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Upper Cretaceous volcanoclastic-sedimentary formations in the Timok Eruptive Area (eastern Serbia): new biostratigraphic data from planktonic foraminifera

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Abstract: The biostratigraphy of the Upper Cretaceous volcanoclastic-sedimentary formations cropping out in the Timok Eruptive Area of the eastern Serbian Carpatho-Balkanides is presented. Four lithostratigraphic units of formation rank are recognized in the Timok area: Stublica Clastics (Upper Albian/Cenomanian), Oštrelj (Lower Turonian/Santonian), Bor Clastics (Campanian/Maastrichtian) and Bukovo (Campanian/?Maastrichtian). Forty two species of planktonic foraminifera have been determined in the studied area. Eight planktonic foraminiferal zones of Middle Cenomanian through Middle Campanian age have been recognized. These are: *Thalmanninella reicheli* Interval Zone (Middle Cenomanian), *Rotalipora cushmani* Taxon Range Zone (Upper Cenomanian), *Helvetoglobotruncana helvetica* Taxon Range Zone (Lower Turonian), *Marginotruncana sigali–Dicarinella primitiva* Interval Zone (Upper Turonian to lowermost Coniacian), *Dicarinella concavata* Interval Zone (Lower Coniacian to lowermost Santonian), *Dicarinella asymetrica* Taxon Range Zone (Santonian), *Globotruncanita elevata* Interval Zone (Lower Campanian) and the *Globotruncana ventricosa* Interval Zone (Middle Campanian). The scarcity or lack of zonal species in the Lower Cenomanian and Upper Campanian/Maastrichtian strata prevents recognition of the nominal zones. The Upper Cretaceous planktonic foraminiferal zones from the Timok Eruptive Area are correlated with coeval zones from adjacent regions of Bulgaria and Romania and from other Tethyan regions.

Key words: Upper Cretaceous, eastern Serbia, Timok Eruptive Area, biostratigraphy, volcanoclastic–sedimentary formations, planktonic foraminifera.

Introduction

The Timok Eruptive Area (further: TEA) is situated in the eastern Serbian Carpatho–Balkanides within the Getic tectono-stratigraphic unit (Kräutner & Krstić 2003). Until recently, this area has been regarded as geotectonically part of the Kučaj-Svrljig tectono-sedimentary zone within the Karpatikum (Andjelković 1978; Andjelković & Nikolić 1980). Nowadays it is adjoined to the Kučaj terrane, one of the several large Alpine geotectonic units of the eastern Serbian Carpatho-Balkanides (Karamata & Krstić 1996). Berza et al. (1998) regarded the TEA as part of the Banatitic Magmatic and Metallogenetic Belt (BMMB), which represents a complex calc-alkaline magmatic arc of Late Cretaceous age. The TEA started its evolution with the Albian transgression, sedimentation continued through the Cenomanian, and during Turonian it became a volcanic area (Djordjević & Banješević 1996). It comprises Turonian (–Coniacian) andesitic, Coniacian–Maastrichtian andesitic-basaltic volcanic rocks and Campanian dioritic, quartz-dioritic and monzonitic plutonic rocks (Milovanović et al. 2005). Although many articles have been published on the petrology of the TEA and the wider area (Divljan 1958; Drovenik et al. 1962; Nikolić & Andjelković 1967; Karamata et al. 1994, 1997; Djordjević & Banješević 1996; Ciobanu et al. 2002; Heinrich 2002; Quadt et al. 2002; Djordjević 2004–2005; Milovanović et al. 2005;

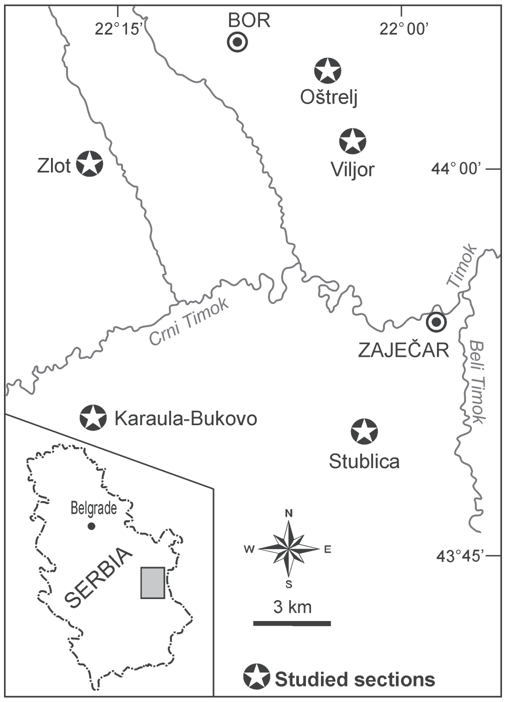


Fig. 1. Location of studied sections within the Timok Eruptive Area, eastern Serbia.

Zimmerman et al. 2008; Banješević 2010) the stratigraphic setting of the Upper Cretaceous formations has received very little attention (Bogdanović 1965; Andjelković & Antonijević 1975; Djajić & Pantić 1998). Up to now biostratigraphic characteristics, as well as lithostratigraphy of the TEA have not been available. A preliminary report on the Timok group of formations is given by Ljubović-Obradović (2010), and in her unpublished PhD thesis (Ljubović-Obradović 2008) it includes the paleontology and biostratigraphy of the Timok Eruptive Area.

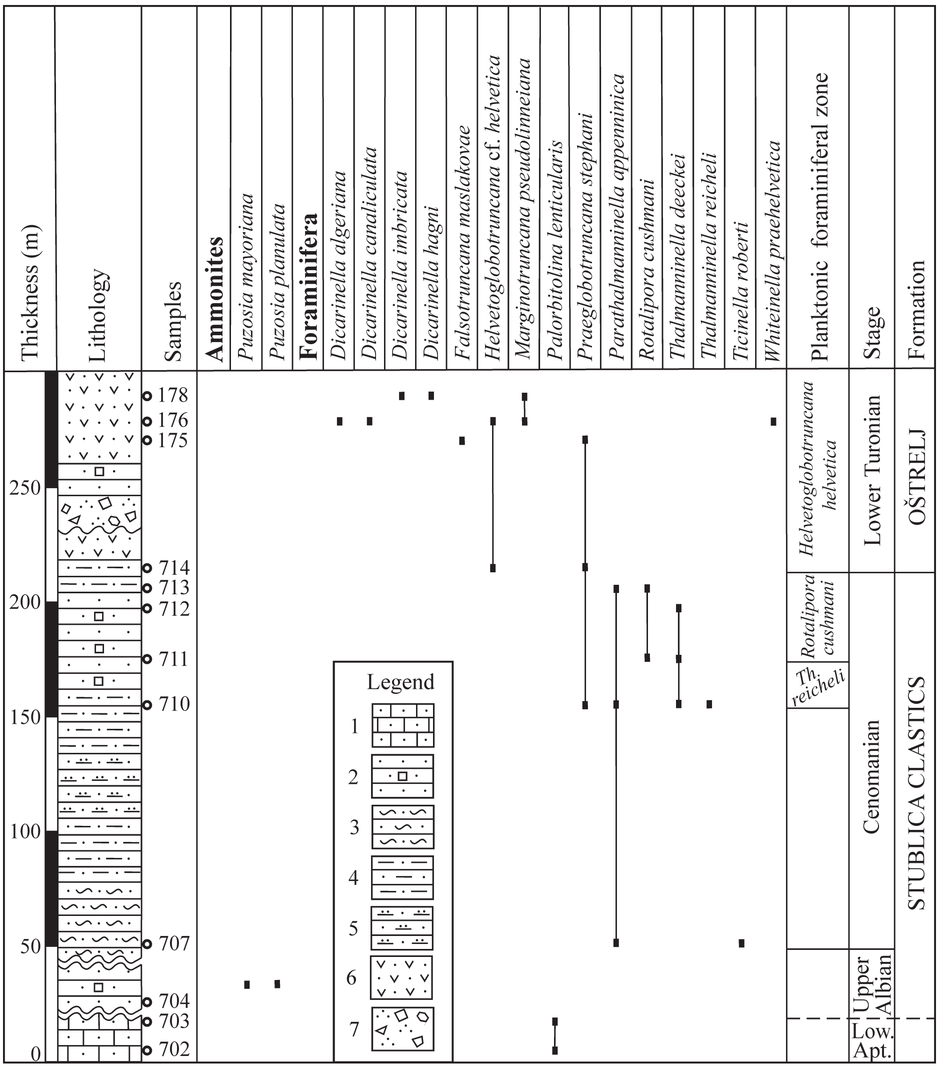
The aim of this paper is to present Upper Cretaceous biostratigraphic data and to propose a zonal scheme of the TEA on the basis of planktonic foraminiferal associations. Eight planktonic foraminiferal zones have been identified based on the occurrence of index planktonic foraminifera. The occurrence and/or disappearance of some index microfossils were used as references for separating these zones.

