filament-*Saccocoma* wackestone (MFT 4, upper Kimmeridgian); (5) *Saccocoma*-radiolarian wackestone (MFT 5, upper Kimmeridgian–lower Tithonian); (6) radiolarian wackestone (MFT 6, upper Kimmeridgian); and (7–8) *Saccocoma* wackestone and spiculitic wackestone (MFT 7 and MFT 8, lower Tithonian). The succession was dated based on calcareous dinocysts, which comprise four zones: *Colomisphaera fibrata* Zone (Oxfordian), *Stomiosphaera moluccana* Zone (upper Kimmeridgian), *Carpistomiosphaera borzai* (upper Kimmeridgian) and *Committosphaera pulla* (lower Tithonian). Calcareous dinoflagellate cysts provide new data and refine ages of the lithostratigraphic units, thereby documenting their diachronous nature when compared to other sections in the Balkan Mts. The *Cadosina parvula* Zone, however, was not detected in the lower Kimmeridgian strata, although it revealed a significant and previously unknown hiatus at this succession. As evidenced by the lithology, microfossils, and carbonate textures, the Oxfordian–lower Tithonian deposits record a discontinuous trend of increasing depth above the upper Bathonian shallow-water strata. After initial deepening, shallower depositional settings developed in the late Kimmeridgian, followed by the imposition of deep, shelf-to-slope environments, located at a moderate distance from the continental margin, from the late Kimmeridgian onward.

Keywords: calcareous dinocysts, microfacies, Upper Jurassic, Central Balkan Mts, Bulgaria

Introduction

Upper Jurassic marine sediments are widespread in Bulgaria. They were commonly found in deep borehole sections of Northern Bulgaria (Moesian Platform and Fore-Balkan Mts) and are preserved in large surface outcrops in the Balkan Mts chain, as well as in the Srednogorie and Kraishte regions (Sapunov 1976a, 1979; see also Sapunov & Ziegler 1976; Sapunov et al. 1985, 1988, 1991; Sapunov & Tchoumatchenco 1987). These strata are remarkably diverse in lithology and fossils. Often, within short lateral distances, shallow-water platform carbonates interfinger with pelagic limestones and deeper-water gravity flow-deposits. Therefore, fossil content varies between shallow marine skeletal remains and pelagic microfossils (e.g., calpionellids, radiolarians), as well as ammonites and aptychi. This variability reflects deposition in an extensive Late Jurassic basin with a marked bathymetric differentiation into submarine plateaus and basins. In this respect, Bulgaria is no exception to the other Late Jurassic Mediterranean and Submediterranean regions in Europe (e.g., Dercourt et al. 1993, 2000; Golonka 2004). This differentiation was less prominent at the beginning of the Late Jurassic, but became striking during the Kimmeridgian and especially the Tithonian when sedimentation took place on geographically- and bathymetrically-separated blocks (cf. Sapunov & Tchoumatchenco 1994).

The Upper Jurassic marine rocks of the Central Balkan Mts (Central North Bulgaria) have been relatively well-studied in both lithological and paleontological aspects (e.g., Nikolov & Sapunov 1970; Nachev 1976; Sapunov 1976a, b, 1977a, b; Bakalova 1977; Lefeld et al. 1986; Ivanova 1994, 1997, 2001a, b); however, from a microfacies point of view, these aspects have not been considered recently, nor has their microfossil content. Diverse and conflicting interpretations have been made on the basis of scattered and unsystematically collected data in the past (e.g., Nikolov & Sapunov 1977; Ivanova 1997). Hence, earlier data needed to be revised on the basis of modern microfacies and biostratigraphic approaches. This study presents a microfacies analysis of the Oxfordian–lower Tithonian deposits in the Zavodna section (Central Balkan Mts), along with a new biostratigraphic record based on calcareous dinocysts. These strata suggest a transition from deep

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shelf to slope, at a moderate distance from the continental margin, as inferred from their lithology, microfossils, and carbonate textures. For these lithologies at Zavodna section, this is the first dinocyst record, which allows for precise age determination and zonation of the strata with its southernmost distribution in Central North Bulgaria.

Geological setting and regional background

One of the most important occurrences of Jurassic marine rocks in Bulgaria is located in the Central Balkan Mts between the towns of Etropole and Troyan (Central North Bulgaria). It includes a broad sector of outcrops, with a W–E trend that is 20–30 km wide and more than 150 km long. This region records a prominent transition from the shallow-water, inner shelf Lower–Middle Jurassic strata, through the Middle–Upper Jurassic pelagic/hemipelagic sediments, to the Upper Jurassic–Lower Cretaceous fine-grained turbidite deposits (Cheshitev et al. 1995). Broadly, the lower boundary of the Jurassic successions is transgressive and represents disconformity to low-angled unconformity resting upon diverse Triassic or Paleozoic rocks. Typically, the upper boundary of the Jurassic is associated with sedimentary environments of continuous deposition. However, east of the Troyan Pass (SE of the town of Troyan), this boundary is associated with post-Jurassic tectonic events, which resulted in Upper Cretaceous unconformably covering the Upper Jurassic rocks. Regionally, the Jurassic rocks belong to the central part of the Balkan Zone (Dabovski & Zagorchev 2009), which forms the highest elevated parts of the Balkan Mts and represents the outer (northern) part of the Alpine Orogen in Bulgaria (Fig. 1a).

The sedimentary succession that was chosen for this study is located to the SE of Ribaritsa Village (Teteven area, Lovech District) and crops out in the valley of the Zavodna River, which is a left tributary of the Beli Vit River (Fig. 1b). It is a part of a long and narrow strip of exposures that comprises four superimposed formations: the Yavorets, Gintsi, and Neshkovtsi formations (fms), and the very base of the Cherni Osam Formation (Fm.) (see also Figs. 2, 3). They overlie shallower Bathonian deposits of the Polaten Fm. With the exception of the sharp boundary between the Polaten and Yavorets fms, which was caused by a regional discontinuity in sedimentation (Cheshitev et al. 1995), the overlying formations grade vertically into each other with rapid lithological transitions. The Yavorets and Gintsi fms are locally formed by highly-condensed beds, the latter of which represents a local equivalent of the Mediterranean *Ammonitico rosso* type facies. Their thicknesses and chronostratigraphic ranges are significantly reduced when compared to corresponding beds in other parts of Bulgaria, even in the Central Balkan region (Cheshitev et al. 1995). In terms of lithology, the Neshkovtsi Fm. represents a transition to the thin-bedded turbidite deposits of the Cherni Osam Fm. Earlier, these two formations were simply termed as “pre-flysch” and “flysch” deposits (Nachev 1976). It appears, however, that they reflect significant changes in paleobathymetry and hydrodynamic conditions within the study area, as well as outside of it, both in regions in Bulgaria that have coeval strata and beyond; further research is to resolve this issue. At a broader supraregional scale, the Late Jurassic deposition in Bulgaria developed on the Moesian Platform, which was located at intermediate northern latitudes along the southern Laurasian continental margin of the Tethys Ocean (cf., Dabovski & Zagorchev 2009; Dercourt et al. 1993; see also Fig. 1c). The Laurasian margin near the Moesian Platform underwent significant paleobathymetric reorganization during the Late Jurassic, which included not only uplifts and emersions, but also subsidence. And so, shallow-marine platform carbonates accumulated in the proximal parts of the basin, while pelagic carbonate strata were deposited in the distal sectors. In contrast, Upper Jurassic gravity flow successions began to be deposited within the Peri-Moesian flexural foredeep, gradually displacing the eupelagic deposits in the distal margin of the platform. This study is being conducted in the Zavodna section to assess the regional and temporal context of these features.

Material and methods

One succession, which is located in the Zavodna River Valley, SE of Ribaritsa Village (Teteven area, Lovech District), with a thickness of ca. 55.0 m, was documented. Biostratigraphy and microfacies analysis were conducted on samples with prefixes Z-1 to Z-30. The sampling resolution ranges from approximately 0.2–0.5 m to 2 m or more, depending on the lithology. The microfacies and stratigraphically-important biomarkers, as well as calcareous dinoflagellates, were studied in 44 thin sections. One set of samples was studied under a Leica DM 2500 transmitting light microscope and documented by the Axiocam ERc 5s camera in the Department of Geology and Paleontology at Comenius University in Bratislava (Slovakia). The second set of samples was studied under transmitted light microscope “Jenaval” in the Geological Institute of the Bulgarian Academy of Sciences, Sofia (Bulgaria).

The calcareous dinoflagellate successions and zonations based on the works by Ivanova (Ivanova 1997; in Lakova et al. 1999) and Reháková (2000) were followed as references. Carbonate rocks were classified according to the Dunham (1962) schemes. Standard microfacies types (SMFs) and facies zones (FZs) were determined by Wilson (1975) and Flügel (2004). For the taxonomic determinations of the calcareous dinocysts, the works of Vogler (1941), Borza (1969), Řehánek (1985, 1987), Řehánek & Heliasz (1993), Ivanova & Kietzmann (2017), and Ciurej & Bąk (2021) were used. The identifications of foraminifers follow the publications of Vašíček et al. (1994), Mišík & Soták (1998), Olszewska (2005), Mathieu et al. (2011), Petrova et al. (2012), Morycowa & Olszewska (2013), Kowal-Kasprzyk (2016), Michalík et al. (2016), Pszczółkowski et al. (2016), Gradstein et al. (2017), Bakhmutov et al. (2018), Ivanova et al. (2019), and Kowal-Kasprzyk et al. (2020).

