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Trans-border (south-eastern Serbia/south-western Bulgaria) correlations of the Jurassic sediments: the Getic and Supra-Getic units

Platon Tchoumatchenco[1], Dragoman Rabrenović[2], Vladan Radulović[3], Nenad Malešević[2] & Barbara Radulović[3]

Abstract. The Getic and Supra-Getic are palaeogeographic units in SE Serbia and SW Bulgaria. Based on the presence (in Eastern) or absence (in Western) of Lower Jurassic marine deposits, the Getic is divided into Eastern and Western. In the Eastern Getic, the Lower Jurassic sedimentation in SE Serbia is represented by the Vidlič Clastites covered by the Lukanja Coal Beds, Lukanja Quartz Sandstones, Lukanja Brachiopods Beds, Lukanja Marlstones, Lukanja Belemnitic-Gryphaean Beds and Lukanja Cephalopod Limestones; in SW Bulgaria, the sedimentation commenced with the Tuden Formation, followed by the Kostina Formation and the Ozirovo Formation with a few members. The Middle Jurassic in SE Serbia commenced with the Senokos Siltstones and Shales and the Gulenovci Beds, while in SW Bulgaria with black shales (the Etropole Formation), followed by marls and clayey limestones of the Bov Formation. The Middle Jurassic sediments are represented in the Western Getic of SE Serbia by the Kurilovo Clastites and the Kurilovo Limestones (synonym to Gumpina Limestones of Kraütner & Krstić 2003); in the Supra-Getic of SE Serbia they are formed by the Jerma Clastites and Jerma Limestones (synonym of the Gumpina Limestones). In SW Bulgaria the Middle Jurassic sediments are represented by the sandstones of the Gradets Formation and by the bioclastic limestones of the Polaten Formation. During the Callovian (Middle?) started the formation of a carbonate platform with micritic limestones. In SE Serbia, it is Basara Limestones, Vidlič Limestones, Beljanica and Ždrelo Limestones, and in SW Bulgarian, the Belediehan Formation of Callovian–Kimmeridgian *p.p.* age. Characteristic for the Supra-Getic is the formation of a few grabens with specific sedimentation: the Svetlya Graben (the Zhablyano and Ozirovo Formations) and the Lobosh Formation; the Treklyano Graben (the Dobridol and Sredorek Formations), and out of it – the Methohya and Sredorek Formation. During the Callovian–Kimmeridgian *p.p.*, in the Svetlya Graben was sedimented the Lobosh Formation, horizontally passing into the Javorets and Gintsi Formations. During the latest Kimmeridgian–Tithonian commenced a big facial diversification: on the Getic in SE Serbia sedimented reef or sub-reef limestones (the Crni Vrh and Kučaj Reef Limestones), while in SW Bulgaria, the Slivnitsa Formation. On the Supra-Getic in SE Serbia formed Lužnica Flysch and in SW Bulgaria pre-flysch of the Neshkovtsi Formation and siliciclastic flysch of the Kostel Formation.

Key Words: Jurassic, Getic, Supra-Getic, lithostratigraphic correlations, SE Serbia, SW Bulgaria.

Апстракт. Гетикум и Супра-гетикум су палеогеографске јединице у ЈИ Србији и ЈЗ Бугарској. На основу присуства и одсуства лијаских морских седимената Гетикум је подељен на источни и западни. У источном Гетику јурска седиментација је представљена, у ЈИ Србији, са видличким кластитима преко којих леже лукањски угљевити слојеви, лукањски кварцни пешчари, лукањски брахиоподски слојеви, лукањски лапорци, лукањски белемнитско-грифејски слојеви и лукањски амонитски кречњаци, а у ЈЗ Бугарској седиментација почиње туденском формацијом преко које леже костина формација и озировска формација са неколико чланова. Средња јура ЈИ Србији почиње са сенокосним алевролитима и шкриљцима и гуле-

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новачким слојевима, док у ЈЗ Бугарској почиње са црним шкриљцима ентрополске формације, затим лапорцима и глиновитим кречњацима бовске формације. Средњојурски седименти у западном Гетикуму источне Србије представљени су куриловским кластитима и куриловским кречњацима (гумпина кречњаци, KRAÜTNER & KRSTIĆ 2003). У Супра-Гетикуму Србије настају јермски кластити и јермски кречњаци (гумпина кречњаци). У ЈЗ Бугарској средњојурски седименти су представљени пешчарима градечке формације и биокластичним кречњацима полетенске формације.

За време келовеја (средњег ?) почиње формирање карбонатне платформе са микритским кречњацима. У ЈИ Србији то су басарски кречњаци, видлички кречњаци, бељанички или ждрелски кречњаци, а у ЈЗ Бугарској то је беледиеханска формација келовејско-кимериџске *p.p.* старости. Карактеристично за Супра-гетикум је формирање неколико ровова са специфичном седиментацијом: светлајски ров (жабљанска и озировска формација) и лобошка формација, трекљански ров (добридолска и рајаначка формација) и ван њих метхохијска и средоречка формација. За време келовеја и кимериџа *p.p.* у светлајском рову се депонује лобошка формација, која бочно прелази у јаворечку и гиначку формацију. За време најкаснијег кимериџ–титона настају велике фацијалне разноликости: на Гетикуму, у ЈИ Србији се таложе спрудни и субспрудни кречњаци (црновршки кречњаци и кучајски кречњаци), док се у ЈЗ Бугарској формира сливничка формација. На Супра-гетикуму у ЈИ Србија депонује се лужнички флиш, а у ЈЗ Бугарској префлиш нешковачке формације и силицикластични флиш костелске формације.

Кључне речи: јура, Гетикум, Супра-гетикум, литостратиграфске корелације, ЈИ Србија, ЈЗ Бугарска.

Introduction

Usually geologic maps (including those of Bulgaria and Serbia) are published only to the state border and geologists do not know many things about the geology of a neighboring country. This is the case with the Serbian and the Bulgarian geological maps on the scale 1:100 000. An exception is the map on the scale 1:300 000 composed by KRAÜTNER & KRSTIĆ (2003). To avoid this incompleteness of our knowledge on the lithostratigraphy of the Jurassic from both sides of the Bulgarian/Serbian border, a team of Bulgarian and Serbian geologists started correlations of the Jurassic sediments and the Jurassic lithostratigraphic units (TCHOUMATCHENCO *et al*. 2006a, b). In the first paper, the large palaeogeographic and palaeotectonic units concerneing the Jurassic, i.e., the Serbian–Macedonian Massif (= Thracian Massif), the Supra-Getic (Lužnica–Koniavo Unit), the Getic and Infra-Getic units, were restituted, and in the second, correlations of the Jurassic sediments from the Infra-Getic unit were commenced. In the present paper, the aim is to make a correlation from both sides of the borders between the sediments of the Getic and the Supra-Getic (Lužnica–Koniavo Unit). The descriptions of these two units were united together because they show many common peculiarities in the Early and the Middle Jurassic development. After one of us (P.T.), these units have been formed within the framework of the Serbian–Macedonian Massif and the large differences started at the end of the Middle Jurassic. During the Early and the Middle Jurassic, the Getic has been divided into two sub-units, the Western and Eastern Getic, on the basis of the presence/absence of the Lower Jurassic and the character of the Middle Jurassic sediments. The largest differences between the two big palaeogeographic areas commenced during the Callovian, probably during the Middle Callovian, when in the Supra-Getic (Lužnica–Koniavo Unit) started neritic calcareous sedimentation, followed by siliciclastic flysch sedimentation, whereas in the Getic started the formation of a carbonate platform with reef or sub-reef shallow water sedimentation. At the same time, in the Infra-Getic started neritic carnonate sedimentation with *"ammonitico rosso"* type sediments. The boundaries, especially the boundary between the Getic and the Infra-Getic, changed in time. During the Early and Middle Jurassic, the sediments near the Kalotina Village (and west of the border, in Serbia), were of Infra-Getic type, with complete Lower–Middle Jurassic sedimentation, whereas during the Callovian–Tithonian–Berriasian, at these localities sedimented platform carbonates, typical for the Getic area. Near the Slivnitsa Town, the Lower Jurassic Ozirovo Formation is thin and formed by ferriferous limestones, which show the western end of the Lower Jurassic basin, the in Bulgaria so-called "Ponor-Kremikovtsi Lias". To the west of Slivnitsa Town, there are no Lower Jurassic sediments; at these localities, the Jurassic sedimentation started at separated localities with only the Lower Jurassic continental sediments of the Zhablyano Formation (in Serbia it is the Gresten Facies), with the Middle Jurassic sandstones of the Gradets Formation, or with the limestones of the Polaten Formation (in Serbia known as the Gumpina Formation).

We would like here to express our gratitude to A. GRUBIĆ, one of our reviewers. In his review he made important notes and we would like to answer some of them and explain our point of view on these problems. The principal note refers to the Infra-Getic. He reacts to our opinion about the Infra-Getic with the following words: "Infra-Getic had been formed on the deep oceanic bottom – there is not neritic there. Please do not make confusion in the Carpatho-Balkanides. The Infra--Getic are: Sinaya, Quasi-Sinaya, Kiloma and ofiolites." We well understand his opinion that the Infra-Getic consists only of deep water sediment, but our notion is larger, not in the narrow *sense* of the word Infra-Getic. As Infra-Getic, we consider one palaeogeographic (palaeotectonic) unit, situated between the Moesian Platform and the Getic carbonate platform, composed in different parts of various sediments, deposited in different parts of this unit, in deep (oceanic) water at some localities and in relatively shallower at other localities. These differences can be produced in different geologic times. In one very interesting paper GRUBIĆ & JANKIČEVIĆ (1972) proposed a very informative figure (Fig. 1), in which the authors showed well, after us, the Getic carbonate platform as a monolithic body with its different parts. The central part of the para-platform, the border zone and, to the east of the carbonate body, the transitional zone between the para-platform and the pelagic facies. To the north–east in north-eastern Serbia, this "transitional facies" consists of Sinaya beds, Quazi-Sinaya, Kiloma and ofiolites, i.e., only these rocks represent the Infra-Getic after GRUBIĆ & JANKIČEVIĆ (1972). The "transitional zone" is located between the Getic carbonate para-platform from the west and the Moesian platform from the east. We prolong the unit "Infra-Getic" to the south to encompass the relatively deep water Upper Jurassic sediments *"ammonitico rosso"* type deposited in the basin situated between the Getic and the Moesian platforms. After ANDJELKOVIĆ *et al*. (1996), this zone represents the Stara Planina–Poreč Unit of the Balkanikum and the Dobri Dol–Grlište Unit of the Karpatikum. In Bulgaria this zone is known as the Jurassic Izdremets Graben (SAPUNOV

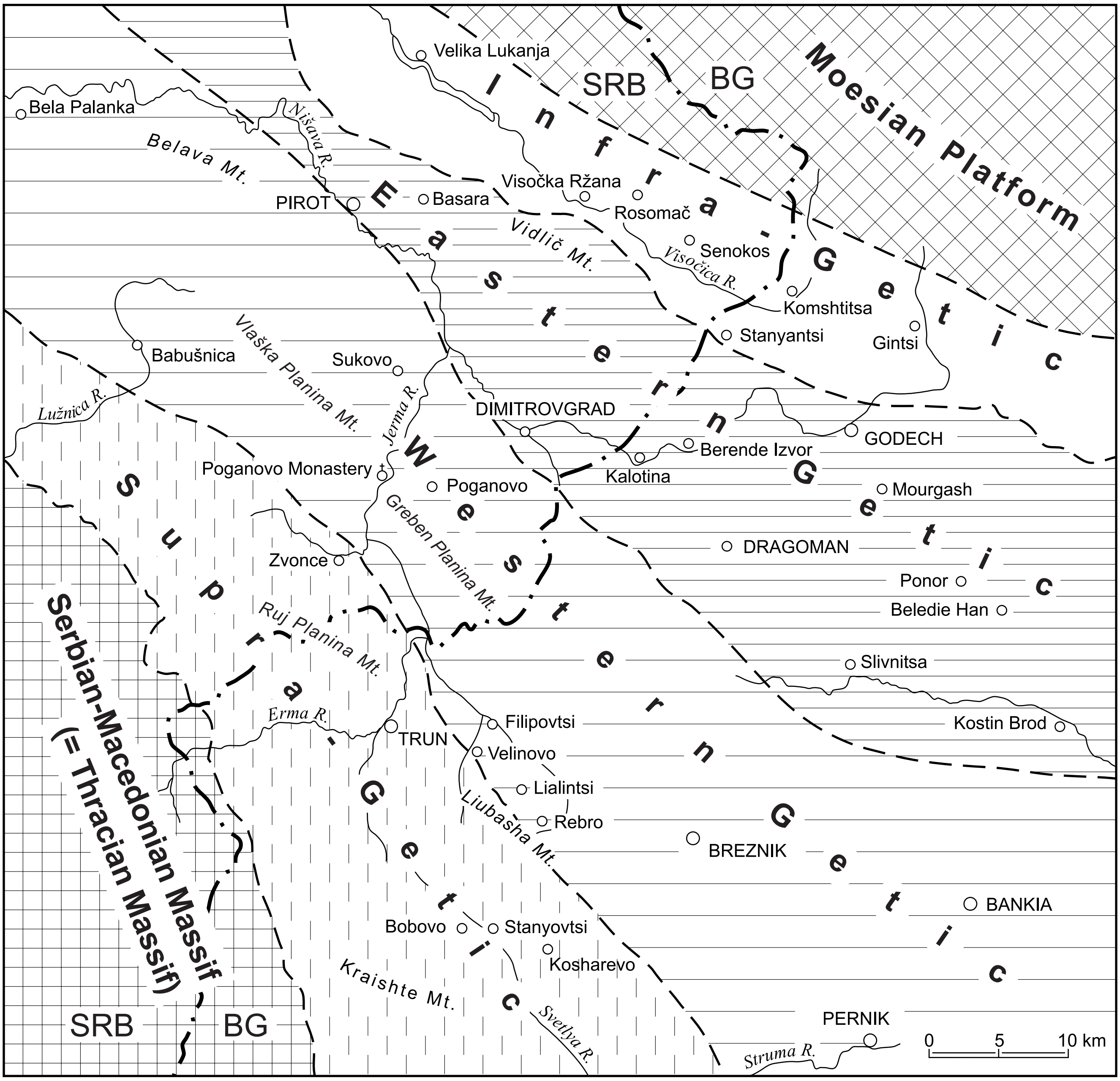

Fig. 1. Main Jurassic palaeogeographic units in south-eastern Serbia and in south-western Bulgaria.

et al. 1985). To the west from the Getic "carbonate para-platform", in the same figure of Grubić & Jankičević (1972), there is a zone with Upper Jurassic and lowermost Lower Cretaceous siliciclastic flysch sediments; this is Lužnica (or Ruj) flysch in Serbia and the Nish-Troyan flysch trough in Bulgaria. This palaeogeographic unit is known as the Lužnica thrust of the Karpatikum of Andjelković *et al.* (1996) or the Supra-Geticum, for which Grubić (2006) indicated to the fact that the Supra-Getic Zone is thrusted over the carbonate platform of the Getic. This is from the tectonic point of view, but we look at the Supra-Getic as a palaeogeographic unit, i.e., during the Jurassic the Supra-Getic Zone represented a trough filled by *"ammonitico-rosso"* pelagic sediments (Callovian–Late Kimmeridgian *p.p.* and by Upper Kimmeridgian *p.p.*–Berriasian siliciclastic flysch, and this zone later thrusted over the Getic.

Getic

The Getic palaeogeographic unit has been divided into two sub-units based on the presence (in Eastern Getic) or the absence (in Western Getic) of Liassic sediments.

Eastern Getic

The Eastern Getic coincides more or less with the Vidlič and Tupižnica-Tepoš units of the Karpatikum of Andjelković *et al.* (1996).

Early–Middle Jurassic (up to the Early Callovian?)

South-eastern Serbia

Vidlič Zone

The Lower–Middle Jurassic sediments are the same as in the Infra-Getic. At the base of the Jurassic occur the Lukanja Clastics, covered by the Lukanja Coal Sediments and the Lukanja Quartz Sandstones (Hettangian–Sinemurian *p.p.*), followed by three levels: (i) Pliensbachian dark grey sandy bioclastic limestones and calcareous sandstones with brachiopods and bivalves; (ii) sandy limestones and clayey sandstones with spiriferinids and ammonites (*Androgynoceras*). These two lower levels correspond to the Lukanja Brachiopod Beds (Andjelković *et al.* 1996), and in Bulgaria to the Dolniloukovit Member of the Ozirovo Formation; (iii) clayey sandstones and sandy limestones with brachiopods, bivalves and belemnites, which correspond to the Upper Pliensbachian Lukanja Belemnitic-gryphaean Beds (Andjelković *et al.* 1996), and in Bulgaria to the Bukorovtsi Member (Ozirovo Formation). During the Toarcian were sedimented aleurolites, argilites, yellow sandstones and sandy limestones with ammonites *Hildoceras bifrons*, *Pseudogrammoceras dispansum*, etc. They correspond to the Senokos Siltstones and Shales in the Infra-Getic Zone and to the Bukorovtsi Member of the Ozirovo Formation in Bulgaria.

Near Radejna Village (Dimitrovgrad area), the Late Pliensbachian is represented by unnamed dark-yellowish sandstones, over which follow brownish sandstones with *Hildoceras bifrons*, *Dactyloceras commune*. They are covered by dark grey calcareous-clayey sandstones. These aleurolites, sandy limestones and argilites can be correlated with the non-divided homogenous Ozirovo Formation near Slivnitsa Town, the so-called Ponor-Kremikovtsi type Early Jurassic in Bulgaria.

In the Vidlič Basin (Andjelković *et al.* 1996) were sedimented Gulenovci Beds represented by thin-bedded and sheeted grey and bluish sandy clays with intercalations of bluish limestones. During the Late Bajocian were deposited aleurolites, clays, sandy limestones, which can be assigned to the Gulenovci Sandstones. During the Early (*Morphoceras multiforme*, *Oxycerites sebachi*, corals, brachiopods) and Middle (*Tulites subcontractus*, *Bullatimorphites* sp.) Bathonian were deposited the Gulenovci Sandstones, beds formed of yellow and bluish coarse and small grained sandstones, detritic limestones and calcarenites (= ? Polaten Formation) with *Acantothyris* (close to the Polaten Formation from the Belogradchik area). Between the Bathonian and the Callovian, there is a level "ferruginous level" (Andjelković *et al.* 1996). These sediments can be correlated partly with the Bulgarian Bov Formation and especially with the Gradets and Polaten Formations, but there are many differences between them.

South-western Bulgaria

Kalotina Village and Slivnitsa Town

In Bulgaria, in the Eastern Getic, around the Kalotina and Berende Izvor villages, the Jurassic sedimentation continued horizontally from the Infra-Getic until the Bajocian–Bathonian (Dodekova *et al.* 1984). Only the Upper Bathonian–Lower(?) Callovian sediments became shallow water and commenced the formation of the Getic carbonate platform.

The sedimentation, analogous to the Infra-Getic sedimentation, started with 24–25 m of continental clays and sandstones of the Tuden Formation (Sapunov *et al.* 1990), which in its upper parts passes into marine clays and sandstones with marine fauna, *Pseudopecten* sp., undeterminable ammonites and thin intercalations of gypsum. Over them follow sandstones of the Kostina Formation, 3–5 m thick, of Hettangian–Sinemurian *p.p.* age (Sapunov *et al.* 1967). On them lie the Sinemurian bioclastic and sandy limestones, 2 m thick, which are the western prolongation of the Romanovdol Member of the Ozirovo Formation and the Sinemurian–Lower Pliensbachian marls, interbedded by cleyey limestones, about 10 m thick, of the Ravna Member of the Ozirovo Formation. They are covered by grey bioclastic limestones with many bivalves and brachiopods, with thin intercalations of marls of Sinemurian –Pliensbachian *p.p.* age of the Dolniloukovit Member of the Ozirovo Formation (SAPUNOV 1983). The Lower Jurassic section finished by marls with rare intercalations of clayey limestones with large *Pseudopecten aequivalvis* of the Bukorovtsi Member (SAPUNOV *et al.* 1967) of the Ozirovo Formation (50–52 m). The section continues upwards with black shales (10–30 m) of the Aalenian–Bajocian Etropole Formation (SAPUNOV *et al.* 1967) and alternation of marls and clayey limestones (30 m) of the predominantly Bathonian Bov Formation.

In the western direction, to the west of Slivnitsa Town end the Lower Jurassic outcrops. To the east of Slivnitsa Town, the Sinemurian sediments are represented by 2–3 m thick quartz sandstones of the Kostina Formation and the Pliensbachian–Toarcian sediments by ferriferous bioclastic limestones, rich in brachiopods, bivalves and ammonites, thick 5–6 m, of the homogenous Ozirovo Formation (DODEKOVA *et al.* 1984). The section continues with 4–5 m sandstones of the Gradets Formation of Aalenian–Bajocian *p.p.* age. They are covered by grey to reddish sandy and bioclastic limestones (about 15 m thick) of the Polaten Formation of the Bajocian *p.p.*–Bathonian age.

The eastern boundary between Getic and Infra-Getic is well outcropped in the region of the Mourgash Village (to the south-west of Godech Town), where tongues of bioclastic limestones of the Polaten Formation intercalated the black shales of the Etropole Formation. Also, near the Kalotina Village, where the section of the Middle Jurassic is finished also with bioclastic limestones of the Polaten Formation which lie above the clayey limestones of the Bov Formation the clayey limestones of the Bov Formation. It can be concluded that the boundary between Infra-Getic and Getic represented a palaeogeographic boundary, probably a fault in the deeper part of the crust, but on the surface it was expressed by a horizontal facial transition over a short distance of a few km, not more than 10 km.