The study area is located between 22°18′ to 22°00′E longitude and 44°06′ to 43°45′N latitude (Fig. 1). Five well-exposed stratigraphic sections of the Albian–Maastrichtian strata were measured and sampled. The microfossil content of the samples was studied in 76 thin-sections with an optical microscope.

The thin-sections are housed in the collection at the Geological Institute of Serbia under inventory numbers which are referred to in the text.

Stratigraphic background

Within the wider area of the studied section, the oldest rocks are represented by Paleozoic conglomerates. They consist of granitoid rocks and crystalline schists. Upwards they are followed by sandstones, siltstones and claystones of the same age (Veselinović et al. 1975). Sedimentation in the Mesozoic started in the Jurassic transgressively over the old basement. Within the framework of the Jurassic succession it is possible to recognize all three ages: the Lower/Middle Jurassic comprise clastic rocks and sandy limestones, while the Upper Jurassic is built up of reef limestones (Djordjević & Banješević 1997). They are unconformably overlain by Barremian/Albian Urgonian limestones and sandstones. These are followed by the Upper Cretaceous Timok Group of Formations described the text below. The Tertiary sedimentary cover is composed mainly of Neogene lacustrine deposits.



Stublica Clastics Formation

The Stublica Clastics Formation unconformably overlies the Lower Aptian sandy limestones with *Palorbitolina lenticularis* and conformably underlies the Oštrelj Formation (Fig. 2). It was first described as Albian "Lenovac Beds" by Andjelković & Antonijević (1975). It is represented by sandstones with siderite at the base dated as Late Albian on the basis of ammonites.

It is transgressively overlain by a continuous succession with sandy claystones, sandy marlstones and sandy siltstones topped by sandstones with siderite. The age of this unit is dated as Cenomanian. It was not possible to recognize the Lower Cenomanian planktonic foraminiferal zones due to the lack of index species, but in the upper part of the unit *Thalman-*

Fig. 2. Lithological column and biostratigraphy of the Lower Aptian/Lower Turonian deposits in the Stublica section. 1 — sandy limestones; 2 — sandstones with siderite; 3 — sandy claystones; 4 — sandy marlstones; 5 — sandy siltstones; 6 — tuffs; 7 — breccias with Fe concretions.

ninella (the generic affiliation of the Albian-Cenomanian rotaliporids introduced in a recently published taxonomy by González-Donoso et al. (2007) and Lipson-Benitah (2008) is adopted in this study, although Gale et al. (2011) suspect that the genus *Thalmanninella* may be polyphyletic) zonal species *Thalmanninella reicheli* and *Rotalipora* zonal species *Rotalipora cushmani* are identified suggesting a Middle and Late Cenomanian age.

The formation thickness at the type section is inferred as about 200 m. It attains a thickness of 241 m at Kravarnik, but it is only 5 m thick at Gamzigrad.

Oštrelj Formation

The Oštrelj Formation was first recorded as a formal clastic unit by Djordjević & Banješević (1997). This formation includes the succession from the Lower Turonian to Santonian. In the section Zlot it conformably overlies the Stublica Clastics of ?Late Albian/Late Cenomanian age. It starts with the Lower Turonian (*Helvetoglobotruncana helvetica* Biozone) sandy limestones and continues upwards with a rhythmic pattern of tuffs, calcareous sandstones and marlstones (Fig. 3). The Upper Turonian (*Marginotruncana sigali–Dicarinella primitiva* Biozone) is represented by sandy limestones, calcareous sandstones, tuffs and marlstones. Upwards it grades into Coniacian (*Dicarinella concavata* Biozone) marlstones and tuffs. The upper part of the formation also consists of marlstones and tuffs dated as Santonian (*Dicarinella asymetrica* Biozone). The Oštrelj Formation's thickness in the Zlot locality reaches about 500 m.

In the type section Oštrelj, the formation is more calcareous and less volcanogenic (Fig. 4). It consists of a 414 m thick succession dominated by sandy limestones interbedded with marly limestones and tuffs. The Late Turonian/Middle Campanian age assignment of the Oštrelj Formation in the type locality is based on planktonic foraminifera with five biozones being recognized: *Marginotruncana sigali–Dicarinella primitiva* in the Upper Turonian to lowermost Coniacian; *Dicarinella concavata* in the Coniacian to lowermost Santonian; *Dicarinella asymetrica* in the Santonian; *Globotruncanita elevata* in the Lower Campanian and *Globotruncana ventricosa* in the Middle Campanian.

The Oštrelj Formation can also be observed in the Viljor section (Fig. 5). There it consists of a similar volcano-sedimentary succession of Late Turonian/Santonian age rich in macrofossils (bryozoans and echinoids) with three planktonic foraminiferal biozones recognized (same as previous). The Lower Turonian (*Helvetoglobotruncana helvetica* Biozone) of the Oštrelj Formation is missing in the Viljor section, but is recorded in the Stublica section conformably overlying the Stublica Formation (Fig. 2).

