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The Campanian–Maastrichtian foraminiferal biostratigraphy of the basement sediments from the southern Pannonian Basin (Vojvodina, northern Serbia): implications for the continuation of the Eastern Vardar and Sava zones

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Abstract: Micropalaeontological and biostratigraphical studies included Campanian–Maastrichtian complexes from five oil exploration wells drilled in northern Serbia (Vojvodina): the first is a carbonate-clastic complex and second is a complex containing ophiolites intercalated with hemipelagic and pelagic sediments. Within the studied complexes, rich associations of planktonic and benthic foraminifera, calcareous nannoplankton, palynomorphs, as well as shallow and deep-water fossil detritus were determined. The presence of relatively rich associations of planktonic foraminifera allowed recognition of two biozones: the Globotruncana ventricosa Zone, observed in the sediments of the carbonate-clastic complex and the Gansserina gansseri Zone, observed in both complexes. Except biozones, based on documented index species, for some units in both complexes, larger benthic foraminifera species had special biostratigraphical value, and in some of them, the calcareous nannoplankton zones were recognized. The studied complexes represent deep-water formations, generated in oceanic island arc and trough zones. The presence of limestones, which originate from destroyed rudist reefs, is explained by transfer by means of gravitational transport mechanisms of shallow-water sediments to deep-water depositional environments. In this paper, the results of more detailed biostratigraphical and palaeo-ecological studies of foraminifera associations in Campanian–Maastrichtian complexes in Vojvodina are presented. Combined with lithological studies, seven units were determined within the complexes. The obtained results are important as a part of multidisciplinary, regional exploration of both complexes, generated in specific geological conditions, that today constitute a part of the pre-Neogene basement complex in the southeastern part of the Pannonian Basin. The Campanian–Maastrichtian carbonate-clastic complex represents sedimentary cover of the Eastern Vardar Ophiolitic Unit, while the ophiolites intercalated with hemipelagic and pelagic limestones belongs to the Sava Zone.

Keywords: Campanian–Maastrichtian, Vardar Zone, Vojvodina, biostratigraphy, palaeo-ecology, foraminifera.

Introduction

Among the Mesozoic rocks of Vojvodina (northern Serbia), constituting a part of the pre-Neogene basement complex in the south-eastern part of the Pannonian Basin, Upper Cretaceous formations have the widest distribution. They are represented by Senonian sediments with volcanoclastic rocks of andesite-trachytic composition (Karadjordjevo Formation) and flysch deposits — Torda Formation (Kemenci & Čanović 1987; Čanović & Kemenci 1988, 1999). Only in a few wells different types of development of the Upper Cretaceous were observed, such as deep-water clastites of Albian–Cenomanian age, organogenic-detritic limestones of Late Turonian–Early Senonian age or red pelagic Santonian limestones (Kemenci & Čanović 1997). A particular development in terms of micro-palaeontological and lithological characteristics is observed in the Campanian–Maastrichtian complexes, which are the subject of study in this paper. A brief overview of the general characteristics of these complexes has been given earlier without considering any other aspects of their interpretation (Dunčić & Bogićević 2008).

The investigated Campanian–Maastrichtian carbonate-clastic complex was encountered in several deep oil exploration wells of the Banat area (Central and North Banat) in Vojvodina. In this paper, all units in this complex, observed in three wells (Fig. 1): Krajišnik Mesozoic-1 (KrMz-1), Sajan-1 (Sa-1) and Medja-3 (Mdj-3). The Campanian–Maastrichtian ophiolites intercalated with hemipelagic and pelagic sediments have been identified in a few wells in the South Bačka area, and the complete development for the studied complex is present in two wells (Fig. 1): Srbobran sever-1 (Srs-1) and Vrbas grad (Vbg-1).

This paper presents the results of the latest micro-palaeontological studies of the Campanian–Maastrichtian carbonate-clastic complex and the next one containing ophiolites intercalated with sediments from wells in Vojvodina, with the aim of establishing a more precise biostratigraphical division and palaeo-ecological interpretation of studied complexes, as well as determining the units within them. Biostratigraphical analysis has enabled recognition of two biozones, based on relatively rich and varied associations of planktonic foraminifera: Globotruncana ventricosa Interval

Zone (Middle to Late Campanian), identified in the sediments of the carbonate-clastic complex (well KrMz-1) and the Gansserina gansseri Interval Zone (Latest Campanian–Early Maastrichtian), observed in sediments of both complexes (wells KrMz-1, Mdj-3 and Vbg-1). In some sediment units from both complexes the biozones were not recognized, however, according to entire microfossil assemblages (especially larger benthic foraminifera species *Siderolites vidali*, *S. charentensis* and *Bulbophragmium aequale*), their age was determined as Upper Campanian. In terms of calcareous nannoplankton, within some of these units, the zones CC21a–CC22 were identified.

The studied complexes can be micropalaeontologically correlated with similar complexes, the development of which is documented in adjacent regions of the Tethyan bio-province. The purpose of this paper is to give a better view of the biostratigraphy of the Campanian–Maastrichtian complexes from wells in Vojvodina, which would contribute to better understanding of the geological history of the exploration area and geodynamic events during the Campanian–Maastrichtian.

The results of recent micropalaeontological, biostratigraphical, palaeo-ecological and lithological studies have indicated that the studied carbonate-clastic complex in North and Central Banat can be very well correlated with the corresponding sediments within the Eastern Vardar Ophiolitic Unit, while the complex, characterized by ophiolites, intercalated with hemipelagic and pelagic sediments from the wells of South Bačka demonstrates analogies with similar units of the Sava Zone.

Geological setting

Pre-Neogene basement complex in the south-eastern part of the Pannonian Basin in Vojvodina consists of tectono-stratigraphic zones of five geotectonic units (Fig. 1). The northern part of Vojvodina belongs to the Tisza Mega-unit, represented by a Proterozoic-Palaeozoic granite-metamorphic complex and Mesozoic formations, corresponding to the Triassic age (Kemenci & Čanović 1997). The Eastern Vardar Ophiolitic Unit and Sava Zone cover the southern part of Vojvodina. The south-easternmost part of Vojvodina belongs to the Serbian-Macedonian Massif. The Jadar Block involves the south-westernmost part of Vojvodina, also comprising adjacent areas of northwest Serbia and northeast Bosnia and Herzegovina.

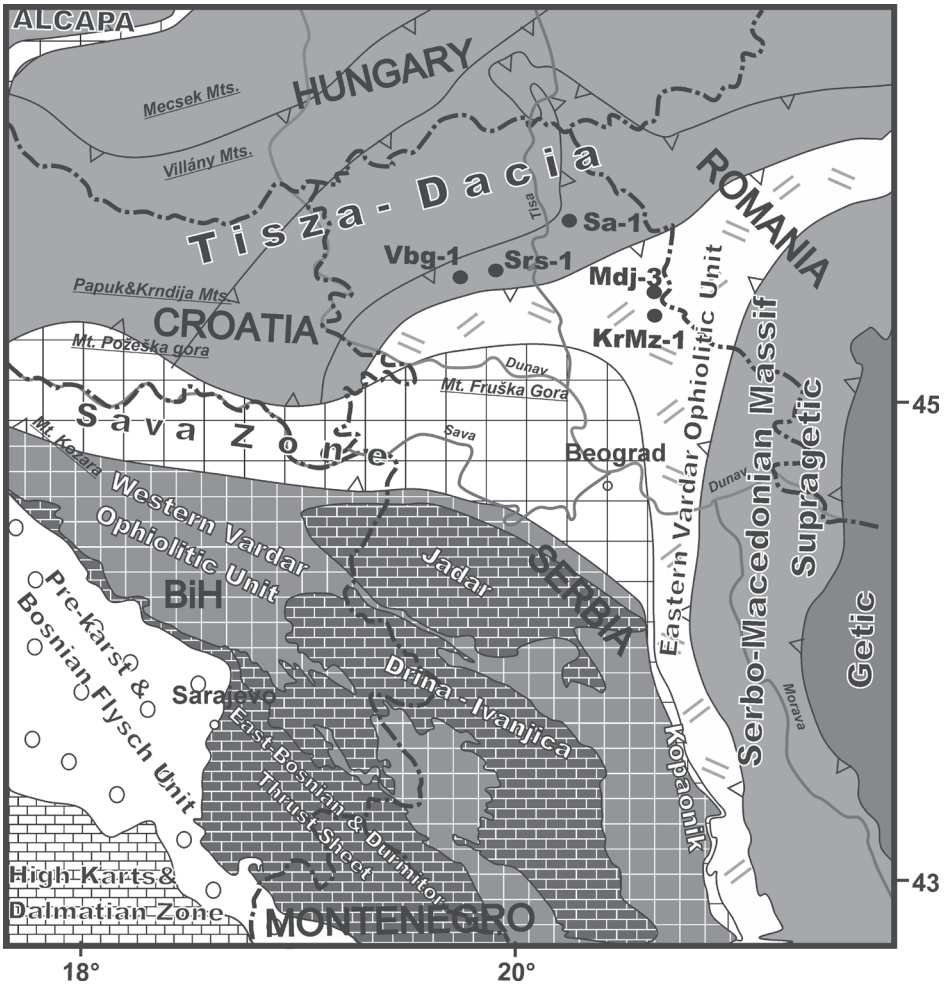

Fig. 1. Simplified and modified geotectonic map with positions of the studied wells in Vojvodina region of northern Serbia (geotectonic regionalization modified after Schmid et al. 2008).

The Mesozoic formations of the Eastern Vardar Ophiolitic Zone (Main Vardar Zone) can be tracked from Transylvania and the South Apuseni Mountains to the north (Schmid et al. 2008), across Vojvodina, where they have been observed in the pre-Neogene basement complex in the Pannonian Basin (Kemenci & Čanović 1997; Čanović & Kemenci 1999), stretching further southwards through east Serbia and Macedonia (Karamata et al. 1997; Schmid et al. 2008; Robertson et al. 2009). Formations corresponding to the Eastern Vardar Ophiolitic Unit were drilled in over 200 oil and gas wells in the Vojvodina area. The oldest Mesozoic formations are represented by Jurassic schistes lustres, while the most striking Jurassic formations are

ophiolites and ophiolite mélange. The sedimentary cover comprising Late Jurassic–Early Cretaceous and Late Cretaceous units is developed transgressively and discordantly over Jurassic ophiolites and trench deposits. Within the Late Jurassic–Early Cretaceous the following formations stand out: pelagic limestones and marlstones of Tithonian–Valanginian age and typically deep-water complexes of Tithonian–Neocomian age, in some wells characterized by presence of syn-sedimentary carbonated spilites (Čanović & Kemenci 1988). The Late Lower Cretaceous and Early Upper Cretaceous are represented by Barremian–Aptian reef deposits of Urgonian type, or deep-water sediments, followed by Aptian–Albian clastites with notable turbidite features and deep-water clastic-carbonate sediments of Albian–Cenomanian age. Within the Late Cretaceous, the Karadjordjevo Formation and Torda Formation have the widest distribution.

According to numerous authors, the Sava Zone or Vardar Zone Western Belt (Karamata et al. 2000, 2005; Robertson et al. 2009) can be traced through southern and central Serbia in the form of a narrow belt, which widens in the outskirts of Belgrade and Mt. Fruška Gora and bends northwestward, going further through northern Bosnia-Herzegovina and Croatia (Robertson et al. 2009). The Sava Zone represents the final suture collision zone between the Tisza and Dacia Mega-unit and the Dinarides (Schmid et al. 2008; Robertson et al. 2009), as the extension of the Periadriatic Zone (Pamić 2002). In its northern part, this zone is usually limited to isolated inselbergs within Cenozoic sediments (Robertson et al. 2009), consisting of Upper Cretaceous ophiolites intercalated with pelagic limestones, trench deposits, flysch, magmatic and metamorphic rocks (Ustaszewski et al. 2010).

Material and methods

Using micropalaeontological methods of studying foraminifera, rock samples from Campanian–Maastrichtian complexes from five deep oil exploration wells in Vojvodina area have been analysed. Analyses included core samples and cuttings. Studies were performed using two methods: washed residues and thin sections method. Foraminifera studies were based on analysing 130 washed residues from cuttings and cores and 180 thin sections from cores. Samples for the washed residues analysis were usually prepared following the classic micropalaeontological method. Micropalaeontological and petrological thin section preparation was also carried out according to standard procedure.