Western Getic

The Western Getic coincides more or less with the Timok, Kučaj–Svrljig, Gornjak–Suva Planina units of the Karpatikum of ANDJELKOVIĆ *et al.* (1996).

On the Western Getic, there are no Lower Jurassic sediments. Only in a few isolated localities, in Bulgaria in Liubasha Mountain, near the Trun Zhdrelo of Erma, in the Greben Planina Mountain (on the stratigraphic columns of the Basic geological map scale 1:100 000), there are continental Lower Jurassic sandstones and clays, which in Bulgaria are correlated with the Zhabliano Formation, and in Serbia, they are involved in the Gresten Facies.

South-eastern Serbia

In Greben Planina Mountain, the lithostratigraphic unit of the Gumpina Limestones (*sensu* KRAÜTNER & KRSTIĆ 2003), described as "Dogger – conglomerates, sandstones, sandy-limestones, marly-limestones, marls" (KRAÜTNER & KRSTIĆ 2003), about 40 m thick (after Basic geological map), represent Middle Jurassic sediments. They are represented in the Ždrelo of the Jerma River near the Poganovo Monastery by grey oolitic limestones with many bioclasts, especially of brachiopods. Below them, at some localities the Kurilovo Clastites crop out, analogous to the Gradets Formation in SW Bulgaria, which covered the predominantly continental sandstones, separated as Gresten Facies (about 20 m thick).

South-western Bulgaria

On the Western Getic, the Jurassic transgression commences with Aalenian sandstones of the Gradets Formation, about 10–15 m thick (SAPUNOV 1969). Over them, the section continues with bioclastic dark-grey limestones of the Bajocian–Bathonian Polaten Formation (STEPHANOV 1966), intercalated by Bajocian sandstones of the Lialintsi Wedge (DODEKOVA *et al.* 1984) of the Gradets Formation. These two lithostratigraphic units, the Polaten Formation and the Lialintsi Wedge, correspond to the Gumpina Limestones in eastern Serbia. The Gradets Formation can be correlated with the Kurilovo Clastites. Below them, at many isolated localities, sandstones (Zhabliano Formation) crop out, which can be correlated with the "Gresten Facies".

Middle Callovian–Tithonian

Eastern Getic

South-eastern Serbia

Vidlič Zone

The sediments of the Early Callovian of the Vidlič Basin, assigned to the Basara Beds (ANDJELKOVIĆ *et al.* 1996), are represented by pinkish and reddish sandstones and sandy limestones with *Macrocephalites macrocephalus*, *Hecticoceras lunnaloides*, bivalves, gastropods, single corals. They can be correlated to the Javorets Formation from SW Bulgaria.

A new sedimentary cycle started over the Basara Beds with calcareous rocks: the Basara Limestones, represented by grey limestones with chert nodules and rare ammonites (thickness 40–120 m) and the Vidlič Limestones, built up of grey to blue, well bedded limestones (ANDJELKOVIĆ *et al.* 1996). The Basara and the Vidlič Limestones are often connected with horizontal and vertical transitions; these limestones embrace the

Late Callovian–Kimmeridgian age. The Basara Limestones are similar to the Belediehan Formation in western Bulgaria, and the Vidlič Limestones can be correlated to the Javorets and to the Gintsi formations from south-western Bulgaria. Similar horizontal transition between the Belediehan Formation and the Javorets and the Gintsi formations can be observed in the vicinities of Beledie Han Village. This horizontal transition between the two types of limestones shows that the eastern boundary of the Getic with the Infra-Getic, also during the Late Jurassic, represented a transition over a short distance, probably the boundary represented a fault, situated deep in the Earth's crust.

During the Early Tithonian started shallowing of the basin and the deposition of the Crni Vrh Limestones – thick bedded reef and sub-reef limestones (thickness of about 350 m). These rocks are analogous to the Slivnitsa Formation from western Bulgaria. In Fig. 28 ANDJELKOVIĆ *et al.* (1996, p. 136) showed that the reef and sub-reef limestones occupied only one part of the lithostratigraphic column – "6b – reef and sub-reef limestones with hydrozoans, gastropods, corals, etc.", and the other part is occupied by "6a – thick-bedded limestones with gastropods, microfossils". The same situation exists also in western Bulgaria, from the Liubasha Mountain to the east from Slivnitsa, Beledie Han, there is a belt with many coral reefs, which rimmed the carbonate platform, and the other part is structured by thick bedded, shallow water limestones. In south-eastern Serbia, as well as in Bulgaria all these limestones are reported to one lithostratigraphic unit – to the Crni Vrh Limestones and to the Slivnitsa Formation of Tithonian–lowermost Early Cretaceous age. Probably the Crni Vrh Limestones marked the north-eastern rim of the Getic carbonate platform.

South-western Bulgaria

Kalotina Village

Similar to the Vidlič Zone by its palaeogeographic situation in the Jurassic basin is the Kalotina area in SW Bulgaria. On the Bathonian parts of the Polaten Formation (which represents a tongue 10–20 meters thick of the Polaten Formation over the clayey limestones of the Bov Formation), with a visible, irregular erosional surface, occur micritic limestones with whitish chert concretions of the Belediehan Formation, about 150 m thick. Their range is Callovian (Middle ?)–Kimmeridgian *p.p.* (IVANOVA *et al.* 2000; IVANOVA & KOLEVA-REKALOVA 2004). They are covered by bioclastic limestones of the Slivnitsa Formation (400–450 m thick), with a range Kimmeridgian *p.p.*–Late Valanginian (IVANOVA *et al.* 2000; IVANOVA & KOLEVA-REKALOVA 2004), or up to the Berriasian (NIKOLOV & TZANKOV 1998). The upper boundary is an irregular, erosional surface, often covered by borings of the *Trypanites* type, connected with a sub-marine gap of sedimentation; it is covered by alternation of marls and micritic limestones of the Salash Formation of Early Hauterivian age (MANDOV 1976; IVANOVA *et al.* 2000).

Near the Slivnitsa Town, the Belediehan Formation is almost the same as in the Kalotina section with the same age (Callovian (Middle?)–Kimmeridgian (*p.p.*) and the same lithology. It is covered by the Slivnitsa Formation, represented by bioclastic limestones with many coral buildings. These coral reefs are the east prolongation of the Lialintsi Coral Belt, coming from the western Getic and which represents the south rimmed part of the Getic calcareous platform. The Slivnitsa Formation has a range up to the Berriasian after NIKOLOV & TZANKOV (1998), Kimmeridgian *p.p.*–Late Valanginian after IVANOVA *et al.* (2000) and covered by the Hauterivian Salash Formation (MANDOV 1976)

In the region of Beledie Han Village, the Belediehan Formation has a range from the Callovian (Middle?) up to parts of the Late Tithonian (proved with calpionellids, SAPUNOV *et al.* 1985) and over a short distance in the eastern direction, passes into the micritic limestones of the Javorets and the lithoclastic limestones of the Gintsi Formations. The Slivnitsa Formation passes into the lithoclastic limestones of the Gintsi Formation and the micritic limestones of the Glozhene Formation. To the south of Beledie Han Village, an Lower Cretaceous tongue of the Slivnitsa Formation (the thickness of which diminishes over a short distance from 100 to 1–2 m and represent the last outcrop of it) covers the Glozhene Formation and over a short distance to the south progressively passes into the flysch alternation of the Cherniosum/Kostel Formation.

Western Getic

South-eastern Serbia

Greben Planina Mountain (near the Poganovo Monastery)

This area is called the Kusovranska Zone in the Basic geological map of Yugoslavia, sheet Breznik. Here crop out the sub-reef (platform) limestones, which were named by ANDJELKOVIĆ & MITROVIĆ-PETROVIĆ (1992) the Beljanica Limestones (or the Ždrelo Limestones), about 40 m thick. These sediments cross the Serbian/Bulgarian border. The Beljanica Limestones can be correlated directly (as it is done in the Basic geological map, sheet Breznik, but with out the lithostratigraphic name) with the Basara Limestones of the Vidlič Mountain (of Callovian–Kimmeridgian age), and with the Belediehan Formation in south-western Bulgaria. The section follow upwards with the reef and sub-reef limestones, which represent the south prolongation of the Kučaj Reef Limestones (ANDJELKOVIĆ & MITROVIĆ-PETROVIĆ (1992), with age "Early Malm, Tithonian and passes into Berriasian" and can be regarded also as the western prolongation of the Crni Vrh Reef and sub-reef limestones from the Vidlič Mountain of the same age. They can be correlated with the Slivnitsa Formation from south-western Bulgaria.

South-western Bulgaria

Liubasha Planina Mountain

In the Eastern Getic in Bulgaria (southern prolongation of the Vidlič Mountain near the Kalotina Village, the Chepun Mountain, the Beledie Han Village, the Slivnitsa Town, etc.) and in the western Getic – Liubasha Mountain (the southern prolongation of the Greben Planina Mountain) existed a carbonate platform. In Bulgaria, this zone is called the Dragoman Palaeo-Horst (SAPUNOV *et al*. 1985).

There are three sections in the Liubasha Mountain which document the three parts of the carbonate platform, to the north, (i) the section of the Velinovo Village, situated in the laguna area; (ii) the Lialintsi section, with many coral reefs, situated at the rimmed carbonate platform, and (iii) the southernmost section near Rebro Village, situated between the rimmed platform and the outer shelf.

In the area of the Western Getic, as well as in the Eastern Getic, two lithostratigraphic units, situated in superposition, are separated. The lower one, consisting of grey, relatively thin-bedded limestones (peloidal packstones), containing many nodules of whitish chert, is called the Beledihan Formation, which is of Callovian (Middle?)–Kimmeridgian age, 100–150 m thick (TCHOUMATCHENCO 2006). It can be correlated with the Basara Limestones from the Vidlič Mountain (ANDJELKOVIĆ *et al*. 1996) or with the Beljanica Limestones from Kučaj and the Ždrelo Limestones from the Greben Mountain (ANDJELKOVIĆ & MITROVIĆ-PETROVIĆ 1992). The Belediehan Formation is covered by whitish to beige, predominantly thick-bedded bioclastic limestones (270–450 m) of the Slivnitsa Formation, containing many coral reef buildings. The age is Kimmeridgian–Tithonian–Berriasian (TCHOUMATCHENCO 2006) or Callovian–Late Valanginian (IVANOVA & KOLEVA-REKALOVA 2004). The upper boundary is discordant, the upper surface of the Slivnitsa Formation is with many borings of the *Trypanites* type, covered by Upper Cretaceous (Turonian) limestones. The Slivnitsa Formation can be correlated with the Crni Vrh Reef and sub-reef limestones from the Vidlič Mountain (ANDJELKOVIĆ *et al*. 1996), as well as with the Kučaj Reef Limestones (ANDJELKOVIĆ & MITROVIĆ-PETROVIĆ 1992). In the Slivnitsa Formation in the vicinities of Lialintsi Village–Slivnitsa Town–Beledie Han Village, there is a belt with many coral reefs, which rimmed the platform. This reef belt is not separated as a lithostratigraphic unit and can be the correlate of the corals described by SUČIĆ (1959) near the Jerma Coal Mine.

Supra-Getic (Lužnica–Koniavo Unit)

This unit coincides more or less with the Lužnica Unit of ANDJELKOVIĆ *et al*. (1996).

Lower–Middle Jurassic

South-eastern Serbia

Zvonce Village

The Jurassic transgression in the Supra-Getic (Lužnica–Koniavo) Unit, as well as in the Western Getic commenced in the so-called "Suvoplaninska Zone" with the Middle Jurassic Gumpina Limestones – "conglomerates, sandstones, sandy-limestones, marly-limestones, marls" (KRAÜTNER & KRSTIĆ 2003), 40 m thick, corresponding to the Polaten and the Gradets Formations. In some localities, below them are separated the Jerma Clastites, analogous to the Gradets Formation in south-western Bulgaria. Below them, in some isolated exposures, there are sandstones, clays and conglomerates with coal measures (e.g., the Jerma Coal Beds), about 100 m thick of Gresten Facies, analogous to the Zhabliano Formation in Bulgaria. In the region of the Lužnica River, they are separated as the Lužnica Clastites. There are no marine Lower Jurassic sediments here.

South-western Bulgaria

Bobovo and Stanyovtsi villages (Kraishte)

In the Bulgarian parts of Supra-Getic (Lužnica–Koniavo Unit), the most characteristic feature is the presence of a few palaeo-grabens, which predestinated the sedimentation. In one of them, the Svetlya Graben, the Lower Jurassic sedimentation started with continental sediments – fire proof clays and sandstones (Zhabliano Formation, Hettangian–Sinemurian–earliest Pliensbachian, thick 60 m). These rocks correspond to the Gresten Facies in eastern Serbia. They are followed by the shallow water marine sandy, bioclastic limestones (Ozirovo Formation, Pliensbachian–Toarcian, *p.p.* thick 10 m).

The succession continues with the sandstones of the Gradets Formation (SAPUNOV 1969) (Toarcian *p.p.*–Aalenian, 50 m thick), and with the bioclastic limestones of the Polaten Formation (Bajocian–Bathonian, 70 m thick). These rocks correspond to the Gumpina Limestones in eastern Serbia.

In the western part of the Supra-Getic in Bulgaria, in the region of the Kraishte Mountain, in the Trekliyano Palaeograben were sedimented sandstones, black shales and radiolarites with Radiolaria of Aalenian–Bathonian age – the Dobridol Formation (Toarcian?–Aalenian, about 10–15 m thick) and the Rayantsi Formation (Aalenian–Bathonian, about 100 m thick) (ZAGORCHEV & TIHO-

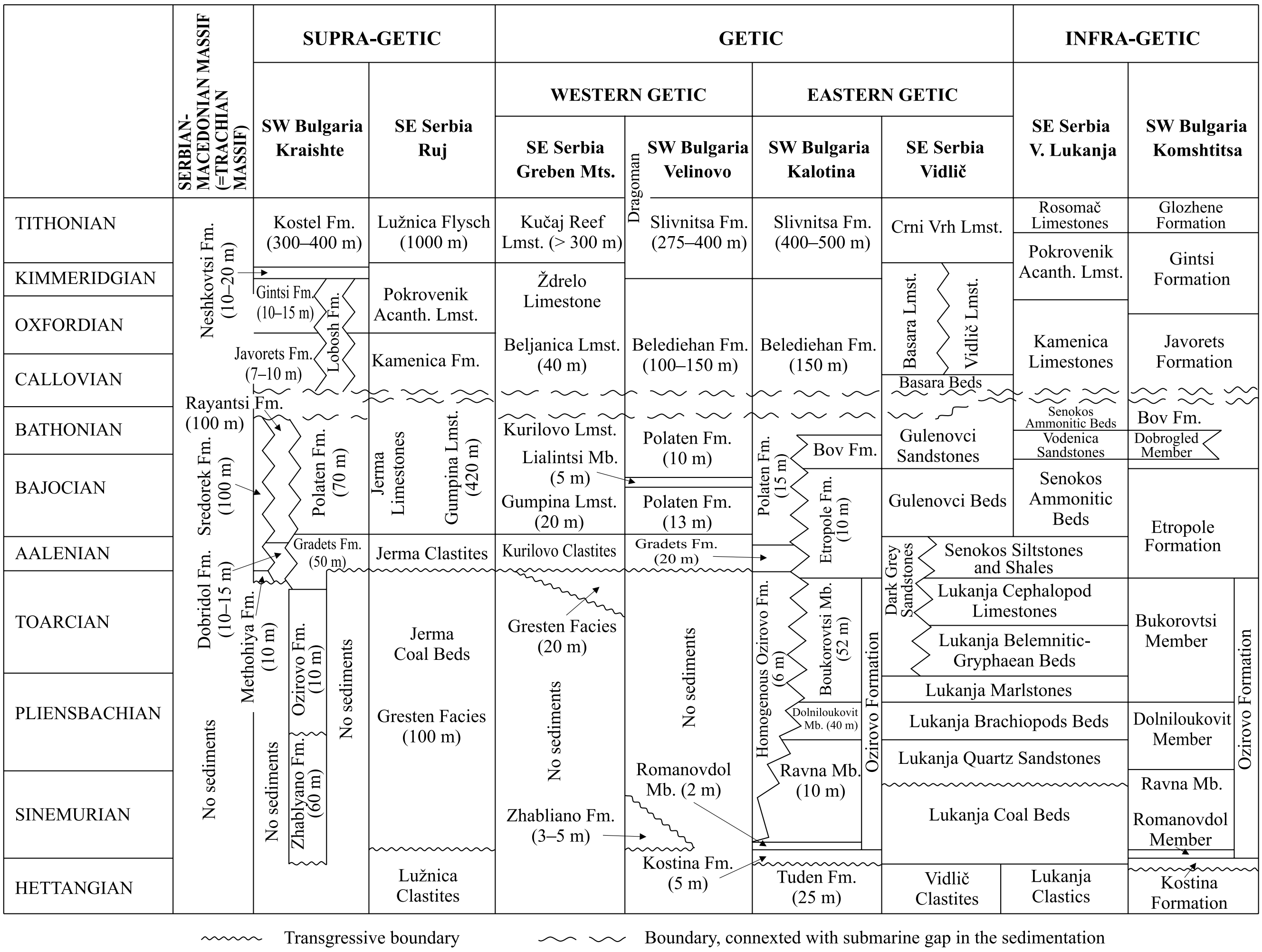

Fig. 2. WIELLER's Diagram of the Jurassic sediments in the Supra-Getic, Getic and Infra-Getic in south-eastern Serbia and south-western Bulgaria.

MIROVA 1986; BONCHEVA *et al*. 2004). The western shallow water board of the Trekliyano Middle Jurassic Graben was the location of sedimentation of the Methohiya Formation (sandstones and conglomerates of the Toarcian?–Aalenian age, 10 m thick), and of the Sredorek Formation built up of bioclastic limestones (Aalenian–Bathonian ?, 80 m thick). There is information (BONCHEVA *et al*. 2004) that these formations crossed the Serbia/Bulgaria state border.

Callovian (Middle ?)–Tithonian

South-eastern Serbia

Zvonce Village

The Callovian (Middle?)–Tithonian succession started with the Callovian (Middle?)–Kimmeridgian *p.p.* limestones with chert nodules, 10–20 m thick, which may represent the prolongation through Bulgaria of the Kamenica Limestones from the Infra-Getic area. In Bulgaria the Javorets Formation corresponds to them.

Over the Kamenica Limestones, the succession continues by nodular limestones, which may represent the prolongation through Bulgaria of the Pokrovenik Acanthicum Limestones from the Infra-Getic. In the Serbian literature, analogous nodular sediments are not mentioned, but they must be part of what is subdivided in the Basic geological map, sheet Breznik as the upper part of the J_3^{1+2} about 20 m thick of Kimmeridgian age. To the Pokrovenik Limestones in Bulgaria corresponds the Gintsi Formation.

Lužnica flysch (Ruj flysch)

The Jurassic section finishes with flysch type sediments. They are described as the Lužnica Flysch, later named by DIMITRIJEVIĆ & DIMITRIJEVIĆ (1987) as the Ruj Flysch. The name Lužnica Flysch has the priority and we conserve this nomination. Its is structured by turbidity alternation of sandstones, marls, clays, aleurolites with fallen blocks (olistolites), more than 1000 m thick. In Serbia its age is reported to the Tithonian (DITRIJEVIĆ & DITRIJEVIĆ 1987, etc.), to the Tithonian––Berriasian (GRUBIĆ 1980) or to the Tithonian–Hauterivian (KRAÜTNER & KRSTIĆ 2003). In Bulgaria it corresponds to the Kostel Formation (SAPUNOV *et al*. 1985) and it was proven palaeontologically that this flysch started in the Late Kimmeridgian to the earliest Early Cretaceous.

South-western Bulgaria

Kraishte

During the Middle (?) Callovian–Tithonian–Berriassian in the Lužnica–Koniavo (Supra-Getic) Unit continues, from the early Middle Jurassic, the regime of the formation of a graben with specific sedimentation, especially continues the regime of the Svetlya Graben. During the Middle(?) Callovian–Kimmeridgian *p.p.*, sedimentation in the Svetlya Graben continues with the formation of calcareous conglomerate, i.e., the Lobosh Formation (SAPUNOV *et al*. 1985), which is a horizontal correlative of the Javorets and the Gintsi formations, and was sedimented to the west and the east from the Svetlya Graben. The Lobosh Formation consists of calcareous fragments coming, probably, from the Polaten, Javorets and Gintsi formations. They are represented by boulders and cobbles in the vicinity of the Lobosh Village (in the southern parts of the Svetlya Graben), and became predominantly pebbles in the northern part of the graben near the Stanyovtsi Village, transported by strong bottom currents, i.e., the source province represented part of the shelf area, situated on the south part of the basin. The lower boundary of the Lobosh Formation is abrupt, unconformable, irregular, connected with sub-marine erosion of the underlying Polaten Formation. The upper contact with the Neshkovtsi Formation, is conformable. An analogue of the Lobosh Formation is not known in south-eastern Serbia. The marine sedimentation, after a sub-marine break during parts of the Bathonian and the Early Callovian, restarted with grey micritic limestones with chert nodules, 7–10 m thick, of the Javorets Formation (NIKOLOV & SAPUNOV 1970) embracing the Middle Callovian–earliest parts of the Oxfordian. These rocks are analogous to the eastern Serbian Kamenica Limestones. They crop out only from west and east of the Svetlya Graben. In some localities, e.g. around Staro Selo Village, Drugan Village, etc., the sub-marine break of the sedimentation continued during the Callovian and the Oxfordian, and the Polaten Formation was covered directly by grey to pinkish nodular limestones of the Gintsi Formation. There, the Gintsi Formation, 10–15 m thick, is of Kimmeridgian age (SAPUNOV *et al*. 1985). In the area where the Javorets Formation had been sedimented, the volume of the Gintsi Formation embraced most of the Early Oxfordian and continued up to the Late Kimmeridgian *p.p.* The Gintsi Formation represents intralithoclastic limestones with a grey or pinkish colour, the result of mass debris flow; they are similar to the Pokrovenik Acanthicum Limestones from east Serbia.