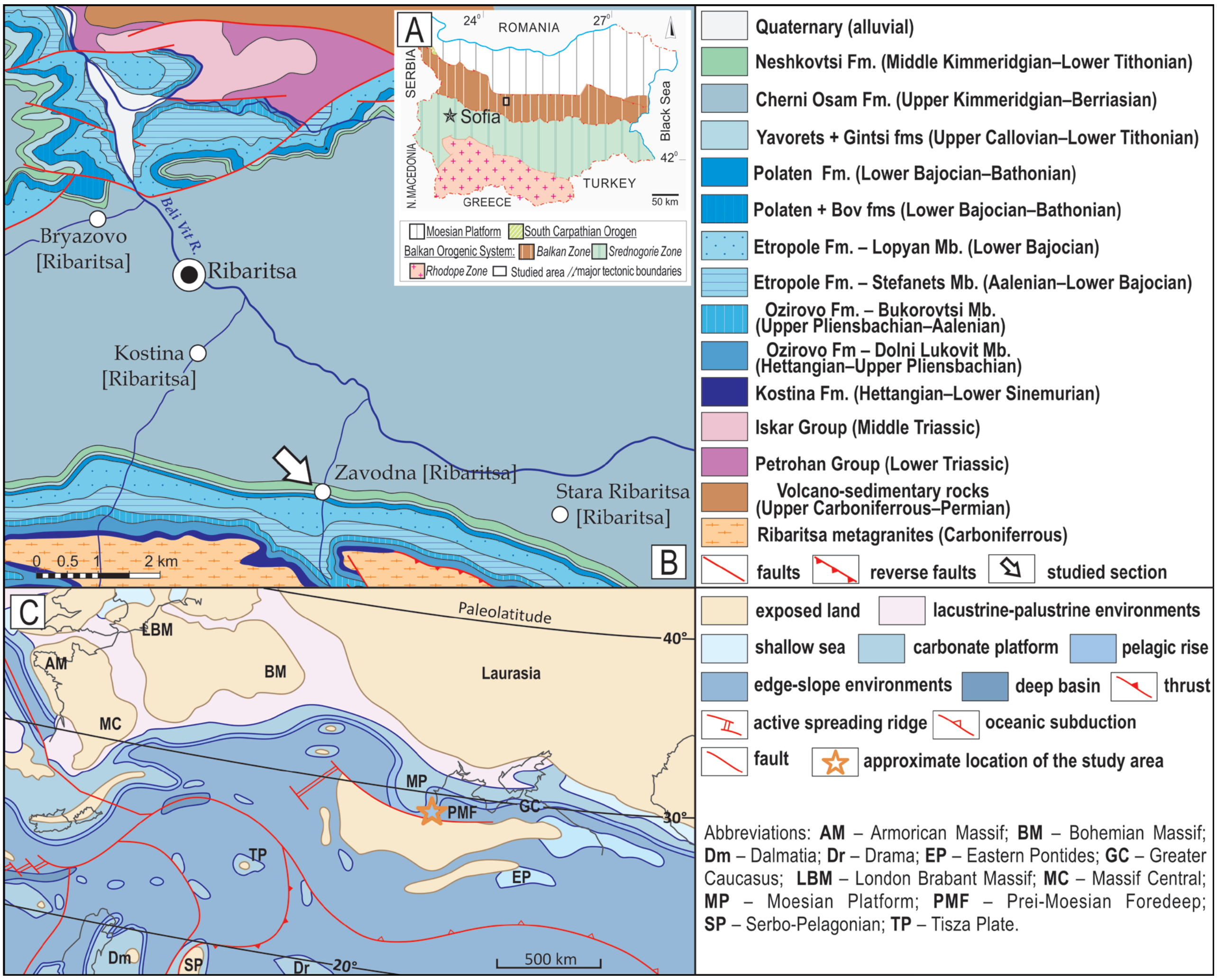


Fig. 1. A — Simplified tectonic sketch showing the position of the studied area within the framework of the Balkan orogenic system and its foreland in Bulgaria (after Dabovski & Zagorchev 2009; modified); **B** — Geological map of the area of Ribaritsa Village (Central Balkan Mts), containing Zavodna section; **C** — Map of the Tithonian paleoenvironments of the Laurasian continental margin of the Tethys Ocean (after Dercourt et al. 1993), showing the location of the study area.

Lithostratigraphy

The Polaten Fm. comprises gray-brown, thin- to medium-bedded, sandy, fine- to coarse-bioclastic limestones and calcareous sandstones, with a total thickness of ca. 30 m. The limestones are commonly interbedded either with calcareous sandstones or clayey-calcareous siltstones. Sedimentary structures include either massive bedding or planar to wavy parallel (both continuous and discontinuous) internal stratification, as well as simple cross-lamination, the latter being very common in lime-sand and lime-silt beds. Bedding planes often have sharp erosional bounding surfaces. According to Cheshitev et al. (1995), the Polaten Fm. spans from the late Bajocian to the early late Bathonian.

The Yavorets Fm. consists of hard, gray, medium-bedded micritic limestones, with a total thickness of 0.50 m. In the area of Ribaritsa, Nikolov & Sapunov (1977) dated it as Callovian–early Oxfordian, while according to Ivanova (1997) the chronostratigraphic extent of this formation varies among sections. In total, on the basis of cyst distribution, it spans from the early Oxfordian to the early Kimmeridgian, including the *Colomisphaera fibrata, Colomisphaera fibrata–Cadosina parvula* and *Cadosina parvula–Stomiosphaera moluccana* zones. A similar, wide age range has also been established by ammonites (cf. Sapunov 1976a; Cheshitev et al. 1995). Previous studies indicated great variability in thicknesses and diachronism of the Yavorets Fm. across the Bulgarian localities.

The Gintsi Fm. comprises gray, gray-green to red, medium- to thin-bedded nodular limestones, and less common laminated limestones (Fig. 2a). The thickness is 5.9 m (Fig. 3). According to Nikolov & Sapunov (1977), it spans the middle Kimmeridgian–middle Oxfordian (*pars.*) in the study area. However, Ivanova (1997) found a broader, but also spatially-

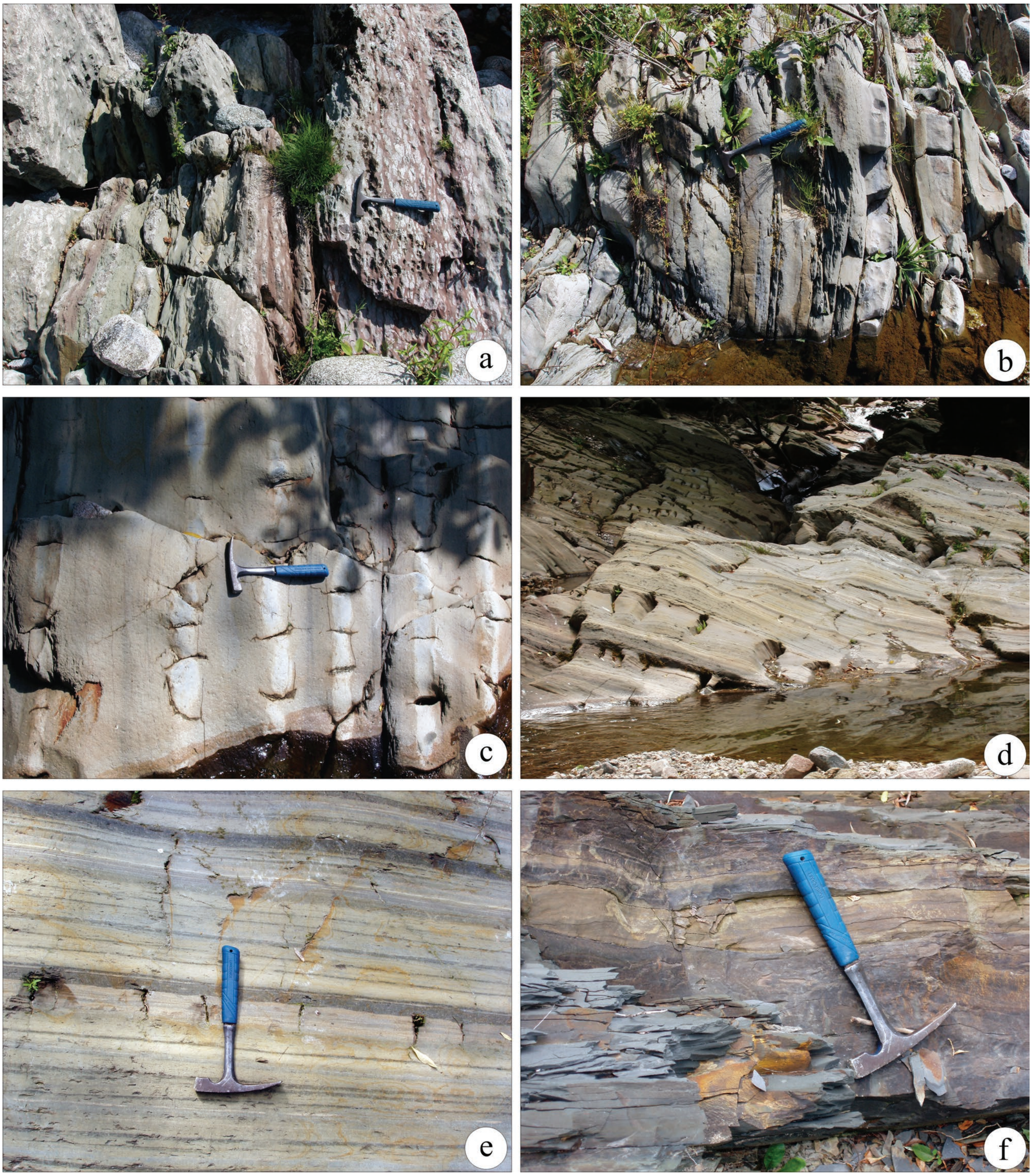
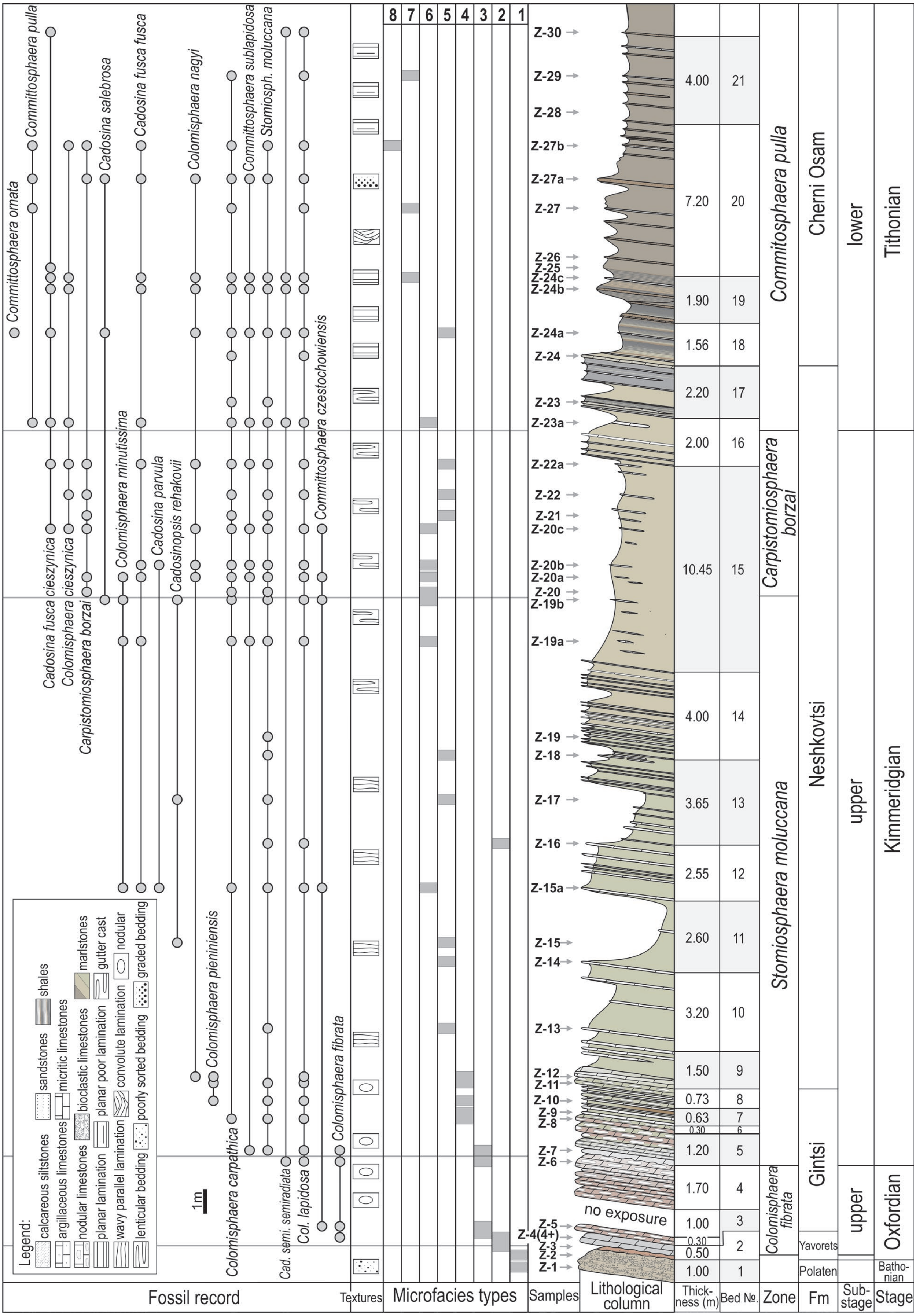