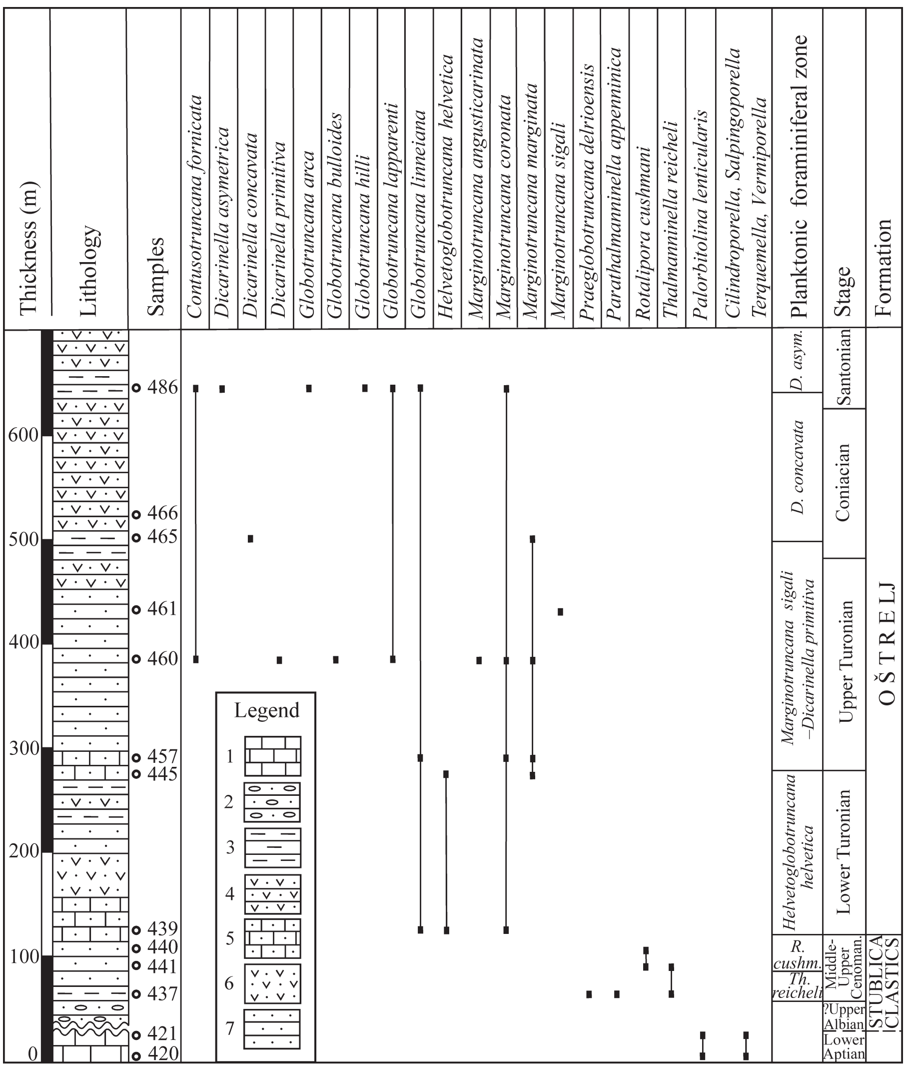


Fig. 3. Lithological column and biostratigraphy of the Lower Aptian/Santonian deposits in the Zlot section. 1 — limestones; 2 — conglomerates; 3 — marlstones; 4 — aglomerates; 5 — sandy limestones; 6 — tuffs; 7 — calcareous sandstones.

Bor Clastics Formation

Petković (1931) was among the first geologists to mention the presence of conglomerates in the TEA, initially named the "Bor conglomerates" after the city of Bor. Subsequently, they were noticed by Marić (1957) and described by Divljan (1958). Their Senonian age was proposed by Bogdanović (1965). Recently, Ljubović-Obradović (2008, 2010) introduced the term Bor Clastics Formation for the succession composed of a mixture of clastic rocks represented by conglomerates, various sandstones and claystones.

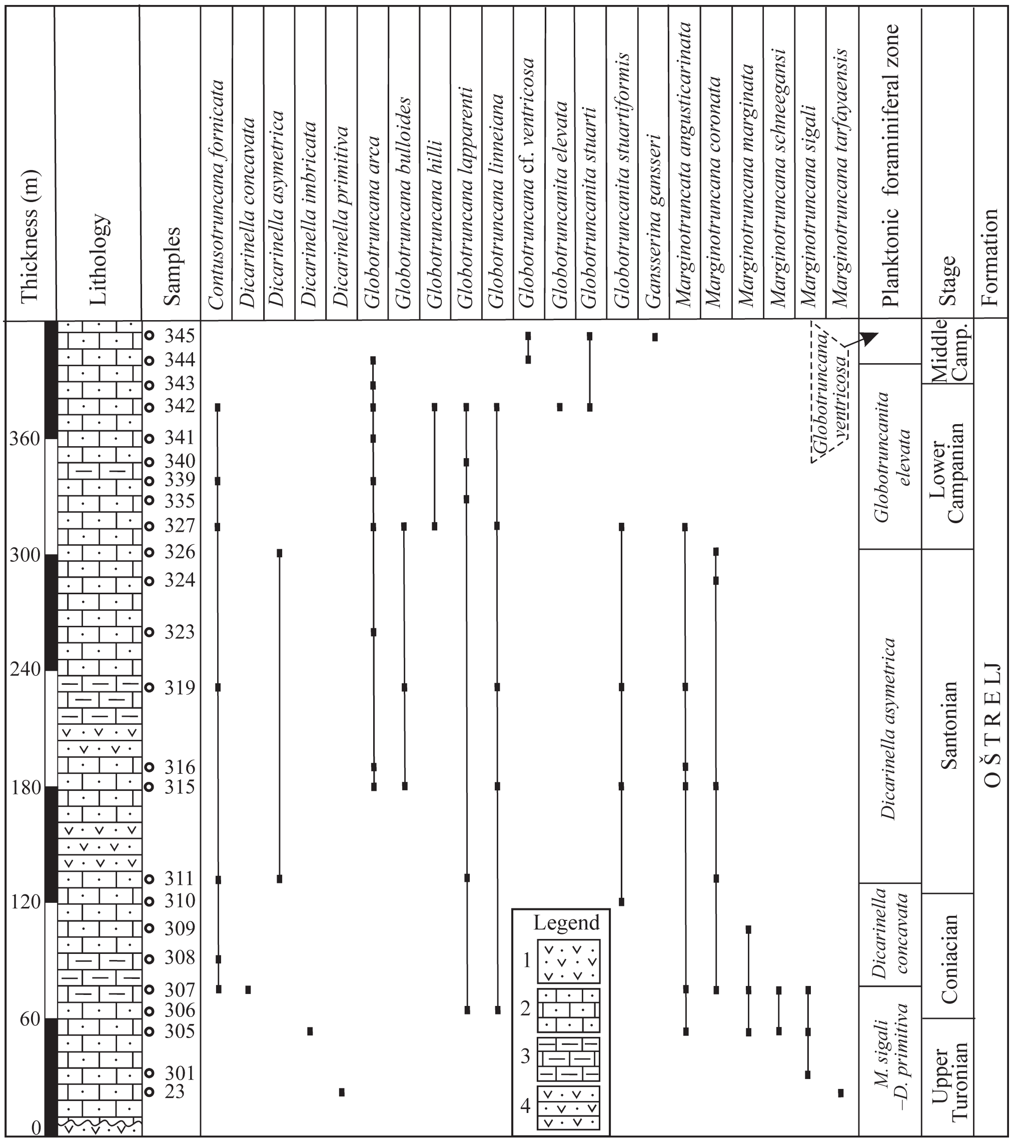


Fig. 4. Lithological column and biostratigraphy of the Upper Turonian/Middle Campanian deposits in the Oštrelj section. 1 — tuffs; 2 — sandy limestones; 3 — marly limestones; 4 — aglomerates.

The transition from the Oštrelj Formation to the Bor Clastics Formation is well visible in the Viljor section (Fig. 5). Above the sandstones the succession is dominated by conglomerates overlain again by sandstones with gastropod remains. The age of this sequence is assigned to the Campanian based on the occurrence of *Globotruncana ventricosa.* The thickness is 80 m. It passes upward to a 30 m thick Maastrichtian sandstone unit with intercalated layers of claystones containing *Gansserina gansseri*. It is topped by grey and yellow calcareous-clayey sandstones rich in well preserved Maastrichtian spores and pollen (Djajić & Pantić 1998). The lack of Campanian/Maastrichtian zonal species in the formation does not allow the nominal zones to be recognized.

Bukovo Formation

In the Karaula-Bukovo section, the Bukovo Formation (Ljubović-Obradović 2008, 2010) overlies the tuffites of the Oštrelj Formation (Fig. 6). At the base, there are claystones and marlstones overlain by sandy limestones with intercalated layers of claystones. Sandy limestones are rich in benthic foraminifera, rudists bioclasts (e.g. *Biradiolites*, *Radiolites*), gastropods, and corals. The following benthic foraminiferal species known from Campanian age are determined: *Orbitoides media*, *Orbitoides tissoti*, *Siderolites charentensis*, *Siderolites vidali* and *Vidalina hispanica*. The age is also supported by the index planktonic foraminiferal species *Globotruncanita elevata* and *Globotruncana ventricosa.* This sequence attains a thickness of about 90 m.

