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Calpionellid biostratigraphy and microfacies of the Upper Tithonian pelagic carbonates in northeastern Serbia (Carpatho–Balkanides)

IVANA CAREVIĆ[1,✉], MORTEZA TAHERPOUR-KHALIL-ABAD[2], MONIKA MIRKOVIĆ[3], VELIMIR JOVANOVIĆ[1], ELHAM MOJTAHEDIN[2] and DRAGANA VUŠKOVIĆ[4]

[1]Faculty of Geography, University of Belgrade, Studentski trg 3/3, 11000 Belgrade, Serbia;
✉carevic.ivana@gmail.com, icarevic@gef.bg.ac.rs, jocavj@gmail.com
[2]Young Researchers and Elite Club, Mashhad Branch, Islamic Azad University, Mashhad, Iran;
m_taherpour@mshdiau.ac.ir, e.mojtahedin@yahoo.com
[3]Geological Institute of Serbia, Rovinjska St. 12, 11000 Belgrade, Serbia; monika.mirkovic@gzs.gov.rs
[4]University of Niš, Faculty of Science, Višegradska 33, 18000 Niš, Serbia; dragana.maric@gmail.com

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Abstract: The occurrence of microfossil assemblage represented by calpionellids in close association with benthic foraminifera and encrusting *Crescentiella morronensis* is reported for the first time from the Upper Tithonian of NE Serbia. The biostratigraphic and sedimentological investigations were carried out on a 250 m thick carbonate succession in Jelenska Stena quarry cropping out along the Danube River Gorge in the border area of Serbian Carpatho–Balkanides and Romanian Southern Carphatians. On the basis of determined benthic foraminiferal taxa *Textularia* sp. cf. *T. bettenstaedti* and *Everticyclammina praekelleri* in the lower part of the succession and calpionellid association dominated by the representatives of calpionellid genera *Tintinnopsella, Crassicollaria* and *Calpionella* the carbonate succession is assigned to the Upper Tithonian. The scarcity of calpionellid zonal species prevents the nominal zones being recognized. Petrographic analysis of thin-sections led to the recognition of three basin microfacies types: bioclastic wackestone, bioclastic peloidal wackestone/packstone and mudstone. These microfacies characterize the SMF 3 and SMF 4 which indicate deposition in slope and toe-of-slope environments. This study extends the palaeogeographical distribution of Upper Tithonian calpionellids along the northern Tethyan margins. The investigated carbonate succession is compared with coeval strata from other northern Tethyan regions.

Keywords: Getic, Carpatho–Balkanides, northeastern Serbia, calpionellids, benthic foraminifera, Upper Tithonian.

Introduction

The Tithonian pelagic carbonates deposited during the Jurassic/Cretaceous transition in northern Alpine Tethys environments have a large extent and thickness in the northern part of Serbian Carpatho–Balkanides. Grubić & Jankičević (1973) considered these sediments as a part of the carbonate shelf platform margin-to-basin transitional environment, which represents the eastern margins of large carbonate platform, initially named the "Kučaj–Tupižnica carbonate paraplatform". Nowadays it is also known as the Getic carbonate platform. During the Late Jurassic and Early Cretaceous the platform attained a position from the Romanian–Serbian border in the north westwards towards the Serbian–Bulgarian border in the east. It started its evolution on the northern rim of the Tethys in the Late Jurassic and end with the formation of "Urgonian"-type sediments during the Barremian/Early Aptian. The general stratigraphy of the further northern parts of the Getic of Carpatho–Balkanides was summarized by Sučić-Protić (1961) and Kalenić et al. (1980). A preliminary report on the pelagic Upper Jurassic carbonate successions from northeast Serbia has recently been presented by Carević et al. (2017).

The study area corresponds to the Kučaj terrane, also known as the Getic tectono-stratigraphic unit and represents the trans-border area towards the South Carpathians of Romania across the Danube (Karamata & Krstić 1996; Krstić et al. 1996; Berza et al. 1998; Bojar et al. 1998; Iancu et al. 2005). Geotectonically it is also regarded as part of the Kučaj–Svrljig tectono-sedimentary zone within the Karpatikum (Anđelković 1978; Anđelković & Nikolić 1974, 1980).

This study aims at presenting the results of biostratigraphic and carbonate microfacies investigation of the Upper Tithonian pelagic carbonates that represent early phases of evolution of the platform-to-basin system in the platform margin sequence. Data obtained for platform margin-to-slope successions in this paper has revealed new information on the stratigraphy and on the form of the basin margin.

Material and methods

The transition from the carbonate platform margin to the adjacent slope environment is exposed on land in the Jelenska Stena quarry, Danube River Gorge (21°44'18.3" E, 44°38’49.4” N). The section is being measured and sampled (Fig. 1). Limestones have been investigated using 30 thin sections. Carbonate classification follows the scheme of Dunham (1962); according to it the section comprises mudstones, wackestones, packstones, grainstones and rudstones. Generic attributions of the calpionellid taxa and biostratigraphic division are based on the papers by Reháková (1995); Reháková & Michalík (1997); Lakova et al. (1999); Petrova et al. (2012). The thin-sections are housed in the collections at the Faculty of Geography, University of Belgrade under inventory numbers which are referred to in the text.

Stratigraphic background

The Upper Tithonian pelagic succession at Jelenska Stena quarry overlies the Middle Jurassic sandy limestones and Oxfordian–Kimmeridgian limestones with cherts (Kalenić et al. 1980; Carević et al. 2011; Ljubović-Obradović et al. 2011). It is transgressively overlain by a Berriasian to Hauterivian carbonate deposits and Barremian/Early Aptian Urgonian limestones (Carević et al. 2013).

In the Jelenska Stena quarry, the pelagic carbonate succession attains a thickness of about 250 m (Fig. 2). The Upper Tithonian is represented by grey and subordinate red-brownish thick bedded limestones. The uppermost 10 m of this succession are represented by marly limestones.