During the Late Kimmeridgian occurred an important change in the Supra-Getic basin, sedimentation started of marls to calcareous clays with rare and thin intercalations of sandstones or limestones of Late Kimmeridgian age. This is the Neshkovtsi Formation built up of pre-flysch sediments, 10–20 m thick (NIKOLOV & SAPUNOV 1970). Above them were deposited siliciclastic turbidite – sandstones (Ta-Tb-Tc Bouma intervals) and marls/clays (Td Bouma interval). In many localities, they contain fallen blocks, predominantly of Upper Jurassic limestones, often with corals. This is the latest the Late Kimmeridgian–earliest Early Cretaceous Kostel Formation (NIKOLOV & SAPUNOV 1970) structured of siliciclastic flysch type sediments with filling pieces of cobbles to boulders in them. The Kostel Formation is analogous to the Lužnica Flysch from south-east Serbia. The lower boundary is placed on the basis of the first thick sandstones bed over the marls-argillites of the Neshkovtsi Formation. In the Kostel Formation, the Bobovo and the Gorochevtsi members are separated. In the vicinity of the Sredorek Village is registered a very important phenomenon – a basal conglomerate of the Kostel Formation (the Antovo Member), lying directly on Middle Jurassic black shales.

Palaeogeography of the Getic and the Supra-Getic units during the Jurassic

During the Early Jurassic, the largest parts of the Getic and Supra-Getic represented dry land; the eastern part of the area, being the western parts of a basin with shallow water sediments, sandstones and ferriferous limestones reached the region of the Slivnitsa and Dimitrovgrad towns. To the east existed a relatively deep water basin of the Infra-Getic. The western part of the Getic and all the Supra-Getic represented dry land cut of by differently deep grabens (on the territory of Bulgaria – the Svetlya Graben, the Rayantsi Graben), with specific sedimentation. A differentiation in the palaeogeography commenced at the end of the Middle Jurassic (probably at the end of the Early Callovian). On the Getic area started the formation of a carbonate platform, which deepened to the south and passed progressively to deep water sediments. On the Supra-Getic started generally relatively deep water sedimentation of the pelagic micritic and nodular limestones ("*ammonitico rosso*" type), cut out by the calcareous clastic sedimentation of the Lobosh Formation in the Svetlya Graben. The greatest diversification of the sedimentation started at the end of the Kimmeridgian and continued during the Tithonian and the earliest Early Cretaceous when turbidity sedimentation (at the base with pre-flysch marls) settled in the Supra-Getic and reef and/or sub-reef on the Getic.

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Резиме

Упоређење јурских седимената Гетске и Супра-гетске јединице у граничној области југоисточне Србије и југозападне Бугарске

Циљ овога рада је упоређење јурских седимената Гетске и Супра-гетске палеогеографске јединице у пограничној области ЈИ Србије и ЈЗ Бугарске. На основу присуства и одсуства лијаских морских седимената Гетикум је подељен на источни и западни. Јурски седименти источног Гетикума упоређени су са онима у Инфра-гетикуму. У источном Гетикуму јурска седиментација започиње са континенталним седиментима који навише прелазе, у ЈИ Србији у хетаншке видличке кластите, који се могу упоредити са морским глинама и пешчарима туденске формације у ЈЗ Бугарској.

Навише у стубу следе лукањски кварцни пешчари у ЈИ Србији и морски пешчари костинске формације у ЈЗ Бугарској са којима започиње јурска трансгресија. Преко њих су седименти озировске формације, која се састоји од различитих литостратиграфских чланова у источном делу источног Гетикума и хомогених седимената у западном делу источног Гетикума. Они указују на западну границу лијаског морског басена. Лукањски брахиоподски слојеви, лукањски лапорци, лукањски белемнитско-грифејски слојеви и лукањски цефалоподски кречњаци у ЈИ Србији одговарају озировској формацији у ЈЗ Бугарској. Средњојурска седиментација у источном Гетикуму започиње, у ЈИ Србији, са сенокосним алевролитима и шкриљцима и гуленовачким слојевима који се могу упоредити у ЈЗ Бугарској са црним алевролитима ентрополске формације и лапорцима и глиновитим кречњацима бовске формације. У западним деловима источног Гетикума, у ЈЗ Бугарској, средњојурска седиментација започиње са градетским пешчарима и биокластичним кречњецима полетенске формације, који леже преко хомогене озировске формације. У западном Гетикуму јурска седиментација започиње за време алена, у ЈИ Србији са куриловским кластитима, а у ЈЗ Бугарској са пешчарима градечке формације. Преко њих су, у ЈИ Србији, куриловски кречњаци (гумпински кречњаци), а у Бугарској биокластични кречњаци полетенске формације. У завршним деловима средње јуре долази до уједначивања палеогеографских услова и настанка Гетске карбонатне платформе, како на западном, тако и на источном Гетикуму. На источном делу источног Гетикума у ЈИ Србији се могу издвојити басарски слојеви преко којих леже басарски кречњаци и видлички кречњаци. Они се могу упоредити у ЈЗ Бугарској са беледиехан формацијом, преко које леже биокластични кречњаци сливничке формације, а у ЈИ Србији ове творевине одговарају црновршким кречњацима Видлич планине.

У западном Гетикуму, за време келовеја и кимерица *p.p.*, у ЈИ Србији стварају се бељанички (или ждрелски) кречњаци прекривени кучајским спрудним пешчарима, а у ЈЗ Бугарској кречњаци беледиеханске формације прекривени биокластичним кречњацима сливничке формације.

За време јуре Супра-гетикум се карактерише присуством многобројних ровова, који условљавају седиментацију. Лијаски седименти формирају се само у светлајском рову – континентални пешчари и глине заблајанске формације, који су аналогни у Србији са лужничким кластитима и угљоносним слојевима Јерме.

Средњојурски седименти у западном Гетикуму источне Србије су представљени куриловским кластитима и куриловским кречњацима (гумпимски кречњаци, KRAÜTNER & KRSTIĆ 2003). У Супра-Гетикуму Србије формирају се јерма кластити и јерма кречњаци (гумпимски кречњаци). У ЈЗ Бугарској средњојурски седименти представљени су са пешчарима градечке формације и биокластичним кречњацима полетенске формације. У западним деловима бугарског Супра-гетикума формира се трекљански ров са радиолитским црним шкриљцима рајаначке формације, а на западном делу овог гребена настају плитководни седименти метхохијске и средоречке формације.

За време келовеја седиментација се наставља у ЈИ Србији каменичким бречастим кречњацима који навише прелазе у покровеничке кречњаке, а у ЈЗ Бугарској микритским кречњацима јаворечке формације праћена литокластичним кречњацима гиначке формације. Највећа седиментолошка разноликост настаје са флишном седиметацијом у Супра-Гетикуму. У ЈИ Србија депонује се лужнички флиш, а у ЈЗ Бугарској префлиш нешковачке формације и силицикластични флиш костелске формације.

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Late Barremian–Early Aptian Urgonian Limestones from the south-eastern Kučaj Mountains (Carpatho-Balkanides, eastern Serbia)

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Abstract. The newest results of sedimentological and paleontological investigations of part of the Urgonian Limestones studied in the surrounding of Boljevac on the SE slopes of the Kučaj Mts. (Carpatho-Balkanides, eastern Serbia) are presented. On two localities, near the village Faca Vajali, four types of microfacies and one subtype within the bioclastic limestones were separated. The characteristics of the depositional environments of the investigated Urgonian Limestones were studied and are discussed. At the base of the established rich micro-associations of foraminifera and algae, the vertical distribution of foraminiferal species was precisely defined which enabled the determination the the age of this part of the Urgonian Limestones as Late Barremian–Early Aptian.

Key words: Late Barremian–Early Aptian, Urgonian Limestones, Sedimentology, Micropaleontology, Stratigraphy, Kučaj Mountains, eastern Serbia

Апстракт. У раду су приказани најновији резултати седиментолошких и микропалеонтолошких истраживања дела ургонских кречњака откривених у околини Бољевца на југоисточним падинама Кучајских планина (Карпато-балканиди, источна Србија). На два локалитета у атару села Фаца Вајали констатована су четири типа микрофација и једна подфација у оквиру биокластичних кречњака. Утврђене и дискутоване су карактеристике депозиционих средина истраживаних ургонских кречњака. Из установљене веома богате микроасоцијације фораминифера и алги прецизно је дефинисано вертикално распрострањење фораминиферских врста које су омогућиле утврђивање старости овог дела ургонских кречњака у оквиру каснобаремског и раноаптског ката доње креде.

Кључне речи: касни барем–рани апт, ургонски кречњаци, седиментологија, микропалеонтологија, стратиграфија, Кучајске планине, источна Србија

Introduction

The rocks of Lower Cretaceous age, belonging to the eastern Serbian Carpatho-Balkanides, are widely distributed and facially heterogeneous. It refer to the Barremian and Aptian sediments and their special type known as Urgonian, Urgonian facies or Urgonian development. The mentioned sediments are most often in the mountainous area of the middle eastern Serbian Carpatho-Balkanides, which extend as an elongated arc from the Danube in the north southwards, then twist toward southeast and east until the Serbian-Bulgarian boundary. The composite range encompasses the mountains: Beljanica, Kučaj Mts., Rtanj, Ozren, Devica, Svrljig Mts., Tupižnica, Tresibaba, Pajež and part of the western slope of Stara planina.

A detailed summary of investigations of the Urgonian sediments of the eastern Serbian Carpatho-Balkanides until 1974 was given by Jankičević (1978). In addition, his monograph contains numerous new and comprehensive data about the paleontology, stratigraphy, and lithology of the Urgonian. Hence in further investigations, just a few authors in Serbia paid attention to the study of these sediments. In addition to papers of Ma-

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RAN (1996, 1998), which dealt mostly with Urgonian echinids of the Kučaj Mts., the Master Thesis of RADULOVIĆ (2003) could be mentioned, in which, together with Upper Barremian and Lower Aptian brachiopods, microassociations from the Urgonian of the Kučaj were separated. It is also necessary to emphasize the paper of JANKIČEVIĆ (1996) who studied the Urgonian of the Carpatho-Balkanides using formational analysis and suggested the name Tupižnica Formation for these carbonate-terrigenous deposits of Upper Barremian and Lower Aptian (Bedoulien and possibly also lower Middle Aptian – Gargasian) time/stratigraphic position.

During field investigations for the Master Thesis of A. MARAN in the period 1994–1995, a few geological columns were made at localities near Boljevac (southeastern slope of the Kučaj Mts.) and macrofossils and material for thin sections were collected. The investigated sites were: Faca Vajali–Izvor, Faca Vajali–Ušće Arnaute, Faca Vajali–Vidikovac, Mali Izvor/1, Mali Izvor/2, Bogovina–Kamenolom and Bogovina–Pećina. At that time, relatively poor sedimentological and micropaleontological studies were used for the determination and explanation of the paleoecological characteristics of the established microassociations, and on that way, indirectly for the analysis and solutions of paleoecological problems of echinoid macrofauna (MARAN 1996).

Afterwards, the complex of the Faca Vajali sections were chosen and proposed for protection within the frame of the Cretaceous Geosite Conservation Program in Serbia as being representative, accessible and available for the geological science (MARAN 1999, MARAN *et al.* 2005).

As part of an ongoing project, in past decade, the localities Faca Vajali–Izvor and Faca Vajali–Ušće Arnaute were investigated several times and new material was collected. The aim of this paper is to present the results of the new detailed micropaleontological and sedimentological studies and evaluate these results in order to contribute to a better understanding of this part of the Urgonian sediments of eastern Serbia. In this way, the fund of our geological knowledge and practice is enriched, which is very important because a 40 m high dam will be built on the Crni Timok River close to locality Faca Vajali–Izvor, the main purpose of which will be to supply regional water to towns in the Timok Region (the towns Bor and Zaječar). As a result, the closest area surrounding the village together with all the geological localities will be submerged and lost forever.

Geological setting

Earlier, this area, was geotectonically most frequently considered as part of the Kučaj–Svrljig Structural-Facial Zone (JANKIČEVIĆ 1978, ANĐELKOVIĆ & NIKOLIĆ 1980 and many other authors), *i.e.* the Kučaj Zone (DIMITRIJEVIĆ 1997). Nowadays, it is adjoined to the Kučaj (Getic) Terrane/Unit, one of several large Alpine geotectonic (structural) units in the Carpatho-Balkanides of eastern Serbia (KARAMATA *et al.* 1997, KRÄUTNER & KRSTIĆ 2003) (Fig. 1).

The Kučaj Terrane had a long (Proterozoic to Neogene) and very complex geological evolution. The western boundary of the Unit is an Alpine eastward thrust, the eastern boundary is mostly of the same character. The time of the docking of the Kučaj Terrane to the Stara Planina–Poreč Terrane at the East is the end of the Viséan.

In the Kučaj Unit, the oldest rocks (Osanica metamorphics) are of Proterozoic age, metamorphosed under amphibolite facies conditions, and represent part of the old crystalline basement. The following Upper Proterozoic to Lower Cambrian rocks are volcanic-sedimentary rocks metamorphosed under greenschists facies conditions. Over this basement, Upper Cambrian to Lower Carboniferous sediments of the Caledonian–Variscan Cycle were deposited: shallow marine clastics (Upper Cambrian–Ordovician), deep-sea black shales (Upper Ordovician–Lower Devonian), pre-flysch (Lower and Middle Devonian) and flysch (Upper Devonian–Lower Carboniferous).

The post-Variscan overstep sequence begins with the Stephanian Limnic sediments grading into the Permian Red Sandstone Formation formed in intramountain depressions. In the Lower until the Middle or even in a part of the Upper Triassic, mainly shallow water carbonate rocks were deposited. In the Bajocian, basal clastics and oolitic limestones were formed transgressively. After that, in the eastern parts of the terrane, shallow water sediments of a carbonate platform (inclusively Urgonian Limestones were deposited up to the end of Lower Aptian. In the western regions of the Unit, Callovian–Valanginian deep water deposits are present. From the Cenomanian to the Maastrichtian, in places to the Paleocene, identical pelagic clastics and carbonate sediments occur, accompanied by a multistage magmatism (the Timok area). Brackish Upper Maastrichtian sediments represent the final stage of the marine regime. Lacustrine Paleogene sediments unconformably ovelie the Upper Cretaceous formations. The Middle and Upper Miocene limnic rocks are a post-Alpine overstep sequence.

The Lower Cretaceous sediments belonging to the Kučaj Unit/Terrane are widely distributed and thick. Differentiation of the sea bottom started in the Upper Jurassic, and continued in the Lower Cretaceous. The main rock types of the Neocomian are different kinds of shallow water limestones, but sandstones and sandy marlstones are also present. The rocks are characterized by rich association of bivalves, gastropods, brachiopods, echinoids, foraminifera and algae. A small flysch depression located in the southwestern part was formed in theUpper Jurassic and was present to the Valanginian. After the flysch sediments post-flysch marlstones and marly limestones were deposited. Over the whole area, Urgonian rocks of Barremian and Aptian age are

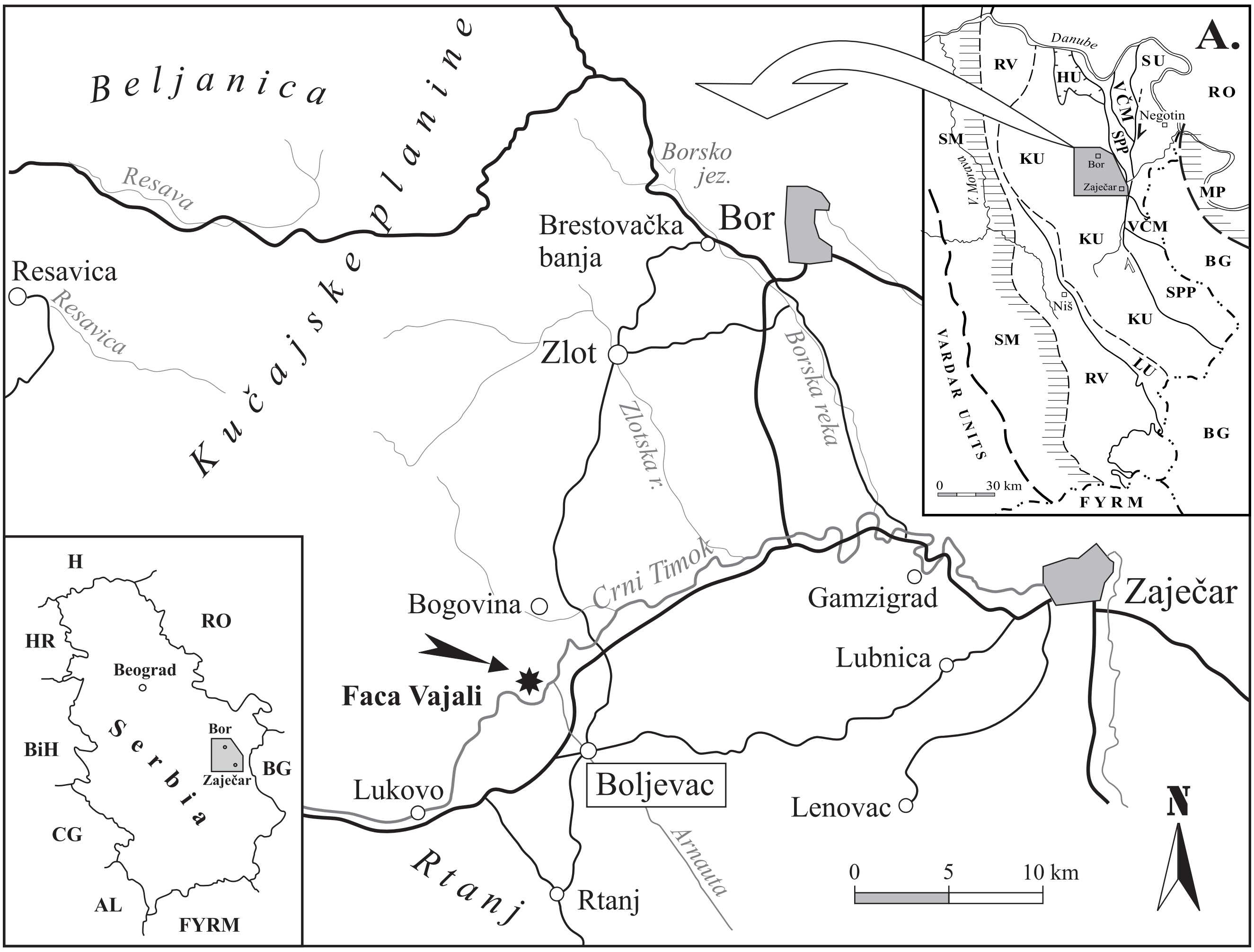


Fig. 1. Location of the Faca Vajali Village in the vicinity of Boljevac, eastern Serbia. **A**. Terranes/units of the eastern Serbia Serbian Carpatho-Balkanides (between horizontal lines) as part of the Balkan Peninsula (KARAMATA *et al*. 1997, KRÄUTNER & KRSTIĆ 2003): **SM,** Serbian-Macedonian Unit; **RV,** Ranovac–Vlasina Unit; **LU,** Lužnica Unit; **KU,** Kučaj Unit; **HU,** Homolje Unit; **SPP,** Stara Planina–Poreč Unit; **VČM,** Vrška Čuka–Miroč Unit; **SU**, Severin (Krajina) Unit; **MP,** Moesian Plate.

represented by carbonate sediments with three facies (limestone facies with rudists, facies of bioclastic limestones with orbitolinids and facies of bioclastic limestones with a terrigenous component and orbitolinids) and terrigenous non-carbonatic rocks with three/four facies (facies of sandstones and marlstones with orbitolinids, sandstone facies with ostreids and sandstone facies with plant detritus) (JANKIČEVIĆ 1978, 1996). Their total thickness is circa 450–500 m and fossils are abundant, especially representatives of rudists (and other bivalves), corals, echinoids, brachiopods, orbitolinids, other foraminifera and algae. The lower boundary of these sediments is not sharp but is undertaken because of the presence of a rich microassociation of Barremian age. The previously mentioned fauna of Neocomian age is very poor. In addition, it is almost impossible to divide the sediments of Barremian and of Aptian age, and the boundary is the most often located conditionally because only a gradual transition exists. The upper boundary is sharp. The Upper Aptian is not found, hence directly over the Lower Aptian lie conglomerates and glauconitic sandstones of Albian age or some other rocks of Upper Cretaceous age.