In the upper part the succession continues with pelagic claystones and marlstones most probably dated as ?Maastrichtian on the basis of scarce planktonic foraminifera. The thickness of this sequence reaches about 70 m.

Biostratigraphy of planktonic foraminifera in the TEA

Planktonic foraminifera are the main components in all microfossil assemblages in the investigated sediments. More

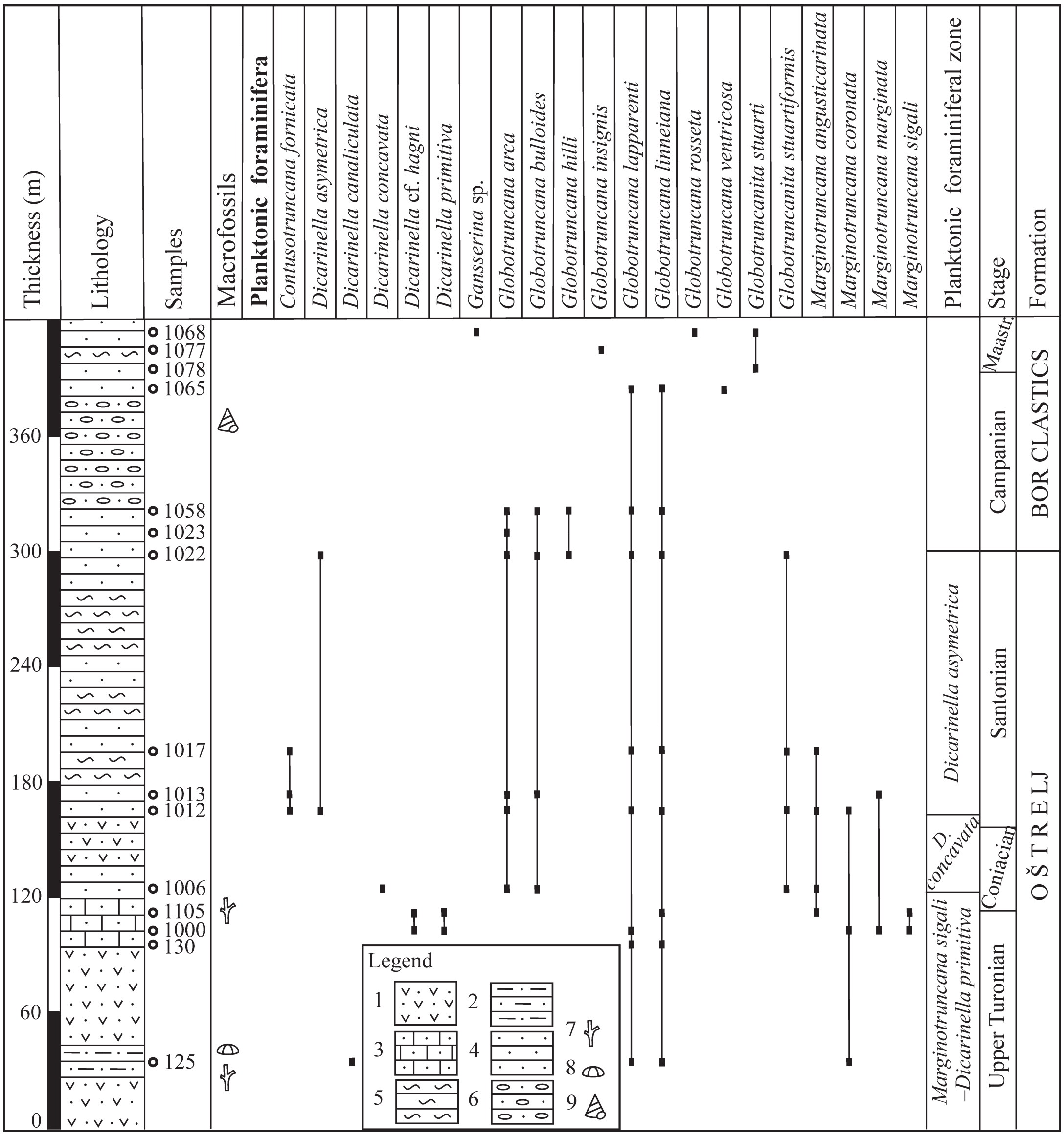


Fig. 5. Lithological column and biostratigraphy of the Upper Turonian/Maastrichtian deposits in the Viljor section. 1 — tuffs; 2 — sandy marlstones; 3 — sandy limestones; 4 — sandstones; 5 — claystones; 6 — conglomerates; 7 — bryozoans; 8 — echinoids; 9 — gastropods.

than forty planktonic species have been identified in the TEA. The recognized biozones span the Middle Cenomanian to Middle Campanian interval. The definitions of the biozones are given following the latest concepts by Premoli Silva & Verga (2004), Robaszynski et al. (2000), Robaszynski & Caron (1995), Premoli Silva & Sliter (1995), as well as Sliter (1989) and Caron (1985). The correlation scheme between the eastern Serbian Upper Cretaceous planktonic foraminiferal zones with adjacent regions of Bulgaria and Romania as well as the other Tethyan regions is given in Fig. 7.

Thalmanninella reicheli Interval Zone

Definition: Biostratigraphic interval from the first occurrence of *Thalmanninella reicheli* to the first occurrence of *Rotalipora cushmani.*

Remarks: This zone is characterized by the presence of *Thalmanninella reicheli*, *Thalmanninella deeckei*, *Parathalmanninella appenninica*, *Praeglobotruncana stephani* and *Praeglobotruncana delrioensis.*

Age and correlation: This zone corresponds to the *Thalmanninella reicheli* Zone of Caron (1985), Sliter (1989), Robaszynski & Caron (1995) and Premoli Silva & Verga (2004); to the lower part of the *Rotalipora cushmani* Zone of Dimitrova & Valchev (2007) and Peryt (1980); to the *R. cushmani* Zone of Ion & Szasz (1994). The age of this zone is Middle Cenomanian.

Distribution: Stublica Clastics Formation (sections Stublica and Zlot).

Rotalipora cushmani Taxon Range Zone

Definition: Biostratigraphic interval represented by the total range of *Rotalipora cushmani*.