Fig. 2. Field photographs from the Zavodna section: **a** — alternation of red and light green thin-bedded intraclastic limestones of the Gintsi Fm., Bed 5–6, upper Kimmeridgian; **b, c** — poorly-laminated marlstones, with interlayers of sheet-like to lenticular micritic and argillaceous limestones, Neshkovtsi Fm., Bed 13, upper Kimmeridgian; **d**–**f** — rhythmic alternation of dozens of laterally-extensive very thin beds and laminae of calcareous siltstones and shales, transition between Neshkovtsi and Cherni Osam fms, d, e – Bed 17, f **–** Bed 18, lower Tithonian.

Fig. 3. Zavodna section: lithology, litho- and biostratigraphy, microfacies, textures and range-chart of the calcareous dinocyst.



Fossil record
Textures
Microfacies types
Samples
Lithological column
Thick-ness (m)
Bed №
Zone
Fm
Sub-stage
Stage
Legend:
calcareous siltstones
sandstones
shales
argillaceous limestones
micritic limestones
nodular limestones
bioclastic limestones
marlstones
planar lamination
planar poor lamination
gutter cast
wavy parallel lamination
convolute lamination
nodular
lenticular bedding
poorly sorted bedding
graded bedding
1m
no exposure
Commitosphaera ornata
Committosphaera pulla
Cadosina salebrosa
Cadosina fusca fusca
Colomisphaera nagyi
Committosphaera sublapidosa
Stomiosph. moluccana
Colomisphaera minutissima
Cadosina parvula
Cadosinopsis rehakovii
Committosphaera czestochowiensis
Cadosina fusca cieszynica
Colomisphaera cieszynica
Carpistomiosphaera borzai
Colomisphaera pieniniensis
Colomisphaera carpathica
Cad. semi. semiradiata
Col. lapidosa
Colomisphaera fibrata
Commitosphaera pulla
Carpistomiosphaera borzai
Stomiosphaera moluccana
Colomisphaera fibrata
Cherni Osam
Neshkovtsi
Gintsi
Yavorets
Polaten
lower
upper
Tithonian
Kimmeridgian
Oxfordian
Batho-nian
Z-30
Z-29
Z-28
Z-27b
Z-27a
Z-27
Z-26
Z-25
Z-24c
Z-24b
Z-24a
Z-24
Z-23
Z-23a
Z-22a
Z-22
Z-21
Z-20c
Z-20b
Z-20a
Z-20
Z-19b
Z-19a
Z-19
Z-18
Z-17
Z-16
Z-15a
Z-15
Z-14
Z-13
Z-12
Z-11
Z-10
Z-9
Z-8
Z-7
Z-6
Z-5
Z-4(4+)
Z-3
Z-2
Z-1
4.00 21
7.20 20
1.90 19
1.56 18
2.20 17
2.00 16
10.45 15
4.00 14
3.65 13
2.55 12
2.60 11
3.20 10
1.50 9
0.73 8
0.63 7
0.30 6
1.20 5
1.70 4
1.00 3
0.30
0.50 2
1.00 1
8 7 6 5 4 3 2 1

variable age range, from early Kimmeridgian to early Tithonian (*Stomiosphaera moluccana–Carpistomiosphaera borzai* and *Carpistomiosphaera borzai* zones at Glozhene, *Carpistomiosphaera borzai* Zone at Koznitsa; both localities NW of the one in this study), and middle Tithonian at Romanov Dol (*Parastomiosphaera malmica* up to *Colomisphaera cieszynica–Colomisphaera tenuis* Zone; ibid.). Based on previous studies, the Bulgarian localities of the Gintsi Fm. exhibit great differences in thicknesses and diachronism similar to those of the Yavorets Formation.

The Neshkovtsi Fm. is composed of three vertically-stacked lithofacies, with a total thickness of ca. 32 m: hemipelagic limestone facies, gutter cast facies, and thin-bedded overbank facies. The lower one is laterally extensive, and dominated by poorly-laminated marlstones, which are interbedded with sheet-like to lenticular micritic and argillaceous limestones (Fig. 2b, c). The mid-lying lithofacies comprises silt-laminated marlstones, often surrounding carbonate gutter casts. It is laterally limited and contains shallow, linear elongate to several tens of centimeters, silty-calcareous casts surrounded by marlstones. The topmost facies includes a rhythmic alternation of dozens of laterally-persistent, very thin beds and laminae of calcareous siltstones and shales (Figs. 2d, e, 3). Siltstones are current, ripple cross- and planar-parallel stratified, as well as sharp and erosive-based, whereas alternating shales are planar-parallel-stratified, in places shallowly bioturbated. In the up-section, this alternation rapidly grades into the fine-grained turbidites of the Cherni Osam Fm. (Nikolov & Sapunov 1977), which is defined by a narrow age range, from the middle Kimmeridgian to the earliest late Kimmeridgian.

The Cherni Osam Fm. consists of thin-bedded turbidites (fine-grained sandstones to coarse siltstones with ripple laminations that are often deformed into convolutions), which alternate with calcareous shales and thin interbeds of limestones (Fig. 2f). Only the lowermost 11.5 m were sampled for the purposes of this study (Fig. 3). Nikolov & Sapunov (1977) dated the lower levels of the Cherni Osam Fm. as late Kimmeridgian–early Tithonian.

Results

Microfacies

Eight microfacies types (MFT 1–8) were distinguished and described (Figs. 3, 4).

MFT 1 Bioclastic to bio-lithoclastic packstone to grainstone (Figs. 3, 4.1, 4.2)

Bioclastic grainstone, in which fragments of crinoid columnalia dominate over bryozoans, ostracods, foraminifers, and lithoclasts, built of micritic matrix with undeterminable small bioclasts. The rock groundmass also contains clastic quartz grains. Bio-lithoclastic packstone to grainstone is composed of fragmentary crinoid columnalia, bryozoans, ostracods, bivalves, foraminifers, and lithoclasts of wackestone structure with small bioclasts. Many encrusting nubeculariid foraminifers are attached to the bioclasts. The matrix also contains clastic quartz grains, locally accumulated in nests. Authigenic quartz and albite crystals are visible in some intraclasts. This microfacies type is present only in the Bathonian Polaten Fm. (samples Z-1, Z-2).

MFT 2 Filamentous wackestone to packstone (Figs. 3, 4.3, 4.4)

This microfacies type is observed in the Oxfordian and Kimmeridgian beds. The Oxfordian strata comprise biomicritic and bioturbated wackestones to packstones dominated by filaments, along with less-abundant fragments of crinoids, brachiopods, belemnites, ostracods, spores of *Globochaete alpina* Lombard 1945, a few planktonic foraminifers *Globuligerina oxfordiana* (Fig. 5.1), as well as small benthic foraminifers (*Involutina* sp., *Spirillina* sp., *Lenticulina* sp. – Fig. 5.8) and microforaminifers. The matrix is penetrated by calcite veins. Pyrite cubes and pyrite-impregnated bioclasts, as well as scattered quartz grains are visible in the matrix. The Kimmeridgian deposits represent slightly-laminated wackestone, in which filaments dominate over planktonic crinoids *Saccocoma* sp., calcified radiolarians, sponge spicules, spores of *Globochaete alpina*, and calcareous dinocysts. Some of the bioclasts are silicified. Pyrite and smooth organic matter are scattered in the matrix. The microfacies type occurs in the Yavorets Fm. (samples Z-3, Z-4), as well as in the Neshkovtsi Fm. (sample Z-16).