Microfacies analysis

Five microfacies were recognized: bioclastic wackestone (MFT 1) is the dominant microfacies; subordinate are bioclastic–peloidal wackestone (MFT 2), bioclastic–peloidal wackestone/packstone (MFT 3), mudstone (MFT 4), and brecciated bioclastic wackestone (MFT 5) (Figs. 3–4).

Microfacies and biota indicate that the limestones deposited in an open-shelf environment below the fair weather base. Limestone consists of microfacies types that can be assigned to the following Standard Microfacies (SMF) types after Flügel (2010): SMF 3 — pelagic lime mudstone and wackestone with pelagic microfossils, and SMF 4 — microbreccia, bioclastic–lithoclastic packstone or rudstone.

Texture and composition of the carbonates are very similar to those of the Rosomač Limestones in eastern Serbia pointing to deposition under slope and toe-of-slope environments (Petrova et al. 2012).

MFT 1 Bioclastic wackestone

The most frequent microfacies type in the limestones is bioclastic wackestone, which was recorded throughout the succession. The matrix is fine bioclastic micrite occasionally crossed by sparry calcite-filled veins (Figs. 3/1–4; 4/1,3,6, 8–10). In the lower part of the succession bioclasts are rare benthic foraminifera (*Lenticulina* sp.), juvenile ammonites, recrystallized calcareous dinocysts, shell fragments and aptychi (Fig. 3/1–4). Bioclastic wackestones observed in the upper horizons contain calpionellids (Figs. 3/7,10; 4/1,9), rare intraclasts (Fig. 3/10), gastropods, shell fragments and calcareous dinocysts (Fig. 4/6,8,10).

Rare skeletal debris from resedimented shallow-water benthic foraminifera and gastropods mixed with finer pelagic sediments was derived from platform-margin environments.

MFT 2 Bioclastic peloidal wackestone

These microfacies occurs as intercalations between the bioclastic wackestones. The main characteristic is the presence of dispersed (Fig. 3/5) or densely packed peloids (Fig. 4/2,4,5) in wackestone formed by debris flows in slope sequences. This microfacies is characterized by the presence of skeletal grains

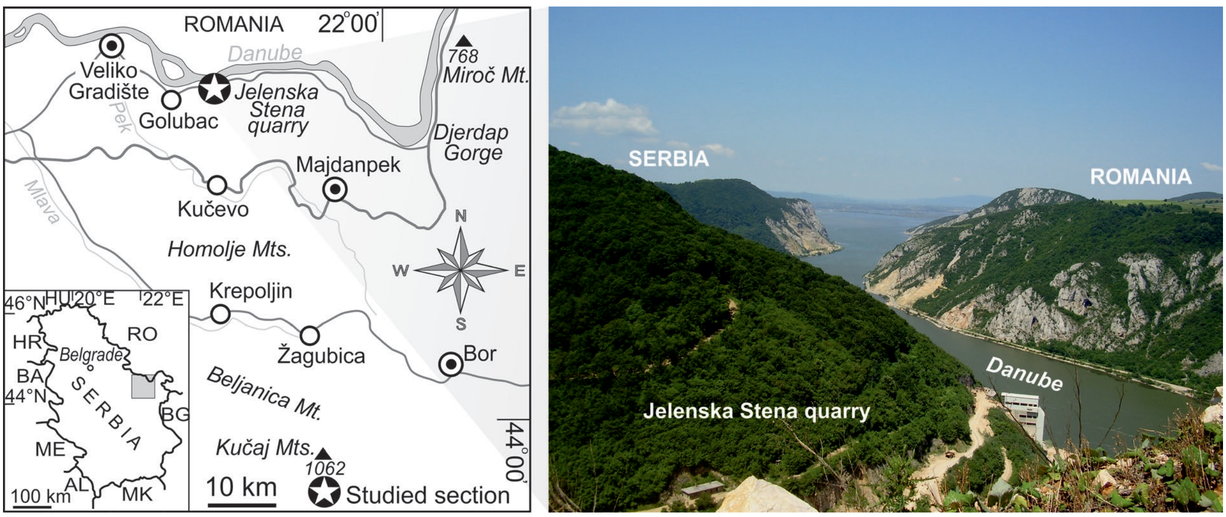

Fig. 1. Location of the Upper Tithonian section studied in Jelenska Stena quarry, Danube River Gorge, Carpatho–Balkanides.