Microfacial analysis of Urgonian Limestones in the investigated sections

The Urgonian sediments located in the vicinity of Boljevac were sampled in detail southwestern from Bogovina near the village Faca Vajali on two sections: Faca Vajali–Izvor and Faca Vajali–Ušće Arnaute (Fig. 1). In both sections are present only a part of the Urgonian Limestones, which are macroscopically, *i.e*., lithologically, represented with two groups of limestones: thick-bedded to massive grey limestones with visible sections of macrofauna and thin- to decimeter thick-bedded friable, disintegrated partly, sandy-marly grey-yel-

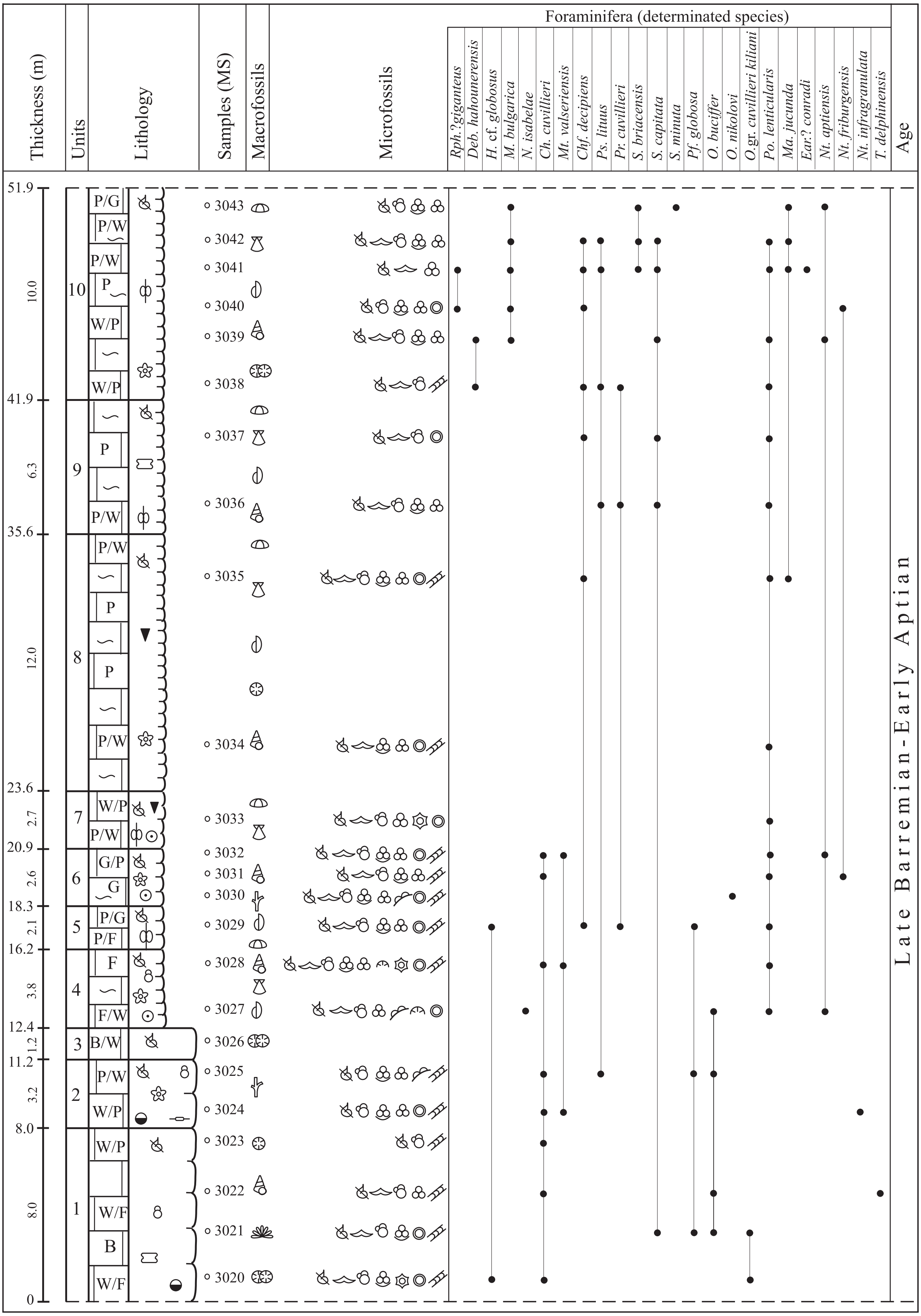


Fig. 2. Geologic column and vertical distribution of the determined foraminifera species in the Late Baremian–Early Aptian of the Faca Vajali–Izvor Section, eastern Serbian Carpatho-Balkanides (for the symbols, see Fig. 5).

lowish limestones with the whole forms of fossils. In these rocks, it was possible, on the basis of sedimentological, macro- and micropaleontological features (depositional textures, biota, *etc*.), to define four microfacies types (MFT 1–4) and one subtype (MFT 2A). The extended version of the DUNHAM (1962) and the methods described by WILSON (1975) and FLÜGEL (2004) were used for the microfacies analysis.

The thin sections are housed in the collection of M. SUDAR (Department of Paleontology, Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia), under the numbers MS 3000-3041.

The Faca Vajali–Izvor Section

The geological column from this locality is located westward of the village Faca Vajali. It begins from the middle parts of a temporary flow which from level 350 descends to the Crni Timok River and continues eastward, on the left side of the local road leading to the center of the village (coordinates: x 4859050, y 7574470). The locality is named by the spring (in Serbian = Izvor) which is situated close below the section, directly along the Crni Timok River.

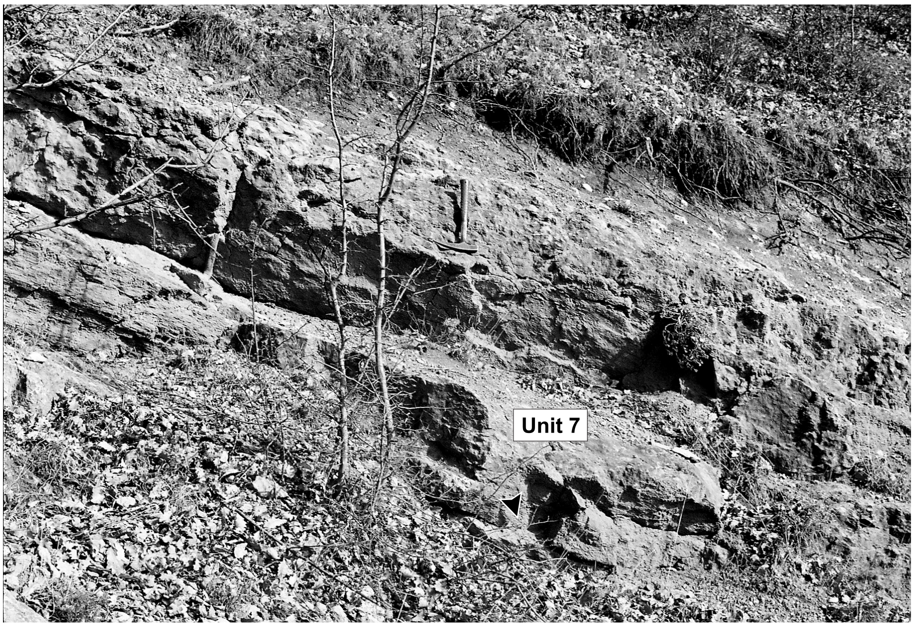


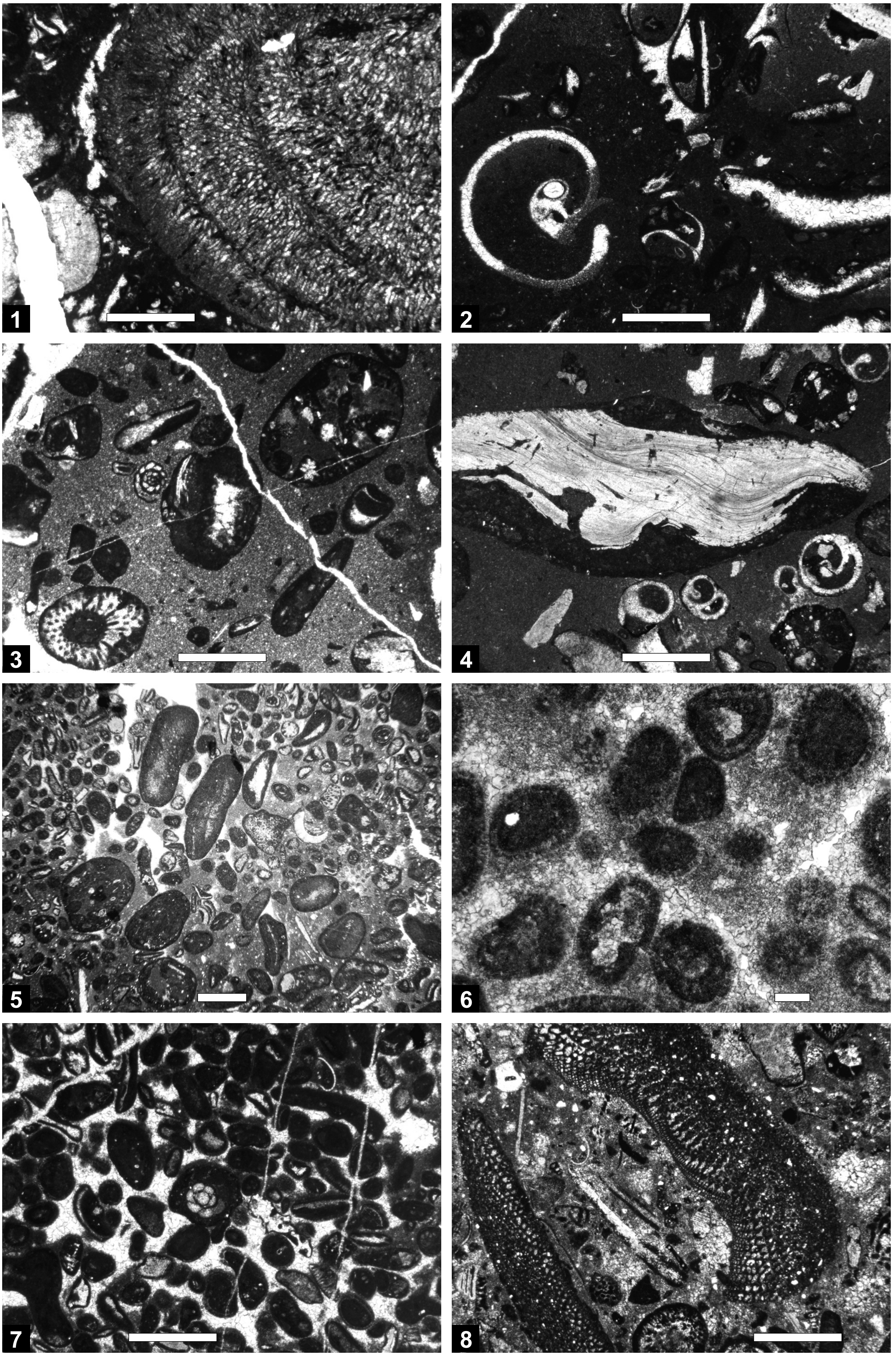
Fig. 3. Thick-bedded, friable and disintegrated grey-yellowish marly limestones from the middle parts (unit 7) of the Faca Vajali–Izvor Section, eastern Serbian Carpatho-Balkanides.

At the locality Faca Vajali–Izvor, the studied column has a thickness 51.9 m (Fig. 2). It is possible to distinguish the lower and upper part of the column on the field. The lower part (3 units, 12.4 m thickness) is composed of compact, grey thick-bedded to massive limestones with a good visible extracted macrofauna on the surfaces – colonial and solitary corals, stromatoporoids, chaetetids, gastropods, bryozoans and other forms. In the upper part of the column (thickness 39.5 m, units 4–10) predominate friable thick- to thin-bedded carbonate sediments, partially enriched by clayey and sandy fractions and with a yellowish weathering of the surfaces. Only sporadically are harder beds, thick to a few dm, visible (Fig. 3). This part of the.column is abundant with whole forms of fossils: bivalves (no rudists), echinoids, gastropods, brachiopods, orbitolinids, *etc*.

On the the Faca Vajali–Izvor Section column are separated the.following two characteristic microfacies types and one subtype, the photomicrographs of which are given in Fig. 4: MFT 1 – *bioclastic wackestone with transitions to packstone, grainstone or floatstone*; MFT 2A – *bioclastic wackestone with transition to packstone, rare boundstone*; and MFT 4 – *orbitolinid packstone*.

MFT 1. ***Bioclastic wackestone with transitions to packstone, grainstone or floatstone*** (Fig. 4, 5–7) are present in rocks, around 70 %, mostly from the upper parts of the column (units 4–10). In addition to rich macrofaunal biota, the microassociation is represented by fragments (bioclasts) of bivalves (but no rudists), gastropods, corals, algae, foraminifera, echinoids, brachiopods, crinoids, *etc*. The bioclasts are unequally distributed in micrite, rarely microsparite, sporadically enriched by Fe-pigment or fine siliciclastic detritus (quartz predominates). Their size varies from 0.1 mm and less to over 2 mm and more. The bioclastic and another allochems (coated grains, grapestone, rarely ooids, pelloids *etc*., sometimes with geopetal fillings) are well rounded, mostly middle to bed sorted. Very often they have micritic envelopes as a result of work of cyanobacterias, fungi *etc*., which are characteristic for protected shoals and lagoons of higher salinity.

The following algae were established: green algae (Chlorophyta), represented by numerous Dasycladaceae (*Neomeris*, *Acroporella*, *Salpingoporella, etc*.), Udoteaceae (*Boueina*, *Lithocodium*), other Halimedaceae and some dasycladacean morphogenera (*Coptocampylodon*, *Terquemella*). Red algae (Rhodophyta) are scarse, represented only by crusty structures of the genus *Polystrata*. Cyanobacterias (blue-green algae – "Cyanophyta"), as endolithic algae and fungi, produce micrite (the result of activities of prokaryotes) which envelopes the allochems.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In association connected with bioclastic wackestone are present numerous benthic foraminifera and between them various orbitolinids (*Orbitolinopsis*, *Palorbitolina*), simple or complex agglutinated forms (*Ammobaculites*, *Charentia*, *Everticyclammina*, *Sabaudia*, *Debarina*, *Nezzazata*, *Nezzazatinella*, *Choffatella*, *Daxia, etc*.), calcareous imperforate, porcelaneous forms, represented by miliolids (*Quinqueloculina*, *Rumanoloculina*, *Pyrgo*, *Sigmolina*, *Dervantina*), calcareous perforate forms (*Neotrocholina*, *Trocholina*, *Spirillina*, *Lenticulina*, *etc*.) and scarse sessile foraminifera (*Coscinophragma* and others).

These sediments were deposited in a shallow subtidal, and/or rather deeper intertidal area (carbonate platform margin, *i.e.,* open shelf lagoon behind a platform margin; WILSON 1975; FLÜGEL 2004).

MFT 2A. ***Bioclastic wackestone with transition to packstone; rare boundstone*** (Fig. 4, 1–4), are minor, in rocks of the lower part of the section (units 1–3) and are present with around 20 %. At coarse sparry calcite are distributed well-rounded, unsorted intraclasts, which represent coated and reworked bioclasts formed by tidal currents and waves. Their cores, as the other fine detritus, is made of fragments of colonial and solitary corals, foraminifera, algae (Fig. 4, 3), crinoids, bryozoans, echinoids, stromatoporoids, chaetetids (Fig. 4, 1), (micro)gastropods (Fig. 4, 2), bryozoans, stromatoporoids, calcareous sponges, some undeterminable "organic" structures, *etc*. In some parts, the carbonate mud is not washed out and rests like small patches.

The microassociation of these rocks is very diverse, as in the previous microfacies. Algae are represented only by green algae: thedasycladacean genera (*Neomeris; Zittelina*), *Boueina* from Udoteaceae, and also with some dasycladacean morphogenera (*Coptocampylodon, Terquemella)*. Aggutinated foraminifera (*Ammobaculites, Evertyciclammina, Charentia, Sabaudia and* numerous orbitolinids) are more typical than benthic calcareous forms (*Neotrocholina* and some tiny miliolids).

MFT 4. ***Orbitolinid packstone*** is present in the rocks of the both parts of the column in an amount of 10 %. Higher contents of sandy-clayey, hence ferruginous matter, is typical in microsparite-micrite. In addition to numerous agglutinated orbitolinids (only *Palorbitolina*, Fig. 4, 8), they contain small coated bioclasts with a core of dasycladaceans, stromatoporoids, and other organisms, whole tiny foraminifera and microgastropods, tiny organic debris (echinoid spines, *etc*.), *etc*.

Their microfossil community is monotonous because of the presence of terrigenous matter which reduced flourishing of the organic world. In addition orbitolinids, *Nezzazata*, *Nezzazatinella*, *Everticyclammina*, and calcareous perforate genera *Neotrocholina*, *Lenticulina* and some miliolids were determined. Algae are present only with rare *Boueina* (Udoteaceae).

These microfacies types were probably formed in the shallow subtidal of a partially protected lagoon in a carbonate platform.

The Faca Vajali–Ušće Arnaute Section

The section is located in the eastern part of the village, on the slope of Cukloj, 200 m SW from the confluence (in Serbian = Ušće) of the Arnauta River into the Crni Timok River (coordinates: x 4858950, y 7576175). The column, thick 45.5 m contains 10 units (Fig. 5). At the base (3 units, thickness 6.2 m) are yellow friable sandy-marly limestones without macrofauna. They are followed by thick-bedded to massive grey limestones (units 4–9, thickness 37 m), which represent thicker and a more imposing part of the column with surfaces where numerous concentrations are visible, coquinas of the rudists and very rare other macrofaunas – corals, stromatoporoids, gastropods, bryozoans, *etc*. (Fig. 6). The highest part of the column (unit 10, thickness 2.3 m) is made.up of yellowish disintegrated sandy-marly limestones, identical to the sandstones at the base of the section and also without fauna.

On the geological column of the Faca Vajali–Ušće Arnaute Section the following characteristic three microfacies types are present and their photomicrographs are given in Fig. 7: MFT 2 – *bioclastic wackestone with transition to packstone*; MFT 3 – *bioclastic grainstone* and MFT 4 – *orbitolinid packstone*.

The MFT 2 microfacies (Fig. 7, 1, 3–6) from the middle part of column and the friable MFT 3, which is present in the lowest and final part of the Faca Vajali–Ušće Arnaute Section (Fig. 7, 2) are dominant. In adition to these, in the whole column also exist rocks with the MFT 4, but with much fewer and rarer microfossils than in the same MFT of the Faca Vajali–Izvor Section.

MFT 2. *Bioclastic wackestone with transition to packstone*. In comparison with the microfacies subtype 2A from the Faca Vajali–Izvor Section, in the MFT 2

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Fig. 4. Thin-section photomicrographs of the sediments from the Faca Vajali–Izvor Section, eastern Serbian Carpatho-Balkanides. **1,** Bioclastic wackestone/floatstone with a large fragment of chaetetids, MS 3020; **2,** Bioclastic wackestone/packstone with numerous bioclasts of gastropods, molluscs *etc*., MS 3022; **3,** Bioclastic wackestone/packstone with dasycladacean algae (*Salpingoporella pygmea*), foraminifera (*Charentia cuvillieri*) and other well-rounded coated grains, MS 3023; **4,** Bioclastic wackestone/packestone with a large shell fragment coated with micrite, small gastropods and other fragments, MS 3024; **5,** Bioclastic grainstone with large and small unsorted intraclasts, peloids and bioclasts (undifferentiated foraminifera, algae, *etc*.), MS 3030; **6,** Bioclastic grainstone/packstone with large, badly preserved ooids, MS 3031; **7,** Bioclastic grainstone/packstone with will sorted micritized ooids and bioclasts (benthic foraminifera, *etc*.), MS 3032; **8,** Bioclastic packestone/wackstone with large orbitlinids (*Palorbitolina lenticularis, Palorbitolina* sp.) and other bioclasts, MS 3035. Scale bar = 1 mm.

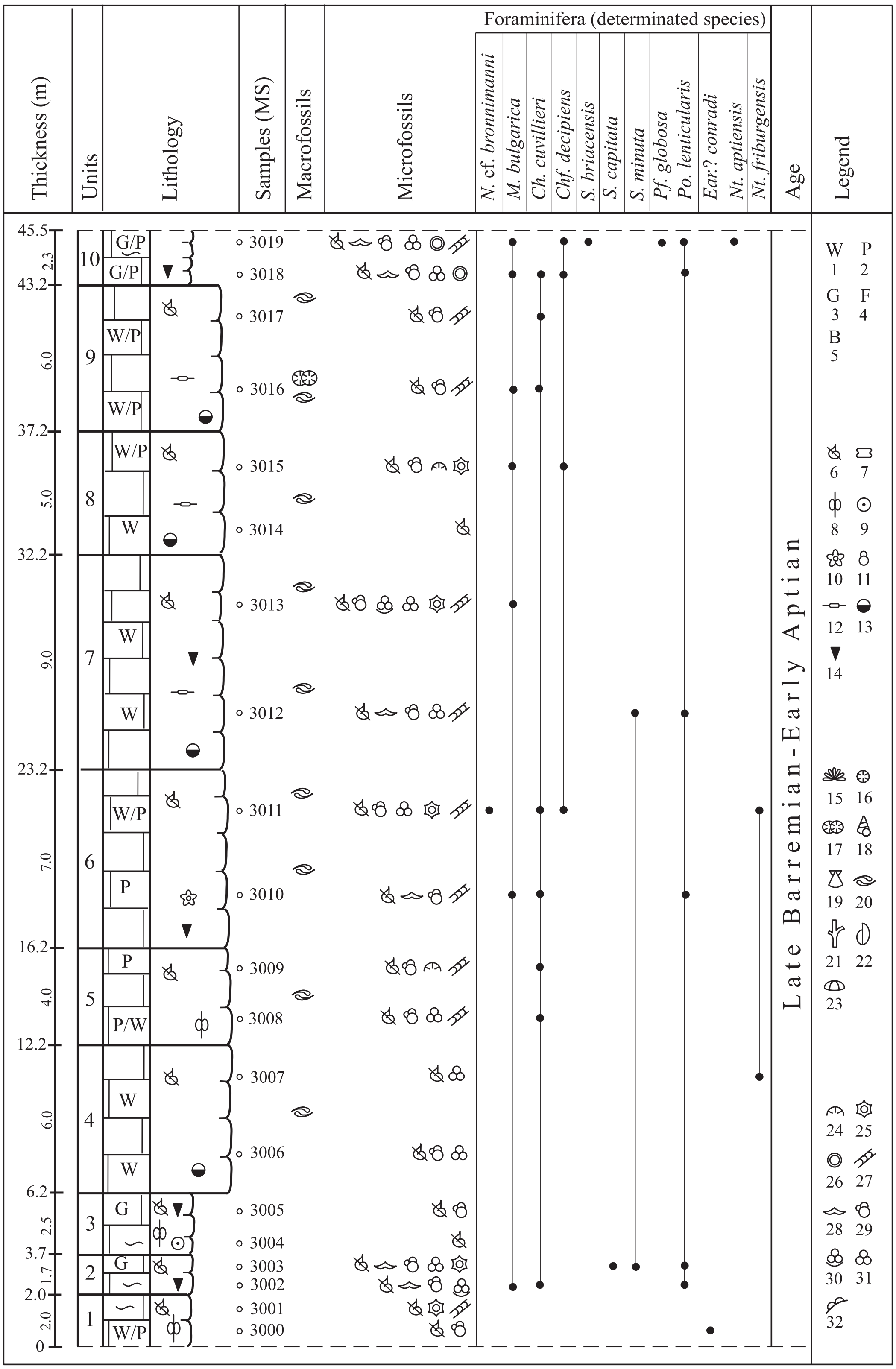

Fig. 5. Geologic column and vertical distribution of the determined foraminifera species in the Late Baremian–Early Aptian of the Faca Vajali–Ušće Arnaute Section, eastern Serbian Carpatho-Balkanides. Legend: **1,** wackestone; **2,** packstone; **3,** grainstone; **4,** floatstone; **5,** boundstone; **6,** bioclasts; **7,** lithoclasts; **8,** pelloids; **9,** ooids; **10,** oncoids; **11,** agregated grains; **12,** fenestrae; **13,** geopetal fabric; **14,** quartz; **15,** chaetetids; **16,** solitary corals; **17,** colonial corals; **18,** gastropods; **19,** bivalves in general; **20,** pachyodonts; **21,** bryozoans; **22,** brachiopods; **23,** echinoids; **24,** cyanobacterias; **25,** rhodophycean algae; **26,** udoteacean green algae; **27,** dasycladacean green algae; **28,** orbitolinids; **29,** other agglutinated foraminifera; **30,** calcareous porcelaneous (imperforate) foraminifera (miliolids *etc.*); **31,** calcareous perforate foraminifera; **32,** sessile foraminifera.