MFT 3 Globuligerina wackestone (Figs. 3, 4.5, 4.6)

Planktonic foraminifers (*Globuligerina oxfordiana*, Fig. 5.2) dominate in this microfacies type. Spores of *Globochaete alpina*, filaments, echinoid spines, crinoid fragments, *Saccocoma* sp., ostracods, juvenile ammonites, fragments of aptychi, rhyncholites, brachiopods, bivalves, belemnites, small benthic foraminifers (*Lenticulina* sp., *Involutina* sp., *Nodosaria* sp., *Spirillina* sp., *Dentalina* sp.), as well as miliolid foraminifers and calcareous dinoflagellate cysts are also observed. The matrix contains scattered pyrite and silty clastic grains of quartz. Some bioclasts are pyritized. MFT 3 is present in the Yavorets (samples Z-4+, Z-5) and Gintsi (samples Z-6, Z-7) fms. This microfacies type is observed in the upper Oxfordian and lowermost upper Kimmeridgian beds.

MFT 4 Filament-Saccocoma wackestone

Slightly-laminated, filament-*Saccocoma* wackestone is characterized by frequent or dominant skeletal elements of *Saccocoma* sp., filaments, common *Globochaete* spores, less-frequent calcified radiolarians, sponge spicules, fragments of crinoids, aptychi, foraminifers, calcareous dinoflagellate cysts, and the microproblematicum *Gemeridella minuta* Borza & Mišík 1975. Burrows are observed in some sectors. The matrix also contains a rich clayey admixture, in which

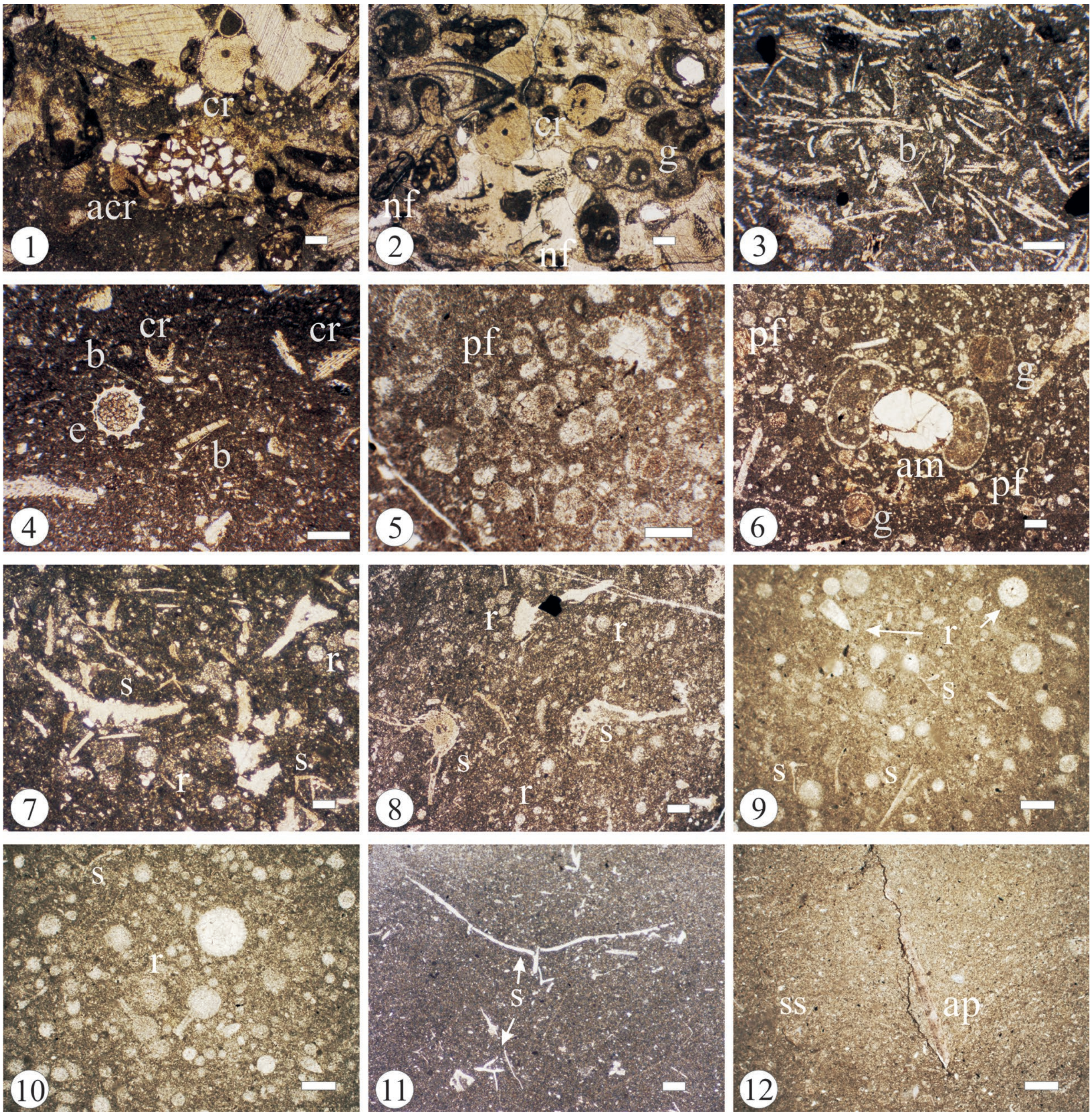


Fig. 4. Microfacies from the Zavodna section: **1**, **2** — bio-lithoclastic packstone to grainstone, 1 – with accumulation in nests of the authigenic crystals, 2 – with nubecularid foraminifers and bioclasts, sample Z-2, Polaten Fm., Bathonian; **3** — filamentous wackestone to packstone, sample Z-3, Yavorets Fm., upper Oxfordian; **4** — filamentous wackestone with crinoids and echinoid ossicle, sample Z-4, Yavorets Fm., upper Oxfordian; **5** — G*lobuligerina* wackestone, sample Z-5, Gintsi Fm., upper Oxfordian; **6** — G*lobuligerina* wackestone with gastropods and juvenile ammonite, sample Z-6, Gintsi Fm., upper Oxfordian; **7**–**9** — *Saccocoma*-radiolarian wackestone, 7 – sample Z-13, 8 – sample Z-17, 9 – sample Z-22a, Neshkovtsi Fm., upper Kimmeridgian; **10** — radiolarian wackestone, sample – Z-20c, Neshkovtsi Fm., upper Kimmeridgian; **11** — *Saccocoma* wackestone, sample – Z-27, Cherni Osam Fm., lower Tithonian; **12** — spicule wackestone, sample – Z-27b, Cherni Osam Fm., lower Tithonian. Note: All images are in plane-polarized light. Scale bars: 200 μm.

muscovite is dominant and clastic grains of quartz also occur. Some bioclasts are silicified. This microfacies was documented in the upper part of the Gintsi Fm. (samples Z-8, Z-9, and Z-10), as well as in the Neshkovtsi Fm. (samples Z-11, Z-12), which both correspond to the upper Kimmeridgian.

MFT 5 Saccocoma-radiolarian wackestone (Figs. 3, 4.7–4.9)

Calcified radiolarians dominate in slightly laminated and recrystallized wackestones. Common planktonic crinoids (*Saccocoma* sp.), recrystallized spores of *Globochaete alpina*, sponge spicules, filaments, calcareous dinocysts, rare aptychi,