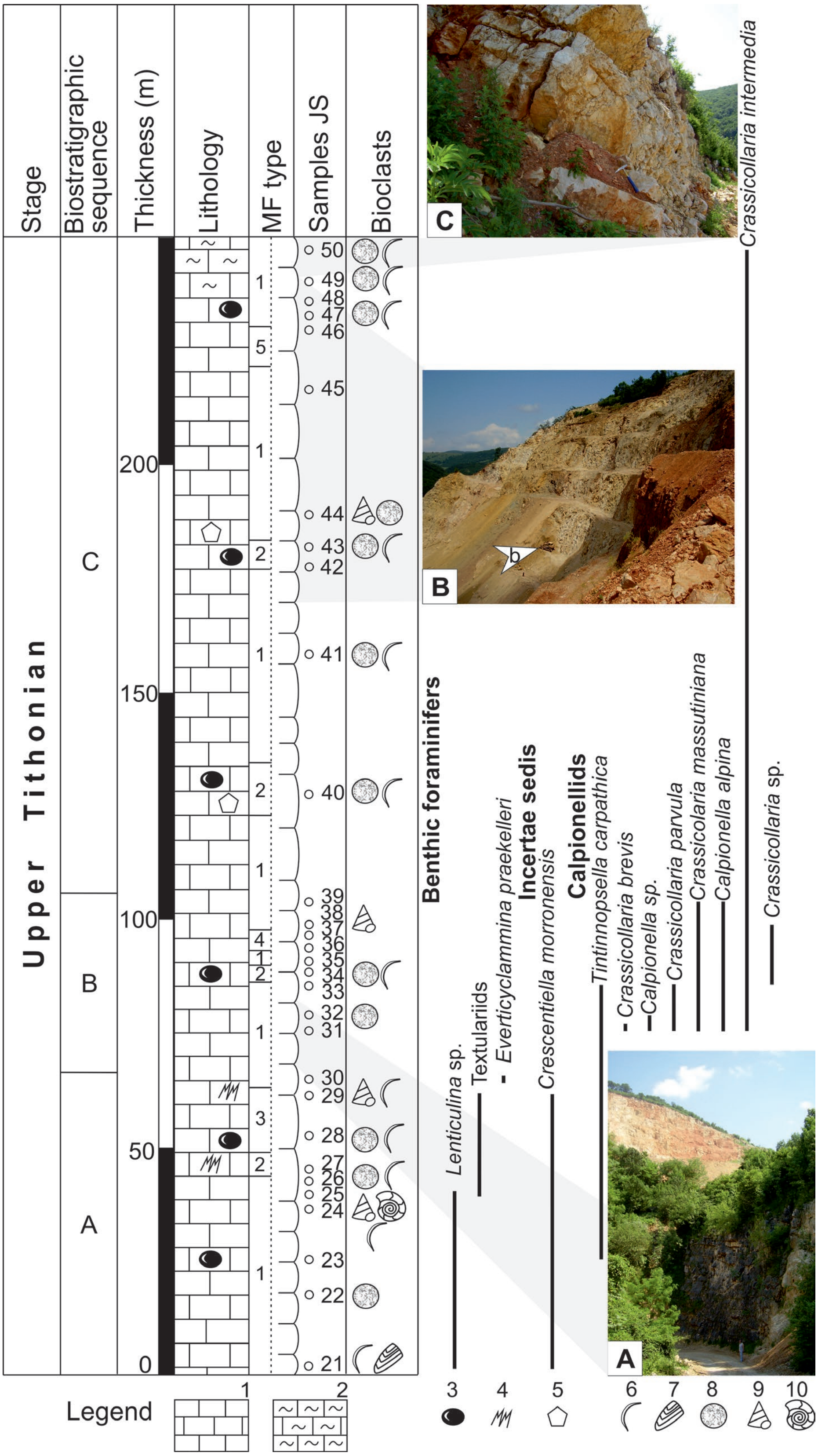

Fig. 2. Lithological column and biostratigraphy of the Upper Tithonian deposits in the Jelenska Stena quarry, Danube River Gorge, Carpatho–Balkanides. **1** — limestone; **2** — marly limestone; **3** — peloid; **4** — stylolite; **5** — intraclast; **6** — shell fragment; **7** — aptychus; **8** — calcareous dinocyst; **9** — gastropod; **10** — ammonite; **A** — thick-bedded grey limestones; **B** — thick-bedded light grey limestones with a bulldozer for scale (b); **C** — marly limestones from the top of the succession with a hammer for scale.