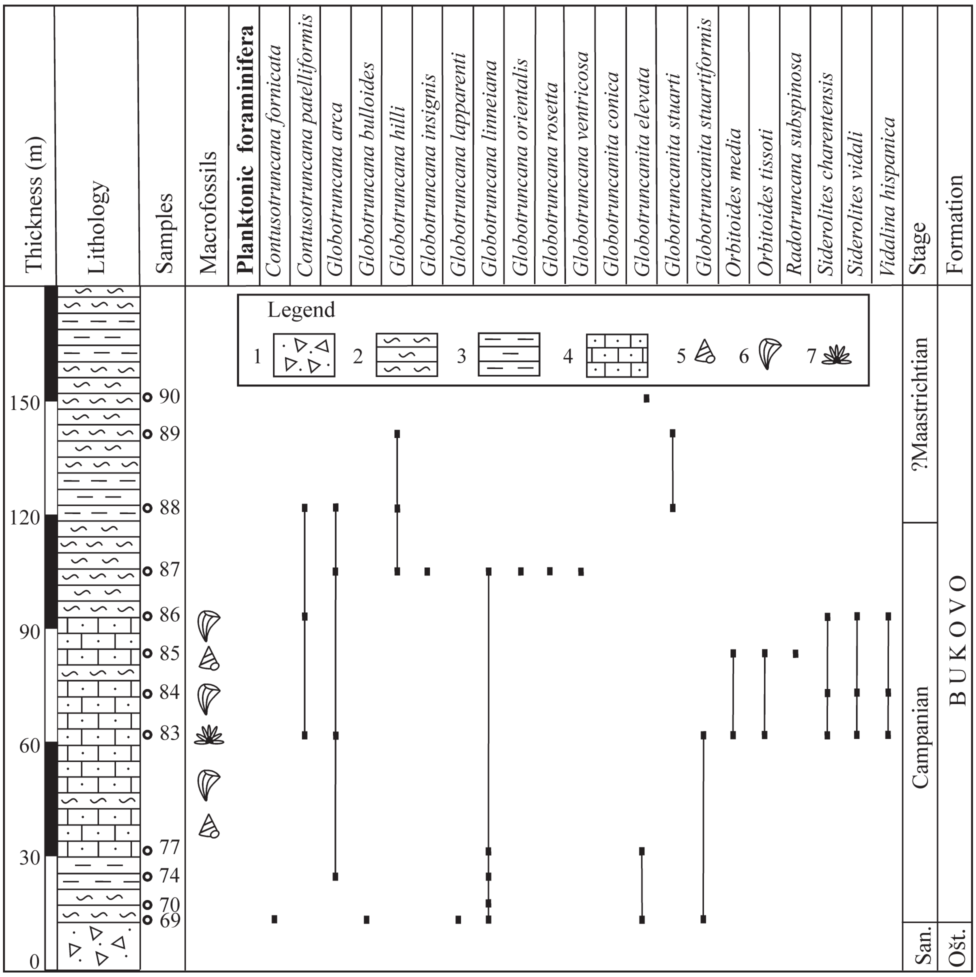


Fig. 6. Lithological column and biostratigraphy of the Campanian/?Maastrichtian deposits in the Karaula-Bukovo section. 1 — tuffites; 2 — claystones; 3 — marlstones; 4 — sandy limestones; 5 — gastropods; 6 — rudists; 7 — corals.

Remarks: The planktonic foraminiferal assemblage of this zone includes *Rotalipora cushmani*, *Thalmanninella deeckei*, *Parathalmanninella appenninica* and *Praeglobotruncana stephani.*

Age and correlation: This zone is the same as the *Rotalipora cushmani* Zone recognized by Caron (1985), Sliter (1989), Robaszynski & Caron (1995) and Premoli Silva & Verga (2004). It corresponds to the upper part of the *R. cushmani* Zone of Dimitrova & Valchev (2007) and Peryt (1980); to the *W. paradubia* Zone and the lower part of the *D. imbricata* Zone of Ion & Szasz (1994). The age of this zone is Late Cenomanian.

Distribution: Stublica Clastics Formation (sections Stublica and Zlot).

Helvetoglobotruncana helvetica Taxon Range Zone

Definition: Biostratigraphic interval represented by the total range of *Helvetoglobotruncana helvetica.*

Remarks: The assemblage of this zone contains *Helvetoglobotruncana* cf. *helvetica* and *Praeglobotruncana stephani* present throughout this interval. *Globotruncana linneiana* and *Marginotruncana coronata* first appeared in the lower part of the interval. Representative species of the upper part of this interval are *Dicarinella algeriana*, *Dicarinella canaliculata*, *Dicarinella imbricata*, *Dicarinella hagni*, *Falsotruncana maslakovae*, *Marginotruncana pseudolinneiana*, *Marginotruncana marginata* and *Whiteinella praehelvetica.*

Age and correlation: This zone can be correlated with the *W. archeocretacea* Zone and *H. helvetica* Zone in the standard zonations (Caron 1985; Sliter 1989; Robaszynski & Caron (1995); Premoli Silva & Verga 2004). It is identical with the *H. helvetica* Zone of Peryt (1980). It corresponds to the *D. imbricata* Zone and the lower part of the *M. renzi–M. sigali* Zone of Dimitrova & Valchev (2007). The *Helvetoglobotruncana helvetica* Zone defined here is correlated with the joint interval from the upper part of the *D. imbricata* Zone to the lower part of *M. sigali* Zone of Ion & Szasz (1994). The age of this zone is assigned to the Early Turonian.

Distribution: Oštrelj Formation (sections Stublica and Zlot).

Marginotruncana sigali–Dicarinella primitiva Interval Zone

Definition: Biostratigraphic interval between the last occurrence of *Helvetoglobotruncana helvetica* and the first occurrence of *Dicarinella concavata.*

Remarks: The assemblage in this interval is characterized by the presence of *Contusotruncana fornicata*, *Dicari-*

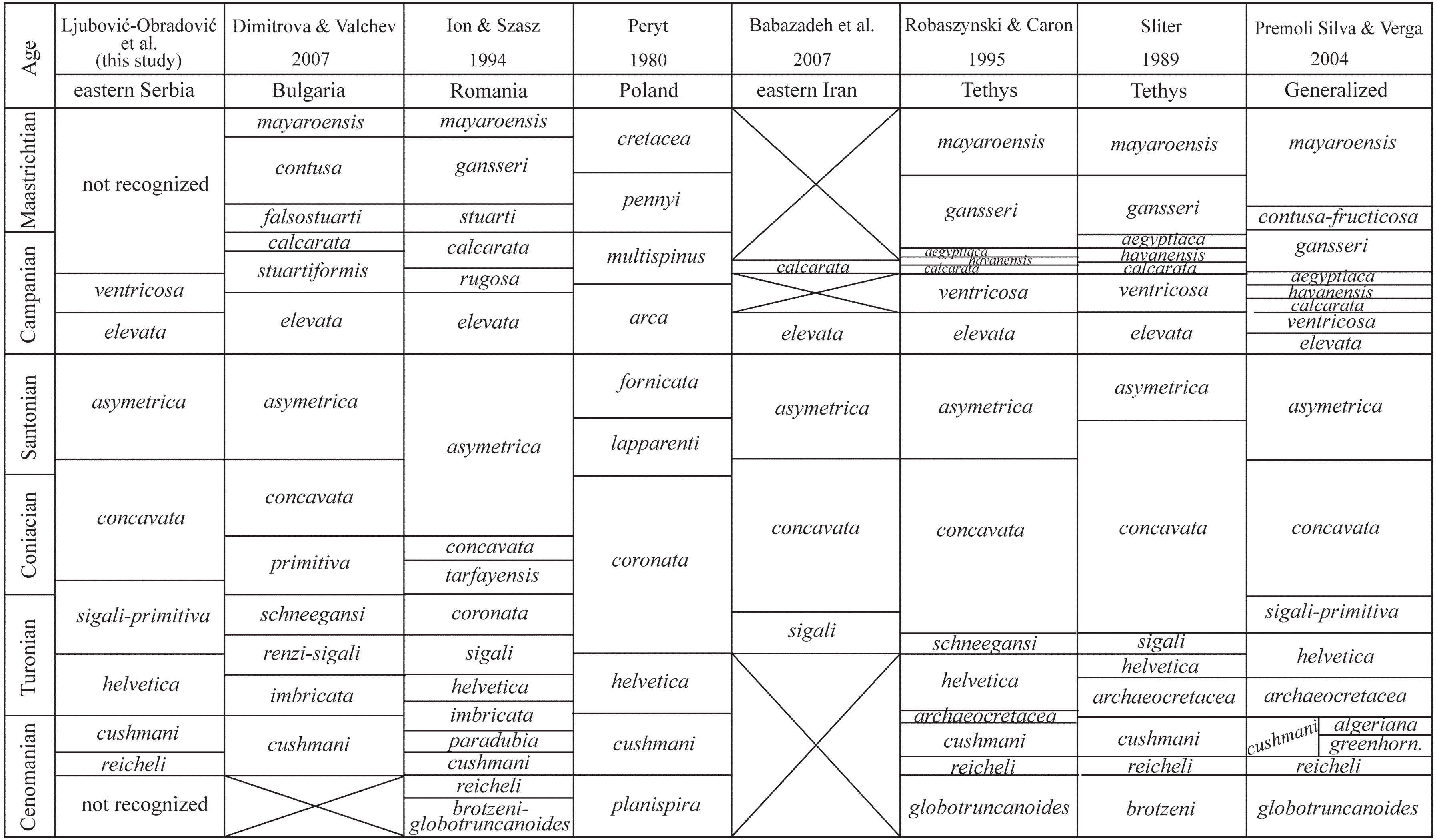


Fig. 7. Proposed zonal scheme for the Upper Cretaceous succession in eastern Serbia compared with the zonations for Bulgaria, Romania, Poland, eastern Iran and some important standard zonations of the Tethys.

nella primitiva, *Globotruncana bulloides*, *Marginotruncana angusticarinata*, *Marginotruncana sigali*, *Dicarinella imbricata*, *Dicarinella primitiva*, *Marginotruncana schneegansi*, *Marginotruncana tarfayaensis*, *Dicarinella canaliculata*, *Dicarinella* cf. *hagni*, *Marginotruncana angusticarinata*, *Dicarinella canaliculata* and *Globotruncana lapparenti*. All of them appear for the first time in this zone. Other characteristic species are *Globotruncana linneiana*, *Marginotruncana coronata* and *Marginotruncana marginata*.