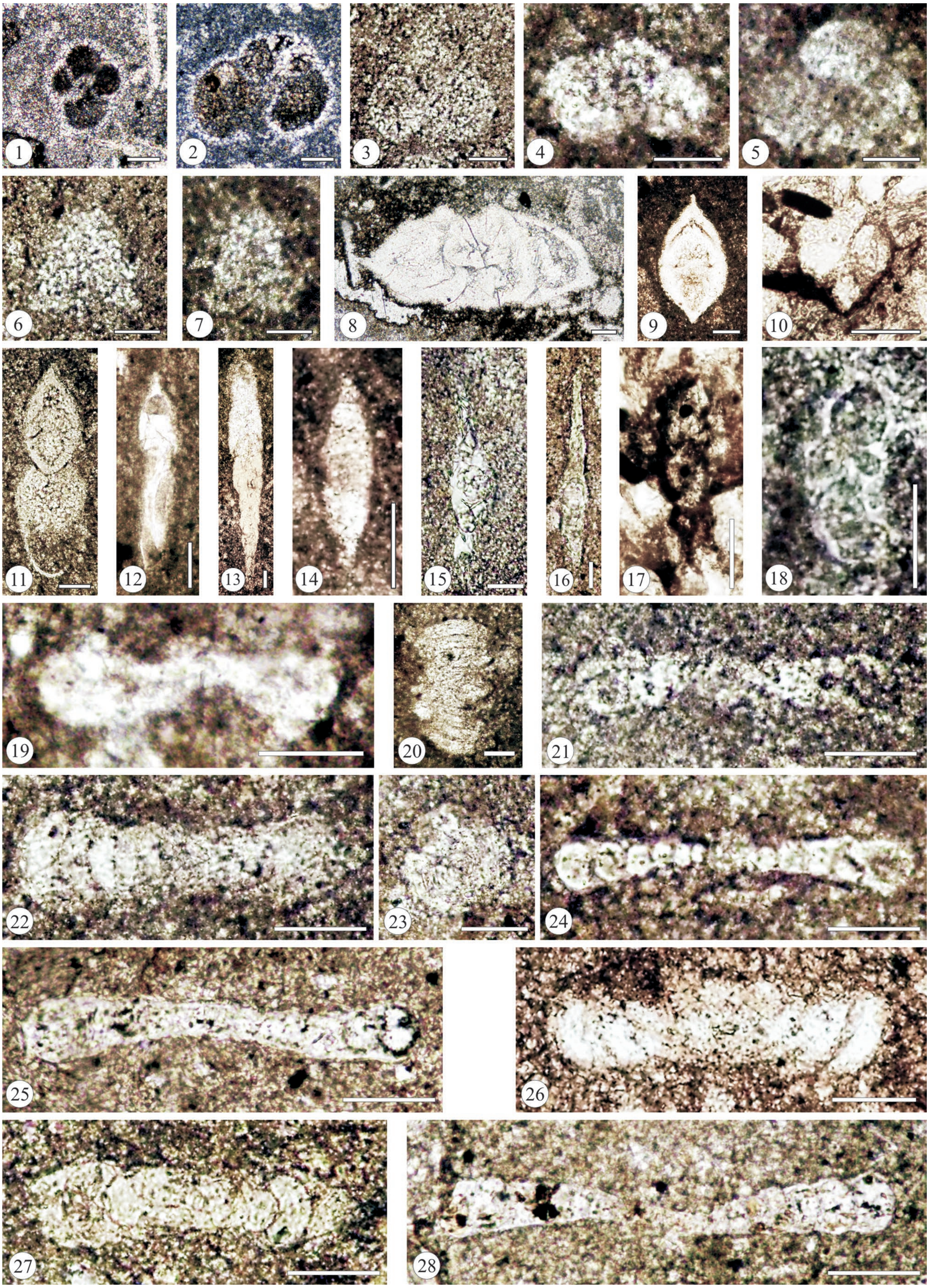

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Fig. 5. Foraminifers from the Zavodna section: **1**, **2** — *Globuligerina oxfordiana* (Grigelis 1958), 1 – sample Z-3, 2 – sample Z-6; **3**–**5** — *Conoglobigerina* sp., 3 – sample Z-20c, 4 – sample Z-22a, 5 – sample Z-23a; **6**, **7** — *Rumanolina* sp., 6 – sample Z-24a, 7 – sample Z-20a; **8**, **9** — *Lenticulina* sp., 8 – sample Z-3, 9 – sample Z-22a; **10** — *Uvigerinammina uvigeriniformis* (Seibold & Seibold 1960), sample Z-27a; **11** — *Nodosaria* sp., sample Z-20c; **12** — *Dentalina* sp., sample Z-24c; **13** — *Laevidentalina* cf. *nana* (Reuss 1863), sample Z-24a; **14**–**16** — *Frondicularia* sp., 14 – sample Z-19a, 15 – sample Z-22a, 16 – sample Z-24a; **17** — *Reophax* sp., sample Z-27a; **18** — *Bullopora* sp., sample Z-20a; **19** — *Coronipora* sp., sample Z-23a; **20** — *Cornuspira* sp., sample Z-20a; **21** — *Cornuspira* cf. *infraoolithica* Terquem 1870, sample Z-22a; **22** — *Spirillina elongata* Bielecka & Pożaryski 1954, sample Z-20c; **23** — *Spirillina minima* Schacko 1892, sample Z-24a; **24** – *Spirillina tenuissima* Gümbel 1862, sample Z-20a; **25**–**28** — *Spirillina* sp., 25 – sample Z-24c, 26, 27 – sample Z-20c, 28 – sample Z-27b. Scale bars: 50 µm.

crinoids, ostracods, small benthic foraminifers (*Rumanolina* sp. – Fig. 5.6, *Lenticulina* sp. – Fig. 5.9, *Frondicularia* sp. – Fig. 5.15, *Cornuspira* cf. *infraoolithica* – Fig. 5.21, *Spirillina* sp.), single planktonic foraminifers (*Conoglobigerina* sp. – Fig. 5.4), gastropods, and holothurian wheels complement the composition of bioclasts. The majority of them have silicified tests. Ferruginized bioclasts are also observed. The silty, clastic admixture is represented by small subangular quartz grains, muscovite flakes and feldspar. There are also dolomite rhombohedra, opaque minerals, and glauconite pellets (in some cases they replace bioclasts). Dispersed organic matter and Fe-oxides spots are also observed in the matrix. The MFT 5 is common in the upper Kimmeridgian–lower Tithonian strata: the Neshkovtsi Fm. (samples Z-13, Z-14, Z-15, Z-17, Z-18, Z-21, Z-22, Z-22a) and the Cherni Osam Fm. (sample Z-24a).

MFT 6 Radiolarian wackestone (Figs. 3, 4.10)

Calcified radiolarians are dominant. Other bioclasts are represented by common to rare *Saccocoma* sp., common calcareous dinocysts, sponge spicules, and rare spores of *Globochaete alpina*, as well as aptychi, small benthic foraminifers (*Rumanolina* sp. – Fig. 5.7, *Nodosaria* sp. – Fig. 5.11, *Frondicularia* sp. – Fig. 5.14, *Bullopora* sp. – Fig. 5.18, *Coronipora* sp. – Fig. 5.19, *Cornuspira* sp. – Fig. 5.20, *Spirillina elongata* – Fig. 5.22, *Spirillina tenuissima* – Fig. 5.24, *Spirillina* sp. – Fig. 5.26), ostracods, crinoids, echinoid spines, single planktonic foraminifers (*Conoglobigerina* sp., Fig. 5.3, 5.5), and gastropods. In some samples, all bioclasts are recrystallized. The matrix is composed of well-preserved micrite. The silty clastic admixture consists of silt-sized subangular quartz grains and muscovite flakes. Rhombohedral dolomite crystals, glauconitic pellets (in some cases replacing the bioclasts), feldspar, and opaque minerals are also documented. Dissolution seams (impregnated by calcite and Fe-oxides), dendrolite fabric, and Fe-oxides spots are also visible in the matrix. This microfacies type is observed only in the Neshkovtsi Fm. (samples Z-15a, Z-19a, Z-19b, Z-20, Z-20a, Z-20b, Z-20c, Z-23a). Chronostratigraphically, it corresponds to the upper Kimmeridgian.

MFT 7 Saccocoma wackestone (Figs. 3, 4.11)

Planktonic crinoids (*Saccocoma* sp.) are dominant. Calcareous dinocysts, small benthic foraminifers (*Dentalina* sp. – Fig. 5.12, *Spirillina* sp. – Fig. 5.25), spores of *Globochaete alpina*, sponge spicules, ostracods, bivalves, aptychi, and rare radiolarians also occur. All bioclasts are recrystallized, and some of them are phosphatized. The matrix contains a silty clastic admixture, which consists of small subangular quartz grains and muscovite flakes. There are also small dolomite rhombohedra and glauconite pellets (in some cases, they are replaced by foraminifers). Pyrite is scattered. Dissolution seams, which were impregnated by calcite and Fe-oxides, are also visible in the matrix. This microfacies is observed in the Cherni Osam Fm. (samples Z-24c, Z-27, Z-29). It corresponds to the lower Tithonian.

MFT 8 Spiculitic wackestone (Figs. 3, 4.12)

Sponge spicules dominate over calcareous dinocysts, *Saccocoma* sp., crinoids, and small benthic foraminifers (*Spirillina* sp. – Fig. 5.28). Rare aptychi, ostracods, fragments of bivalves, serpulids, and globochaetes are also observed. Many foraminifers were replaced by glauconite. The matrix contains a silty clastic admixture represented by muscovite flakes and silt-sized quartz grains, as well as glauconite grains. Dolomite crystals and opaque minerals are also documented. The matrix is locally penetrated by calcite fractures and pressure sutures, which are filled by Fe-oxides. There are also very small fragments of charred plants. The MFT 8 is recorded in Cherni Osam Fm. only (sample Z-27b), and corresponds to the lower Tithonian.

Calcareous dinoflagellate stratigraphy

Nineteen species of calcareous dinoflagellates, belonging to seven genera, have been identified. They are often poorly preserved, and cysts are recrystallized in some beds. The cyst succession allows us to distinguish four calcareous dinoflagellate cyst zones (Fig. 3): the *Colomisphaera fibrata* Zone (Oxfordian), *Stomiosphaera moluccana* Zone (upper Kimmeridgian), *Carpistomiosphaera borzai* (upper Kimmeridgian), and *Committosphaera pulla* (lower Tithonian). It is also noteworthy that the *Cadosina parvula* Zone (lower Kimmeridgian) was not detected at the Zavodna section.

The Upper Oxfordian Colomisphaera fibrata Zone, sensu Ivanova (1997) and Reháková (2000)

The lower boundary of the *Colomisphaera fibrata* Zone is defined at first occurrence (FO) of the index species (sample

Z-4, Fig. 6.1, 6.2). The FO of another typically Oxfordian species, *Committosphaera czestochowiensis,* is also characteristic (see Řehánek & Heliasz 1993; Fig. 6.3). The dinocyst association is complemented by the first occurrences of *Colomisphaera lapidosa* and *Cadosina semiradiata semiradiata* in the uppermost part of the zone. The *Colomisphaera fibrata* Zone falls in both the Yavorets Fm. (samples Z-4, Z-4+) and the lower part of the Gintsi Fm. (samples Z-5–Z-6); its thickness is about 3.30 m (Fig. 3).

The Upper Kimmeridgian Stomiosphaera moluccana Zone, sensu Reháková (2000)

According to the definition of Reháková (2000), the lower boundary of the zone is marked by the FO of *Stomiosphaera moluccana* (Fig. 6.5, 6.6) and its upper boundary by the FO of *Carpistomiosphaera borzai*. This zone is characterized by an increase in diversity of dinocyst species. In addition to the FO of the index species, the first occurrences of following taxa were also documented: *Committosphaera sublapidosa*, *Colomisphaera carpathica* (Fig. 6.7), *Colomisphaera nagyi* (Fig. 6.9, 6.10), *Colomisphaera pieniniensis* (Fig. 6.11), *Cadosinopsis rehakovii* (Fig. 6.13–16), *Cadosina parvula*, *Cadosina fusca fusca*, *Colomisphaera minutisima* (Fig. 6.17), and *Cadosina salebrosa* (Fig. 6.19). At the base of the zone falls the last occurrence (LO) of *Colomisphaera fibrata*. *Colomisphaera pieniniensis* is limited to the lower half of the zone, and *Cadosinopsis rehakovii* occurs in its upper half. The association is complemented by *Committosphaera czestochowiensis* and *Colomisphaera lapidosa*. The zone covers a ca. 23 meter-thick interval, including the upper part of the Gintsi Fm. (samples Z-7–Z-11) and the greater part of the Neshkovtsi Fm. (samples Z-12–Z-19b, Fig. 3). This zone corresponds to the *Stomiosphaera moluccana-Carpistomiosphaera borzai* Interval-Zone introduced by Ivanova (1997).