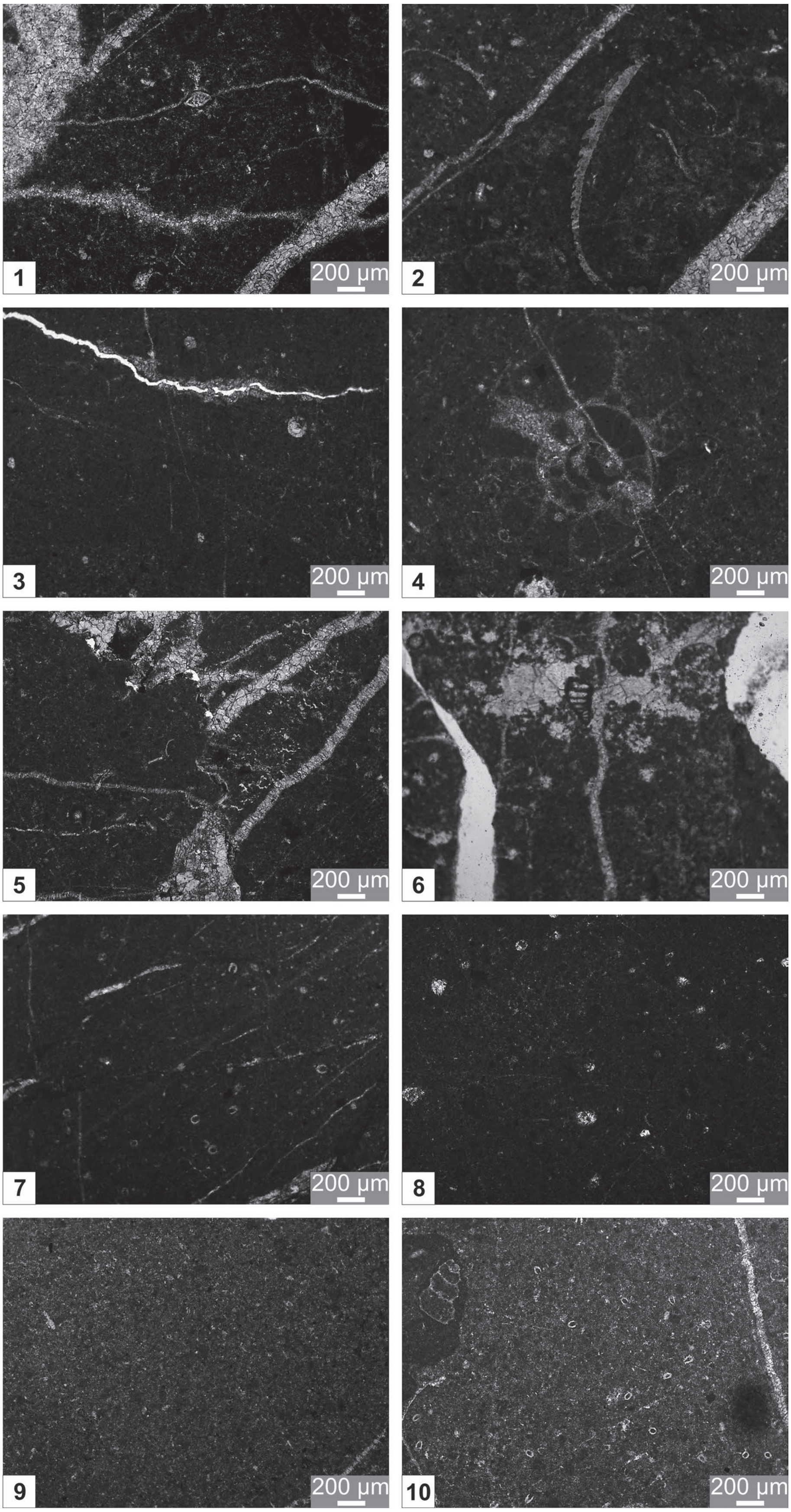

Fig. 3. Thin-section photomicrographs of the determined microfacies types from the Upper Tithonian section in Jelenska Stena quarry, showing characteristic component distributions and fabrics. **1, 2** — bioclastic wackestone with micritic matrix crossed by sparry calcite-filled veins; *filaments* and aptychi are present; low-diversity benthic foraminifera association, predominantly hyaline forms represented by *Lenticulina* sp., sample 21; **3, 4** — bioclastic wackestone with micritic matrix crossed by subparallel sparry calcite-filled veins; subordinate recrystallized calcareous dinocysts are present; juvenile ammonite crossed by calcite-filled crack can be seen, 3 – sample 22, 4 – sample 24; **5** — bioclastic–peloidal wackestone with micritic matrix crossed by sparry calcite-filled veins; dispersed peloids in micritic matrix; skeletal grains are predominately *filaments*, sample 27; **6** — bioclastic–peloidal wackestone/packstone with micritic matrix crossed by sparry calcite-filled veins; common bioclasts are textulariids, *filaments* and calcareous dinocysts, sample 29; **7** — bioclastic wackestone with micritic matrix; longitudinal and transversal sections of calpionellids can be seen; calcareous dinocysts are also present, sample 32; **8, 9** — mudstone with micritic and microspar calcite matrix and calcareous dinocysts, 8 – sample 36, 9 – sample 37; **10** — bioclastic wackestone with microspar matrix; intraclasts consisting of micrite associated with a gastropods are common; longitudinal sections of a high-spired gastropod and calpionellids can be noticed; sample 38.