In semiquantitative analysis of foraminifera both thin sections and washed residues were used. Semiquantitative analysis included determination of relative abundance of planktonic and benthic foraminifera, then agglutinated and calcareous benthic foraminifera taxa, as well as other fossil remains, present in studied sediments (microplankton of calcisphaere type, detritus of shallow or deep-water fossils). The obtained results were used for palaeo-ecological interpretation. The results of these analyses, performed on each sample, were presented within stratigraphic well sections, using StrataBugs software (Figs. 2–6). The relative abundance of foraminiferal and other taxa is shown in four categories: rare (<5 %), few (5–10 %), common (10–25 %) and abundant (>25 % of whole microfossil assemblages).

All core and cutting samples, thin sections and micro-faunal foraminifera specimens are stored in NTC NIS-Naftagas LLC Novi Sad (collections of Regional geology and unconventional resource department and Central Laboratory Upstream).

Results

Among the studied Campanian–Maastrichtian complexes in Vojvodina, development of seven units was observed, based on the results of micropalaeontological, biostratigraphical and lithological studies. Five units were determined in the stratigraphic line of the carbonate-clastic complex of Middle Campanian–Lower Maastrichtian age from three wells in the Banat area (Figs. 2–4), and two units within the complex characterized by ophiolites intercalated with hemipelagic and pelagic sediments of Upper Campanian–Lower Maastrichtian age from two wells in the Bačka area (Figs. 5–6). While defining the units, the data obtained by earlier micro-palaeontological and petrological studies were also used (Kemenci & Čanović 1997), as well as the results of well log data interpretation and correlation (unpublished NTC NIS-Naftagas LLC Novi Sad in-house data).

Interpreted units of the investigated Campanian–Maastrichtian carbonate-clastic complex of the Central and North Banat area

The limestones from destroyed reefs of the Middle-Late Campanian (unit 1)

The limestones of destroyed reefs of Middle-Late Campanian (unit 1) are determined in well KrMz-1, depth interval 3019–2939 m. This unit is in tectonic contact with Albian–Cenomanian deep-water clastites, which have been drilled in its basement, and underlies the following unit of this complex (Fig. 2).

The unit consists of sandy biosparites and biosparudites (Grainstone and Rudstone microfacies) and microconglomeratic calcareous breccias. Fossil content in limestones is represented by very small detritus of shallow-water fossil: rudists (inner lamellar radiolitids layer, hippuritids fragments) and other bivalve shells, serpulid tube-worms and calcareous algae Coralinales. The age of unit 1 is indicated by the fact that the studied sediments in well section conformably underlie the next unit 2, the age of which was determined as Middle to Late Campanian, based on foraminiferal data. These limestones with reef-fossil detritus were formed from redeposited rudist reefs, transported into deeper depositional environments.

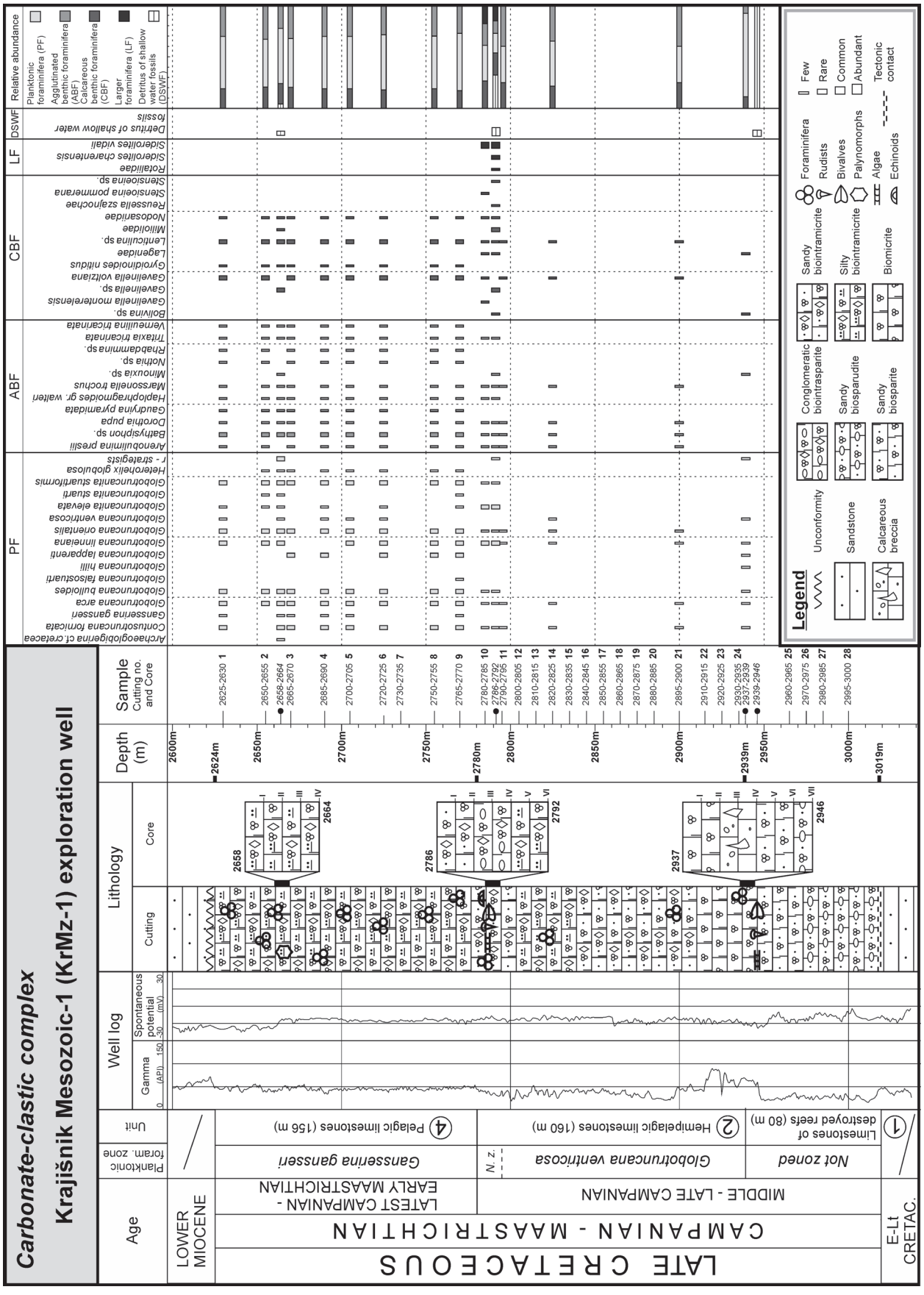

Fig. 2. Stratigraphic column of the Krajišnik Mesozoic-1 (KrMz-1) well with distribution and relative abundance of foraminifera and shallow-water fossils detritus.

The hemipelagic limestones of the Middle-Late Campanian and Late Campanian (unit 2)

The hemipelagic limestones of the Middle-Late Campanian and Late Campanian (unit 2) have also been determined in the well KrMz-1, depth interval 2939–2780 m (Fig. 2). Sediments of this unit conformably overlie unit 1 and underlie unit 4 of the carbonate-clastic complex.

These sediments are represented by light-grey to dark-grey slightly sandy biointramicrites and biomicrites (Mudstone-Wackstone microfacies), interchanging with silty biointramicrites (Wackstone microfacies). In the higher parts of the unit (interval 2792–2780 m) these limestones contain centimetre- to decimetre-sized fragments of conglomeratic biointrasparites (Grainstone-Rudstone microfacies). Based on the determined globotruncanid association, in biointramicrite and biomicrite limestones of this unit in interval 2939–2792 m Globotruncana ventricosa Interval Zone (Middle-Late Campanian) was recognized. The Late Campanian age of the sandy and silty biointramicrites and conglomeratic biointrasparites of the higher part of unit 2 (interval 2792–2780 m), was based on the entire microfossil assemblage or selected taxa, among which a special biostratigraphical value is given to the globotruncanid species *Globotruncanita elevata* and larger benthic foraminifera species *Siderolites vidali* and *S. harentensis*.

The coarse-grained clastites and limestones of destroyed reefs from the Late Campanian (unit 3)

The coarse-grained clastites and limestones of destroyed reefs from the Late Campanian (unit 3) are determined in the well Sa-1, depth interval 2415–2349 m (Fig. 3). Sediments of this unit are in tectonic contact with Proterozoic–Palaeozoic mylonite metamorphites of the Tisza Mega-unit.

The lower part of unit 3 consists of coarse-grained clastites (interval 2415–2380 m), represented by interbedding of subarkoses and siltstones with conglomeratic arkose. Presence of microfauna was not registered in the studied coarse-grained clastites, but a Late Cretaceous palynomorph association (angiosperms from the *Normapolles* group) was identified. The studied sediments most probably correspond to the Upper Campanian, for in the well section, they underlie the limestones, the age of which was determined as Upper Campanian, according to foraminiferal data. The upper part of unit 3 consists of limestones from destroyed reefs (depth interval 2380–2349 m). These are light-grey biosparites to sandy biosparites (Grainstone-Packstone microfacies) and dark-grey biomicrites (Packstone-Floatstone microfacies). The Late Campanian age of the upper part of unit 3 was determined based on larger benthic foraminifera species.

The presence of Late Campanian alodapic limestones in deep-water complex, with reef-fossil detritus, larger calcareous benthic foraminifera of deeper parts of the euphotic zone, as well as typical deep-water agglutinated benthic foraminifera, is explained by transportation of material from shallow-water environments into deeper parts of the basin.

The pelagic limestones from the Latest Campanian–Early Maastrichtian (unit 4)

The pelagic limestones from the Latest Campanian–Early Maastrichtian were distinguished as unit 4, determined in well KrMz-1, depth interval 2780–2624 m (Fig. 2). Sediments of this unit conformably overlie the deposits of the older unit 2.

Unit 4 consists of silty biointramicrites (Wackestone microfacies), containing numerous fault mirrors. The Gansserina gansseri Interval Zone (Latest Campanian–Early Maastrichtian) was recognized in the studied pelagic limestones on the basis of globotruncanids. The Campanian–Maastrichtian age of limestone was also confirmed based on the identified palynomorph association, represented by a rich association of fern spores and angiosperms belonging to the *Normapolles* group as well as remains of marine phytoplankton (algae Dinoflagellata).

The pelagic laminated limestones from the Early Maastrichtian (unit 5)

The pelagic laminated limestones from the Early Maastrichtian have been determined in well Mdj-3, depth interval 1738.1–1732 m (Fig. 4). The basement to the sediments of this unit is unknown, for exploration drilling was terminated in these deposits.

This unit is represented by laminar interbedding of grey-green biomicrites and sandy limestones with grey marly siltstones. According to Čanović & Kemenci (1988), these sediments were defined as a specific type of pelagic limestone, corresponding to Late Maastrichtian. On the basis of the newer micropalaeontological and biostratigraphical studies, Gansserina gansseri Interval Zone was recognized in sediments of this unit, most likely the uppermost part of this zone, belonging to the Early Maastrichtian.

Interpreted units of investigated Campanian–Maastrichtian complex containing ophiolites intercalated with hemipelagic and pelagic sediments of the Southern Bačka area

The hemipelagic carbonates and clastites from the Late Campanian with basic volcanites and their tuffs (unit I)

Unit I is determined in well Srs-1, depth interval 2105–1826 m (Fig. 5). The rocks which belong to this unit are in tectonic contact with Proterozoic-Palaeozoic metamorphites of the Tisza Mega-unit.