The Upper Kimmeridgian Carpistomiosphaera borzai Zone, sensu Ivanova (in Lakova et al. 1999) and Reháková (2000)

The FO of *Carpistomiosphaera borzai* (Fig. 7.1, 7.2) defines the lower boundary of the zone. The first occurrences of *Colomisphaera cieszynica* and *Cadosina fusca cieszynica* are also documented. The last occurrences of *Committosphaera czestochowiensis* (Fig. 6.4), *Cadosina parvula* (Fig. 6.12) and *Colomisphaera minutisima* (Fig. 6.18) fall in this zone. Ranging upwards from the underlying zones, *Colomisphaera lapidosa*, *Colomisphaera carpathica* (Fig. 6.8), *Stomiosphaera moluccana*, *Committosphaera sublapidosa* (Fig. 7.4, 7.5), *Colomisphaera nagyi*, and *Cadosina fusca fusca* also occur. The *Carpistomiosphaera borzai* Zone occurs in the upper part of the Neshkovtsi Fm.; its thickness is approximately 9.15 m (samples Z-20–Z-22a, Fig. 3).

The Lower Tithonian Committosphaera pulla Zone, sensu Reháková (2000)

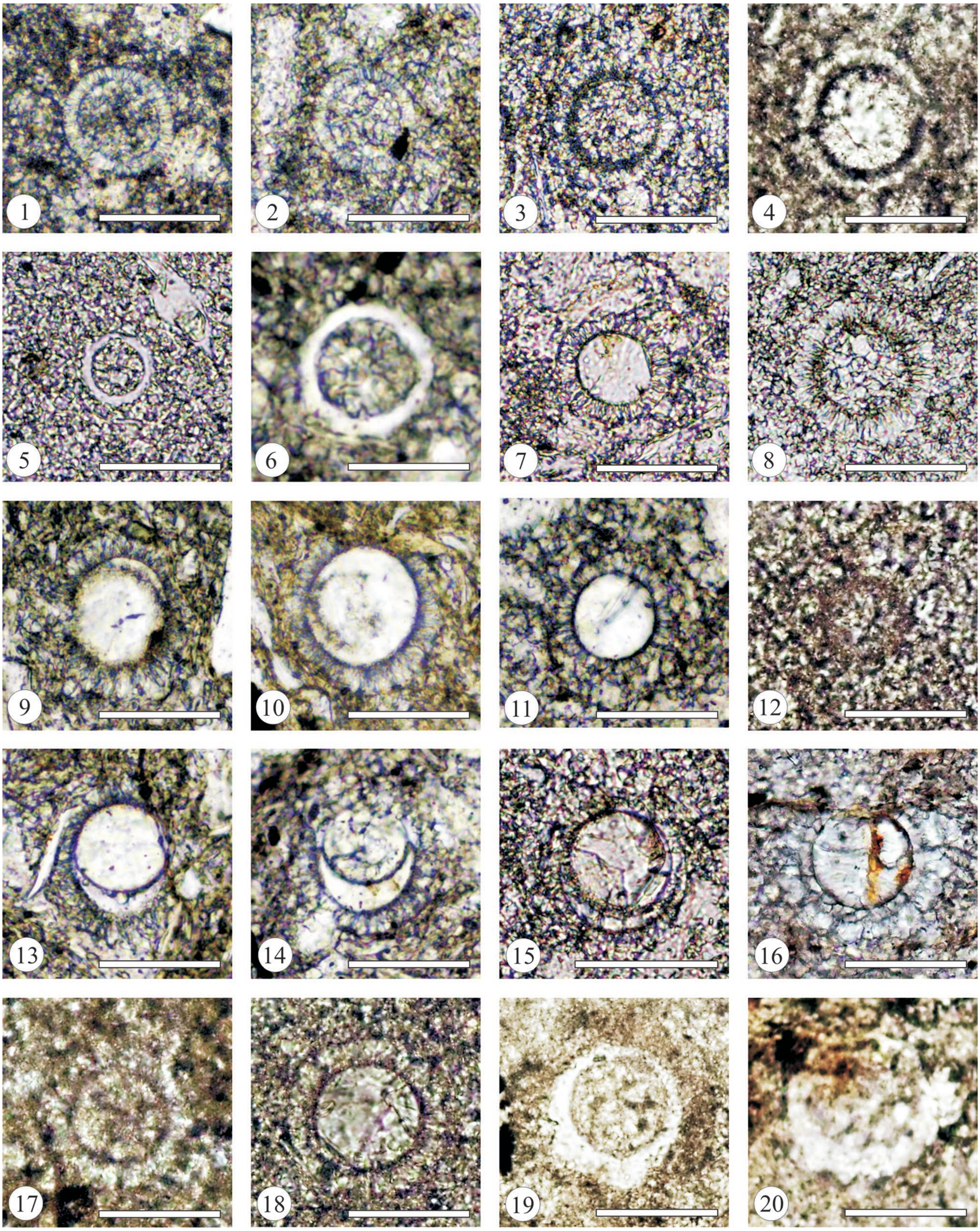
The base of the zone is defined by the FO of the index species *Committosphaera pulla* (Fig. 7.6, 7.7). The association is complemented by *Cadosina salebrosa* (Fig. 6.20), *Carpistomiosphaera borzai* (Fig. 7.3), *Cadosina semiradiata semiradiata* (Fig. 7.11, 7.12), *Colomisphaera lapidosa* (Fig. 7.13, 7.14), *Stomiosphaera moluccana*, *Committosphaera sublapidosa*, *Colomisphaera carpathica*, *Colomisphaera nagyi, Colomisphaera cieszynica* (Fig. 7.15, 7.16), *Cadosina fusca fusca* (Fig. 7.17, 7.18), and *Cadosina fusca cieszynica* (Fig. 7.19, 7.20). *Committosphaera ornata* (Fig. 7.8–10) has its FO within the zone. The *Committosphaera pulla* Zone corresponds to the top of the Neshkovtsi Fm. (samples Z-23a and Z-23) and the basal strata of the Cherni Osam Fm. (samples Z-24 to Z-30). Its thickness is ca. 19 m (Fig. 3). This zone is analogous to the lower part of the *Parastomiosphaera malmica* Range-Zone according to Ivanova (1997) and the *Carpistomiosphaera tithonica* Zone according Ivanova (in Lakova et al. 1999).

Discussion

Implications from calcareous dinoflagellates records

The earliest dinocyst record of Zavodna is that of the Yavorets Fm., which is based on the recognition of the upper Oxfordian *Colomisphaera fibrata* Zone. The dinocyst occurrences from the Gintsi Fm. assign these strata to the upper Oxfordian *Colomisphaera fibrata* Zone, but also to the upper Kimmeridgian *Stomiosphaera moluccana* Zone. It is notable that the lower Kimmeridgian *Cadosina parvula* Zone is absent, i.e., there is a stratigraphic hiatus within the Gintsi Fm. The Yavorets and Gintsi fms show a specific development in the succession of the Zavodna section. Typically, the Yavorets Fm. has a wider chronostratigraphic range, from the Callovian to the Kimmeridgian, as previously established in other

Fig. 6. Calcareous dinoflagellate cysts from the Zavodna section: **1**, **2** — *Colomisphaera fibrata* (Nagy 1966), sample Z-4, *Col. fibrata* Zone; **3**, **4** — *Committosphaera czestochowiensis* Řehánek 1993, 3 – sample Z-5, *Col. fibrata* Zone, 4 – sample Z-20a, *Carpi. borzai* Zone; **5**, **6** — *Stomiosphaera moluccana* Wanner 1940, 5 – sample Z-18, 6 – sample Z-13, *St. moluccana* Zone; **7**, **8** — *Colomisphaera carpathica* (Borza 1964), 7 – sample Z-8, *St. moluccana* Zone, 8 – sample Z-22, *Carpi. borzai* Zone; **9**, **10** — *Colomisphaera nagyi* Borza 1969, sample Z-12, *St. moluccana* Zone; **11** — *Colomisphaera pieniniensis* (Borza 1969), sample Z-10, *St. moluccana* Zone; **12** — *Cadosina parvula* Nagy 1966, sample Z-20b, *Carpi. borzai* Zone; **13**–**16** — *Cadosinopsis rehakovii* Ciurej & Bąk 2021, 13, 14 – sample Z-15, 15 – sample Z-17, 16 – cyst with slightly recrystallized outer layer, sample Z-19b, *St. moluccana* Zone; **17**, **18** — *Colomisphaera minutisima* sensu Nowak 1968, 17 – sample Z-15a, *St. moluccana* Zone, 18 – sample Z-20a, *Carpi. borzai* Zone; **19**, **20** — *Cadosina salebrosa* Řehánek 1985, 19 – sample Z-19b, *St. moluccana* Zone, 20 – sample Z-24a, *Comm. pulla* Zone. Scale bars: 50 µm.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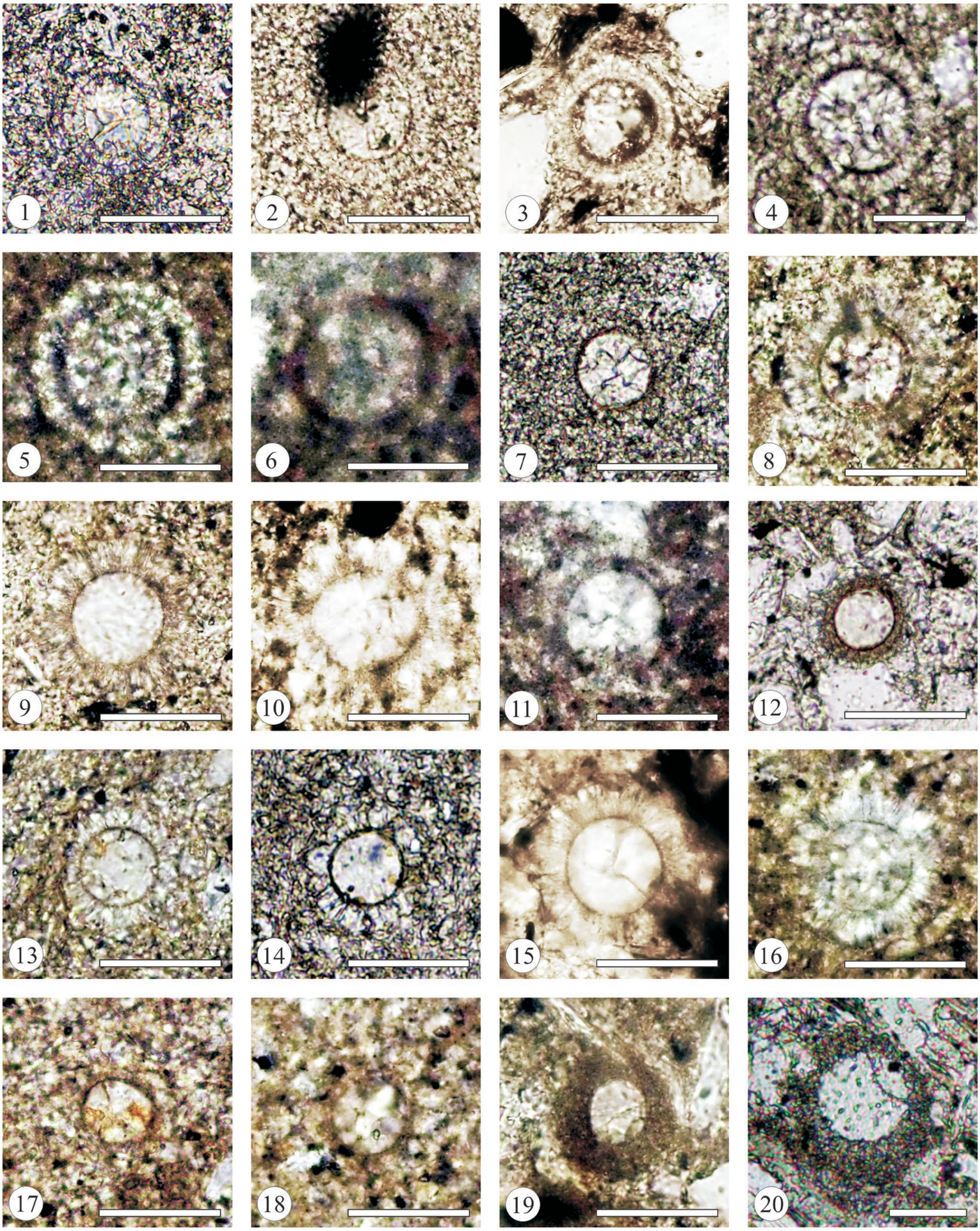