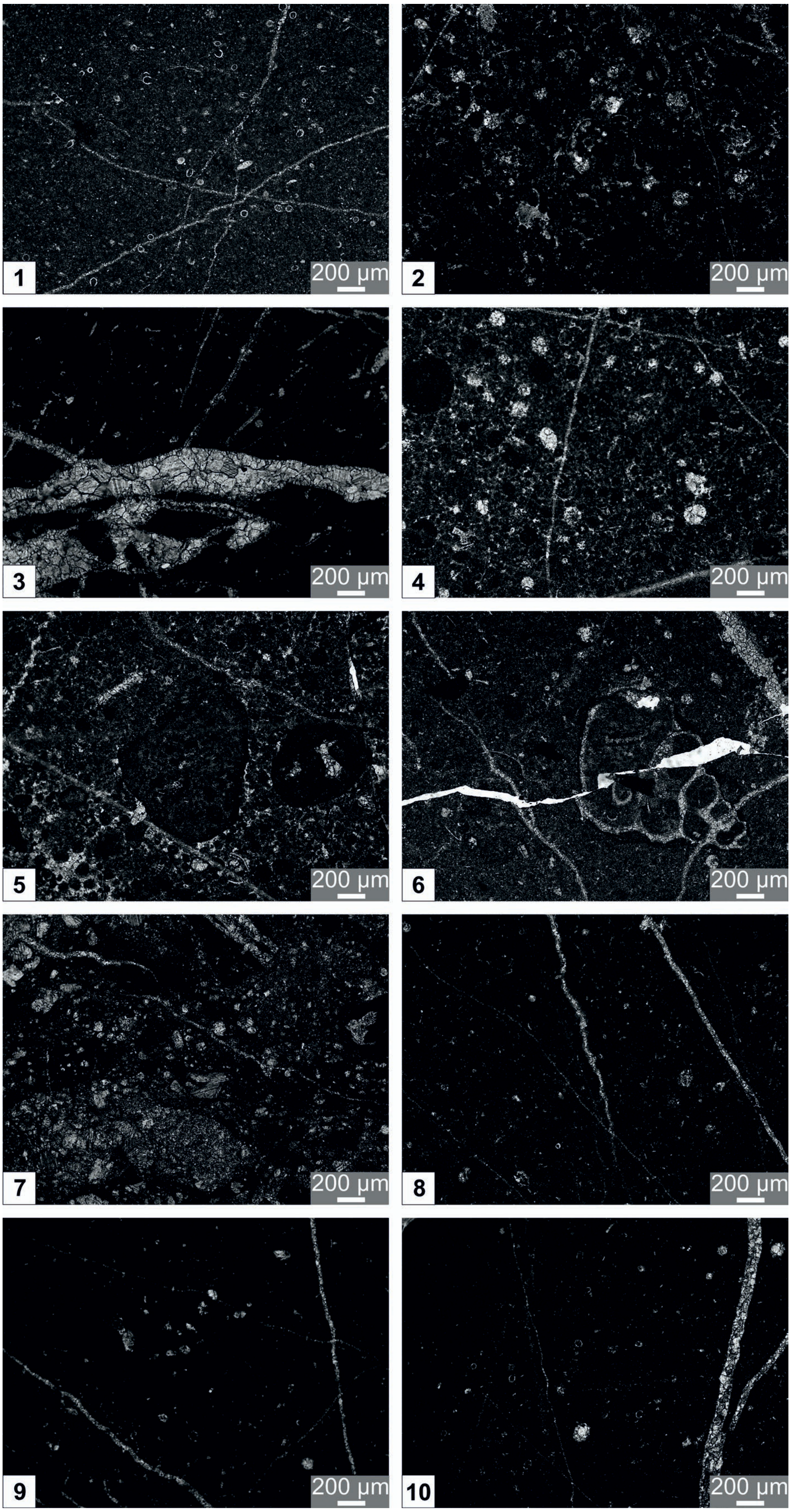

Fig. 4. Thin-section photomicrographs of the determined microfacies types from the Upper Tithonian section in Jelenska Stena quarry, showing characteristic component distributions and fabrics. **1** — bioclastic wackestone with micritic matrix crossed by sparry calcite-filled veins; numerous longitudinal and transversal sections of calpionellids, sample 39; **2** — bioclastic–peloidal wackestone with micritic matrix; peloids are densely packed; subordinate intraclasts consist of micrite and skeletal grains, sample 40; **3** — bioclastic wackestone with micritic matrix crossed by sparry calcite-filled veins; skeletal grains are predominately calcareous dinocysts and *filaments*, sample 42; **4, 5** – bioclastic–peloidal wackestone with micritic matrix; skeletal grains are predominately calcareous dinocysts and *filaments*; peloids are densely packed; intraclasts consist of a micrite, peloids and skeletal grains, sample 43; **6** — bioclastic wackestone with micritic matrix crossed by sparry calcite-filled veins; common bioclasts are gastropods, *filaments* and calcareous dinocysts; longitudinal section of a high-spired gastropod displaced along sparry calcite-cement filled microfractures, sample 44; **7** — brecciated bioclastic wackestone with micritic matrix crossed by sparry calcite-filled veinlet, sample 46; **8** — bioclastic wackestone with micritic matrix crossed by sparry calcite-filled veinlet; common bioclasts are recrystallized calcareous dinocysts, sample 47; **9, 10** — bioclastic wackestone with micritic matrix crossed by sparry calcite-filled veinlet; skeletal grains are predominately calcareous dinocysts and calpionellids, 9 – sample 49, 10 – sample 50.

predominately shell fragments (Fig. 3/5), but it also contains intraclasts (Fig. 4/4,5).

MFT 3 Bioclastic–peloidal wackestone/packstone

Bioclastic–peloidal wackestone/packstone contains textulariids, elongated shells and calcareous dinocysts in peloidal micritic matrix (Fig. 3/6). Peloids are small and densely packed. Veins are filled by calcite that is commonly sparry. This microfacies is observed only in the lower part of the succession having a thickness of about 13 m.

MFT 4 Mudstone

Mudstone microfacies has been found in horizons about 5 m thick intercalated between bioclastic wackestones in the middle part of the succession. Rare fragmented bioclasts occur in a matrix of micrite and microspar (Fig. 3/8,9).

MFT 5 Brecciated bioclastic wackestone

The microfacies has only been found in horizons about 5 m thick near the top of the succession. Many bioclasts are hardly recognizable in a strongly tectonized micritic matrix containing angular fragments crossed by sparry calcite-filled veinlet (Fig. 4/7). The microfacies is interpreted as a debris-flow deposit.

Microfossils and biostratigraphy

Biostratigraphic sequence A

Benthic foraminifera occur only in the lower part of the succession (Fig. 2). This sequence attains a thickness of about 65 m. It is represented by grey thick-bedded limestones marked by rare occurrence of textulariids (Fig. 5/1) with *Textularia* sp. cf. *T. bettenstaedti* (Fig. 5/2), associated with *Lenticulina* sp. (Fig. 5/3), *Everticyclammina praekelleri* (Fig. 5/4) and the encrusting organism *Crescentiella morronensis* (Fig. 5/5). A specimen of *Tintinnopsella carpathica* (Fig. 6/1) has also been found in this sequence.

Benthic foraminifers

Although taxonomic diversity of benthic foraminifera is low, they represent significant biostratigraphic markers useful for palaeoenvironmental interpretation, too.

Everticyclammina praekelleri represents the most biostratigraphically important taxon for the lower part of succession. It is typical for the Kimmeridgian–Tithonian (Banner & Highton 1990; Krajewski & Olszewska 2007; Olszewska et al. 2012; Pleş et al. 2015; Mircescu et al. 2016). The species is a common internal-platform constituent, but has also been recorded in carbonate margin deposits (Mircescu et al. 2016), back-arc basins (Krajewski & Olszewska 2007), and pelagic environments (Bubík & Reháková 2017), thus indicating transport to deep-water settings.