The sediments in the lower and middle part of unit (interval 2105–1905 m) are represented by dark-grey and whitish coarse-grained calcareous sandstones with sandy limestone boulders, fine-grained sandstones, laminated silty-clayey marls and light-grey biointrasparites (Packstone microfacies). The upper part of the unit (interval 1905–1826 m) consists of

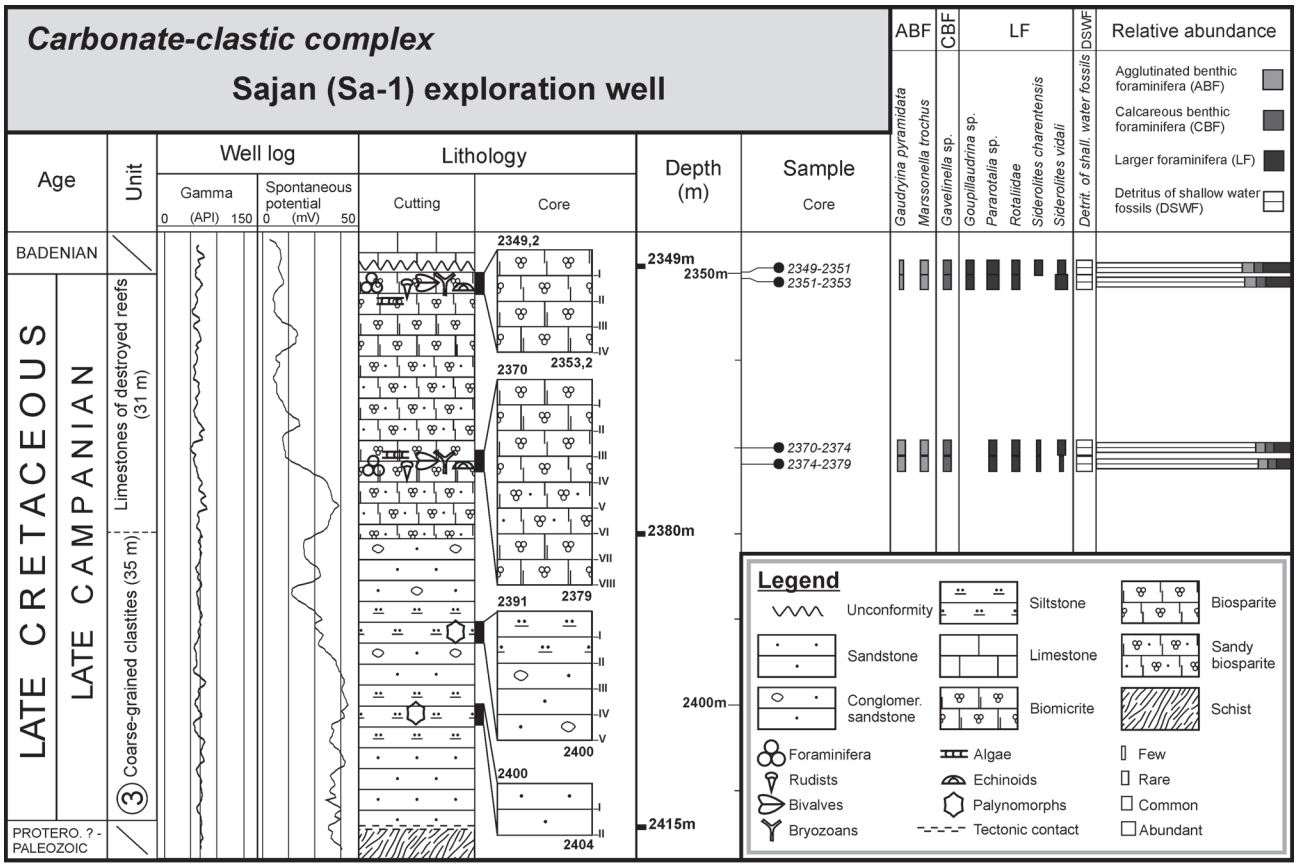

Fig. 3. Stratigraphic column of the Sajan-1 (Sa-1) well with distribution and relative abundance of foraminifera and shallow-water fossils detritus.

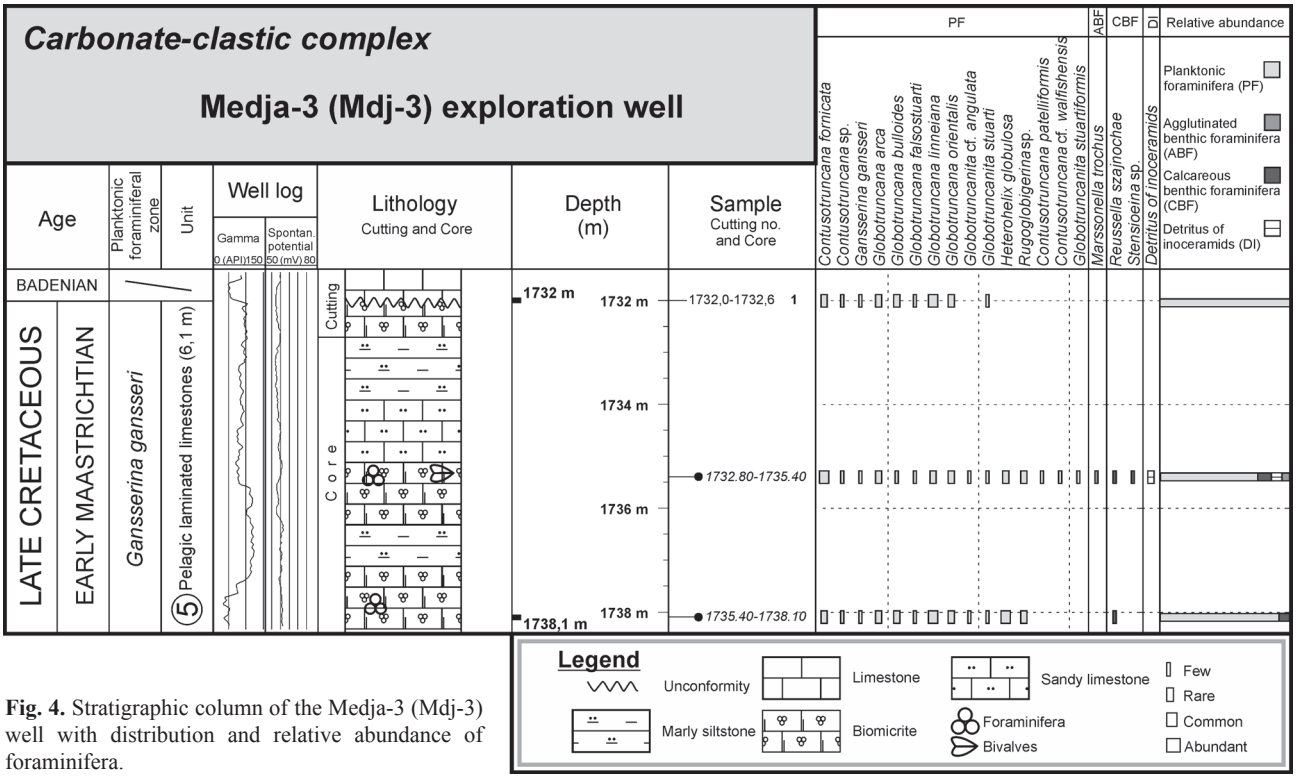

Fig. 4. Stratigraphic column of the Medja-3 (Mdj-3) well with distribution and relative abundance of foraminifera.

dark-grey laminated sandy marls and sandstones, while the highest levels consist of ferrous-calcareous sandstones and sandy limestones. The main feature of this unit is that the sediments in the lower and middle part alternate with basic volcanites (diabases, spilites, pyroclastic breccia) and derived tuffs (synchronous multi-phase submarine ultrabasic volcanism). The determined microfossil assemblage or biostratigraphically significant globotruncanid species and larger benthic foraminifera species indicate that the studied unit corresponds to the Late Campanian. Nannozones were also recognized in the sediments of the upper part of the unit CC21a–CC22.

The pyroclastic breccia interbedded with pelagic limestones from the Latest Campanian-Early Maastrichtian (unit II)

Unit II is determined in well Vbg-1, depth interval 2500–1885 m (Fig. 6). The well was terminated in pyroclastic breccias, so that their basement in this well is unknown.

The pyroclastic breccias are composed of millimetre- to centimetre-sized angular fragments of diabases, spilites, rhyolites and vitroclastic tuffs. Rock fragments are usually melded together, less frequently cemented with tuffitic matrix (devitrified, zeolitized, volcanic glass). In a number of separate intervals (2100–2059 m, 1995–1975 m and 1905–1885 m) pyroclastic breccias are intrastratified with intercalations of brownish-red and grey-green pelagic biomicrites (Wackstone microfacies). The Gansserina gansseri Interval Zone was recognized in the studied biomicrites on the basis of the identified globotruncanid association.

Biostratigraphical comments

In the studied sediments of some units, two planktonic foraminiferal zones have been recognized, based on the first and last occurrence of the index taxa: Globotruncana ventricosa Interval Zone and Gansserina gansseri Interval Zone. The biostratigraphy of the Late Campanian units is based on entire microfossil assemblages, which are grouped in three types of foraminiferal assemblage.

The biostratigraphical distributions of selected planktonic and benthic foraminiferal species from the studied area and other Tethyan regions are shown in Fig. 7. In this paper, the zonal scheme of planktonic foraminifera according to Premoli Silva & Verga (2004) was adopted, for it represents the synthesis of numerous zone schemes, which were distinguished for different tropical-subtropical palaeogeographic areas.

Notable considerations on the differences in chronostratigraphic position of a certain zonal species of planktonic foraminifera were given in the paper Kędzierski et al. (2015). Emphasizing that far more precise biostratigraphic data could be obtained by integrating the results of a number of different methods, such as palaeomagnetostratigraphy and biostratigraphy based on different fossil groups, the authors indicated the existance of the problem of diachronicity of the first and the last occurrence of zonal species, caused by palaeoenvironmental conditions in different bioprovinces.

Globotruncana ventricosa Interval Zone

Age: Middle to Late Campanian (Premoli Silva & Verga 2004).

Distribution: KrMz-1 well — hemipelagic limestones of Middle-Late Campanian (lower and middle part of unit 2), depth interval 2939–2792 m (Fig. 2).

Assemblage: The lower boundary of Globotruncana ventricosa Zone corresponds to the first occurrence of the zonal marker, while the upper boundary is assumed below the first occurrence of the species *Gansserina gansseri* and larger benthic foraminifera species *Siderolites vidali* and *S. charentensis* (Fig. 2).

The planktonic foraminifera are most abundantly represented by: *Contusotruncana fornicata*, *Globotruncana arca*, *G. bulloides*, *G. hilli*, *G. lapparenti*, *G. linneiana* and *G. orientalis*. Small, simple morphotypes of planktonic foraminifera (*r*-strategists) are also present, represented by hedbergellids and biserial heterohelicids. The zonal species *Globotruncana ventricosa* is shown in Figures 8 and 9. The identified planktonic foraminifera are dominated by keeled forms of complex (K-strategists) morphotypes, as specialized forms of planktonic foraminifera. They are typical for oligotrophic environmental conditions and indicate good stratification of the water column in tropical and subtropical environments (Petrizzo 2002). These keeled planktonic foraminifera represent the bathypelagic group (Caron & Homewood 1983; Gasiński et al. 1999).

Among benthic foraminifera, agglutinated taxa (*Arenobulimina preslii*, *Bathysiphon* sp., *Dorothia pupa*, *Marssonella trochus* and *Minouxia* sp.) and calcareous taxa (*Bolivina* sp., *Gavelinella voltziana*, *Lenticulina* sp. and Lagenidae) were identified. The determined forms of agglutinated benthic foraminifera belong to deep-water forms and include mixed types (upper and middle to lower bathyal zone). Outer shelf to upper bathyal environments are characterized by specimens of *Gavelinella* (Hradecká et al. 1999). On the other hand, specimens of lagenids, and specimens of *Bolivina* and *Lenticulina* are associated with inner, middle or outer shelf to bathyal environments (Olsson & Nyong 1984; Murray 1991). These are rarely present in the studied foraminifera associations.

Remarks: The Globotruncana ventricosa Zone, recognized in the studied area, corresponds to the zone of the same range of Premoli Silva & Verga (2004). Based on regional and global comparative study of planktonic foraminifera, Petrizzo et al. (2011) indicated the variations of the first occurrence of *G. ventricosa* across latitudes and the difficulties in using this species as a zonal marker in tropical and subtropical low latitude areas. Instead of *G. ventricosa* species, the authors pointed out that first occurrence of species *Contusotruncana plummerae* is a reliable bioevent and singled out this species as a zonal marker in tropical and subtropical areas.