Fig. 7. Calcareous dinoflagellate cysts from the Zavodna section: **1**–**3** — *Carpistomiosphaera borzai* (Nagy 1966), 1 – sample Z-20, 2 – sample Z-22a, *Carpi. borzai* Zone, 3 – sample 27a, *Comm. pulla* Zone; **4**, **5** — *Committosphaera sublapidosa* (Vogler 1941), sample Z-20a, *Carpi. borzai* Zone; **6**, **7** — *Committosphaera pulla* (Borza 1964), 6 – sample Z-23a, 7 – sample Z-27, *Comm. pulla* Zone; **8**–**10** — *Committosphaera ornata* (Nowak 1968), sample Z-24a, *Comm. pulla* Zone; **11**, **12** — *Cadosina semiradiata semiradiata* (Wanner 1940), 11 – sample Z-23a, 12 – sample Z-30, *Comm. pulla* Zone; **13**, **14** — *Colomisphaera lapidosa* (Vogler 1941), 13 – sample Z-27a, 14 – sample Z-29, *Comm. pulla* Zone; **15**, **16** — *Colomisphaera cieszynica* Nowak 1968, 15 – sample Z-24b, 16 – sample Z-24c, *Comm. pulla* Zone; **17**, **18** — *Cadosina fusca fusca* Wanner 1940, sample Z-27b, *Comm. pulla* Zone; **19**, **20** — *Cadosina fusca cieszynica* Nowak 1966, 19 – sample Z 24b, 20 – sample Z 25, *Comm. pulla* Zone. Scale bars: 50 µm.

parts of the Central Balkan (Ivanova 1997) and Western Balkan Mts (Lakova et al. 2007). However, in this section, this formation is limited only to the Oxfordian Stage, similarly to the Glozhene section in the Central Balkan Mts (Ivanova 1997). The Gintsi Fm. spans the Oxfordian and the late Kimmeridgian at the Zavodna section, while both Ivanova (1997) and Lakova et al. (2007) indicated that the formation developed in the Kimmeridgian and ended in the early or mid-Tithonian at other locations in the Central or Western Balkan Mts. Upwards, the succession continues with the Neshkovtsi Fm., which covers the upper Kimmeridgian (*Stomiosphaera moluccana* and *Carpistomiosphaera borzai* zones) and the basal lower Tithonian (*Committosphaera pulla* Zone). The Cherni Osam Fm. yielded calcareous dinocysts, which belong to the lower Tithonian *Committosphaera pulla* Zone. In terms of their microfossil contents, calcified radiolarians and *Saccocoma* sp. dominate both in the Neshkovtsi and Cherni Osam fms, while calcareous dinocysts are rare to moderately abundant.

Implications from depositional environment

The grain-supported texture, fossil association (i.e., the presence of fragmentary crinoid columnalia, bryozoans, ostracods, bivalves, foraminifers), as well as common, rounded intraclasts suggest that MFT 1 was deposited in a high-energy, shallow-marine setting affected by sediment reworking, with normal salinity and open water circulation. The components are often well-sorted, and some beds exhibit cross-stratification. This microfacies type corresponds to SMF 10, which is interpreted here as a manifestation of facies zone (FZ) 7 – open marine platform (Flügel 2004). In contrast, MFT 2, MFT 3, MFT 4, MFT 5, MFT 6, and MFT 7 are characterized by a micritic matrix, with common to abundant pelagic microfossils (calcified radiolarians, sponge spicules, planktonic and small benthic foraminifers, calcareous dinoflagellate cysts, *Globochaete alpina* spores, and microproblematics) and macrofossils (planktonic crinoids *Saccocoma* sp., filaments, crinoids, echinoid spines, juvenile ammonites, fragments of aptychi, rhyncholites, brachiopods, belemnites, ostracods, gastropods). The matrix and bioturbation fabrics point to low sedimentation rates and predominantly low-energy hydrodynamic, yet well-oxygenated conditions. They can be referred to SMF 3 (SMF 3-Fil, SMF 3-For, SMF-Rad), which occurs in an open deep shelf (FZ 3) and basin (FZ 1-B; Flügel 2004). The last microfacies type (MFT 8) coincides with SMF 1. It occurs on slope and in basinal, deep-water environments with slow sedimentation, below the wave base and below the euphotic zone (FZ 1, see Flügel 2004). Excluding MFT 1, pelagic carbonate deposits of varying water depths, but always below the photic zone, dominate at the Zavodna section. A general trend of deepening of deposition is observed. The deepening is considered to be biphasic-stepwise, with onset after the late Bathonian, when the shallow-marine, terrigenous-carbonate setting was replaced by thinly-developed pelagic deposition in the earliest recorded late Oxfordian, following a prolonged hiatus. After that, the *Ammonitico rosso* facies indicates toe-of-slope sedimentary environments in the late Oxfordian–late Kimmeridgian, in which nodulation and sediment-winnowing took place on a topographically high seafloor, resulting in another significant sedimentary gap. From the late Kimmeridgian onward, a considerable change in paleobathymetry and hydraulic conditions becomes evident. Storm-influenced deposition along distributary channel is indicated by the vertical transition from hemipelagic limestone facies–gutter cast facies–thin-bedded overbank facies to thin-bedded turbidites. As inferred from the observed textures and microfossils, the deposition took place in a deep shelf to slope setting, at a moderate distance from the continental edge.

From a geographical standpoint, the Glozhene, Romanov Dol, and Koznitsa sections (around Teteven) are closest to Zavodna. They have previously been studied by Ivanova (1994, 1997). Despite their proximity and partially-overlapping lithologies, these successions differ from the study sequence. The thicknesses and ages of the Yavorets Fm. (Glozhene section: 65 m; Romanov Dol section: 25 m; upper Callovian–lower Kimmeridgian) and Gintsi Fm. (Glozhene section: 10.5 m; Romanov Dol section: 28 m; lower Kimmeridgian–lower Tithonian) are distinctly different from those in Zavodna. The main distinction is the Glozhene Formation, which is equivalent to Biancone or Maiolica type limestones (Glozhene section: 50 m thick, lower Tithonian–lower Berriasian), with its type section at Glozhene Village, lying above the Yavorets (Oxfordian–lower Kimmeridgian) and Gintsi (lower Kimmeridgian–lower Tithonian) fms. This typical, pelagic unit laterally passes into the Neshkovtsi Fm. (see Cheshitev et al. 1995). Overall, the sequence in the Glozhene section runs continuously from the upper Callovian to the lower Berriasian. A stratigraphic gap, from the uppermost Kimmeridgian to the lowermost Tithonian, was found around the boundary between the Yavorets and Gintsi fms in the Romanov Dol section (Ivanova 1994, 1997). The Koznitsa section, which has the closest lithological development to Zavodna, corresponds to the following succession: (1) Yavorets Fm. (3 m thick, Oxfordian); (2) Gintsi Fm. (10 m thick, upper Kimmeridgian–lower Tithonian); (3) Glozhene Fm. (20 m thick, lower–upper Tithonian); (4) Glozhene-Neshkovtsi Fm. (110 m thick, upper Tithonian–lower Berriasian); and (5) Glozhene-Cherni Osam Fm. (38 m thick, lower Berriasian). Here, a gap covering almost the entire Kimmeridgian stage (without its uppermost parts) was recorded between the Yavorets and Gintsi fms. A transitional pelagic-slope setting is evident in the Glozhene–Neshkovtsi–Cherni Osam fms, which had been deposited during the late Tithonian–early Berriasian.