Age and correlation: The zone corresponds to the joint interval from the upper part of the *M. renzi–M. sigali* Zone to the lower part of the *D. primitiva* Zone of Dimitrova & Valchev (2007); from the upper part of the *M. sigali* Zone to the lower part of the *M. tarfayensis* Zone of Ion & Szasz (1994). It corresponds to the lower part of the *M. coronata* Zone of Peryt (1980); to the *M. sigali* Zone and the lowermost part of *D. concavata* Zone of Babazadeh et al. (2007) and Sliter (1989). This zone can be correlated with the *M. sigali*–

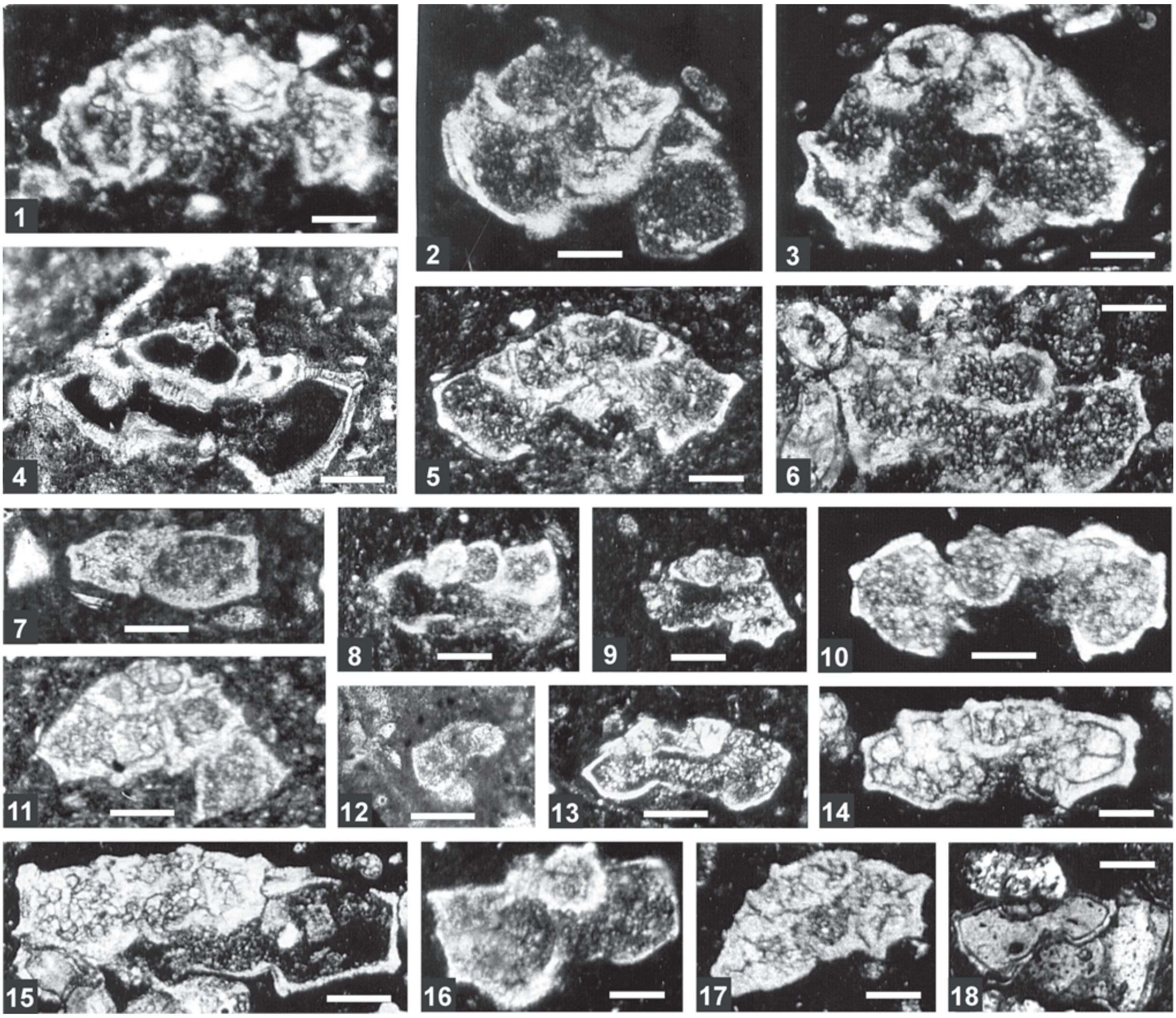


Fig. 8. Thin-section photomicrographs of the determined foraminifera from the Timok Eruptive Area. **1** — *Contusotruncana fornicata* (Plummer), sample 69, Karaula-Bukovo section; **2** — *Contusotruncana patelliformis* (Gandolfi), sample 86, Karaula-Bukovo section; **3** — *Contusotruncana patelliformis* (Gandolfi), sample 83, Karaula-Bukovo section; **4** — *Dicarinella* cf. *hagni* (Scheibnerova), sample 1105, Viljor section; **5** — *Globotruncana arca* (Cushman), sample 74, Karaula-Bukovo section; **6** — *Dicarinella concavata* (Brotzen), sample 465, Zlot section; **7** — *Dicarinella canaliculata* (Reuss), sample 125, Viljor section; **8** — *Gansserina gansseri* Bolli, sample 345, Oštrelj section; **9** — *Contusotruncana fornicata* (Plummer), sample 339, Oštrelj section; **10** — *Globotruncana bulloides* Vogler, sample 69, Karaula-Bukovo section; **11** — *Globotruncanita conica (*White), sample 90, Karaula-Bukovo section; **12** — *Helvetoglobotruncana* cf. *helvetica* (Bolli), sample 176, Stublica section; **13** — *Globotruncana rosetta* (Carsey), sample 87, Karaula-Bukovo section; **14** — *Globotruncana linneiana* (d'Orbigny), sample 87, Karaula-Bukovo section; **15** — *Marginotruncana coronata* (Bolli), sample 486, Zlot section; **16** — *Globotruncana hilli* (Pessagno), sample 1058, Viljor section; **17** — *Globotruncana arca* (Cushman), sample 486, Zlot section; **18** — *Gansserina* sp., sample 1068, Viljor section. Scale bar = 100 μm.