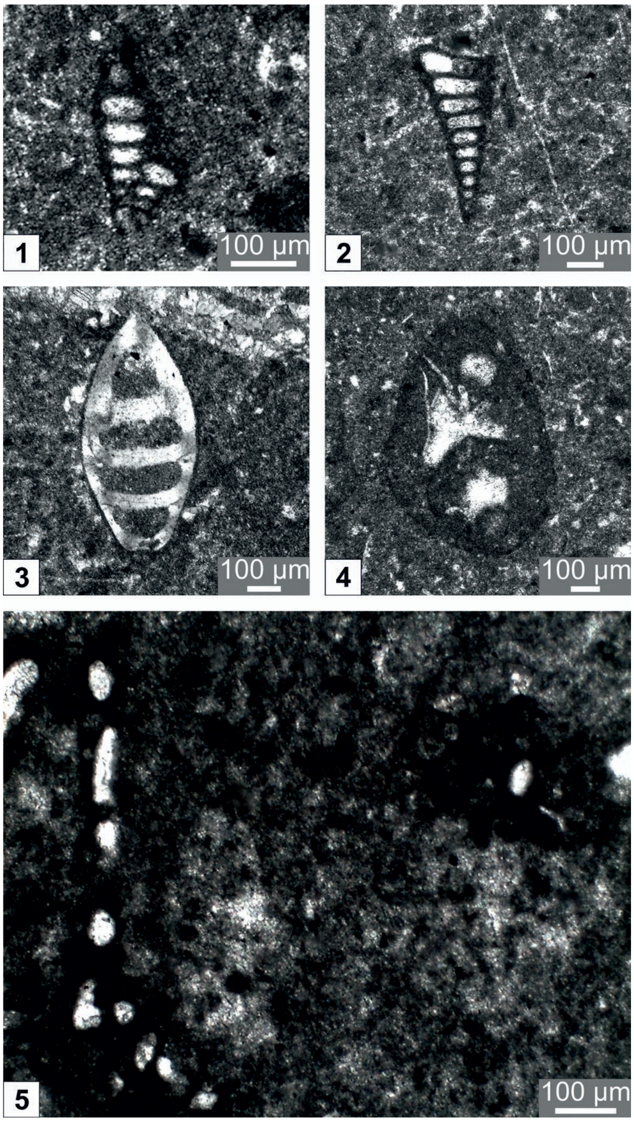

Fig. 5. Thin-section photomicrographs of the determined benthic foraminifera and microproblematica from the Upper Tithonian section in Jelenska Stena quarry. **1** — textulariids; sample 25; **2** — *Textularia* sp. cf. *T. bettenstaedti* Bartenstein & Oertli; sample 25; **3** — *Lenticulina* sp.; sample 25; **4** — *Everticyclammina praekelleri* Banner & Highton; sample 30; **5** — *Crescentiella morronensis* (Crescenti), sample 29.

Textularia* sp. cf. *T. bettenstaedti has longer stratigraphic distribution from Berriasian to Aptian in the Northern Tethys Margin (Salaj 1984; Gradstein et al. 1999), but it is also known from the Upper Tithonian pelagic limestones of Stara Planina–Poreč Zone in the trans-border area of eastern Serbia and Bulgaria (Petrova et al. 2012).

***Lenticulina* sp**. *has* a greater *stratigraphic range*, as it occurs *throughout* the Jurassic and Cretaceous. It is common in open-sea environments along the shelf-to-basin transition (Hughes 2000; Reolid et al. 2008a, b).