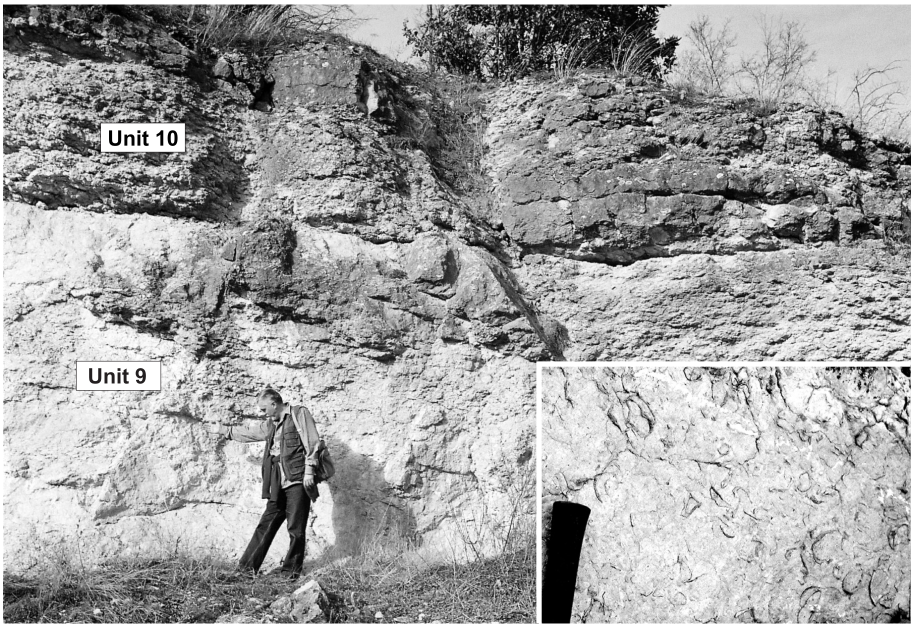

Fig. 6. The uppermost middle (massive grey limestone of unit 9) and upper (thin- to decimetre thick-bedded grey-yellowish friable and disintegrated limestones of unit 10) parts of the Faca Vajali–Ušće Arnaute Section (eastern Serbian Carpatho-Balkanides) with the detail of a rudist coquina.

of this site, the most important differences lie in the biota and the diversity of the macrofaunal species, which is more dominant. Except for rare colonial and solitary corals, the macrofauna is represented by abundant rudist genera *Toucasia, Matheronia, Monopleura* and *Requienia,* which build coquinas. Fragments of shells, stromatoporoids, chaetetids, *etc*. which are distributed in micrite can be rounded (rarely angular) because of transport. Usually they are unsorted, often with micritized coats. Corals, which fix the base, are scarse and fragmented. Due to periodical and intense movements and wave actions, robust forms of fossils were accumulated in the tidal area.

In parts with an unequal presence of a sandy fraction, the development of an abundant organic world was enabled but it was also suitable for agglutinated foraminifera (orbitolinids). They rarely appear together with algae in the bioclastic packstone (MFT 4).

Microfossils are poorer than in the previous sections: rarely algae (cyanobacterias, red – *Polystrata*, dasycladaceans – *Neomeris*, "*Epimastopora*", dasycladacean morphogenera *Coptocampylodon*, *Terquemella)*; simple or complex agglutinated (*Charentia*, *Sabaudia*, *Pseudotextulariella*, orbitolinids) and forms of calcareous perforate foraminifera (*Neotrocholina)*.

These rocks have two main characteristics: an abundance of rudists (and rare specimens of other reef macrofaunas) and a bioclastic character. Although the first characteristic indicates reef origin, the fauna present in the bioclastic, very fragmented limestones is not sufficient to mark the limestone of MFT 2 and MFT 2A as reefal. This was confirmed with their view, manner of appearance, structure, *etc*. For the other characteristics of these limestone with rudists and an interpretation of their depositional nature see in the penultimate chapter of this paper.

MFT 3. ***Bioclastic grainstone*** appears subordinately in yellowish, partially friable and thicker limestone beds without macrofauna but with a relatively rich and diverse microfossil community.

Limestone of this microfacial type were deposited in intertidal (WILSON 1975, washed grains of a platform margin; LOGMAN 1981, backreef sands).

* * *

For comparison with the given investigated sections, existing results of sedimentological and paleontological analyses from a few other localities near to Boljevac were used but the given data will not be presented separately. These localities are: Faca Vajali–Vidikovac, Mali Izvor/1, Mali Izvor/2, Bogovina–Pećina and Bogovina–Kamenolom. The established microfacial types and subtype are distinguished on the following sections.

MFT 1 and especially MFT 4: Faca Vajali–Izvor (units 4–10), Bogovina–Pećina, and Mali Izvor (both fossiliferous sites). MFT 3 is found only in the lower and higher part of the Faca Vajali–Ušće Arnaute Section (units 1–3 and 10). MFT 4 is also present in remaining sections but in smaller amounts than other microfacial types.

MFT 2 is the most common in the middle part of the Faca Vajali–Ušće Arnaute Section (units 4–9) and at the locality Bogovina–Kamenolom. MFT 2A, characterized by rarer presence or almost without rudists, is found in the lower units (1–3) of the Faca Vajali–Izvor Section and at the site Faca Vajali–Vidikovac.

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In comparison with the facies studied in the Barremian–Lower Aptian sediment complex established by

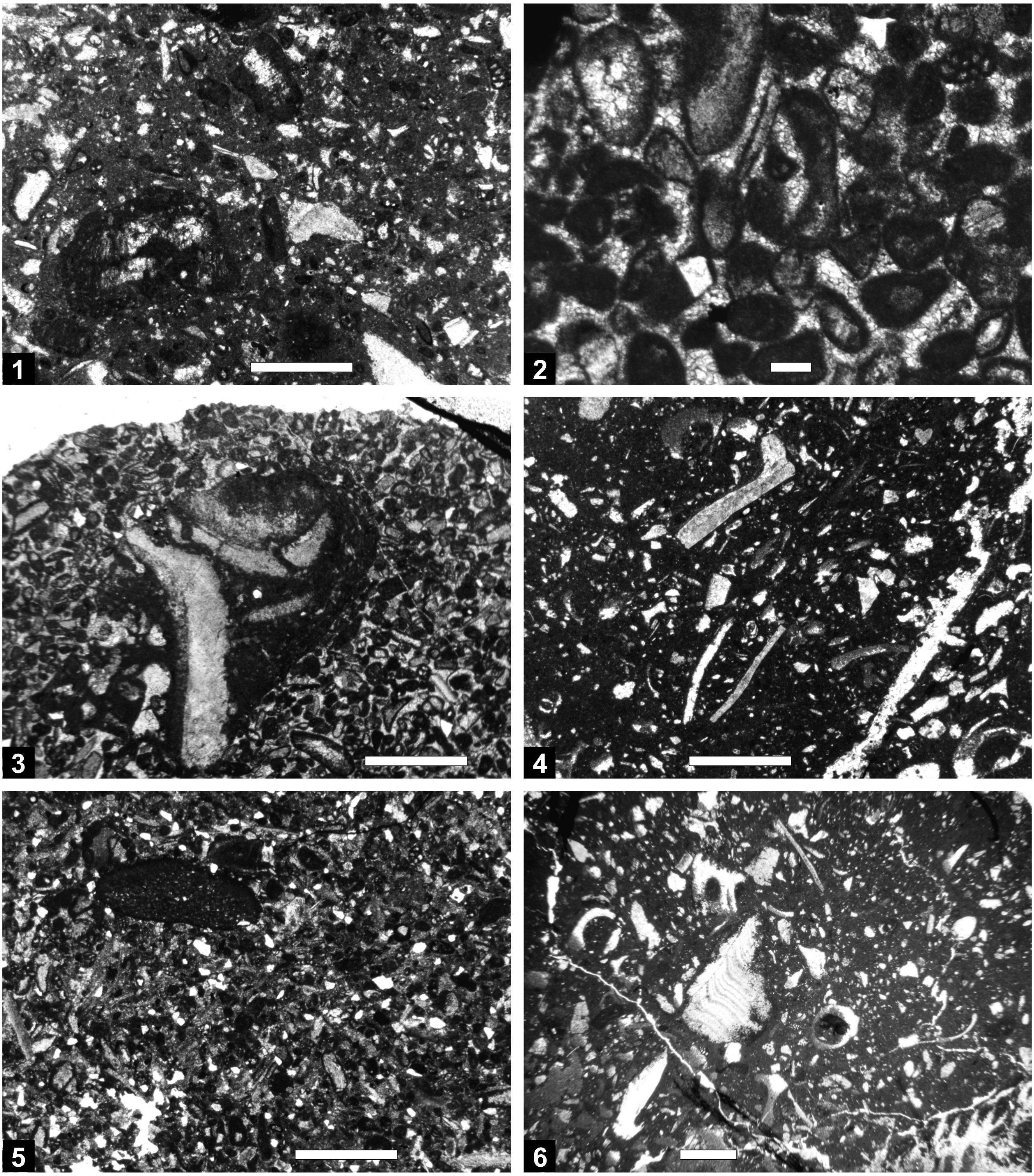


Fig. 7. Thin-section photomicrographs of the sediments from the Faca Vajali–Ušće Arnaute Section, eastern Serbian Carpatho-Balkanides. **1,** Biolithoclastic wackestone/packestone with angular, unsorted bioclasts, MS 3001; **2,** Well sorted bioclastic grainstone with rare foraminifera (miliolids), MS 3002; **3,** Bioclastic wackestone/packestone with one large lithoclast (fragments of bivalve shells) and numerous other small, well sorted grains, MS 3003; **4,** Bioclastic wackestone with abundant detritus (mostly of bivalve shells), MS 3006; **5,** Sandy wackestone/packstone with a large undeteriminable orbitolinid, MS 3011; **6,** Bioclastic wackestone/packestone with fragments exclusively from bivalve shells, MS 3015. Scale bar = 1 mm.

JANKIČEVIĆ (1978), the microfacial types and subtypes separated and described herein could be probable equalized with the facies with rudists (= MFT 2 and 2A), *i.e.,* with facies of bioclastic limestones (= MFT 1, 3 and 4). The first type of limestones (the present MFT 2 and 2A) was define by the mentioned author as Urgonian facies *sensu stricto* and, according to his opinion, it was formed in a reef environment, i.e., in infralittoral, more in his internal part (*op. cit*., p. 172). As was pointed out in the previous section, sufficient reasons which would allow this limestone with rudists to be designated as reefal do not exist. The second type of JANKIČEVIĆ (1978), *i.e*., the present MFT 1, 3 and 4, was signified as bioclastic (para-Urgonian) limestones deposited in a para-reef environment – internal and/or external infralittoral (*op. cit*., p. 174).

Summary and conclusions

The herein presented results of a detailed sedimentological and paleontological (especially micropaleontological) study of a part of the Urgonian bioclastic limestones from near to the village Faca Vajali, the Boljevac Area on the SE slopes of the Kučaj Mts. (Carpatho-Balkanides, eastern Serbia), some summary discussions and conclusions in relation to the interpretation of their depositional environment and stratigraphy can be made.

Interpretation of the depositional environment

Sedimentological and paleontological data of the Late Barremian–Early Aptian Urgonian Limestones of the studied area of eastern Serbia confirmed shallow water carbonate sedimentation of a platform type under conditions of a tropical to subtropical climate on a wide unstable shelf of developed relief in a warm sea of the Tethyan areal. In French literature, this area is traditionally known as the "carbonate (Urgonian) platform" (ARNAUD-VANNEAU 1980; MASSE & PHILIP 1981; MASSE 1993, *etc*. and many other earlier and newer references) and in Serbian literature, it is defined as the "paraplateforme carbonatique" (GRUBIĆ & JANKIČEVIĆ 1973) or the "shelf carbonate platform" (JANKIČEVIĆ 1978, 1996).

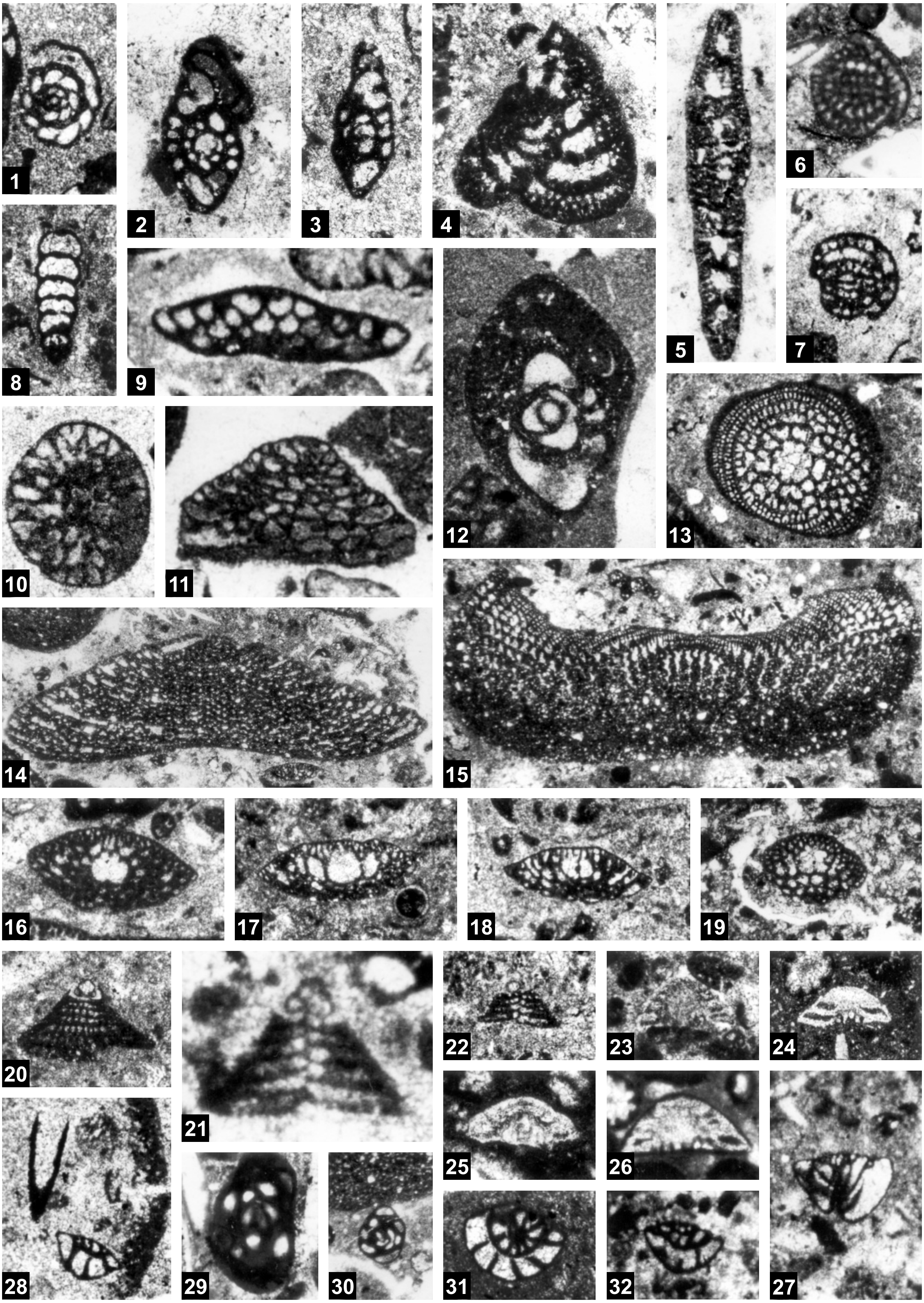
GUŠIĆ & JELASKA (1990) while establishing some depositional environments of the Upper Cretaceous of the Brač Island made comparisons with the ambients of the middle shelf in sense of WILSON & JORDAN (1983). The investigated biotop of part of the Urgonian sediments near to Boljevac could be correlated with the ambient and characteristics of that area. It represents an extensive and morphologically differentiated backreef platform, partially opened (presence of sceletal carbonate sands of higher water energy formed in sandy shoals, beaches, tidal accumulations, submarine rises – bioclastic grainstone), with a depth from shallow low and/or high energy infralittoral (subtidal less than 10 m) to littoral (intertidal, tidal flat). Different microfacies rich with carbonate mud from the protected shelf lagoon of limited circulation below the wave base are very frequent.

Bioclasts (whole or fragmented fossil specimens) mostly derived from rudist shells and also from other reef fauna: corals, chaetetids, stromatoporoids, *etc*. indicate the interspersing of these organisms on the platform or accumulation in coquinas. According to WILSON & JORDAN (1983) and MASSE (1990, 1993), the Urgonian forms of rudists were formed on the middle shelf, *i.e*., on the internal parts of the external platform margin and in an intraplatform lagoon (margin or inside), in which occupy different paleoecological niches.

These small ecologic reefs (small biostromes, carbonate build-up or patch reefs) built by the mentioned bioclasts and other reef organisms were formed as elevations a few meters over the sea bottom (3–6 m in recent analogues, JAMES 1983) in the interior of the platform. In addition, they represented immature ecosystems in the initial stabilization/colonization stadium and because of their fast destruction, nowadays, just products of their erosion and disintegration are found, such us in the limestone B group, *i.e*., in MFT 2.

Fig. 8. Overthurned colonial coral from the lower part (unit 3) of the Faca Vajali–Izvor Section, eastern Serbian Carpatho-Balkanides.

A special characteristic of the sedimentary area of the investigated Urgonian Limestones of the Faca Vajali area is the exclusive presence of bioclastic varieties of all the included limestones. In addition, some fauna was found in an abnormal position, as an example the overturned coral colony in the beginning of the FacaVajali–Izvor section (Fig. 8). Chaotical distribution of the rest of macrofauna (especially rudists), recognizable transport and erosion of allochems (for example many of the orbitolinids have not a top with an embryonic chamber). All this points to constant transport, *i. e*., to parautochthonity of all the presented biota and other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material in a depositional marine environment of very shallow subtidal and/or somewhat deeper intertidal.

Hence, it can be concluded that all these paleoenvironments, essentially infralittoral to partially or rarely littoral, with a more or less distinct water energy, probably occupy an area linked either just before the outer edge of a platform or just inside, *i. e.,* also before the inner open, to more of less protected parts of the platform lagoon.

Stratigraphy

The age of the Urgonian sediments from eastern Serbia is of great importance. Usually it is determined as Barremian–Aptian, Upper Barremian–Lower Aptian, *etc*. As is shown in the geological setting, their boundaries are distinctly determined, the upper more than the lower. In spite of the presence of rich fossil material, especially macrofauna and the absence of lithological variabilities, the precise determination of Barremian–Aptian boundary is not always sure and simple. For this reason, during earlier geological investigations of the Lower Cretaceous of eastern Serbia, the presence of Urgonian sediments and their Barremian and/or Aptian age was mostly established.

In the Serbian geological literature attempts were made to subdivide the mentioned stages. The first results were given by V. PETKOVIĆ who considered that the boundary between the Barremian and the Aptian on the Tupižnica Mt. lies "eventually between limestones with pachydont shells and orbitolinid limestones" (PETKOVIĆ 1908 from JANKIČEVIĆ 1978, p. 161). The question of boundary in the investigated Urgonian complex of eastern Serbia was of special interest for JANKIČEVIĆ (1978). The same author defined the whole complex as Barremian–Lower Aptian, although he considered all separated limestone facies as Barremian (whole, or only their upper part) to Lower Aptian, and other terrigenous non-carbonate sediments as only Lower Aptian.