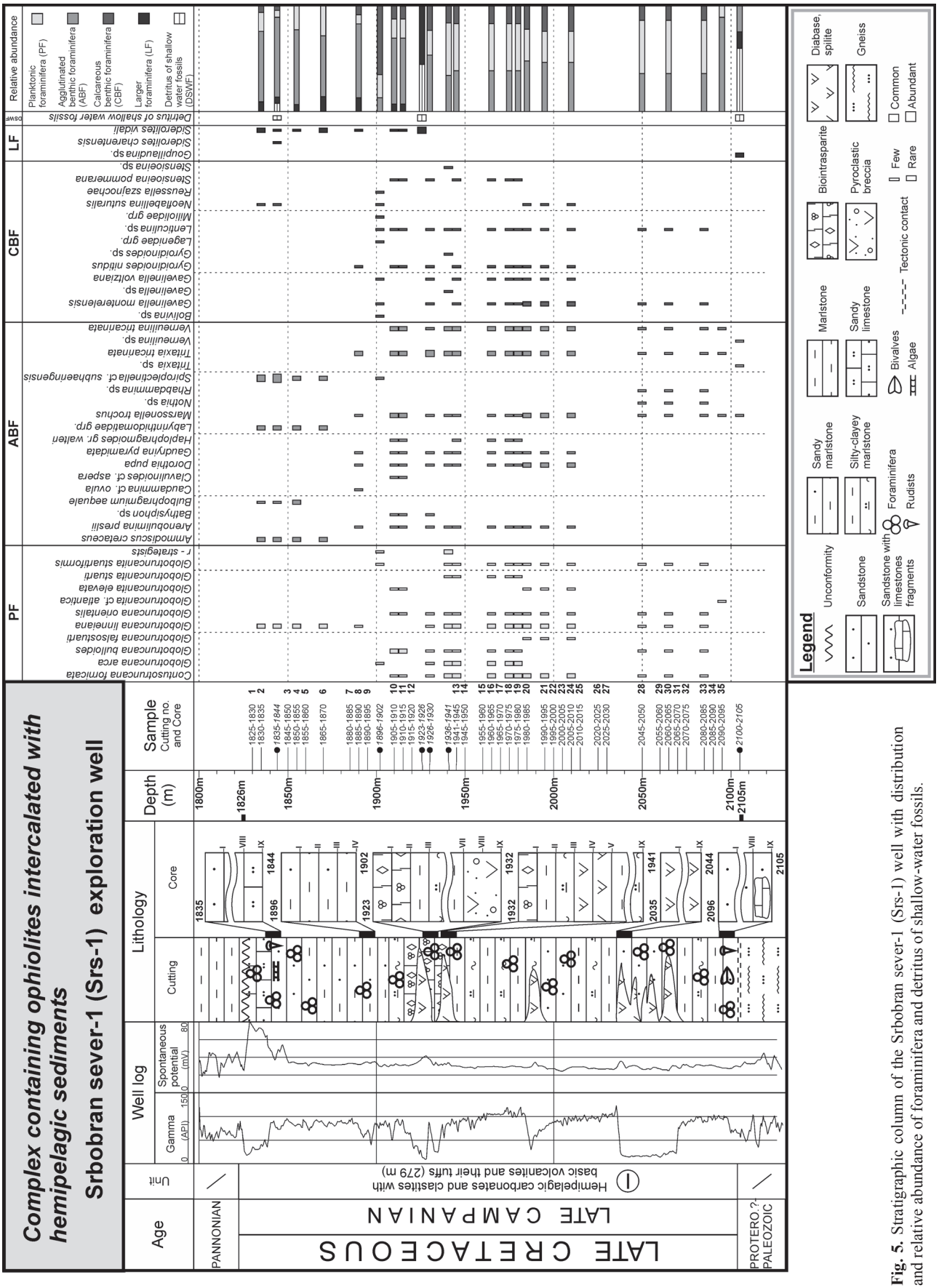

Fig. 5. Stratigraphic column of the Srbobran sever-1 (Srs-1) well with distribution and relative abundance of foraminifera and detritus of shallow-water fossils.

The Contusotruncana plummerae Zone is determined as the stratigraphic interval between the lowest occurrence of this species and the lowest occurrence of species *R. calcarata*. Ogg & Hinnov (2012), while determining the age of epoch/series and age/stage boundaries of the Cretaceous, among other things, stated the planktonic foraminiferal biozones, which were determined as composite according to numerous authors. The Contusotruncana plummerae Zone was distinguished in the Middle-Upper Campanian (Fig. 7).

Types of foraminiferal assemblage from the Late Campanian

The first foraminiferal assemblage in the Late Campanian sediments characterizes the higher part of unit 2

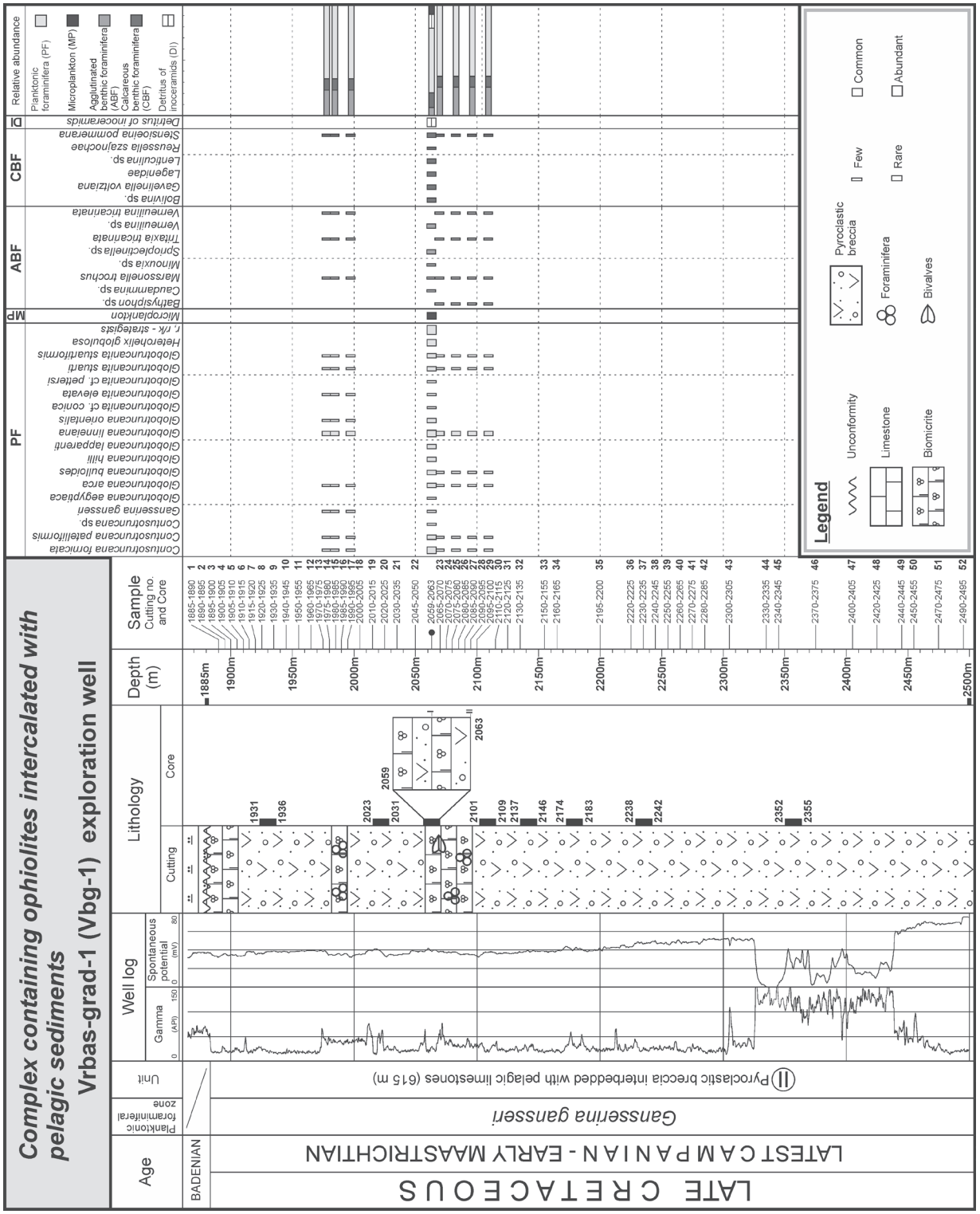

Fig. 6. Stratigraphic column of the Vrbas grad-1 (Vbg-1) well with distribution and relative abundance of foraminifera, microplankton and detritus of inoceramids.

in the well KrMz-1, interval 2792–2780 m. Foraminiferal association comprises planktonic, calcareous and agglutinated benthic foraminifera, among which larger benthic foraminifera forms predominate. Among other fossil remnants, the presence of shallow-water fossil detritus is notable (Fig. 2). The keeled planktonic foraminifera as well as most of the benthic foraminifera indicate a deep-water character of the studied unit. Besides them, shallow-water foraminifera, represented by specimens of *Siderolites* have also been identified in the studied unit. These are characteristic for deeper parts of the euphotic zone in open shelves (Gušić & Jelaska 1990). Very rich and diverse biodetritus originates mainly from rudists (radiolitids, hippuritids), ostreids and other bivalve shells, while echinoid spines, serpulid tube-worms and calcareous

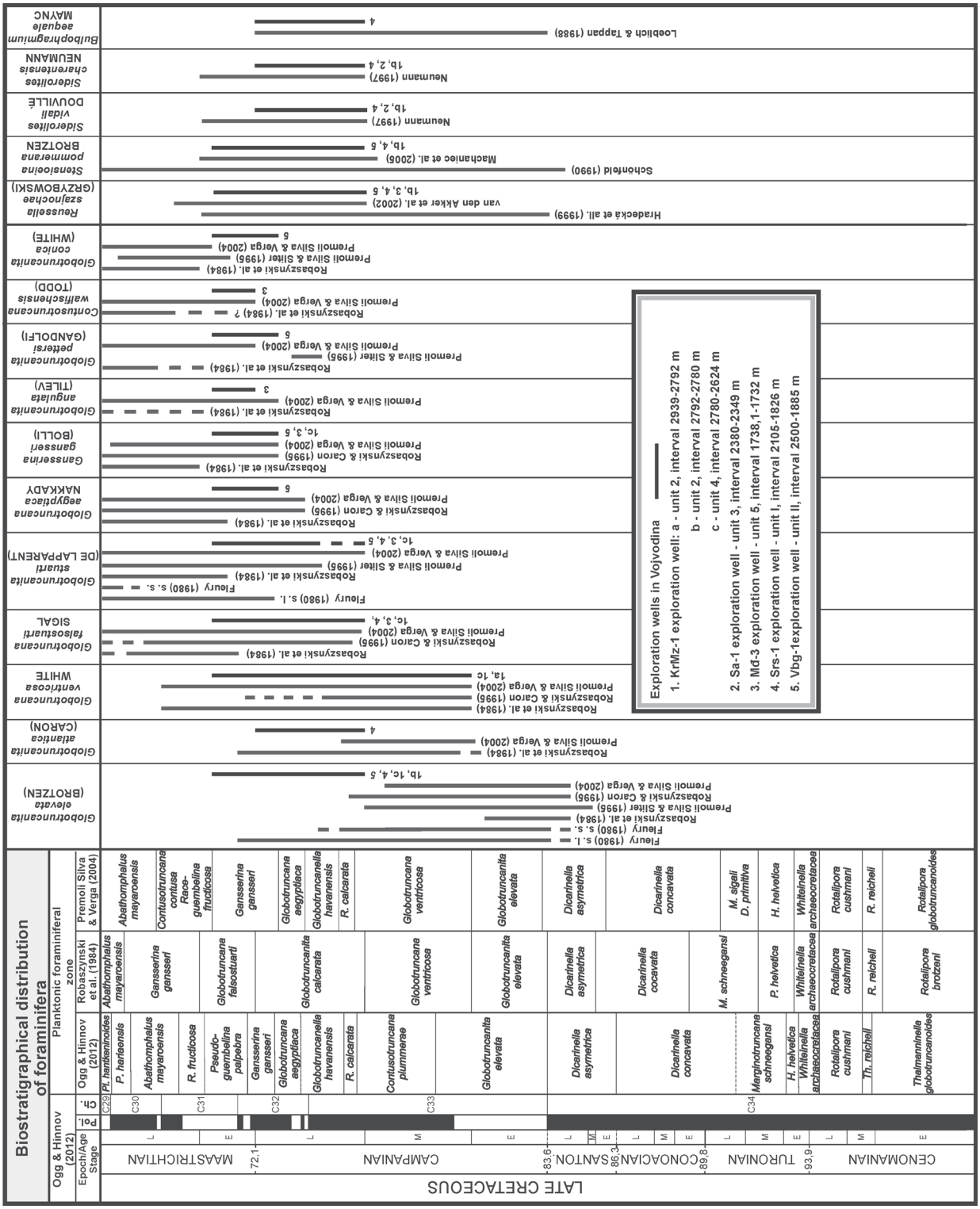

Fig. 7. Correlation scheme of biostratigraphical distribution of selected planktonic and benthic foraminifera species from studied area and other Tethyan regions.