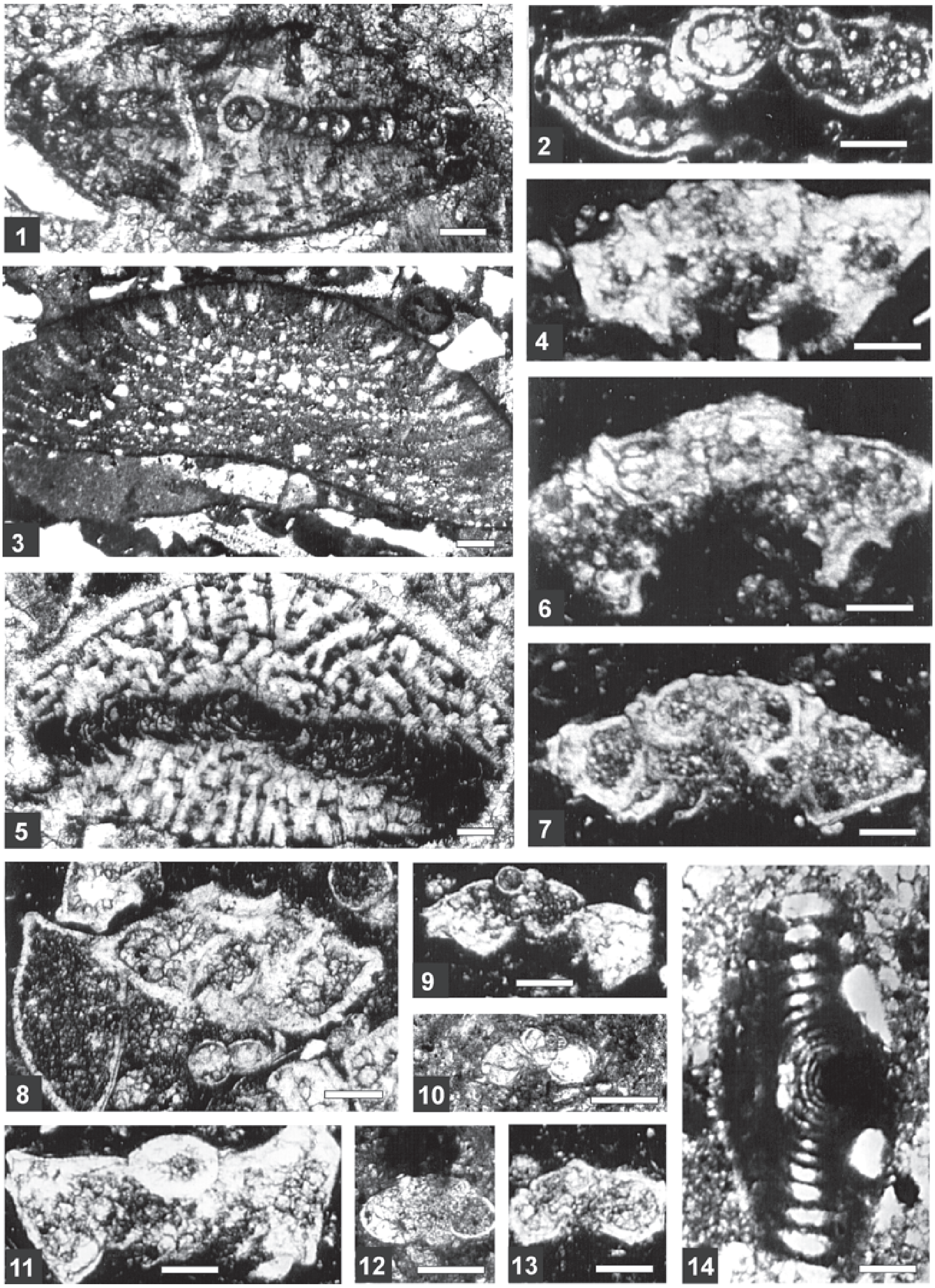


Fig. 9. Thin-section photomicrographs of the determined foraminifera from the Timok Eruptive Area. **1** — *Orbitoides tissoti* Schlumberger, sample 85, Karaula-Bukovo section; **2** — *Marginotruncana pseudolinneiana* Pessagno, sample 176, Stublica section; **3** — *Palorbitolina lenticularis* (Blumenbach), sample 703, Stublica section; **4** — *Globotruncana* cf. *ventricosa* White, sample 345, Oštrelj section; **5** — *Orbitoides media* d'Archiac, sample 85, Karaula-Bukovo section; **6** — *Globotruncana* cf. *ventricosa* White, sample 344, Oštrelj section; **7** — *Marginotruncana sigali* (Reichel), sample 461, Zlot section; **8** — *Globotruncanita elevata* (Brotzen), sample 342, Oštrelj section; **9** — *Marginotruncana schneegansi* (Sigal), sample 307, Oštrelj section; **10** — *Praeglobotruncana delrioensis* Plummer, sample 437, Zlot section; **11** — *Dicarinella asymetrica* (Sigal), sample 1022, Viljor section; **12** — *Praeglobotruncana stephani* (Gandolfi), sample 714, Stublica section; **13** — *Whiteinella praehelvetica* (Trujillo), sample 176, Stublica section; **14** — *Vidalina hispanica* Schlumberger, sample 83, Karaula-Bukovo section. For the figures 9.1, 9.3, and 9.5 scale bar = 200 μm, for all other figures scale bar = 100 μm.

D. primitiva Zone of Premoli Silva & Verga (2004). The age of this zone is Late Turonian to earliest Coniacian.

Distribution: Oštrelj Formation (sections Zlot, Oštrelj and Viljor).

Dicarinella concavata Interval Zone

Definition: Biostratigraphic interval between the first occurrence of *Dicarinella concavata* and the first occurrence of *Dicarinella asymetrica*.

Remarks: The planktonic foraminiferal assemblage of this zone includes *Dicarinella concavata*, *Marginotruncana marginata*, *Globotruncanita stuartiformis*, *Marginotruncana angusticarinata*, *Marginotruncana coronata*, *Marginotruncana marginata*, *Marginotruncana schneegansi*, *Marginotruncana sigali*, *Globotruncana arca* and *Globotruncana bulloides.*

Age and correlation: The *D. concavata* Zone corresponds to the zone of the same name recognized by Sliter (1989), Robaszynski & Caron (1995), Premoli Silva & Sliter (1995), Robaszynski et al. (2000), Premoli Silva & Verga (2004), Peryt (1980) and Babazadeh et al. (2007). It corresponds to the upper part of the *D. primitiva* Zone and the *D. concavata* Zone of Dimitrova & Valchev (2007); to the joint interval from the upper part of the *M. tarfayensis* Zone to the lower part of the *D. asymetrica* Zone of Ion & Szasz (1994). The age of this zone is Early Coniacian to earliest Santonian.

Distribution: Oštrelj Formation (sections Zlot, Oštrelj and Viljor).

Dicarinella asymetrica Taxon Range Zone

Definition: Biostratigraphic interval represented by the total range of *Dicarinella asymetrica.*

Remarks: The assemblage of this zone contains *Dicarinella asymetrica*, *Contusotruncana fornicata*, *Globotruncana arca*, *Globotruncana hilli*, *Globotruncana lapparenti*, *Globotruncana linneiana*, *Marginotruncana coronata*, *Globotruncana bulloides*, *Globotruncanita stuartiformis* and *Marginotruncana angusticarinata.*

Age and correlation: This zone is identical with the *D. asymetrica* Zone of Dimitrova & Valchev (2007), Babazadeh et al. (2007), Robaszynski & Caron (1995), Premoli Silva & Sliter (1995), Robaszynski et al. (2000) and Premoli Silva & Verga (2004). It corresponds to the upper part of the *D. asymetrica* Zone of Ion & Szasz (1994); to the upper part of the *G. lapparenti* Zone and *C. fornicata* Zone of Peryt (1980); to the upper part of the *C. fornicata* Zone and to the uppermost part of the *D. concavata* Zone and *D. asymetrica* Zone of Sliter (1989). The age of this zone is Santonian.

Distribution: Oštrelj Formation (sections Zlot, Oštrelj and Viljor).