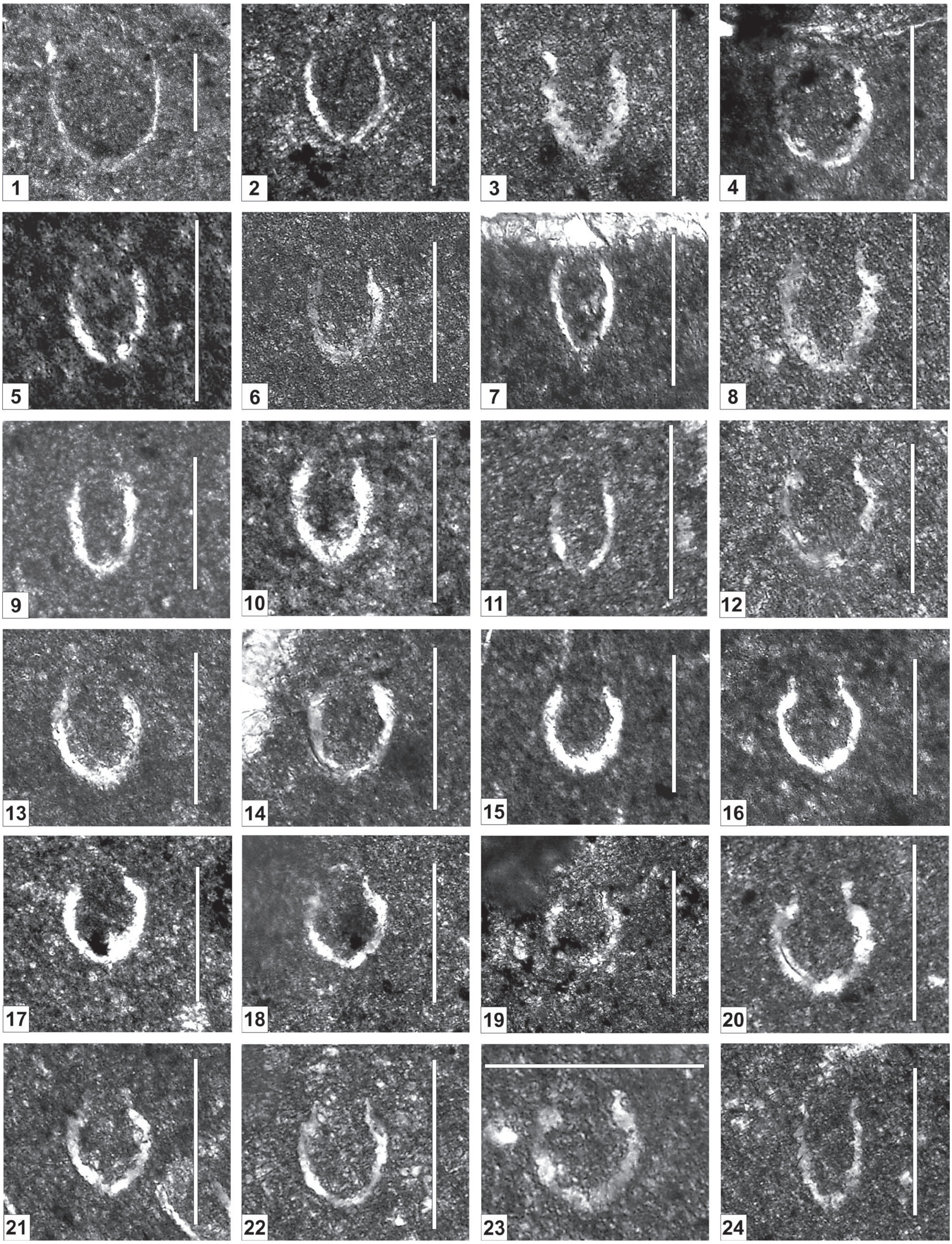

Fig. 6. Thin-section photomicrographs of the determined calpionellids from the Upper Tithonian section in Jelenska Stena quarry. **1, 2** — *Tintinnopsella carpathica* (Murgeanu & Filipescu); 1 – sample 23, 2 – sample 33. **3** — *Crassicollaria brevis* Remane; sample 31. **4–5** — *Calpionella* sp.; 4 – sample 31, 5 – sample 32. **6–7** — *Crassicollaria parvula* Remane; 6 – sample 31, 7 – sample 33. **8–11** — *Crassicollaria massutiniana* (Colom); 8–9 – sample 31, 10 – sample 32, 11 – sample 39. **12–23** — *Calpionella alpina* Lorenz; 12–13 – sample 31, 14–15 – sample 32, 16–19 – sample 33; 20–23 – sample 39. **24** — *Crassicollaria intermedia* (Durand-Delga); sample 31. Scale bar=100 µm.

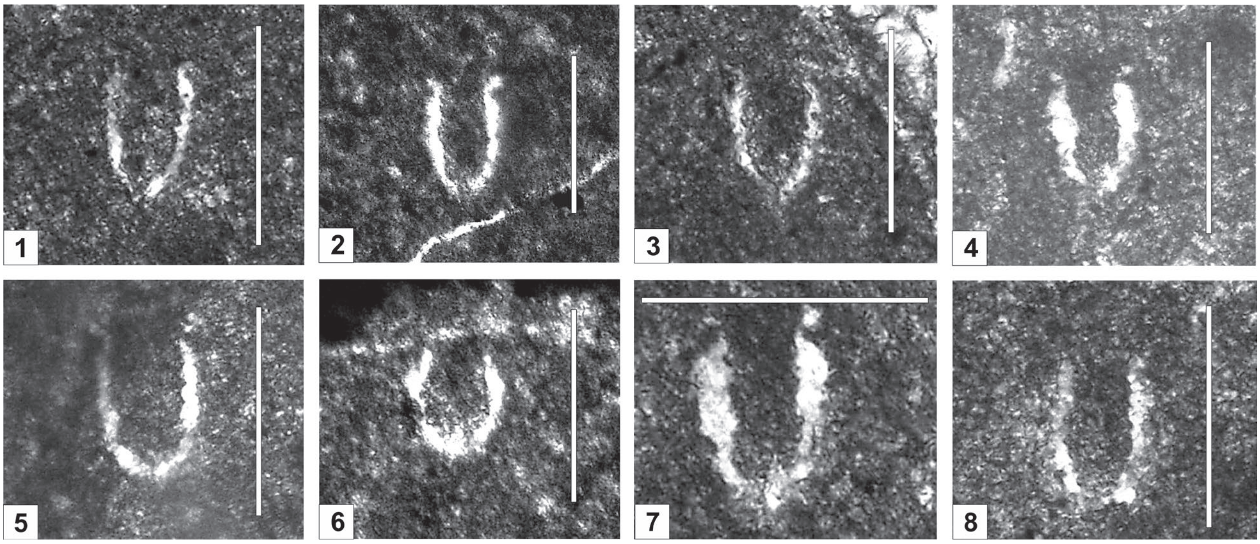

Fig. 7. Thin-section photomicrographs of the determined calpionellids from the Upper Tithonian section in Jelenska Stena quarry. **1–5** — *Crassicollaria intermedia* (Durand-Delga); 1 – sample 31, 2–3 – sample 32, 4 – sample 38; 5 – sample 50. **6-8** – *Crassicollaria* sp.; 6 – sample 33, 7–8 – sample 38. Scale bar=100 µm.

Incerate sedis

Crescentiella morronensis is associated with benthic foraminifers in the lower part of succession. This species is abundant in Upper Jurassic and Lower Cretaceous platform and slope deposits (Flügel 2010). Senowbari-Daryan et al. (2008) considered *Crescentiella morronensis* as a symbiosis between a nubeculariid foraminifera and calcifying cyanobacteria common in open marine environments of the Tethyan Realm. The significance of the *C. morronensis* is of less importance in age determination as it ranges from the Upper Oxfordian to the Aptian (Matyszkiewicz & Felisiak 1992; Senowbari-Daryan et al. 2008; Schlagintweit 2012; Kaya & Altiner 2015). However, the Kimmeridgian–Tithonian interval was a blooming period of the *Crescentiella morronensis* in the Tethyan Realm (e.g. Pleş et al. 2017).

Age and correlations

The microfossil assemblage from the lower part of the succession indicates a Late Tithonian age. Of special stratigraphic interest is the first occurrence of the calpionellid species *Tintinnopsella carpathica* with a range from early Late Tithonian through early Valanginian (Remane 1963, 1983). *Textularia* sp. cf. *T. bettenstaedti* with a first appearance in the Late Tithonian also worth mentioning. The age of the sequence is also supported by the presence of *Everticyclammina praekelleri* because its range does not extend into the Early Berriasian. *Crescentiella morronensis* represents a very common microencruster species for the Upper Tithonian carbonate deposits in the Getic carbonate platform and Southern Carpathians (e.g., Bucur et al. 2010; Catincuţ et al. 2011; Mircescu et al. 2016). We are thus assured of the Late Tithonian age for the lower part of the succession.