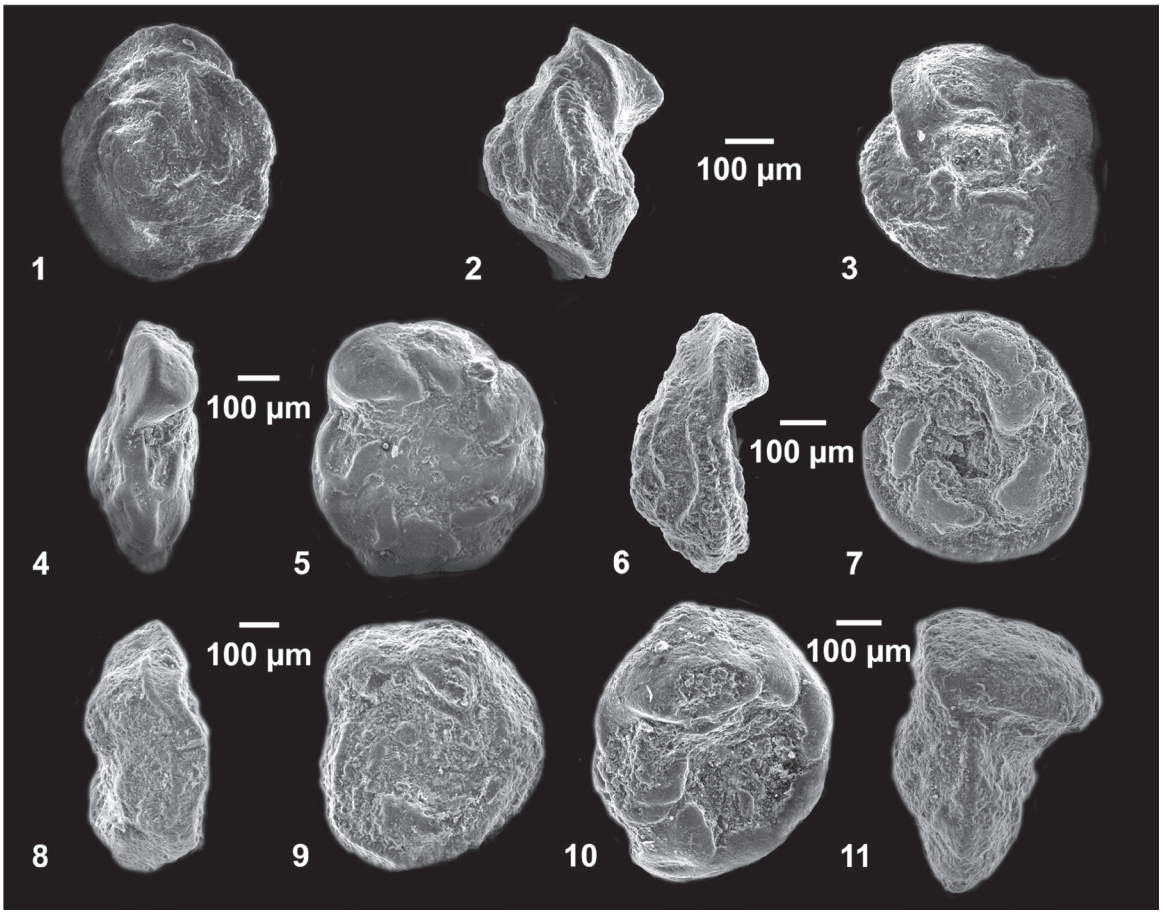

Fig. 8. SEM photomicrographs of the selected planktonic foraminifera from the third foraminiferal assemblage of Late Campanian rocks (1–7), Globotruncana ventricosa Zone (8–9) and Gansserina gansseri Zone (10–11). **1–3** — *Globotruncanita* cf. *atlantica* Caron, Srs-1, cutting 2095–2090 m; **4–5** — *Globotruncana falsostuarti* Sigal, Srs-1, cutting 1985–1980 m; **6–7** — *Contusotruncana fornicata* (Plummer), Srs-1, cutting 1965–1960 m; **8–9** — *Globotruncana ventricosa* White, KrMz-1, cutting 2825–2820 m and **10–11** — *Globotruncanita elevata* (Brotzen), Vbg-1, cutting 1985–1980 m.

algae Coralinales and Dasycladales detritus are also present. Their presence in the studied sediments indicates the existence of reef environments during the Late Campanian.

For determination of the Late Campanian age of the studied sediments, globotruncanids bear a special biostratigraphical value, above all the species *Globotruncanita elevata*, larger benthic foraminifera species *Siderolites vidali* and *S. charentensis*, as well as some other benthic foraminifera species, such as *Reussella szajnochae* and *Stensioeina pommerana* (Fig. 7).

The second foraminiferal assemblage in the Late Campanian sediments is characteristic for the upper part of unit 3 in the well Sa-1, interval 2380–2349 m (Fig. 3). Planktonic foraminifera species are not present in the foraminiferal association, while larger benthic foraminifera taxa dominate among the benthic foraminifera. Nevertheless, shallow-water fossil detritus is the most frequent within the microfossil association. Larger benthic foraminifer taxa consist of: *Goupillaudina* sp., *Pararotalia* sp., *Siderolites charentensis*, *Siderolites vidali*, as well as rotaliids. Other identified benthic foraminifera are *Gaudryina pyramidata*, *Marssonella trochus* (agglutinated benthic foraminifera) and *Gavelinella* sp. (calcareous benthic foraminifera), which are characteristic for outer shelf to upper bathyal environments. Shallow-water fossil detritus comprises: bivalves (rudist fragments – radiolitids, hippuritids predominate), echinoid spines, bryozoans and calcareous algae Coralinales and Dasycladales. Some species of benthic foraminifera from the second foraminiferal assemblage are shown in Figure 10.

The third foraminiferal assemblage in Late Campanian rocks is identified in hemipelagic carbonates and clastites of the older unit I in the well Srs-1 (Fig. 5). The diversity of foraminiferal and other fossil assemblages and their relative abundance change within the studied unit according to lithological changes.

In coarse-grained calcareous sandstones in the lower part of the unit larger benthic foraminifera (*Goupillaudina* sp.) and deep-water agglutinated benthic foraminifera (*Marssonella trochus*, *Tritaxia* sp. and *Verneuilina* sp.) are seldom present. These sediments are characterized by detritus of different shallow-water fossils (fragments of inner lamellar layers with radiolitids and hippuritids shells, bryozoan fragments and

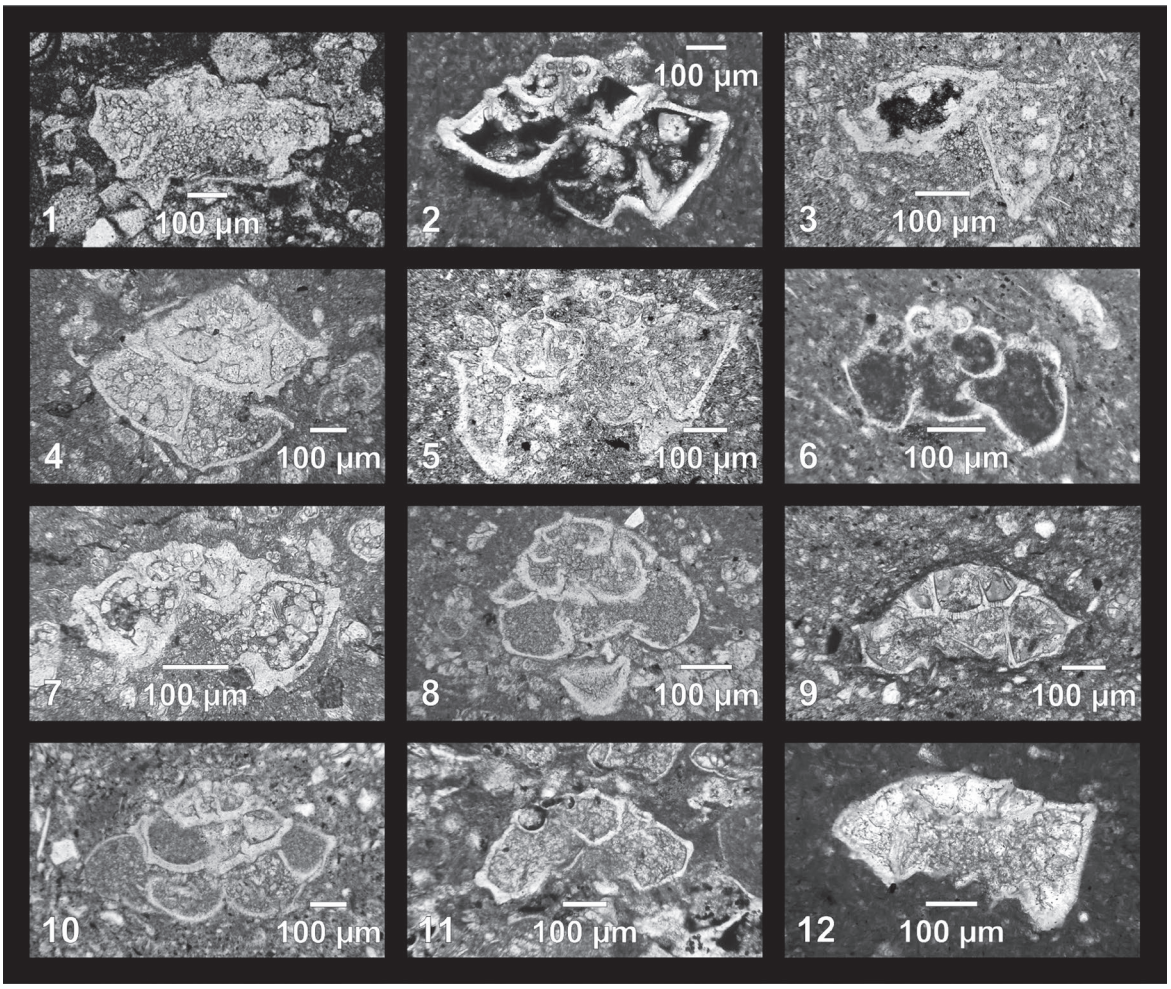

Fig. 9. Thin section photomicrographs of the selected planktonic foraminifera from Globotruncana ventricosa Zone (1) and Gansserina gansseri Zone (2–12). **1** — *Globotruncana ventricosa* White, KrMz-1, core 2946–2937 m (I m); **2** — *Globotruncanita stuarti* (de Lapparent), KrMz-1, core 2664–2658 m (IV m); **3** — *Globotruncanita* cf. *pettersi* (Brotzen), Vbg-1, core 2063–2059 m (II/15 m); **4** — *Globotruncanita* cf. *conica* (White), Vbg-1, core 2063–2059 m (II/15 m); **5** — *Globotruncanita elevata* (Brotzen), Vbg-1, core 2063–2059 m (II m); **6** — *Gansserina gansseri* (Bolli), Vbg-1, core 2063–2059 m (I/10 m); **7** — *Globotruncana aegyptiaca* Nakkady, Vbg-1, core 2063–2059 m (I m); **8** — *Contusotruncana* cf. *walfischensis* (Todd), Mdj-3, core 1735,4–1732,8 m (II m); **9** — *Globotruncana arca* (Cushman), Mdj-3, core 1735,4–1732,8 m (II m); **10** — *Globotruncana falsostuarti* Sigal, Mdj-3, core 1735,4–1732,8 m (II m); **11** — *Contusotruncana patelliformis* (Gandolfi), Mdj-3, core 1735,4–1732,8 m (I m); **12** – *Globotruncanita* cf. *angulata* (Tilev), Mdj-3, core 1735,4–1732,8 m (I m).

fragments of calcareous algae), which were transported from shallower to deeper parts of the basin.