Also of interest is part from his conclusion: "The boundary between the Barremian and Aptian stage is most often provisory undertaken, because exists a gradual transition. But, the fossil association of organisms, in which are numerous *Palorbitolina lenticularis* (Blum.), surely confirms Lower Aptian" (*op. cit*., p. 183). A very similar is opinion is shared by RADULOVIĆ (2003). She decided that the parts of the columns of Urgonian sediments at the localities Faca Vajali and Mali Izvor with a defined microassociation of *Palorbitolina lenticularis* and *Neotrocholina aptiensis* are of Lower Aptian age. Unfortunately, their conclusions were not confirmed with detailed defined stratigraphic characteristics of the whole microassociation and their members. In addition, the mentioned foraminifera have a range from the Late Barremian to the earliest Late Aptian (ARNAUD-VANEAU *et al*. 1991, and many other earlier and newer papers).

However, for stratigraphic/biostratigraphic subdivision of the Urgonian sediments, microfossils are much more suitable than the present macrofauna. This paper is one attempt to precisely define the stratigraphic ranges of the present foraminifera, *i.e*., to separate characteristic microfossil associations into Barremian and/or Aptian. For this reason, the vertical distributions of the determined foraminifera species in both studied sections were given (Figs. 2 and 5). It was possible to separate three foraminiferal microassociations:

– first, for the Barremian (*Charentia cuvillieri* (even from the Berriasian), *Praereticulinella cuvillieri* and *Neotrocholina* cf. *friburgensis*),

– second, for the Late Barremian and the Early Aptian (*Melathrokerion valserinensis*, *Choffatella decipiens* (even from the Hauterivian), *Sabaudia minuta*, *Pfenderina* cf. *globosa*, *Orbitolinopsis buccifer*, *Orbitolinopsis* gr. *cuvillieri kiliani*, *Palorbitolina lenticularis*, *Neotrocholina* cf. *aptiensis*, and *Neotrocholina* cf. *infragranulata* (even from the Berriasian), and

– third, for the Aptian, even the Albian (*Mayncina bulgarica*, *Sabaudia* cf. *briacensis* and *Sabaudia capitata*).

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Fig. 9. Late Baremian–Early Aptian foraminifera from the Faca Vajali–Izvor Section, eastern Serbian Carpatho-Balkanides (determined by S. POLAVDER). **1,** *Charentia cuvillieri* NEUMANN, thin-section MS 3023; **2, 3,** *Mayncina bulgarica* LAUG, PEYBERNES & REY, Fig. 5.2, thin-section MS 3040, Fig. 5.3, thin-section MS 3041; **4, 5,** *Choffatella decipiens* SCHLUMBERGER, thin-section MS 3041; **6, 7,** *Praereticulinella cuvillieri* DELOFRE & HAMAOUI, Fig. 5.6, thin-section MS 3029, Fig. 5.7, thin-section MS 3038; **8,** *Martinottiella jucunda* ARNAUD-VANNEAU, thin-section MS 3041; **9–11,** *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY, Fig. 5.9, and 5.10, thin-section MS 3027, Fig. 5.11, thin-section MS 3022; **12,** *Melathrokerion valserinensis* BROENNIMANN & CONRAD, thin-section MS 3028; **13–19,** *Palorbitolina lenticularis* (BLUMENBACH), Figs. 5.14. and 5.16–18, thin-section MS 3036, Fig. 5.13, thin-section MS 3034, Figs. 5.15. and 5.19, thin-section MS 3035; **20, 21,** *Sabaudia* cf. *capitata* ARNAUD-VANNEAU, Fig. 5.20, thin-section MS 3042, Fig. 5.21. thin-section MS 3036; **22,** *Sabaudia* cf. *briacensis* ARNAUD-VANNEAU, thin-section MS 3041; **23, 24,** *Neotrocholina* cf. *aptiensis* IOCHEVA, Fig. 5.23, thin-section MS 3039, Fig. 5.24, thin-section MS 3027; **25,** *Neotrocholina* cf. *infragranulata* (NOTH), thin-section MS 3024; **26,** *Neotrocholina* cf. *friburgensis* GUILLAUME & REICHEL, thin-section MS 3031; **27,** *Nezzazatinella* sp., thin-section MS 3038; **28,** *Earlandia*? *conradi* ARNAUD-VANNEAU (left) and *Nezzazata* sp. (right), thin-section MS 3041; **29, 30,** Miliolids (?*Quinqueloculina* sp.), Fig. 5.29, thin-section MS 2029, Fig. 5.30, thin.section MS 3037; **31, 32,** *Nezzazata* sp., Fig. 5.31, thin-section MS 3039, Fig. 5.32, thin-section MS 3041. Figs. 5.14, 5.15, 5.29, 5.30. are × 6,5 and all other Figs. are × 13.

However, some foraminiferal taxa from different associations in the whole investigated interval appear together, mutually overlap, and it was not possible to put a boundary between them, *i.e.*, between Barremian and Aptian. Therefore, in this paper, the age of the studied part of the Urgonian Limestones is still treated as the interval Late Barremian–Early Aptian. Most probably, the main cause for this is the exclusively bioclastic character of the investigated part of the Urgonian Limestones, in which are obviously inserted organisms of different ages and from different biotops.

A large part of the mentioned interval belongs to the *Palorbitolina lenticularis* Zone according to the range of this foraminifera, one of the most important taxon and geographically widespread in the Tethys. Since detailed investigations and a more exact dating of the whole Urgonian geologic column of eastern Serbia are missing, their later biostratigraphic sudivision was not possible. Also, real knowledge about the lower and upper boundary of the investigated Late Baremian–Early Aptian Urgonian Limestone in the Boljevac area does not exist.

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Appendix: Determined limestone types and fossils in the thin sections

Faca Vajali–Izvor Section

MS 3020. Bioclastic wackestone/floatstone; fragments of bivalves, brachiopods, bryozoans, corals, echinoderms; chaetetids *Chaetetopsis rumanus* (SIMONESCU); *Orbitolinopsis* gr. *cuvillieri kiliani, Haplophragmoides* cf. *globosus* LOZO, *Charentia cuvillieri* NEUMANN, *Rumanoloculina* sp.; Solenoporaceae*, Coptocampylodon fontis* PATRULIUS, *Terquemella* sp.

MS 3021. Bioclastic wackestone/floatstone; fragments of bivalves, brachiopods, bryozoans, corals, stromatoporoids, echinoderms; *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY, *Orbitolinopsis* gr. *cuvillieri kiliani, Sabaudia* cf. *capitata* ARNAUD VANNEAU, *Pfenderina* cf. *globosa* FOURY, miliolids; *Lithocodium aggregatum* ELLIOT, *Salpingoporella pygmea* (GUEMBEL), *Coptocampylodon fontis* PATRULIUS, *Zittelina* sp., *Triploporella* sp.

MS 3022. Bioclastic wackestone/packstone; fragments of bivalves, brachiopods, bryozoans, corals, echinoderms; *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY, *Charentia cuvillieri* NEUMANN, *Trocholina* sp.; *Boueina* sp., *Gyroporella* cf. *lukicae* SOKAC & VELIC, *Salpingoporella pygmea* (GUEMBEL), *Salpingoporella* sp.

MS 3023. Bioclastic wackestone/packstone; fragments of bivalves, brachiopods, bryozoans, corals, echinoderms; *Charentia cuvillieri* NEUMANN; *Salpingoporella pygmea* (GUEMBEL), *Neomeris* sp., *Zittelina* sp.

MS 3024. Bioclastic wackestone/packstone; fragments of bivalves (rudists and others), corals, calcareous sponges, bryozoans, stromatoporoids, and others; *Charentia* cf. *cuvillieri* NEUMANN, *Melathrokerion* cf. *valserinensis* BROENNIMANN & CONRAD, *Neotrocholina* cf. *infragranulata* (NOTH), *Pseudotriloculina* sp., *Pyrgo* sp., *Rumanoloculina* sp., *Spirillina* sp.; *Lithocodium aggregatum* ELLIOT, *Coptocampylodon fontis* PATRULIUS, *Neomeris* sp., *Terquemella* sp., *Zittelina* sp.

MS 3025. Bioclastic packstone/wackstone; fragments and sceletal detritus of bivalves, gastropods, echinoderms, bryozoans; *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY, *Charentia cuvillieri* NEUMANN, *Pseudocyclammina* cf. *P. lituus* (YOKOHAMA), *Pfenderina* cf. *globosa* FOURY, *Nezzazata* sp., *Verneuilina* sp., *Sigmoillina* sp. (and other miliolids), *Neotrocholina* sp., *Spirillina* sp., sessile foraminifera; undeterminable dasycladaceans.

MS 3026. Bioclastic boundstone/wackestone; large colonial coral structure.

MS 3027. Bioclastic floatstone/wackestone; fragments of bivalves (rudists: *Monopleura* sp. and others), gastropods, calcareous sponges, bryozoans, *etc*.; *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY, *Palorbitolina lenticularis* (BLUMENBACH), *Orbitolinopsis* sp., *Nezzazata isabellae* ARNAUD-VANNEAU & SLITER, *Neotrocholina* cf. *aptiensis* IOCHEVA, *Ammobaculites* sp., *Charentia* sp., *Melathrokerion* sp., *Everticyclammina* sp., *Bolivinopsis* sp., sessile foraminifera *Coscinophragma* sp.; cyanobacterial crusts, *Boueina* cf. *hochstetteri* TOULA, *Boueina* sp.; other Halimedaceae; *Acroporella* sp.

MS 3028. Bioclastic floatstone; fragments of bryozoans; microgastropod *Nerinea* sp.; *Palorbitolina lenticularis* (BLUMENBACH), *Charentia cuvillieri* NEUMANN, *Melathrokerion valserinensis* BROENNIMANN & CONRAD, *Mayncina* sp., tiny miliolids, *Lenticulina* sp.; cyanobacterial crusts, *Polystrata album* (PFENDER), *Lithocodium aggregatum* ELLIOT, *Gyroporella lukicae* SOKAC & VELIC, *Triploporella* sp., *Neomeris* sp.

MS 3029. Bioclastic packstone/floatstone; fragments of gastropods, *etc*.; *Palorbitolina lenticularis* (BLUMENBACH) and many other undeterminable orbitolinids, *Haplophragmoides* cf. *globosus* LOZO, *Choffatella decipiens* SCHLUMBERGER, *Praereticulinella cuvillieri* DELOFRE & HAMAOUI, *Pfenderina* cf. *globosa* FOURY, *Nezzazatinella* sp., *Everticyclammina* sp., *Lenticulina* sp., miliolids (? *Quinqueloculina* sp. and others); Udoteaceae (*Boueina* cf. *hochstetteri* TOULA, *Boueina* sp.); other Halimedaceae; *Terquemella* sp.

MS 3030. Bioclastic grainstone; fragments and detritus of macrofauna, *e.g*., bryozoans and others; microgastropod; *Orbitolinopsis* cf. *nikolovi* PEYBERNES, CONRAD & CUGNY, and many other undeterminable orbitolinids, *Ammobaculites* sp., *Everticyclammina* sp., miliolids, sessile foraminifera; *Boueina* cf. *hochstetteri* TOULA, *Boueina* sp.; other Halimedaceae; *Coptocampylodon fontis* PATRULIUS, *Terquemella* sp.

MS 3031. Bioclastic grainstone/packstone; tiny organic debris of crinoids, bryozoans; microgastropod (*Nerinea* sp.); *Palorbitolina lenticularis* (BLUMENBACH), *Orbitolinopsis* sp. and many other undeterminable orbitolinids, *Charentia cuvillieri* NEUMANN, *Neotrocholina aptiensis* IOCHEVA, *Neotrocholina* cf. *friburgensis* GUILLAUME & REICHEL, *Ammobaculites* sp., small miliolids, *Neotrocholina* sp., *Lenticulina* sp.; *Terquemella* sp.

MS 3032. Bioclastic packstone/grainstone; fragments of macrofauna, *e.g*., bryozoans and others; microgastropods; *Palorbitolina lenticularis* (BLUMENBACH), *Charentia cuvillieri* NEUMANN, *Melathrokerion valserinensis* BROENNIMANN & CONRAD, *Neotrocholina* cf. *aptiensis* IOCHEVA, *Mayncina* sp., *Sabaudia* sp., *Rumanoloculina* sp., *Neotrocholina* sp.; *Boueina* sp., *Coptocampylodon fontis* PATRULIUS, *Terquemella* sp., *Neomeris* sp. and numerous algal fragments.

MS 3033. Bioclastic wackestone/packstone; tiny sceletal detritus with numerous bryozoans; *Palorbitolina lenticularis* (BLUMENBACH) and other orbitolinids, *Nezzazata* sp., *Lenticulina* sp.; *Marinella lugeoni* PFENDER, *Boueina hochstetteri* TOULA and other algal debris.

MS 3034. Bioclastic packstone/wackestone; fragments of bryozoans, crinoids, echinoids (*e.g*., spines, *etc*.), stromatoporoids, annelids, *etc*.; *Palorbitolina lenticularis* (BLUMENBACH) and other numerous orbitolinids, *Neotrocholina aptiensis* IOCHEVA, *Sabaudia* sp., *Neotrocholina* sp.; *Boueina* sp., *Terquemella* sp.

MS 3035. Bioclastic packstone/wackestone with orbitolinids; fragments of different macrofauna; *Palorbitolina lenticularis* (BLUMENBACH) and other numerous orbitolinids, *Choffatella decipiens* SCHLUMBERGER, *Martinottiella jucunda* ARNAUD-VANNEAU, *Neotrocholina* cf. *infragranulata* (NOTH), miliolids, *Neotrocholina* sp, *Lenticulina* sp.; *Boueina* sp., *Terquemella* sp., *Neomeris* sp.

MS 3036. Bioclastic packstone/wackestone; fragments and detritus of macrofauna; *Palorbitolina lenticularis* (BLUMENBACH) and other numerous orbitolinids, *Pseudocyclammina* cf. *lituus* (YOKOHAMA), *Praereticulinella cuvillieri* DELOFRE & HAMAOUI, *Sabaudia* cf. *capitata* ARNAUD-VANNEAU, *Debarina* sp., numerous miliolids, *Lenticulina* sp.

MS 3037. Bioclastic packstone with orbitolinids; fragments and detritus of macrofauna; *Palorbitolina lenticularis* (BLUMENBACH) and other numerous orbitolinids, *Choffatella decipiens* SCHLUMBERGER, *Sabaudia capitata* ARNAUD-VANNEAU, *Ammobaculites* sp., *Nezzazatinella* sp., *Pseudotextulariella* sp., *Dobrogelina* sp., numerous miliolids (?*Quinqueloculina* sp. and others); *Boueina* sp.

MS 3038. Bioclastic wackestone/packstone; fragments of bivalves, crinoids, echinoid spines, corals; microgastropod; *Palorbitolina lenticularis* (BLUMENBACH), *Debarina hahounerensis* FOURCADE, RAOULT & VILA, *Choffatella decipiens* SCHLUMBERGER, *Pseudocyclammina* cf. *lituus* (YOKOHAMA), *Praereticulinella cuvillieri* DELOFRE & HAMAOUI, *Nezzazatinella* sp., *Everticyclammina* sp., *Sabaudia* sp., *Neotrocholina* sp.; *Vermiporella*? *tenuipora* CONRAD.

MS 3039. Bioclastic wackestone/packstone with coral; fragments of bivalves, crinoids, echinoid spines; *Palorbitolina lenticularis* (BLUMENBACH), *Debarina hahounerensis* FOURCADE, RAOULT & VILA, *Mayncina bulgarica* LAUG, PEYBERNES & REY, *Neotrocholina* cf. *aptiensis* IOCHEVA, *Sabaudia capitata* ARNAUD-VANNEAU, *Daxia* sp., *Ammobaculites* sp., *Nezzazata* sp., miliolids, *Lenticulina* sp.

MS 3040. Bioclastic packstone; fragments and detritus of bivalves, corals, *etc*.; microgastropod; *Reophax*? *giganteus* ARNAUD-VANNEAU, *Mayncina bulgarica* LAUG, PEYBERNES & REY, *Choffatella decipiens* SCHLUMBERGER, *Neotrocholina* cf. *friburgensis* GUILLAUME & REICHEL, *Pseudocyclammina* sp., *Sabaudia* sp., *Quinqueloculina* sp. and numerous other miliolids, *Lenticulina* sp.; *Boueina* sp.

MS 3041. Bioclastic packstone/wackestone; fragments and detritus of bivalves, corals, *etc*.; *Palorbitolina lenticularis* (BLUMENBACH), *Reophax*? *giganteus* ARNAUD-VANNEAU, *Mayncina bulgarica* LAUG, PEYBERNES & REY, *Choffatella decipiens* SCHLUMBERGER, *Sabaudia* cf. *briacensis* ARNAUD-VANNEAU, *Sabaudia* cf. *capitata* ARNAUD-VANNEAU, *Pseudocyclammina* cf. *lituus* (YOKOHAMA), *Martinottiella jucunda* ARNAUD-VANNEAU, *Earlandia*? *conradi* ARNAUD VANNEAU, *Nezzazata* sp., *Lenticulina* sp.

MS 3042. Bioclastic packstone/wackestone; fragments and detritus of bivalves, corals, *etc*.; *Palorbitolina lenticularis* (BLUMENBACH), *Mayncina bulgarica* LAUG, PEYBERNES & REY, *Choffatella decipiens* SCHLUMBERGER, *Pseudocyclammina lituus* (YOKOHAMA), *Sabaudia briacensis* ARNAUD-VAN-

NEAU, *Sabaudia* cf. *capitata* ARNAUD-VANNEAU, *Martinottiella jucunda* ARNAUD-VANNEAU, *Lenticulina* sp.

MS 3043. Bioclastic packstone/grainstone; fragments and detritus of bivalves, corals, *etc*.; *Mayncina bulgarica* LAUG, PEYBERNES & REY, *Sabaudia briacensis* ARNAUD-VANNEAU, *Sabaudia minuta* (HOFKER JR.), *Martinottiella jucunda* ARNAUD-VANNEAU, *Neotrocholina aptiensis* IOCHEVA, *Daxia* sp., *Nezzazata* sp., *Rumanoloculina* sp., *Quinqueloculina* sp. and other miliolids, *Trocholina* sp.

Faca Vajali – Ušće Arnaute Section

MS 3000. Biolithoclastic wackestone /packstone; tiny organic debris, predominantly from bivalves, gastropods, *etc*.; *Earlandia*? *conradi* ARNAUD-VANNEAU, *Nautiloculina* sp., *Bolivinopsis* sp.

MS 3001. Lithobioclastic wackestone/packstone; tiny organic debris, predominantly from bivalves, gastropods, *etc*.; *Polystrata album* (PFENDER) DENIZOT, "*Epimastopora*" sp.; *Vermiporella*? *tenuipora* CONRAD.

MS 3002. Bioclastic grainstone; tiny organic debris of bivalves, echinoderms (small echinoid spines, *etc*.), algae, *etc*.; microgastropods.; *Palorbitolina lenticularis* (BLUMENBACH), *Mayncina bulgarica* LEUG, PEYBERNES & REY, *Charentia cuvillieri* NEUMANN, *Nezzazata* sp., *Pseudotextulariella* sp.; *Polystrata album* (PFENDER) DENIZOT.

MS 3003. Bioclastic wackestone/packstone; tiny organic debris of bivalves, echinoderms (echinoid spines, *etc*.), algae, *etc*.; microgastropods.; *Palorbitolina lenticularis* (BLUMENBACH), *Sabaudia capitata* ARNAUD-VANNEAU, *Sabaudia minuta* (HOFKER), miliolids, *Neotrocholina* sp.

MS 3004. Bioclastic grainstone; fine organic debris, bioclasts of molluscs and tiny benthic foraminifera.

MS 3005. Bioclastic grainstone; fine organic debris, bioclasts of molluscs and tiny benthic foraminifera; *Bolivinopsis* sp.

MS 3006. Bioclastic wackestone; fragments of rudists and other bivalves; microgastropods; *Nautiloculina* sp., *Neotrocholina* sp.

MS 3007. Bioclastic wackestone; fragments of rudists and other bivalves; microgastropods; *Neotrocholina* cf. *friburgensis* GUILLAUME & REICHEL.

MS 3008. Bioclastic packstone/wackestone; fragments of rudists, stromatoporoids, *etc*.; *Charentia cuvilllieri* NEUMANN, *Nezzazata* sp., *Neotrocholina* sp.; different algal structures (e.g. cyanobacterias, *etc*.).

MS 3009. Bioclastic packstone**;** fragments of rudists, stromatoporoids, *etc*.; *Charentia cuvillieri* NEUMANN, *Sabaudia* sp.; *Terquemella* sp.

MS 3010. Bioclastic packstone; fragments and detritus of rudists and other bivalves, gastropods, crinoids, echinoids (*e.g*. spines, *etc*.), stromatoporoids, and others; *Palorbitolina lenticularis* (BLUMENBACH) and other undeterminable orbitolinids; *Mayncina bulgarica* LEUG, PEYBERNES & REY, *Charentia cuvillieri* NEUMANN, *Nautiloculina* sp.; large algal nodule, *Coptocampylodon fontis* PATRULIUS.

MS 3011. Bioclastic wackestone/packstone; fragments and detritus of rudists and other bivalves, gastropods, crinoids, echinoid spines, stromatoporoids, and others; *Nautiloculina* cf. *bronnimanni* ARNAUD-VANNEAU & PEYBERNES, *Charentia cuvillieri* NEUMANN, *Choffatella decipiens* SCHLUMBERGER, *Neotrocholina* cf. *friburgensis* GUILLAUME & REICHEL, *Nezzazata* sp., *Sabaudia* sp., *Neotrocholina* sp.; *Polystrata album* (PFENDER) DENIZOT, *Coptocampylodon fontis* PATRULIUS, "*Epimastopora*" sp.

MS 3012. Bioclastic wackestone; *Palorbitolina lenticularis* (BLUMENBACH), *Sabaudia minuta* (HOFKER), *Debarina* sp., *Quinqueloculina* sp., *Pyrgo* sp. and other miliolids, *Neotrocholina* sp.; *Terquemella* sp.