Lenticulina sp. is recorded globally and *Crescentiella morronensis* has a wide geographical distribution, as it is described from many localities in the Tethyan Realm. *Everticyclammina praekelleri* has recently been recorded from the northern Tethyan margins in the Getic carbonate platform of the Romanian Southern Carpathians where it is reported for the first time by Mircescu et al. (2016), and from southern Poland (Olszewska et al. 2012). It was also documented from other localities, including the southern Ukraine (Krajewski & Olszewska 2007), and more recently from the Czech Republic (Bubík & Reháková 2017), where it was recorded within the Late Tithonian *Crassicolaria* Zone. *Textularia* sp. cf. *T. bettenstaedti* was previously found in the trans-border area of eastern Serbia and Bulgaria (Petrova et al. 2012).

Benthic foraminiferal and encrusting assemblages in north-eastern Serbia are most similar to those from Romania and border area of eastern Serbia and Bulgaria.

Biostratigraphic sequence B

The calpionellids become totally dominant from 65 to 105 m above the base of the succession through a thickness of about 40 m. The calpionellid-bearing sequence is marked by the first occurence of calpionellid association in the sample 31. It is represented by grey thick-bedded limestones with calpionellid association dominated by crassicollarians accompanied by genus *Calpionella.*

Calpionellids

The calpionellid species belong to the Crassicollaria Standard Zone. This association is characterized by the explosion in variety of species. The crassicolarian association is diverse and represented by *Crassicollaria brevis* (Fig. 6/3), *Crassicollaria parvula* (Fig. 6/6–7), *Crassicollaria massutiniana* (Fig. 6/8–11), *Crassicollaria* sp. (Fig. 7/6–8), and *Crassicollaria intermedia* (Figs. 6/24, 7/1–4). *Calpionella* sp. (Fig. 6/4–5) and *Calpionella alpina* (Fig. 6/12–23) are common. The sequence also includes rare *Tintinnopsella carpathica* (Fig. 6/2). All taxa disappeared in the uppermost part of the sequence apart from *Crassicollaria intermedia.*

All calpionellid species are widely known worldwide from the Upper Tithonian and reveal a strong similarity to the Tethyan Realm.

Age and correlations

Crassicollaria intermedia and *Crassicollaria massutiniana* are very good age markers, being confined to the early Late Tithonian (Remane 1983). These species clearly indicate the presence of Upper Tithonian calpionellid associations just below the Jurassic/Cretaceous boundary.

The calpionellid association marked by maximum diversification of the genus *Crassicollaria* is referred to the *Crassicolaria* Zone, *Intermedia* Subzone in Olóriz et al. (1995), Pop (1997), Andreini et al. (2007), Grabowski et al. (2010). The association also refers to *Crassicolaria* Zone, *Massutiniana* Subzone in the Western Balkanides (Lakova et al. 1999; Petrova et al. 2012; Lakova & Petrova 2013), or *Brevis* Subzone (*sensu* Reháková & Michalík 1997).

The Upper Jurassic sequence may be also compared to other well-documented sites in adjacent regions of Romania and Bulgaria. The biostratigraphic sequence B corresponds in general lithologic character and calpionellid association to the Upper Tithonian Marila limestones of the Reşita–Moldova–Nouă zone north of Danube in the Romanian Southern Carpathians (Pop 1997; Bucur 1997). Towards the Serbian–Bulgarian border in the east, the calpionellid-bearing sequence can be compared to the *Massutiniana* Subzone (*Crassicolaria* Zone) of the Rosomač Limestones in the Stara Planina–Poreč Zone and the Glozhene limestone formation in the West Balkan (Lakova et al. 1999; Petrova et al. 2012).

Biostratigraphic sequence C

In the overlying uppermost part of the succession calpionellids are very rare. The thickness of the sequence C reaches about 145 m. It was only possible to recognize *Crassicollaria intermedia* (Fig. 7/5) in the topmost parts of the succession represented by marly limestones through a thickness of about 13 m.

According to the occurrence of isolated *Crassicollaria intermedia,* the biostratigraphic sequence C should have been deposited in the Late Tithonian, too. The whole succession from base to top is therefore certainly of Late Tithonian age.

Conclusion

The present study documents an Upper Tithonian carbonate succession in NE Serbia deposited in a deep shelf margin along the northern margin of the Alpine Tethys Ocean. Slope and toe-of-slope environments prevailed in the study area. The depositional setting of carbonate succession corresponds to the standard facies zones 3 and 4 by Flügel (2010).

The microfossil assemblage although not rich in number of species represents the first records of Late Tithonian pelagic microfossil biota from the further north Getic of the Serbian Carpatho–Balkanides and, therefore, expands the current knowledge on their palaeogeographical distribution.

Recognized benthic foraminifers represent cosmopolitan taxa in the northern Tethyan Realm shelves during the Late Tithonian. Benthic foraminiferal associations in northeastern Serbia are similar to those from adjacent regions of Romania and Bulgaria. The majority of calpionellid taxa correspond to the widely known *Crassicollaria* Zone. Scarcity of some important stratigraphic markers prevents precise establishment of subzones.

The Tithonian–Berriasian boundary was not documented because stratigraphic succession lacks the topmost calpionellid-bearing intervals with important stratigraphic markers due to complicated tectonic framework in the further Getic of northeastern Serbian Carpatho–Balkanides.

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Appendix

List of microfossils recognized in this study, arranged in alphabetical order. Taxa are illustrated in Figs. 5–7.

a) Calpionellids

Tintinnopsella carpathica (Murgeanu & Filipescu)
Crassicollaria brevis Remane
Crassicollaria intermedia (Durand-Delga)
Crassicollaria massutiniana (Colom)
Crassicollaria parvula Remane
Crassicollaria sp.
Calpionella alpina Lorenz
Calpionella sp.

b) Benthic foraminifera

Textulariids
Textularia sp. cf. *T. bettenstaedti* Bartenstein & Oertli
Lenticulina sp.
Everticyclammina praekelleri Banner & Highton

c) Incertae sedis

Crescentiella morronensis (Crescenti)