The above-given examples for thickness, lithology and age variations suggest essential differences in paleotopography, depositional mechanisms, and subsidence, which occur locally, however, this also applies to the more distant Upper Jurassic strata in West Balkan and Fore-Balkan Mts, WNW Bulgaria–ENE Serbia (Lakova et al. 2007; Tchoumatchenco et al. 2006, 2011). Hence, in the Barlya–Kamenitsa area,

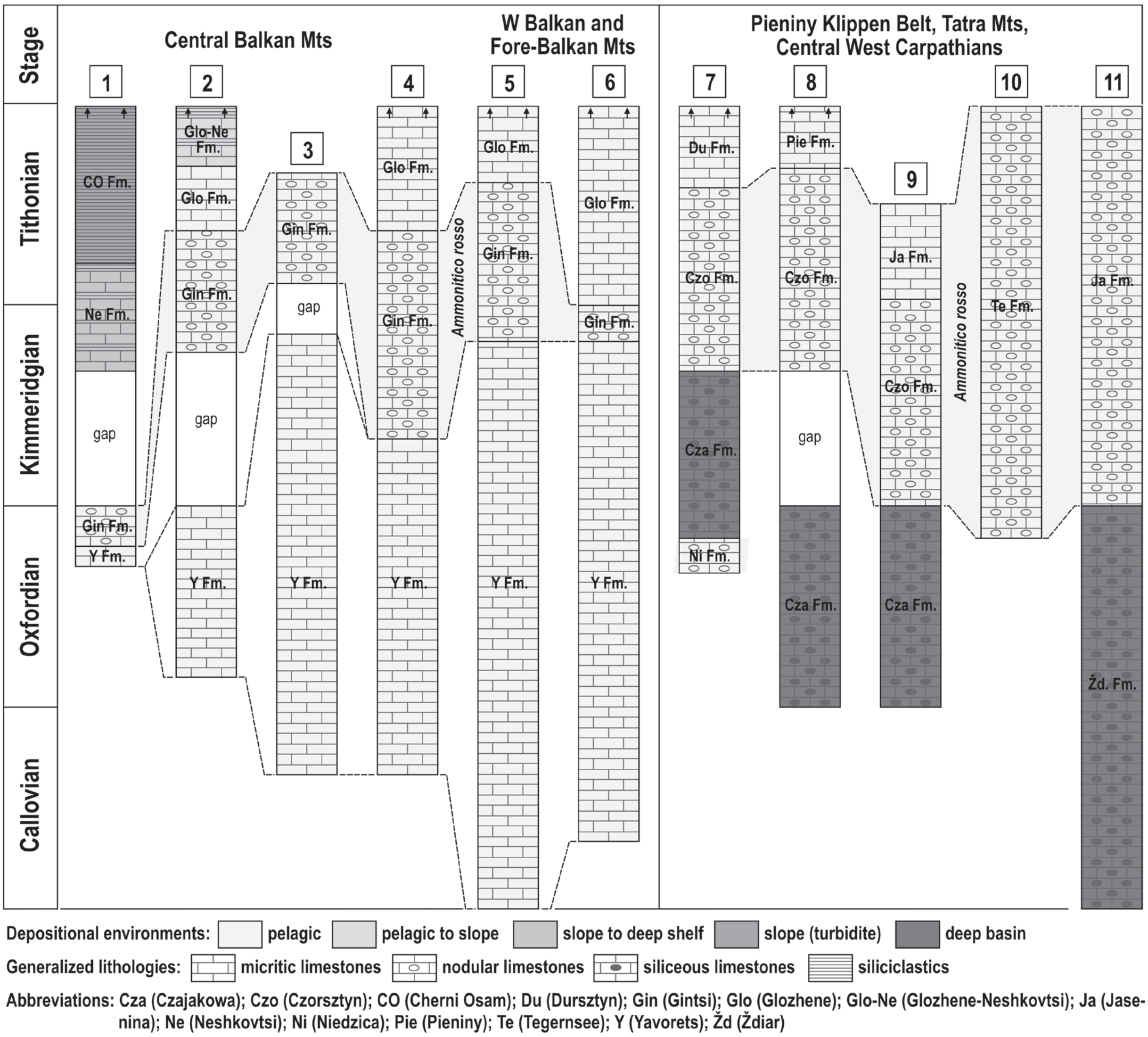

Fig. 8. Stratigraphic comparison between selected Middle–Upper Jurassic sections from the Balkan Mts, Bulgaria (1–6), Pieniny Klippen Belt (7–9), and Krížna Nappe in Malé Karpaty Mts and Strážovské vrchy Mts of the Western Carpathians (10, 11): **1** – Zavodna (this study); **2** – Koznitsa (Ivanova 1994, 1997); **3** – Romanov Dol (ibid.); **4** – Glozhene (ibid.); **5** – Barlya–Kamenitsa (Tchoumatchenco et al. 2006, 2011; Lakova et al. 2007); **6** – Belotintsi–Novo Korito (Ivanova et al. 2006; Tchoumatchenco et al. 2006, 2011); **7** – Velykyi Kamianets (Reháková et al. 2011; Grabowski et al. 2019); **8** – Długa Valley (Jach et al. 2014; Jach & Reháková 2019); **9** – Snežnica (Michalík et al. 2021); **10** – Hlboča (Grabowski et al. 2010); **11** – Strážovce (Michalík et al. 2017).

the Yavorets Fm. has a thickness of ca. 25 m and stratigraphically ranges from the Callovian to the upper Kimmeridgian. The Gintsi Fm. is of approximately the same thickness, and late Kimmeridgian–early Tithonian in age. The upper part of the succession corresponds to the Glozhene Fm. (37 m thick), which stratigraphically ranges from the lower Tithonian to the topmost lower Berriasian. In the Gorno Belotintsi-Novo Korito area, the thicknesses of these strata markedly increase. The Yavorets Formation has a thickness of 100 m and spans stratigraphically from the middle Callovian to the upper Kimmeridgian, while the Gintsi Formation is 40 m thick, ranging from the upper Kimmeridgian to the lower Tithonian. The Glozhene Formation has a thickness exceeding 200 m and spans from the lower Tithonian to the Valanginian (see also Ivanova et al. 2006).

Even more striking are the differences between the Zavodna and the Bulgarian Upper Jurassic successions and the other sections in the Carpatho–Balkan region. It has previously been noted by Lefeld et al. (1986) that the Upper Jurassic strata from the Polish Inner Carpathians and their counterparts from the Balkan Mts share some similarities, although major differences exist, since the marl-limestone alternation, which is typical of the Neshkovtsi Formation, does not have equivalents in the Western Carpathians. Recent studies on successions from the Pieniny Klippen Belt (Reháková & Wierzbowski 2005; Grabowski et al. 2019) and the Zliechov Basin

(Grabowski et al. 2010; Jach et al. 2012, 2014; Michalík et al. 2017, 2021; Jach & Reháková 2019) have confirmed and extended these findings. The main similarity is the widespread development of pelagic carbonates in the Kimmeridgian–Tithonian interval, the particularly *Ammonitico rosso* type at most localities. These deposits were generally deposited on submarine intrabasinal highs-and-slopes that have become prominent in many places in the Mediterranean Tethys. The Zavodna succession, however, displays open, deep shelf to basin facies. As opposed to the Balkan Mts Area, the Pieniny Klippen Belt and Zliechov basins have Upper Jurassic deeper basin facies, but have shallower successions as well (see Tomašových & Schlögl 2008; Tomašových et al. 2020, and discussions therein). Although evaluating the overall picture is difficult, it appears that the settings from the Oxfordian onwards have been characterized by increasing water depths, even though the local water depths were modulated by extensional tectonics that led to the formation of unstable blocks, on which various sediments had deposited, often diachronically (cf. Dercourt et al. 1993, 2000). The thickness-age variations of several Bulgarian Upper Jurassic successions and their counterparts from the Carpatho–Balkanides (Fig. 8) illustrate how variable these strata are.

Conclusions

A set of eight successive microfacies were identified: (1) bioclastic to bio-lithoclastic packstone to grainstone (MFT 1, Polaten Fm., Bathonian); (2) filamentous wackestone to packstone (MFT 2, Yavorets Fm., upper Oxfordian; Neshkovtsi Fm., upper Kimmeridgian); (3) *Globuligerina* wackestone (MFT 3, Yavorets and Gintsi fms, upper Oxfordian– upper Kimmeridgian), (4) filament-*Saccocoma* wackestone (MFT 4, upper part of the Gintsi Fm., and the Neshkovtsi Fm., upper Kimmeridgian); (5) *Saccocoma*-radiolarian wackestone (MFT 5, Neshkovtsi Fm., upper Kimmeridgian–lower Tithonian); (6) radiolarian wackestone (MFT 6, Neshkovtsi Fm., upper Kimmeridgian); (7) *Saccocoma* wackestone (MFT 7, Cherni Osam Fm., lower Tithonian); and (8) spiculitic wackestone (MFT 8, Cherni Osam Fm., lower Tithonian). The temporal ranges of those microfacies were established by the presence of four calcareous dinocyst zones: The *Colomisphaera fibrata* Zone (Oxfordian), *Stomiosphaera moluccana* Zone (upper Kimmeridgian), *Carpistomiosphaera borzai* (upper Kimmeridgian), and *Committosphaera pulla* (lower Tithonian). Calcareous dinoflagellate cysts provided new evidence for the late Oxfordian–late Kimmeridgian age of the Gintsi Fm., the late Kimmeridgian–earliest Tithonian age of the Neshkovtsi Fm., as well as the earliest Tithonian age of the lower part of the Cherni Osam Fm at the Zavodna section. A significant stratigraphic gap is documented in the middle of the Gintsi Fm. because the *Cadosina parvula* Zone (lower Kimmeridgian) is absent in the succession at this section. The sediments belonging to the Yavorets Fm. are limited only to the Oxfordian stage, while the Gintsi Fm. is characterized here by relatively early development, starting in the Oxfordian and ending in the late Kimmeridgian. As inferred from the general lithology, microfossil constituents, and carbonate textures, the Oxfordian–lower Tithonian strata appear to reflect a deepening from deep shelf to slope deposition, at a moderate distance from the continental edge. Therefore, the Zavodna section can be used as a reference for the long strip of outcrops in the Central Balkans with the southernmost distribution, and further stratigraphic research with new sections will shed light on how the basin developed.

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