MS 3013. Bioclastic wackestone; *Mayncina bulgarica* LEUG, PEYBERNES & REY, *Debarina* sp., *Quinqueloculina* sp., *Pyrgo* sp. and other miliolids, *Neotrocholina* sp.; *Polystrata album* (PFENDER) DENIZOT, *Coptocampylodon fontis* PATRULIUS.

MS 3014. Bioclastic wackestone; fragments and tiny debris of rudists, *etc*.; microgastropod; cyanobacterias, *Polystrata album* (PFENDER) DENIZOT.

MS 3015. Bioclastic wackestone/packstone; fragments and tiny debris of rudists, *etc*.; *Mayncina bulgarica* LEUG, PEYBERNES & REY, *Choffatella decipiens* SCHLUMBERGER; cyanobacterias, *Polystrata album* (PFENDER) DENIZOT.

MS 3016. Bioclastic wackestone/packstone; detritus of macrofauna (*e.g*., rudists, *etc*.); *Mayncina bulgarica* LEUG, PEYBERNES & REY, *Charentia cuvillieri* NEUMANN, *Ammobaculites* sp.; *Terquemella* sp.

MS 3017. Bioclastic wackestone/packstone; detritus of macrofauna (*e.g*., rudists, *etc*.); *Charentia* cf. *cuvillieri* NEUMANN; *Neomeris* sp.

MS 3018. Bioclastic grainstone/packstone; detritus of bryozoans, echinoderms, bivalves, *etc*.; *Palorbitolina lenticularis* (BLUMENBACH), *Mayncina* cf. *bulgarica* LEUG, PEYBERNES & REY, *Charentia cuvillieri* NEUMANN, *Choffatella decipiens* SCHLUMBERGER, *Everticyclammina* sp., *Sabaudia* sp., *Neotrocholina* sp.; *Lenticulina* sp.; *Boueina* sp.

MS 3019. Bioclastic grainstone/packstone; detritus of bryozoans, echinoderms (*e.g*. echinoid spines, *etc*.), and others; *Palorbitolina lenticularis* (BLUMENBACH), *Mayncina bulgarica* LEUG, PEYBERNES & REY, *Choffatella decipiens* SCHLUMBERGER, *Sabaudia briacensis* ARNAUD-VANNEAU, *Pfenderina globosa* FOURY, *Neotrocholina aptiensis*

IOCHEVA, *Ammobaculites* sp., *Sabaudia* sp., *Dobrogelina* sp., miliolids, *Trocholina* sp., *Neotrocholina* sp., *Lenticulina* sp.; *Boueina* sp., *Clypeina* sp., *Terquemella* sp.

Резиме

Ургонски кречњаци касног барема и раног апта југоисточних падина Кучајских планина (Карпато-балканиди, источна Србија)

У оквиру распрострањених и фацијално разноврсних доњокредних седимената Кучајског терана Карпато-балканида источне Србије нарочито су карактеристичне творевине баремског и аптског ката и посебан тип њиховог развића познат под именом ургон, ургонска фација или ургонско развиће. На два локалитета у атару села Фаца Вајали које се налази у околини Бољевца, на југоисточним падинама Кучајских планина, извршена су детаљна седиментолошка и микропалеонтолошка истраживања једног њиховог дела.

Резултати проучавања су указали да је он искључиво изграђен од биокластичних варијетета кречњака у којима су, уз бројне макро и микрофосиле, констатована четири типа микрофација: MFT 1 тј. биокластични векстони са прелазом ка пекстонима, грејнстонима или флоутстонима; MFT 2 тј. биокластични векстони са прелазом ка пекстонима; MFT 3 тј. биокластични грејнстони и MFT 4 тј. орбитолински пекстони. Такође је одређен и један тип подфација – МФТ 2А тј. биокластични векстони са прелазом ка пекстонима, ређе баундстонима. Кречњаци из MFT 1 и 3 налазе се у танко до дебело банковитим трошним до делимично распаднутим, песковито-лапоровитим, и сиво-жућкастим кречњацима са целим облицима фосила. У дебело банковитим до масивним сивим кречњацима у којима је макрофауна, најчешће рудистна, присутна искључиво у пресецима заступљени су кречњаци MFT 2 и 2A. Орбитолински пекстони (MFT 4) појављују се у оба типа биокластичних кречњака у проучаваним локалитетима села Фаца Вајали.

За дефинисање депозиционих средина истраживаних ургонских кречњака коришћене су и палеоеколошке особине утврђених микрофосила, међу којима су нарочито бројни фораминифери, а ређе алге. Скоро искључиво су присутне бентоске форме док су причвршћени фораминифери доста ретки. Међу првима се запажају аглутинантни (међу којима су нарочито бројни орбитолиниди), кречњачко порцелански (имперфоратни) тј. милиолиди и др., као и кречњачко перфоратни облици. Цијанобактерије, црвене и зелене (примерци фамилија Udoteaceae и Dasycladaeae) алге су подређене.

Интерпретација целокупне депозиционе палеосредине истраживаног дела ургонских кречњака Фаца Вајали показала је да су они стварани у морској средини веома плитког субтајдала и/или мало дубљег интертајдала. Ове, пре свега инфралиторалне до делимично, али ређе и литоралне палеосредине, са више или мање израженом динамиком воде, највероватније заузимају просторе везане за спољну ивицу платформе, или за њену унутрашњост, тј. такође за унутрашње отворене, до више или мање заштићене делове платформне лагуне. Сви присутни палеоекосистеми и недовољно консолидовани депонати у наведеним срединама су у великој мери били подложни брзом разлагању што је условило да у истраживаним деловима ургонских кречњака локалитета Фаца Вајали данас искључиво наилазимо на биокластичне варијетете кречњака и фрагментиране фосиле.

У оквиру веома богате микроасоцијације фораминифера и алги прецизно су дефинисана вертикална распрострањења утврђених фораминиферских врста што ипак није омогућило раздвајање творевина баремског и аптског ката. Утврђена је каснобаремска и раноаптска старост овог дела ургонских кречњака при чему већи део интервала припада зони *Palorbitolina lenticularis*.

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The Albian–Cenomanian Kotroman Formation of Mokra Gora (western Serbia)

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Abstract. Cretaceous deposits in the wider area of Mokra Gora village (western Serbia) were studied previously during basic, thematic mapping and detailed metallogenic investigations. These former studies neither distinguished the clearly defined formations, nor defined the lower rank lithostratigraphic units. The oldest Cretaceous formation in the area of Mokra Gora, the "Basal series", lies above peridotite and serpentinite and below the "Hemipelagic series" (Radoičić 1995, and references therein). This study preliminary defines the "Basal series" as a formation and proposes the lithostratigraphic term "Kotroman Formation". The stratigraphic column of the Kotroman Formation consists of three separate members of lower rank. The ferruginous sandstone and conglomerate of the Kamišna Member occupy the lower part, nodular bedded marly limestone of the Uroševići Member are in the middle part and thin bedded bioclastic limestone of the Jatare Member made up the upper part of the formation. Fossils are represented by sporadic assemblages of mollusks, foraminifers, algae, brackish water charophytes and ostracodes, which indicate an Albian–Cenomanian age of the formation.

Key words: Kotroman Formation, palaeontology, sedimentology, Albian–Cenomanian, Mokra Gora, western Serbia.

Апстракт. Кредне творевине у широј околини Мокре Горе (западна Србија) биле су проучаване током основних геолошких истраживања и детаљних истраживања лежишта минералних сировина. Ниједним од ових истраживања нису дефинисане формације, нити је одређен ранг појединих литостратиграфских јединица. Најстарија кредна формација у околини Мокре Горе, тзв. "Базална серија", лежи преко перидотита и серпентинита, а испод "Хемипелашке серије" (Радоичић 1995). Овом студијом је прелимарно дефинисана "Базална серија", за коју је предложен назив "Формација Котроман" и у којој су издвојена три посебна члана нижег реда. Гвожђевити пешчари и конгломерати члана Камишна заузимају најнижи ниво, квргави кречњаци члана Урошевићи се налазе у средњем нивоу, док је највиши члан представљен танкослојевитим кречњацима и лапорцима члана Јатаре. Фосилна заједница представљена је спорадичним асоцијацијама мекушаца, фораминифера, алги, слатководним харофитама и остракодима, који указују на алб-ценоманску старост формације.

Кључне речи: Формација Котроман, палеонтологија, седиментологија, Алб-ценоман, Мокра Гора, западна Србија.

Introduction

Cretaceous sediments have a limited extent in western and south-western Serbia. However, in the wider area of Mokra Gora, there exist well defined Cretaceous exposures, which have been studied by numerous authors, e.g., Milovanović (1933, *cum. lit.*), Pejović & Radoičić (1971), Radoičić (1995), Banjac (1994) and Dulić (2003). Some detailed mapping of the formations and lower rank units was made during

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basic and thematic geologic investigation. OLUJIĆ & KAROVIĆ (1986) distinguished units of Cenomanian, Cenomanian–Turonian and Senonian age, while MOJSILOVIĆ *et al*. (1978) distinguished Cenomanian–Turonian and Turonian units. JOVANOVIĆ *et al*. (2004) distinguished three well defined and mappable formations: The oldest, so called "Basal Series" of Albian–Cenomanian age, which lies directly over serpentinite or its weathered crust; the middle, "Hemipelagic series" of Cenomanian age (thin bedded marly limestone with pithonellas, rarely heterohelicides, hedbergellas, ammonites, echinoderms and gastropods), and the youngest, shallow water reef formation of Turonian age (massive reef limestone with numerous rudists). A detailed description of the basal part of the succession, with special emphasis on microfauna assemblages, was presented in RADOIČIĆ & SCHLAGINTWEIT (2007). Exposures at Vardište in Bosnia (5 km southwestward from Mokra Gora, Fig. 1), with rocks similar to Basal Series, were object of detailed lithological investigations by BORTOLOTTI *et al*. (1971). Their level 1 and 2 could be correlated with lower part of Kotroman Formation, while their level 3 (with abundant fossil associations), could be correlated with upper part of Kotroman Formation, or with Jatare member as lateral equivalent. On the contrary, the authors refer to Upper Jurassic age of these rocks.

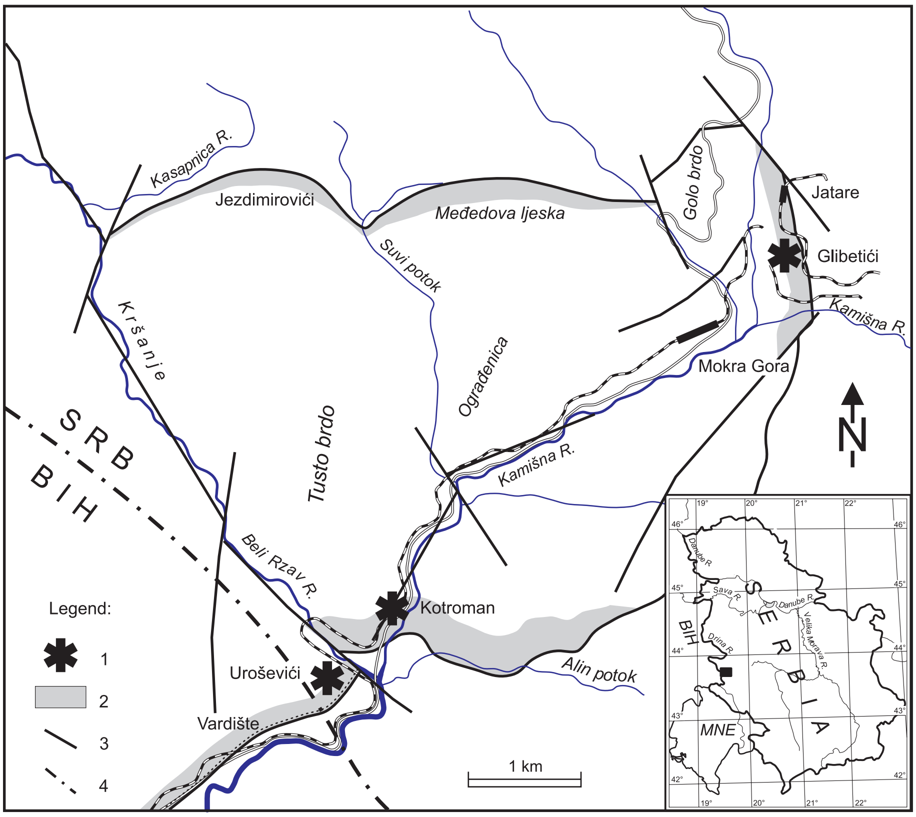

Fig. 1. Distribution of the Kotroman Formation in the Mokra Gora area. Legend: **1,** Position of investigated stratigraphic columns; **2,** Distribution of the Kotroman Formation; **3,** Major faults; **4,** State boundary.

Distribution and main features of the Kotroman Formation ("Basal Series")

The "Basal Series" is best exposed in the close vicinity of the Kotroman village (43°46'3.81'' N, 19°28'22.05'' E), which can be regarded as the type locality (Fig. 1). We propose and define the new lithostratigraphic term "Kotroman Formation" for the former "Basal Series" of JOVANOVIĆ *et al*. (2004). The aforementioned locality by the Kotroman village is adopted as the type section of the Kotroman Formation. Other localities are distributed on the surrounding of Mokra Gora, the Rzav syncline, and include: the Valley of the Beli Rzav River and Kršanje, Vardište, Međedova Ljeska and Jezdimirovići villages. Some limited exposures are present at a larger distance, i.e., Jagoštica, Pozderčić and Ljuto Polje hamlets.

In the western part of the study area, in the Kotroman and Uroševići localities, the Kotroman Formation directly overlies serpentinite, while in the eastern part of the study area it is located over a few meters thick weathering crust. It is of nontronite type with nickel concentrated in a smectite zone. There is relative enrichment of Fe_2O_3 and Al_2O_3 and some trace elements in the uppermost part of the crust MAKSIMOVIĆ (1996). The Kotroman Formation is overlain by the Hemipelagic Series (Formation).

The Kotroman Formation is about 50 m thick and consists of a clastic sequence in the lower part and limestone beds in the upper part of the stratigraphic column. The lower limit is a sharp transgressive boundary with serpentinite or a few meters thick weathering crust, while upper limit is a gradual transition to the Hemipelagic Series.

Three separate members can be distinguished: The Kamišna Member, the Uroševići Member and the Jatare Member, even though the last one can be consider as lateral equivalent of Kotroman Formation.

The Kamišna Member is represented by a clastic sequence consisting of reddish conglomerates and thin-

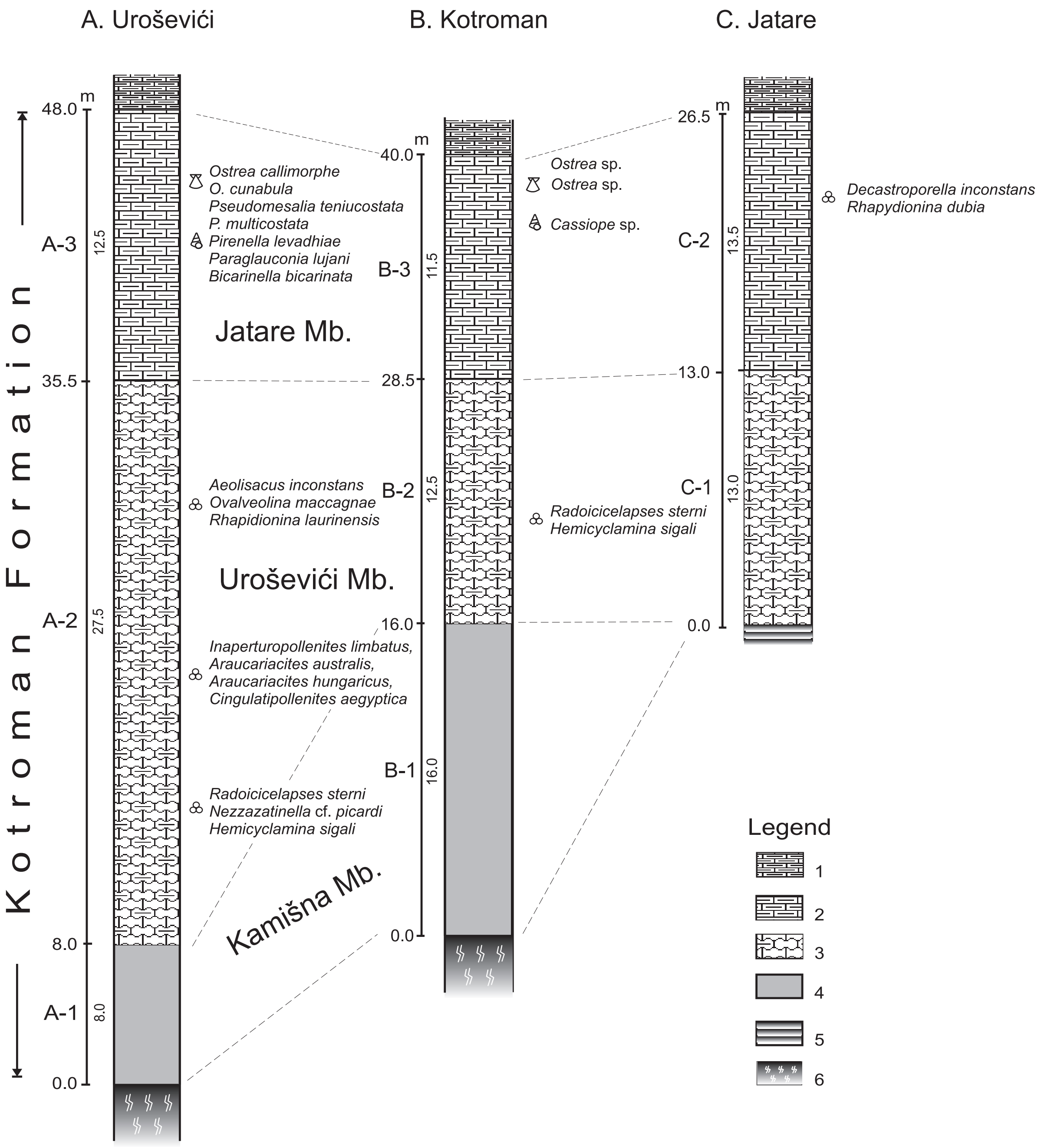

Fig. 2. Simplified stratigraphic columns (A. Uroševići, B. Kotroman, C. Jatare) in which appears the Kotroman Formation. Legend: **1,** "Hemipelagic series"; **2,** bedded limestone intercalated with marlstone (Jatare Member); **3,** nodular gray redish limestone (Uroševići Member); **4,** conglomerate and sandstone (Kamišna Member); **5,** base, weathering crust of ultramafics; **6,** base, altered ultramafics.

bedded oolitic iron-rich sandstones with cherty nodules. The lower segment of the Kotroman Formation is adopted as the type section of the Kamišna Member. This clastic sequence can also be found close to Vardište, at the northern slope of Međeđova ljeska and Jezdimirovići. Here, the polymict basal conglomerate is composed of serpentinite, gabbro, chert, diabase and limestone fragments in a sandstone matrix. These conglomerates are interbedded with gradational sandstones. The upper part of the clastic sequence is characterized by red chert and alevrolite. There is a smooth transition to the overlain Uroševići Member. Conglomerates and clastites are increasingly replaced with calcareous fine grained sandy limestone with ostreids, algae and microfauna. An economic potential of the Fe–Ni ore has been reported for the lower part of the clastic sequence (Fotić 1965, Janković 1990).

The middle part of the Kotroman Formation is dominated by nodular limestone of the Uroševići Member, mostly biomicrites, with frequent yellowish marl intercalations, as well as macro and microfossils associations. Smooth transition to the upper part of the Kotroman Formation is marked by decreasing thickness of beds and less nodular limestone. Upper segment of Formation, which is represented by thin bedded bioclastic limestone, is here adopted as Jatare Member.

Schematic stratigraphic columns of the Uroševići, Kotroman and Jatare localities are presented in Fig. 2. The Kotroman section is designated as the type section of the formation.

Description of the stratigraphic columns

A – Uroševići

The cumulative thickness of the Kotroman Formation in the Uroševići locality is 48 m. Here, the basal conglomerates of the Kamišna Member (A-1 in Fig. 2) transgressively overlie serpentinite rocks. Iron rich dark green chamosite ooides and serpentinite particles can be frequently found in conglomerate fragments. The grains are cemented with calcareous or clay-ironstone cement. In addition to conglomerates, loose dark gray sandstone predominated in this Member (Fig. 3). Small cherty fragments as well as sand particles of different size are bound by clayey or limonitic red or brown cement. The bedding surfaces in the entire lower Member are not well expressed. Floral remnants, such as fine dispersed plant particles and fragments of branches and tree trunks, are common. In addition, bisect particles of conifers, dominated by *Pinus* and rarely *Podocarpus, Cedrus* can be found.

Fig. 3. Oolitic sandstone of basal part of the Kotroman Formation (Kamišna Member), 250 m north-westward from Beli Rzav and Crni Rzav mouth (43°46'01'' N, 19°28'06'' E).

The Uroševići Member of the stratigraphic column is nodular biomicrite interbedded with yellowish marl (A-2 in Fig. 2). The type section is at the Uroševići hamlet (43°46'1.44'' N, 19°28'7.11'' E). Nodules of floatstone and wackestone are enclosed in an intimate mixture of clay and carbonate. Extremely small crystals of quartz, pyrite and hematite can be found in the clayey matrix. The microfauna assemblage consists of codiacean fragments and *Radoicicelapses sterni*, *Nezzazatinella* cf. *picardi*, *Salpingoporella urladanasi*, *Aeolisacus* sp., *Glomospira* sp. The macrofauna is represented by gastropod fragments (*Cassiope* sp.). Rare oogonias and charophyte trunks represent the microflora association. Also there are frequent inaperturate pollen grains of xerophile conifers (*Inaperturopollenites limbatus, Araucariacites australis, A. hungaricus, Cingulatipollenites aegyptica, Caliallasporites,* rare *Cycadopites, Ephedripites, Steevesiapollenites, Eucommiidites* etc.). A rich assemblage of fern spores can also be found (*Gleicheniaceae, Anemiaceae, Schizaceae, Cyathaceae, Disconiaceae*). Among the angiosperm pollen grains, the most frequent are *Retimonocolpites reticulatus – peroreticulatus* (rarely genera *Clavatipollenites*), as a rich assemblage of the genera *Tricolpites* and *Tricolporoidites*. Rarely triporate pollen grain of normapolles (*Complexiopollis* sp.) can be found.