Globotruncanita elevata Interval Zone

Definition: Biostratigraphic interval between the last occurrence of *Dicarinella asymetrica* and the first occurrence of *Globotruncana ventricosa.*

Remarks: The last occurrence of *Globotruncana bulloides*, *Globotruncanita stuartiformis* and *Marginotruncana angusticarinata* comprise the lower part of the zone. *Globotruncanita stuarti* first appears in the upper part of the zone. *Contusotruncana fornicata, Globotruncana arca*, *Globotruncana hilli*, *Globotruncana lapparenti*, *Globotruncana linneiana* and *Globotruncanita elevata* are common throughout this interval.

Age and correlation: This zone corresponds to the widely recognized Tethyan *Globotruncanita elevata* Interval Zone (Caron 1985; Sliter 1989; Robaszynski & Caron (1995); Premoli Silva & Sliter (1995); Babazadeh et al. 2007); to the lower part of *G. elevata* Zone of Dimitrova & Valchev (2007) and Ion & Szasz (1994); to the lower part of *G. arca* Zone of Peryt (1980). Premoli Silva & Verga (2004) recognized this zone in the lowermost Campanian. The age of this zone is assigned to the Early Campanian.

Distribution: Oštrelj Formation (section Oštrelj).

Globotruncana ventricosa Interval Zone

Definition: Biostratigraphic interval defined by the first occurrence of *Globotruncana ventricosa* and the first occurrence of *Radotruncana calcarata.*

Remarks: The common species are *Globotruncana ventricosa*, *Globotruncana arca*, *Globotruncanita stuarti* and *Gansserina gansseri*.

Age and correlation: The *G. ventricosa* Zone corresponds to the zone of the same range of Sliter (1989), Premoli Silva & Sliter (1995) and Robaszynski & Caron (1995); to the *G. calcarata, G. havanensis* and *G. aegyptiaca* Zones of Premoli Silva & Verga (2004); to the uppermost part of the *G. arca* Zone and lowermost part of the *G. multispinus* Zone of Peryt (1980); to the uppermost part of the *G. elevata* Zone and *G. rugosa* Zone of Ion & Szasz (1994) and to the uppermost part of the *G. elevata* Zone and the lower part of the *G. stuartiformis* Zone of Dimitrova & Valchev (2007). The age of this zone is assigned to the Middle Campanian.

Distribution: Oštrelj Formation (section Oštrelj).

Conclusion

The Upper Cretaceous succession of the Timok Eruptive Area in eastern Serbia includes four formations from base to top: Stublica Clastics, Oštrelj, Bor Clastics and Bukovo. Detailed investigations of the five measured stratigraphic sections have yielded new data to establish the Upper Cretaceous planktonic foraminiferal biostratigraphy of the TEA.

The planktonic foraminiferal assemblages of eastern Serbia belong to the northern Tethyan bioprovince characterized by representatives of the genera *Contusotruncana*, *Dicarinella*, *Falsotruncana*, *Gansserina*, *Globotruncana*, *Globotruncanita*, *Helvetoglobotruncana*, *Marginotruncana*, *Parathalmanninella*, *Praeglobotruncana*, *Radotruncana*, *Rotalipora*, *Thalmanninella* and *Whiteinella*. The stratigraphic range of 42 planktonic foraminiferal species identified in the studied successions had allowed recognition of eight biozones covering the Middle Cenomanian/Middle Campanian interval. These are: the *Thalmanninella reicheli* Interval Zone (Middle Cenomanian), *Rotalipora cushmani* Taxon Range Zone

(Upper Cenomanian), *Helvetoglobotruncana helvetica* Taxon Range Zone (Lower Turonian), *Marginotruncana sigali–Dicarinella primitiva* Interval Zone (Upper Turonian to lowermost Coniacian), *Dicarinella concavata* Interval Zone (Lower Coniacian to lowermost Santonian); *Dicarinella asymetrica* Taxon Range Zone (Santonian), *Globotruncanita elevata* Interval Zone (Lower Campanian) and the *Globotruncana ventricosa* Interval Zone (Middle Campanian).

The main result of this study is the establishment of an Upper Cretaceous biozonal scheme of the eastern Serbian Carpatho-Balkanides that may serve as a basis for further biostratigraphic zonations in the Carpathians. The high-diversity planktonic foraminiferal assemblages from the Timok Eruptive Area of eastern Serbian Carpatho-Balkanides reveal a strong similarity to the Tethyan (Mediterranean) Realm (Robaszynski & Caron 1995). Correlation of the proposed zonation for eastern Serbia highlights good correlation of the stratigraphic distribution of the *Helvetoglobotruncana helvetica* Taxon Range Zone (Lower Turonian) from Poland, *Dicarinella asymetrica* Taxon Range Zone (Santonian) from Bulgaria and eastern Iran and *Globotruncanita elevata* Interval Zone (Lower Campanian) from eastern Iran.

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Appendix

List of planktonic and benthic foraminifera species recognized in this study, arranged in alphabetical order. Selected species are illustrated in Figs. 8–9.

Planktonic foraminifera

Contusotruncana fornicata (Plummer); Figs. 8.1, 9
Contusotruncana patelliformis (Gandolfi); Fig. 8.2,3
Dicarinella algeriana (Caron)
Dicarinella asymetrica (Sigal); Fig. 9.11
Dicarinella canaliculata (Reuss); Fig. 8.7
Dicarinella concavata (Brotzen); Fig. 8.6
Dicarinella cf. *hagni* (Scheibnerova); Fig. 8.4
Dicarinella imbricata (Monrod)
Dicarinella primitiva (Dalbiez)
Falsotruncana maslakovae Caron
Gansserina gansseri Bolli; Fig. 8.8
Gansserina sp.; Fig. 8.18
Globotruncana arca (Cushman); Fig. 8.5,17
Globotruncana bulloides Vogler; Fig. 8.10
Globotruncana hilli (Pessagno); Fig. 8.16
Globotruncana insignis (Gandolfi)
Globotruncana lapparenti (Brotzen)
Globotruncana linneiana (d'Orbigny); Fig. 8.14
Globotruncana orientalis Ei-Naggar
Globotruncana rosetta (Carsey); Fig. 8.13
Globotruncana cf. *ventricosa* White; Figs. 9.6, 4
Globotruncanita conica (White); Fig. 8.11
Globotruncanita elevata (Brotzen); Fig. 9.8
Globotruncanita stuarti (de Lapparent)
Globotruncanita stuartiformis (Dalbiez)
Helvetoglobotruncana cf. *helvetica* (Bolli); Fig. 8.12
Marginotruncana angusticarinata (Gandolfi)
Marginotruncana coronata (Bolli); Fig. 8.15
Marginotruncana marginata (Reuss)
Marginotruncana pseudolinneiana Pessagno; Fig. 9.2
Marginotruncana schneegansi (Sigal); Fig. 9.9
Marginotruncana sigali (Reichel); Fig. 9.7
Marginotruncana tarfayaensis (Lehmann)
Parathalmanninella appenninica (Renz)
Praeglobotruncana delrioensis Plummer; Fig. 9.10
Praeglobotruncana stephani (Gandolfi); Fig. 9.12
Radotruncana calcarata (Cushman)
Radotruncana subspinosa (Pessagno)
Rotalipora cushmani (Morrow)
Thalmanninella deeckei (Francke)
Thalmanninella reicheli Mornod
Ticinella roberti (Gandolfi)
Whiteinella praehelvetica (Trujillo); Fig. 9.13

Benthic foraminifera

Orbitoides media d'Archiac; Fig. 9.5
Orbitoides tissoti Schlumberger; Fig. 9.1
Palorbitolina lenticularis (Blumenbach); Fig. 9.3
Siderolites charentensis (Neumann)
Siderolites vidali (Douvillé)
Vidalina hispanica Schlumberger; Fig. 9.14