Planktonic and deep-water benthic foraminifera are present in the foraminiferal association of fine-grained sandstones and laminated silty-clayey marls of the lower and middle part of the unit (interval 2105–1905 m) (Fig. 5). Globotruncanids comprise: *Contusotruncana fornicata*, *Globotruncana arca*, *G. bulloides*, *G. falsostuarti*, *G. linneiana*, *G. orientalis*, *Globotruncanita* cf. *atlantica*, *Gl'ita elevata*, *Gl'ita stuarti* and *Gl'ita stuartiformis*. Apart from globotruncanids, the opportunistic (r-strategists) morphotypes (epipelagic group) are very seldom present. Agglutinated benthic foraminifera are represented by: *Arenobulimina preslii*, *Clavulinoides* cf. *aspera*, *Dorothia pupa*, *Gaudryina pyramidata*, *Haplophragmoides* gr. *walteri*, *Marssonella trochus*, *Tritaxia tricarinata*, *Verneuilina tricarinata* and simple tubular forms *Bathysiphon* sp., *Nothia* sp. and *Rhabdammina* sp. Most of these are characteristic for the upper bathyal zone, such as specimens of *Arenobulimina*, *Dorothia*, *Gaudryina*, *Marssonella* and *Verneuilina* (Olsson & Nyong 1984; Chacón et al. 2004). Some of them can also occur in lower bathyal environments, such as specimens of *Tritaxia* (Olsson & Nyong 1984), and some among the identified representatives of agglutinated foraminifera (*Bathysiphon*, *Clavulinoides*, *Dorothia*, *Gaudryina*, *Haplophragmoides*, *Marssonella*, *Rhabdammina*) are indicated as typical flysch-type foraminiferal microfauna or typical for oceanic (abyssal) environments (Kuhnt 1990; Kuhnt & Kaminski 1997). Deep-water calcareous benthic foraminifera consist of: *Gavelinella monterelensis*, *Gavelinella voltziana*, *Gyroidinoides nitidus*, *Lenticulina* sp., *Neoflabellina suturalis* and *Stensioeina pommerana*. On the other hand, biointrasparites in the middle

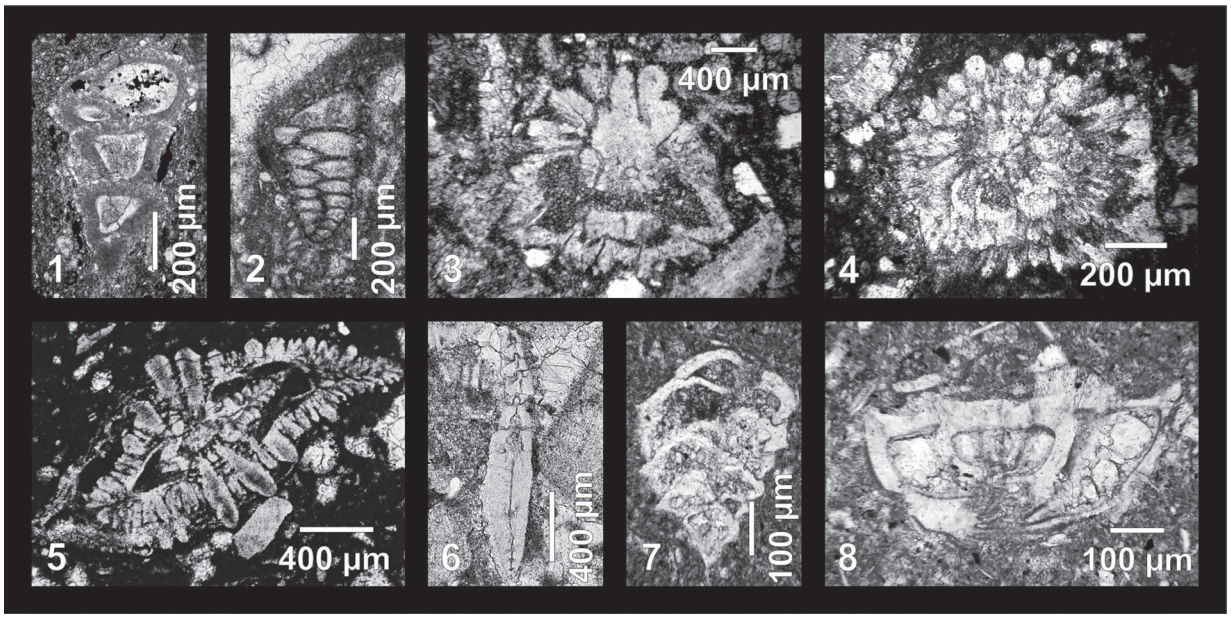

Fig. 10. Thin section photomicrographs of the selected benthic foraminifera from the second type foraminiferal assemblage of Late Campanian sediments (1–4), the third type foraminiferal assemblage of Late Campanian rocks (5–6) and Gansserina gansseri Zone (7–8). **1** — *Gaudryina* cf. *pyramidata* Cushman, Sa-1; core 2353,2–2349,2 m (III m); **2** — *Marssonella trochus* (Orbigny), Sa-1, core 2353,2–2349,2 m (II m); **3** — *Pararotalia* sp., Sa-1, core 2379–2370 m (VII m); **4** — *Siderolites charentensis*, Sa-1, core 2379–2370 m (I m); **5** — *Siderolites vidali* Douvillé, Srs-1, core 1844–1835 m (III/50 m); **6** — *Goupillaudina* sp., Srs-1, core 2105–2096 m (IX/100 m); **7** — *Reussella szajnochae* (Grzybowski), Vbg-1, core 2063–2059 m (II m); **8** — *Stensioeina pommerana* Brotzen, Vbg-1, core 2063–2059 m (II m).

part of the unit are characterized by the presence of *Siderolites vidali*.

Within the foraminiferal association in the laminated sandy marls and sandstones of the upper part of the unit (interval 1905–1826 m) deep-water agglutinated benthic foraminifera dominate. Calcareous benthic foraminifera taxa are also present, while the planktonic foraminifera are seldom present (Fig. 5). In the studied sediments, a rich association of calcareous nannoplankton was determined: *Arkhangelskiella cymbiformis* Vekshina, *Calculites obscurus* (Deflandre), *Eiffellithus eximius* (Stover), *Microrhabdulus decoratus* Deflandre, *Micula concava* (Strander), *Micula decussata* Vekshina, *Quadrum gothicum* (Deflandre) etc. The main feature of ferruginous-calcareous sandstones and sandy limestones of the uppermost part of the unit is the presence of larger agglutinated foraminifera *Bulbophragmium aequale* and forms which belong to the family Labyrinthidomatidae (Fig. 5).

Globotruncanid species *Globotruncanita elevata*, *Gl'ita* cf. *atlantica*, *Gl'ita stuarti* and *Globotruncana falsostuarti* and larger benthic foraminifera species *Bulbophragmium aequale*, *Siderolites charentensis* and *S. vidali* had a great bio-stratigraphic value in determination of the Late Campanian age of the studied sediments (Fig. 7). Within certain levels of the upper part of the unit (samples of core 1902–1896 m), CC21a–CC22 Nannozones were recognized. The selected planktonic and benthic foraminifera from this foraminiferal assemblage of Late Campanian rocks are shown in Figures 8, 10 and 11.

Gansserina gansseri Interval Zone

Age: Latest Campanian–Early Maastrichtian (Premoli Silva & Verga 2004).

Distribution: KrMz-1 well — unit 4, depth interval 2780–2624 m (Fig. 2), Mdj-3 well — unit 5, depth interval 1738,1–1732 m (Fig. 4) and Vbg-1 well — unit II, depth interval 2500–1885 m (Fig. 6).

Assemblage: In the studied area this zone corresponds to sediment units in which the species *Gansserina gansseri* is constantly present (Figs. 2, 4 and 6). Planktonic foraminifera are represented by: *Archaeoglobigerina* cf. *cretacea*, *Contusotruncana fornicata*, *C. patelliformis*, *C.* cf. *walfischensis*, *Globotruncana aegyptiaca*, *G. arca*, *G. bulloides*, *G. falsostuarti*, *G. hilli*, *G. lapparenti*, *G. linneiana*, *G. orientalis*, *G. ventricosa*, *Globotruncanita* cf. *angulata*, *Gl'ita* cf. *conica*, *Gl'ita elevata*, *Gl'ita* cf. *pettersi*, *Gl'ita stuarti*, *Gl'ita stuartiformis* and *Heterohelix globulosa*. Besides heterohelicids and archeoglobigerinids, other r-strategists as well as r/K intermediate morphotype group are present: hedbergelids, globigerinelloids and rugoglobigerinids. Complex morphotypes (K-strategists) represent the bathypelagic group. According to Abramovich et al. (2003), most of them belong to subsurface or thermocline (even subthermocline) groups of foraminifera. The more K-selected of the r/K intermediates are represented by trochospiral forms with hemispheric small chambers and one peripheral keel, the example of which is zonal species *Gansserina gansseri*. Representatives of trochospiral genera *Archaeoglobigerina*

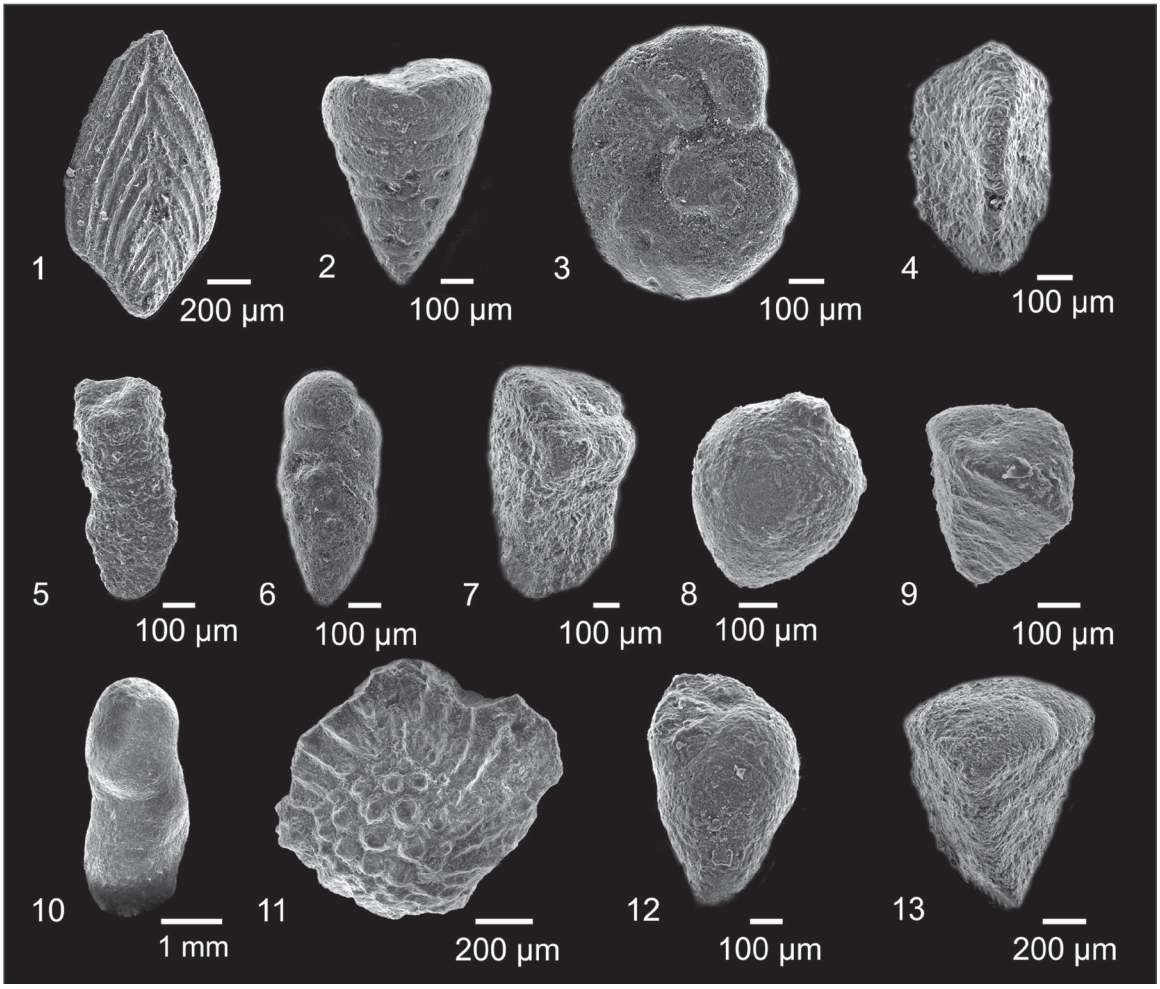

Fig. 11. SEM photomicrographs of the selected benthic foraminifera from the third type foraminiferal assemblage of Late Campanian rocks (1–11) and Gansserina gansseri Zone (12–13). **1** — *Neoflabellina suturalis* (Cushman), Srs-1, cutting 1995–1990 m; **2** — *Marssonella trochus* (Orbigny), Srs-1, cutting 1985–1980 m; **3** — *Gavelinella voltziana* (d'Orbigny), Srs-1, cutting 1980–1975 m; **4** — *Tritaxia tricarinata* (Reuss), Srs-1, cutting 1965–1960 m; **5** — *Clavulinoides* cf. *aspera* (Cushman), Srs-1, cutting 1915–1910 m; **6** — *Dorothia pupa* (Reuss), Srs-1, cutting 1915–1910 m; **7** — *Gaudryina pyramidata* Cushman, Srs-1, cutting 1915–1910 m; **8** — *Caudammina* cf. *ovula* (Grzybowski), Srs-1, cutting 1890–1885 m; **9** — *Spiroplectinella* cf. *subhaeringensis* (Grzybowski), Srs-1, core 1844–1835 m (II m); **10** — *Bulbophragmium aequale* Maync, Srs-1, cutting 1855–1850 m;**11** — *Siderolites vidali* Douvillé, Srs-1, cutting 1835–1830 m; **12** – *Arenobulimina preslii* (Reuss), KrMz-1, cutting 2770–2765 m; **13** — *Verneuilina tricarinata* d'Orbigny, KrMz-1, cutting 2755–2750 m.

and *Rugoglobigerina* and planspiral genus *Globigerinelloides* are some of the more r-selected of the r/K intermediate morphotype groups. Zonal marker *Gansserina gansseri* is distinguished as a thermocline group foraminifera in the Lower Maastrichtian, while unkeeled intermediate morphotypes belong to the subsurface water foraminifera group (Abramovich et al. 2003). The species *Heterohelix globulosa*, as an opportunistic taxon (r-strategists), also belongs to the thermocline group of foraminifera.

Agglutinated benthic foraminifera have a deep-water character (bathyal environments) and consist of: *Arenobulimina preslii*, *Bathysiphon* sp., *Caudammina* cf. *ovula*, *Dorothia pupa*, *Gaudryina pyramidata*, *Haplophragmoides* gr. *walteri*, *Marssonella trochus*, *Minouxia* sp., *Nothia* sp., *Rhabdammina* sp., *Spiroplectinella* sp., *Tritaxia tricarinata* and *Verneuilina tricarinata*. Calcareous benthic foraminifera taxa are represented by mixed forms: *Bolivina* sp., *Gavelinella monterelensis*, *Gavelinella voltziana*, *Gyroidinoides nitidus*, *Lenticulina sp*., *Reussella szajnochae*, *Stensioeina pommerana* and forms from families Lagenidae, Miliolidae and Nodosariidae. Other fossil remnants are represented by microplankton (pithonellae and other calcisphaerae), which are very rare in the studied pelagic units, and inoceramid detritus.

Biostratigraphical subdivision within a zone could be done only for the sediments of unit 5 from Mdj-3 well, based on the presence of *Contusotruncana* cf. *walfischensis* species and greater presence of rugoglobigerinids, characteristic of the Maastrichtian sediments (Fig. 4). Considering all of this, the studied sediments most probably correspond to the upper part of the Gansserina gansseri Zone, of Early Maastrichtian age. The selected planktonic and benthic foraminifera from the Gansserina gansseri Zone are presented in Figs. 8–11.

Remarks: The Gansserina gansseri Interval Zone, recognized in the studied area, corresponds to the zone of the same stratigraphic range of Premoli Silva & Verga (2004).

According to previous zonal schemes of planktonic foraminifera the Gansserina gansseri Interval Zone was attributed to the middle part of the Maastrichtian (Fleury 1980; Robaszynski et al. 1984) or Late Maastrichtian (Caron 1985). Later, after updating biozone boundaries according to the results of palaeomagnetostratigraphic measurements, the Gansserina gansseri Zone corresponded to the Latest Campanian–Early Maastrichtian (Premoli Silva & Sliter 1995; Robaszynski & Caron 1995; Premoli Silva & Verga 2004). Ogg & Hinnov (2012) accepted the chrono-stratigraphical position of this zone in the Latest Campanian–Earliest Maastrichtian (Fig. 7).

Discussion

Micropalaeontological, biostratigraphical, palaeo-ecological, as well as lithological studies of both complexes from the wells in Vojvodina, indicated the development of a deep trough during the Campanian–Maastrichtian age. The studied complexes have a deep-water character and were most probably formed in ocean island arc and trough zones. Information on the deep-water character of the studied units was obtained on the basis of relative abundance and diversity of identified planktonic foraminifera (complex morphotypes and the more K-selected of the r/K intermediates morphotypes) and deep-water calcareous and agglutinated benthic foraminifera. The carbonate-clastic complex in Banat is characterized by development of five units, which were determined in three wells (Figs. 2–4). Their superposition from the older towards the younger units indicates the process of trough formation, deepening and creation of pre-conditions for development of flysch formations. The other complex characterized by ophiolites intercalating with hemipelagic and pelagic deposits, was determined in two wells in South Bačka and consists of two units (Figs. 5 and 6). It should be noted that the studied Campanian–Maastrichtian complexes are in tectonic contact with the older, deeper formations, such as Proterozoic-Palaeozoic granite-metamorphic complex of the Tisza Mega-unit (wells Sa-1 and Srs-1) or the Albian–Cenomanian deep-water formation of the Vardar Zone (well KrMz-1). Up to now, the history of the trough's development and precise timing of its formation have not been clearly defined.

Study of the palaeo-ecological characteristics of foraminifera, as well as the lithological characteristics of the units of both complexes, indicated that during the Campanian–Maastrichtian, concurrently with deep trough development, shallow-water areas where reefs were developed, also existed. When it comes to the carbonate-clastic complex in Banat, it is indicated by the following determined units (Figs. 2 and 3): limestones of destroyed reefs of Middle-Late Campanian age (KrMz-1 well) — unit 1, hemipelagic limestones of Middle-Late and Late Campanian age (KrMz-1 well) — unit 2 and coarse-grained clastites and limestones from destroyed reefs of Late Campanian age (Sa-1 well) — unit 3. When it comes to the other complex, the existence of reef environments during the Late Campanian is indicated by the development of the older unit I from Srs-1 well (Fig. 5). These units comprise sandy biosparites, biosparudites, biomicrites, sandy and silty biointramicrites with fragments of conglomeratic biointrasparites, microconglomeratic calcareous breccias, coarse-grained clastites, calcareous sandstones with fragments of sandy rudist limestones, which occur within deep-marine carbonate-clastic sediments. The sediments of these units, except for planktonic and deep-water benthic foraminifera, are characterized by the presence of larger benthic foraminifera (specimens of *Siderolites*, *Pararotalia* and *Goupillaudina*) as well as other shallow-water fossils (rudist detritus and other bivalve shells, serpulid tube-worms, echinoids, calcareous algae and bryozoans), which indicate the existence of reef environments in island arc zones during the Middle and Late Campanian. The presence of limestones and other sediments with reef-fossil detritus in these deep-water complexes can be associated with tectonically unstable conditions in the areas of their generation, when the transfer of shallow-water rock and fossil material from shallow-water to deep-water depositional environments occurred by means of gravitational or other transport mechanisms.

In the well Sa-1 (Fig. 3) Proterozoic-Palaeozoic metamorphites of the Tisza Mega-unit were drilled in the basement of the studied deep-water carbonate-clastic complex and the two units are in tectonic contact. This indicates the presence of large thrust systems, formed during the Palaeogene.

The studied complex, characterized by Campanian–Maastrichtian ophiolites, intercalated with hemipelagic and pelagic sediments from the wells Srs-1 and Vbg-1 (Figs. 5 and 6), can be very well correlated with similar formations belonging to the Sava Zone. By its analogous palaeontological and lithological characteristics, the studied complex of South Bačka shows a connection with the prospects in North-West Bosnia (northern parts of Mt. Kozara — Karamata et al. 2000, 2005) and East Croatia (Mt. Požeška Gora — Pamić & Šparica 1983). In the well Srs-1 hemipelagic carbonates and clastites in some levels interbed with diabases, spilites, their tuffs and pyroclastic breccias, while in the well Vbg-1 the red biomicrite interbeds were determined in pyroclastic breccias. On the northern slopes of Mt. Kozara (surroundings of Gornji Podgradci village) and Mt. Požeška Gora (locality Nakop stream) sediments that alternate with Late Cretaceous basalts (pillow basalts and tuffs) are represented by red and grey pelagic biomicrites and sandy limestones. Very rich globotruncanid associations are characteristic of pelagic limestones.

The Late Campanian–Early Maastrichtian age of the ophiolites from the wells of South Bačka is documented on the basis of micropalaeontological studies of the sediments which interbed with basic volcanites and their tuffs. Documenting the Late Cretaceous age of the ophiolites from South Bačka

wells indicated that the dislocation of the blocks corresponding to the Sava Zone extended more towards the north (Fig. 1), compared to previous knowledge of their position (Schmid et al. 2008). It is important to note that below the Campanian–Maastrichtian ophiolites in the wells of South Bačka the Tisza Mega-unit metamorphites (well Srs-1) were drilled, as is the case with the Campanian–Maastrichtian carbonate-clastic complex in the well Sa-1 in North Banat. Thus, in this case the presence of remains of the large thrust systems in Late Cretaceous formations in the south-eastern part of the Pannonian Basin can be assumed as well.

Conclusion

Both studied complexes have a deep-water character and were most probably formed in ocean island arc and trough zones. Significant information on the deep-water character of studied units was obtained on the basis of relative abundance and diversity of identified planktonic and benthic foraminifera and analysis of their palaeobathymetrics.

The carbonate-clastic complex of Banat is characterized by five units: limestones from destroyed reefs of Middle-Late Campanian age (KrMz-1 well) — unit 1, hemipelagic limestones from the Middle-Late and Late Campanian (KrMz-1 well) — unit 2, coarse-grained clastites and limestones of destroyed reefs from the Late Campanian (Sa-1 well) — unit 3, pelagic limestones of the Latest Campanian–Early Maastrichtian (KrMz-1 well) — unit 4 and pelagic laminated limestones of the Early Maastrichtian (Mdj-3 well) — unit 5. These units represent blocks, which were defined in three wells, and indicate the deepening trough where they were formed. The complex, characterized by Late Cretaceous ophiolites intercalated with hemipelagic and pelagic sediments of South Bačka consists of two units: hemipelagic carbonates and clastites of the Late Campanian with basic volcanites and their tuffs (Srs-1 well) — older unit I and pyroclastic breccia interbedded with pelagic limestones of the Latest Campanian–Early Maastrichtian (Vbg-1 well) — younger unit II.

The studied complexes show analogous lithological and palaeontological characteristics to Senonian pelagic and rudist sediments from localities in the Vardar Zone, such as Mt. Fruška Gora in Vojvodina (Dulić et al. 2004), Struganik quarry in western Serbia (unpublished PhD thesis by Gajić, 2014), but also to sediments from some localities in the Carpatho-Balkanides, such as the complex Vrbovački reef in eastern Serbia (Sladić-Trifunović 1992). Some units also show characteristics analogous to the Senonian carbonate formations in the Transdanubian Range Zone, such as the Ugod Limestone and Polány Marl, typical bathyal Izsák Marl Formation of the Mecsek Facies Unit within the Tisza Mega-unit (Haas et al. 2012), as well as Senonian, red pelagic limestones of the Scaglia facies of the western Mediterranean (Kuhnt 1990).

The complex characterized by Upper Cretaceous ophiolites intercalated with hemipelagic and pelagic sediments can be very well correlated with similar formations in other Sava Zone localities, such as Mt. Požeška Gora or North Kozara Mountain. This is important in terms of obtaining significant data on the spatial distribution of blocks containing Late Cretaceous ophiolites. There is an assumption of their presence in several localities in Vojvodina, as well as in the wider region, which certainly indicates a need for future studies of the distribution of these blocks, in order to get as precise as possible information about the process of final closure of the Tethyan realm.

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References

Abramovich S., Keller G., Stüben D. & Berner Z. 2003: Characterization of Late Campanian and Maastrichtian planktonic foraminiferal depth habitats and vital activities based on stable isotopes. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 202, 1–29.

Caron M. 1985: Cretaceous planktic foraminifera. In: Bolli H. M., Saunders J. B. & Perch-Nielsen K. (Eds.): Plankton stratigraphy. *Cambridge Univ. Press*, Cambridge, 17–86.

Caron M. & Homewood P. 1983: Evolution of early planktic foraminifers. *Mar. Micropaleontol.* 7, 453–462.

Chacón B., Martínchivelet J. & Gräfe K.U. 2004: Latest Santonian to Latest Maastrichtian planktonic foraminifera and biostratigraphy of the hemipelagic succession of the Prebetic Zone (Murica and Alicante provinces, south-east Spain). *Cretaceous Res.* 25, 585–601.

Čanović M. & Kemenci R. 1988: The Mesozoik of the Pannonian basin in Vojvodina (Yugoslavia) — Stratigraphy and facies, magmatism, paleogeography. *Matica srpska*, Novi Sad, 1–337 (in Serbian with English summary).

Čanović M. & Kemenci R. 1999: Geologic setting of the Pre-Tertiary basement in Vojvodina (Yugoslavia). Part II: The north part of the Vardar zone in the south of Vojvodina. *Acta Geol. Hung.* 42, 4, 427–449.

Dulić. I., Sladić-Trifunović M., Žumberković V., Dunčić M. & Bogićević G. 2004: Upper Cretaceous red beds of Serbia. *32nd International Geological Congress*, Abstracts, Florence, 1, 2.

Dunčić M. & Bogićević G. 2008: Late Cretaceous microfossils of Vojvodina, northern Serbia. *33rd International Geological Congress*, Abstract, Oslo, 198.

Fleury J.J. 1980: Les Zones de Gavrovo-Tripolitza et du Pinde-Olonos (Grèce continentale et Péloponnèse du Nord). Evolution d'une plateforme et d'un bassin dans leur cadre alpin. *Ann. Soc. Geol. Nord.* 4, 2, 1–648.

Gajić V. 2014: Sedimentology Upper Cretaceous Central part of Vardar Zone. *Unpubl. Ph.D. Thesis, Univ. Belgrade*, 1–260 (in Serbian with English abstract).

Gasiński M.A., Jugowiec M. & Ślączka A. 1999: Late Cretaceous foraminiferids and calcareous nannoplankton from the Weglówka Marls (Subsilesian Unit, Outer Carpathians, Poland). *Geol. Carpath.* 50, 1, 63-73.

Gušić I. & Jelaska V. 1990: Upper Cretaceous stratigraphy of the island Brač within the geodynamic evolution of the Adriatic carbonate platform. *JAZU, Institut za geološka istraživanja*, Zagreb, 1–160.

Haas J., Hámor G., Jámbor Á., Kovács S., Nagymarosy A. & Szederkényi T. 2012: Geology of Hungary. *Regional Geology Reviews*, Budapest, 1–244.

Hradecká L., Lobitzer H., Ottner F., Švábenická L. & Svobodová M., 1999: Biostratigraphy and Facies of selected Exposures in the Grünbach-Neue Welt Gosau-Group (Coal-Bearing Series, Inoceramus-Marl and Zweiersdorf-Formation, Late Cretaceous and Paleocene, Lower Austria). *Abh. Geol. B.-A.* 56, 2, 519–551.

Karamata S., Krstić B., Dimitrijević D.M., Dimitrijević M.N., Knežević V., Stojanov R. & Filipović I. 1997: Terranes between the Moesian plate and the Adriatic sea. In: Papanikolaou D. (Ed.): Annales géologiques des pays Helléniques, IGCP Project, 276. *Terrane maps and terranes pescriptions* 157, Panepistimiopolis, Athines, 429–477.

Karamata S., Olujić J., Protić Lj., Milovanović D., Vujnović L., Popević A., Memović E., Radovanović Z & Resimić-Šarić K. 2000: The Western belt of the Vardar zone — the remnant of a marginal sea. In: Karamata S. & Janković S. (Eds.): Proc. Intern. Symp. Geol. and Metall. of Dinarides and the Vardar Zone. *Acad. Sci. and Arts of Rep. of Srpska, I, Depart. Nat. Math. Techn. Sci*., Banja Luka/Srpsko, Sarajevo, 131–135.

Karamata S., Sladić-Trifunović M., Cvetković V., Milovanović D., Šarić K., Olujić J. & Vujnović L. 2005: The western belt of the Vardar Zone with special emphasis to the ophiolites of Podkozarje — the youngest ophiolitic rocks of the Balkan Peninsula. *Bull. Acad. Serbe Sci. Arts, Classe Sci. Math. Nat.* CXXX, 43, 85–96.

Kędzierski M., Gasiński M.A. & Uchman A. 2015: Last occurrence of *Abathomphalus mayaroensis* (Bolli) foraminiferid index of the Cretaceous-Paleogene boundary: the calcareous nannofossil proof. *Geol. Carpath.* 66, 3, 181–195.

Kemenci R. & Čanović M. 1987: Flysches of Vojvodina, The Torda Flysch. In: Dimitrijević M. & M. (Eds.): The Turbidite Basins of Serbia. *Monographs, DLXXVI, Depart. Nat. Math. Sci.* 61, 160–164.

Kemenci R. & Čanović M. 1997: Geologic setting of the Pre-Tertiary basement in Vojvodina (Yugoslavia). Part I: The Tisza Mega-unit of North Vojvodina. *Acta Geol. Hung.* 40, 1, 1–36.

Kuhnt W. 1990: Agglutinated foraminifera of western Mediterranean Upper Cretaceous pelagic limestones (Umbrian Apennines, Italy and Betic Cordillera, Southern Spain). *Micropaleontology* 36, 4, 297–330.

Kuhnt W. & Kaminski M.A. 1997: Cenomanian to lower Eocene deep-water agglutinated Foraminifera from the Zumaya section, northern Spain. *Ann. Soc. Geol. Polon.* 67, 257–270.

Loeblich A.R. & Tappan H. 1988: Foraminiferal genera and their classification, Treatise on invertebrate paleontology. *Univ. of California*, *L.A, 1, 2, Van Nostrand Reinhold*, New York, 1–970.

Machaniec E. & Zapalowicz-Bilan B. 2005: Foraminiferal biostratigraphy and palaeobathymetry of Senonian marls (Upper Cretaceous) in the vicinity of Kraków (Januszowice-Korzkiew area, Bonarka quarry) — preliminary study. In: Tyszka J., Oliwkiewicz-Miklasińka M., Gedl P. & Kaminski M.A. (Eds.): Methods and Applications in Micropalaeontology. *Stud. Geol. Polon.* 124, 285–295.

Murray J.W. 1991: Ecology and Palaeoecology of Benthic Foraminifera. *Longman Scientific & Technical, John Wiley and Sons Inc.*, Essex, New York, 1–329.

Neumann M. 1997: Le genre *Siderolites* (Foraminifères). Révision des différentes espèces, I[re] partie: Analyse bibliographique, méthodologie, description des espèces du Campanien. *Revue de Micropaléontologie* 40, 3, 227–271.

Ogg J.G. & Hinnov L.A. 2012: Chapter 28: Cretaceous. In: Gradstein F.M., Ogg J.G., Schmitz M. & Ogg G. (Eds.): The Geologic Time Scale 2012. *Elsevier*, Oxford, Amsterdam, Waltham, 793–853.

Olsson R.K. & Nyong E.E. 1984: A paleoslope model for Campanian-lower Maastrichtian foraminifera of New Jersey and Delaware. *Journal of Foraminiferal Research* 15, 50–69.

Pamić J. 2002: The Sava-Vardar Zone of the Dinarides and Hellenides versus the Vardar Ocean. *Eclogae Geol. Helv.* 95, 99–113.

Pamić J. & Šparica M. 1983: The age of the volcanic rocks of Požeška Gora (Croatia, Yugoslavia). *JAZU, Razred za prirodne znanosti* 404, 19, Zagreb, 183–198 (in Croatian with English abstract).

Petrizzo M.R. 2002: Palaeoceanographic and palaeoclimatic inferences from Late Cretaceous planktonic foraminiferal assemblages from the Exmouth Plateau (ODP Sites 762 and 763, eastern Indian Ocean). *Mar. Micropaleontol.* 45, 117–150.

Petrizzo M.R., Falzoni F. & Premoli-Silva I. 2011: Identification of the base of the lower to Middle Campanian *Globotruncana ventricosa* Zone: comments on reliability and global correlations. *Cretaceous Res.* 32, 387–405.

Premoli Silva I. & Sliter W.V. 1995: Cretaceous planktonic foraminiferal biostratigraphy and evolutionary trends from the Bottaccione section, Gubbio, Italy. *Palaeontographia Italica* 82, I, 1–89.

Premoli Silva I. & Verga D. 2004: Practical manual of Cretaceous planktonic foraminifera. In: Verga D. & Rettori R. (Eds.): 3° course Cretaceous planktonic Foraminifera. *Universities of Perugia and Milan, Tipografia Pontefelcino*, Perugia, 1–283.

Robaszynski F. & Caron M. 1995: Foraminifères planctoniques du Crétacé: commentaire de la zonation Europe-Méditerranée. *Bull. Soc. Géol. France* 166, 6, 681–692.

Robaszynski F., Caron M., Gonzales Donoso J.M. & Wonders A.H. 1984: Atlas of Late Cretaceous Globotruncanids. *Revue de Micropaléontologie* 26, 3–4, 145–305.

Robertson A., Karamata S. & Šarić K. 2009: Overview of ophiolites and related units in the Late Palaeozoic–Early Cenozoic magmatic and tectonic development of Tethys in the northern part of the Balkan region. *Lithos* 108, 1–36.

Schmid M.S., Bernoulli D., Fügenschuh B., Matenco L., Schefer S., Schuster R., Tischler M. & Ustaszewski K. 2008: The Alps-Carpathians-Dinarides-connection: a correlation of tectonic units. *Swiss J. Geosci.* 101, 139–183.

Schönfeld J. 1990: Zur Stratigraphie und Ökologie bentischer Foraminiferen im Schreibkreide-Richtprofil von Lägerdorf/ Holstein. *Geol. Jahrb. A*117, 1–151.

Sladić-Trifunović M. 1992: On the significance of Late Senonian rudist faunas in Yugoslavia for reconstructions of the palaeobiogeographic relations in Central Tethys. *Comptes rendud des séances de la Société Serbe de Géologie, livre jubilaire (1891–1991)*, 159–173 (in Serbian with English summary).

Ustaszewski K., Kounov A., Schmid S.M., Schaltegger U., Krenn E., Frank W. & Fügenschuh B. 2010: Evolution of the Adria-Europe plate boundary in the northern Dinarides: From continent-continent collision to back-arc extension. *Tectonics* 29, 6, TC6017.

van den Akker T.J.H.A., Kaminski M.A. & Gradstein F.M. 2002: Campanian and Maastrichtian biostratigraphy in the Foula Sub-Basin, west of the Shetland Islands (UK). In: Wagreich M. (Ed.): Aspects of Cretaceous Stratigraphy and Palaeobiogeography. *Österr. Akad. Wiss., öriftenr. Erdwiss. Komm.* 15, 401–420.