In the upper part of the Uroševići stratigraphic column (A-3 in Fig. 2), thin bedded nodular bioclastic limestone represents the third, Jatare Member. Calcareous and silty marlstones in some places contain abundant microfauna associations, which are represented by: *Aeolisacus inconstans*, *Ovalveolina maccagnae* and *Rhapidionina laurinensis*. Macrofauna is discovered at numerous localities, sometimes forming coquina beds. Frequently, it is represented by mollusk fragments, bivalves *Amphidonte conicum*, *Ostrea callimorphe*, *O. cunabula*, and gastropods *Pseudomesalia teniucostata*, *P. multicostata*, *Pirenella* cf. *levadhiae*, *Paraglauconia lujani*, *Bicarinella bicarinata* and *Cassiope kotromanensis*. In addition charophyte remnants can be found.

The Jatare Member of the Kotroman Formation is here overlain by bituminous, thin bedded, marly limestone of hemipelagic series. The bedding surfaces of the above series are plain and well expressed.

B – Kotroman

The cumulative thickness of the Kotroman Formation at its type section (Kotroman Village) is 48 m. The stratigraphic column at the Kotroman locality (B-1 in Fig. 2) has a lithology which can be compared with the previous column. Similarly to Uroševići, the lowermost Kamišna Member is transgressive iron rich sandstone. The type section of the Member is at same locality as the Kotroman Formation (43°46'3.81'' N, 19°28'22.05'' E). This Member here is characterized by well rounded pyritized grains and fragments of serpentinite, without any fossils. Subsequently, sediments of the Uroševići Member can be found. It is well bedded sandy reddish nodular limestone with bivalve and gastropod shells

(Figs. 4, 5). These beds contain rare ostracode remnants, gyrogonytes, charophytes, algae *Radiocicelapses* sp., etc. Rarely, cm-scale lenses of calcirudite and calcarenite rich in bio- and lithoclasts, fragments of mollusks, peridotites and siliceous rocks can be found. These are replaced by nodular reddish limestone with rare macrofauna (B-2 in Fig. 2). Above these, thin bedded yellowish biomicrite – wackstone (B-3 in Fig. 2) of the Jatare Member can be found. These beds contain ostracodes, bivalves and the algae fragments. The palynomorph association is similar to that at the Uroševići locality.

Fig. 4. Nodular (knobby) limestone of the Uroševići Member (43°46'05'' N, 19°28'22''E).

Fig. 5. Limestone with mollusk fragments of the Uroševići Member (43°46'05'' N, 19°27'57'' E).

C – Jatare

The cumulative thickness of the Jatare stratigraphic column is 26 m. Here, nodular limestones of the Uroševići Member are superimposed on top of a weathered crust. Field observations indicated that no clastic section comparable to that at the Kamišna Member is present. Here, gray and yellowish marly limestone is the dominating lithological constituent of the stratigraphic column (C-1 in Fig. 2). The beds contain mollusk shells with geopetal fillings, foraminifers, ostracodes and rare charopohyte remnants. The latter ones indicate intermittent fresh water influx. The uppermost part of the stratigraphic column (C-2 in Fig. 2) is represented by thin bedded marly limestone of the Jatare Member (Fig. 6). The type section of this Member is situated southward of the Jatare Hamlet (43°47'45.60'' N, 19°31'4.45'' E). Numerous foraminifers (Miliolidae, Nezzazatidae, *Glomospira* sp. etc.), ostracodes and cyanobacteria *Decastroporella inconstans* are present. Rarely *Rhapydionina dubia* and some orbitolins can be found. The above-mentioned microfuna association indicate an Albian/Cenomanian age of the Kotroman Formation.

Fig. 6. Thin bedded biomicrite of the Jatare Member (43°46'29.94'' N, 19°28'36.41'' E).

The Kotroman Formation at Jatare is, like at some other localities, overlain with thin bedded, marly, bituminous limestone of the Hemipelagic series with plain and well expressed bedding surfaces.

Depositional environment and stratigraphical problems

During the Early Cretaceous period, the area of the Inner Dinarides was a landmass composed of mafic and utramafic rocks with widespread weathering crust, due to intensive and deep weathering under humid climate conditions. Transgression, which started at the mid-Albian, initiated erosion and redeposition of sediments that include the basal series of the Cretaceous succession, i.e., the Kotroman Formation. This also includes the deposition of nickel/iron rich oolithic sandstones.

The sedimentation occurred in littoral and sublittoral environments. The water was shallow, warm, with limited circulation. Depending on the morphology of the sea-bottom, the water table was characterized by low energy conditions in isolated and uneven depressions. The presence of charophytes and ostracodes in some layers strongly suggest irregular fresh water influx from the aforementioned land masses. There were periods of time when rapid input of clastic sediment ceased and calm environmental conditions allowed the fast growth of mollusk fauna. The origin of the nodular limestone texture is the product of later differential compaction, diagenesis and pressure dissolution of the sediment due to the clay content (JENKYNS 1974).

Detailed stratigraphic analyses in the area of Mokra Gora were not easy because of the somehow restricted character of the fossil assemblage. The collected lagoonal gastropod fauna, with *Pseudomesalia teniucostata*, *P. multicostata*, *Pirenella* cf. *levadhiae*, *Paraglauconia lujani*, *Bicarinella bicarinata* and *Cassiope kotromanensis*, indicates isolated sublittoral areas with limited aerial coverage, and with some features of endemism. This makes the comparison and correlation with other faunal assemblages from surrounding localities problematic and doubtful. This is supported by the fact that the gastropod family *Cassiopidae is* characterized by rapid ontogenical and phylogenical changes, e.g. MILOVANOVIĆ (1933), CLEEVELY & MORRIS (1988), MENNESSIER (1984), AKOPYAN (1976), KOLLMANN (1979).

The microfauna assemblage is represented by *Radoicicelapses sterni*, *Nezzazatinella* cf. *picardi*, *Hemicyclamina sigali*, *Salpingoporella urladanasi*, *Aeolisacus inconstans*, *Ovalveolina maccagnae*, *Rhapdionina laurinensis*, which indicate an Albian and possibly early Cenomanian age.

Conclusion

This preliminary research paper investigates a Cretaceous formation in western Serbia known as the Basal Series. A new lithostratigraphic term is proposed for this unit, the "Kotroman Formation" after the type locality and type section at the Kotroman village.

The stratigraphic columns from the described localities imply three members within the Kotroman Formation: (1) The Kamišna Member consist of clastites, up to 8 m thick, (2) The Uroševići Member consist of nodular limestone up to 27.5 m thick, and (3) the thin bedded marly limestone of Jatare Member up to 12.5 m in thickness. Nodular limestones are more or less present in all horizons of the Formation, although they predominate in the Uroševići Member. Paleontological analyses indicate an Albian–Cenomanian age. Deposition probably started during the mid-Albian, and continued up to Cenomanian.

Numerous beds of terrigenous clastics with gradual transitions to nodular limestones and fossiliferous strata point to frequent changes in the local environmental conditions during the mid Cretaceous time. We believe that, in some future work, the recognition and correlation of the depositional sequences of the investigated strata will lead to the assemble of a convenient model of the sequence stratigraphy for these deposits, which will be helpful in defining the stratigraphy of a wider area in western Serbia. The present study shows that in spite of the limited data, a definition of the formations and a detailed mapping of these lithostratigraphic units is possible.

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Резиме

Албско-ценоманска Формација Котроман (Мокра Гора – западна Србија)

Кредне творевине су мало распрострањене у западној и северозападној Србији. Међутим, шира околина Мокре Горе је услед великог броја изданака проучавана од стране више аутора: МИЛОВАНОВИЋ (1933, *cum. lit.*), ПЕЈОВИЋ & РАДОИЧИЋ (1971), РАДОИЧИЋ (1995), БАЊАЦ (1994) и ДУЛИЋ (2003). Тада су извршена и прва стратиграфска рашчлањавања. Детаљна истраживања изведена су током израде листова ОГК 1:100 000. МОЈСИЛОВИЋ *и др*. (1978), ОЛУЈИЋ и КАРОВИЋ (1986). ЈОВАНОВИЋ *и др*. (2004) издвојили су више јединица нижег реда, које стратиграфски припадају албу, ценоману и турону. Најстарија тзв "Базална серија" лежи директно преко серпентинита или коре распадања. Асоцијација присутне микрофауне детаљно је описана од стране RADOIČIĆ & SCHLAGINTWEIT (2007). Следи "Хемипелашка серија" РАДОИЧИЋ (1995), ценоманске старости, као и најмлађа серија плитководних спрудних творевина туронске старости.

"Базална серија" је откривена у непосредној околини Котромана, где је утврђена на неколико локалитета. За ову серију предложен је назив "Формација Котроман" према локалитету који је усвојен за типски профил ове формације (43°46'3.81" С, 19°28'22.05" И). Остали локалитети налазе се дуж долина Белог и Црног Рзава, око Кршања, Вардишта, Међедове љеске и на другим местима. У западном делу терена око Котромана и Урошевића, формација Котроман лежи директно преко серпентинита, док у источном делу лежи преко коре распадања дебеле неколико метара. Формација Котроман има дебљину од 50 m, а састоји се од кластита у нижем делу и лапоровитих кречњака у вишем делу стратиграфског стуба. Доња граница је оштра, трансгресивна, док је горња граница представљена постепеним прелазом према Хемипелашкој серији.

Издвојена су три члана нижег реда, названа према локалитетима где су развијени: Камишна, Урошевићи и Јатаре. Члан Камишне представљен је кластитима са гвожђевитим ооидима, фрагментима серпентинита, везаним карбонатним или глиновитим цементом. Поред конгломерата тамно сиви пешчари чине најважнији део овог члана. Остаци флоре и фауне су у овом члану ретки. Члан Урошевићи представљен је нодуларним биомикритима, који се смењују са жућкастим лапорцима. Најбоље је развијен код засеока Урошевићи (43°46'1.44" С, 19°28'7.11" И). Нодуле су уклопљене у мешавину глине и карбоната. Асоцијација микрофауне састоји се од примерака *Radoicicelapses sterni*, *Nezzazatinella* cf. *picardi*, *Salpingoporella urladanasi*, *Aeolisacus* sp., *Glomospira* sp. Макрофауна је представљена фрагментима *Cassiope* sp. Честа су инапертуратна зрна полена ксерофилних конифера (*Inaperturopollenites limbatus, Araucariacites australis, A. hungaricus, Cingulatipollenites aegyptica, Caliallasporites,* ретко *Cycadopites, Ephedripites, Steevesiapollenites, Eucommiidites* и др.). Међу зрнима полена ангиосперми чести су примерци *Retimonocolpites reticulates*. Ретко могу да се нађу и зрна Normapolles (*Complexiopollis* sp.). Члан Јатаре заузима највише делове формације и представљен је карбонатним лапорцима које местимично садрже богате асоцијације микрофауне у којима доминирају: *Aeolisacus inconstans*, *Ovalveolina maccagnae* и *Rhapidionina laurinensis*. Макрофауна је откривена на бројним локалитетима, местимично градећи праве лумакеле. Најчешће су то фрагменти мекушаца: *Amphidonte conicum*, *Ostrea callimorphe*, *O. cunabula*, *Pseudomesalia teniucostata*, *P. multicostata, Pirenella* cf. *levadhiae, Paraglauconia lujani*, *Bicarinella bicarinata* и *Cassiope kotromanensis*.

Бројни слојеви теригених кластита са постепеним прелазима ка нодуларним кречњацима указују на честе промене локалних услова седиментације током средње креде. Анализа присутне палеофлоре и палеофауне указала је на стратиграфску припадност формације Котроман алб-ценоману. Седиментација је највероватније почела током средњег алба и наставила се кроз ценоман.

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Late Triassic radiolarians from the Ovčar-Kablar Gorge (SW Serbia)

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Abstract. Detailed micropalaeontological research of Triassic siliceous rocks was carried out at a locality in the Ovčar–Kablar gorge, NE of Ovčar Banja. According to the determined radiolarian associations, the investigated chert and radiolarite are of Late Carnian–Early Norian age.

Key words: Late Triassic, radiolarians, Ovčar–Kablar Gorge, SW Serbia.

Апстракт. Детаљна микропалеонтолошка истраживања тријаских силицијских седимената извршена су на локалитету у Овчарско-кабларској клисури, СИ од Овчар Бање. На основу одређених радиолари-јских асоцијација утврђено је да су рожнаци и радиоларити локалитета Овчар Бања горње карнијске до доње норичке старости.

Кључне речи: Горњи тријас, радиоларије, Овчарско-кабларска клисура, ЈЗ Србија.

Introduction

Siliceous sedimentary rocks, such as cherts and radiolarites, are widespread in southwestern Serbia. Noteworthy is that they originated in different geological settings and during different geological intervals (Dimitrijević 1997, Karamata 2006). They mostly occur in the internal parts of the Dinarides, in the vicinity of ophiolitic units and/or within ophiolitic mélange formations, less frequently in other geological environments. The maximum accumulation of radiolarian cherts occurred in the Middle to Late Triassic, as well as in the Middle to Late Jurassic, occasionally extending into the Cretaceous.

The territory of Serbia is rather interesting for studies of Mesozoic Radiolaria. Within the Serbian part of the internal Dinarides, Triassic and Jurassic radiolarians were described for the first time by Š. Goričan (personal communication 1988, 1990) as well as by Obradović & Goričan (1988) and Obradović *et al*. (1986, 1987/1988). Recent works reflect the increase of radiolarian studies in Serbia and their importance for stratigraphic, palaeogeographic, tectonic and palaeotectonic implications (Goričan *et al*. 1999, Karamata *et al*. 2004, Djerić & Vishnevskaya 2005, 2006; Vishnevskaya & Djerić 2006a, b; Djerić *et al*. 2007a, b; Gawlick *et al*. 2007a). Despite this considerable progress, knowledge of the Mesozoic Radiolaria from Serbia is still insufficient. Actually, there are only a few published data on Middle and Late Triassic radiolarians, as well as on Middle and Late Jurassic radiolarians. The main aim of this study was to obtain information on the late Triassic Radiolaria from SW Serbia.

Geological setting

The studied area is located in SW Serbia, about 2 km NE of Ovčar Banja (7434755, 4861714). This region belongs to the Vardar Zone Western Belt (Fig. 1), according to Karamata *et al*. (2000). On the territory of western Serbia, there are two belts of ophiolitic mélange overlain by large ultramafic massifs. The more external belt is known as the Dinaridic Ophiolites or

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Dinaridic Ophiolite Belt (Pamić *et al*. 2002, Karamata 2006) or as the Central Dinaridic Ophiolite Belt (Lugović *et al*. 1991). The more internal belt is referred to as the Vardar Zone Western Belt by Karamata (2006) The Western oceanic basin of the Vardar Ocean, existing from the Late Triassic, became a wide oceanic basin during the Jurassic–Early Cretaceous and then closed by the latest Cretaceous; its suture is the Vardar Zone Western Belt (VZWB).

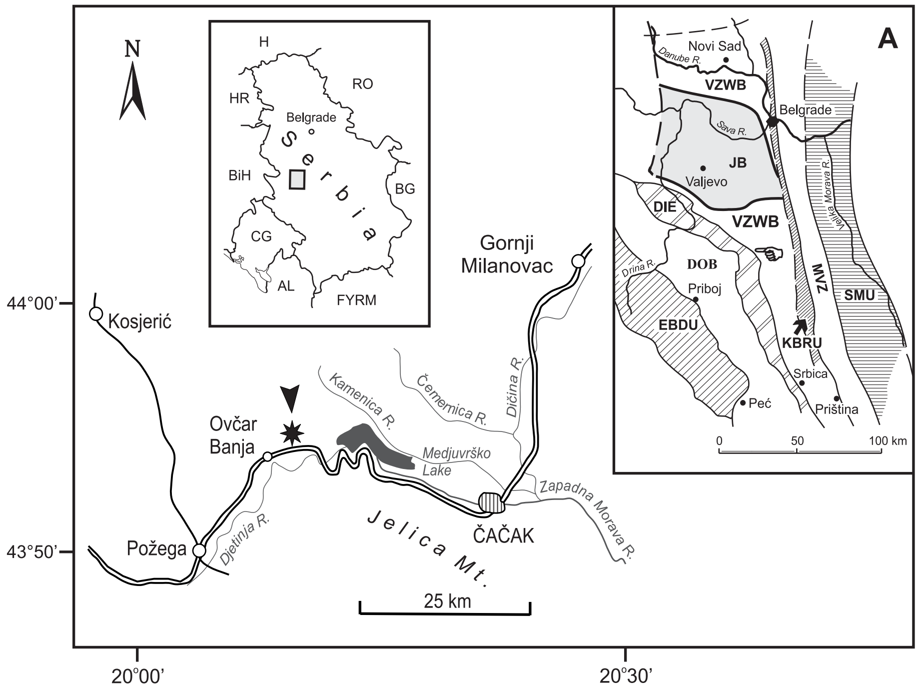

Fig. 1. Location of the Ovčar Banja section, SW Serbia. **A,** Tectonic units and terranes of part of the Balkan Peninsula in the *sense* of Karamata *et al*. (2000) and Karamata (2006): **EBDU,** East Bosnian–Durmitor Unit; **DOB,** Dinaridic Ophiolite Belt; **DIE,** Drina–Ivanjica Element; **VZWB,** Vardar Zone Western Belt; **JB,** Jadar Block; **KBRU,** Kopaonik Block and Ridge Unit; **MVZ,** Main Vardar Zone; **SMU,** Serbian–Macedonian Unit.

According to Karamata (2006), within the Western Basin of the Vardar Ocean, representing the precursor of the Vardar Zone Western Belt (VZWB), deep-water cherts and shales were deposited over basalts of the ophiolitic association from the Late Triassic to the Kimmeridgian. Large masses of trench deposits, represented by olistostrome mélange and gravity slides from the oceanic crust and the continental margin, accumulated within this basin from the Mid-Jurassic time.

According to Schmid *et al*. (2008), there is a single Jurassic ophiolite sheet in the Dinarides, namely the Western Vardar Ophiolitic Unit that was obducted onto the passive margin of Adria during the latest Jurassic times. The ophiolitic mélange, which occurs below the metamorphic sole flooring the obducted ophiolites, typically contains a mixture of (1) rock types derived from the lower plate, mechanically scraped off and accreted to the upper plate, and (2) gravitationally emplaced olistoliths derived from the upper plate. The blocks derived from the lower plate consist, amongst other lithologies, of Triassic ultramafics and mafics (MORB-type ophiolitic blocks up to several km in diameter) that were derived from the Meliata-Maliac-Vardar Ocean, the age of which was inferred from preserved stratigraphic contacts with Triassic radiolarites (Schmid *et al*. 2008). Amongst the blocks derived from the lower plate, Triassic strata derived from the adjacent Adria passive margin predominate over ophiolites. These Triassic strata, consisting of platform carbonates, slope to basinal facies, such as Hallstatt limestone, cherty limestone, thin-bedded radiolarite – pelagic limestone successions or radiolarites, of Late Anisian to Norian age (e.g. Chiari *et al*. 1996, Dimitrijević *et al*. 2003, Goričan *et al*. 1999, 2005; Bortolotti *et al*. 2005, Gawlick *et al*. 2007b).

According to S. Schmid (personal comm. 2007), this particular part of the mélange formation does not contain ophiolites but Triassic sediments, which probably derived from the adjacent passive margin. These Triassic sediments consist not only of radiolarites but also of cherty or micritic limestones of presumably Triassic age. These sediments were also sheared off during mélange formation, but they are tectonically underneath (and further W) of the ophiolitic blocks described above. These large (km-size) slices of Triassic sediments are analoguous to similar occurrences in Greece ("Maliac" nappes). The mélange formation underlies W-Vardar ophiolites, i.e. the Maljen ophiolite (S. Schmid personal communication 2007).

The first findings of radiolarians in the chert from this locality were described in papers by Obradović (1986), Obradović *et al*. (1987/1988), Obradović & Goričan (1988). The studied siliceous sediments contain associations of radiolarians which points to Ladinian age (Obradović 1986, Obradović *et al*. 1987/1988, Obradović & Goričan 1988). These authors are of the opinion that sediments at this locality are olistoliths of the Porphyrite-Chert Formation.

Material and Methods

The described radiolarian assemblages originate from one single section at the Ovčar–Kablar Gorge (Fig. 1). Three samples were collected from the radiolarian cherts. The chert samples were only treated with dilute 5–7 % hydrofluoric acid, following the method of PESSAGNO & NEWPORT (1972). In all samples, spumellarians were much more abundant than nassellarians. The residues of the acid treatment, which yielded well preserved faunas, were studied for biostratigraphic purposes. In order to establish the age of the radiolarian assemblages, the zonation schemes proposed by TEKIN (1999) were used. An SEM microscope ISI-160 in GIN RAN (Moscow) was utilized for the precise identification and illustration of the radiolarians. These are illustrated in Plates 1 and 2. The micropalaeontology material is housed at the Faculty of Mining and Geology in Belgrade (registration numbers NDJ 100 to NDJ 103).

Section description and biostratigraphy

Characteristic layered chert with siliceous claystone and subordinate limestone occurs on a 70 m wide section along the road Čačak–Požega (Fig. 1), about 2 km NE of Ovčar Banja (7434755, 4861714).

The lowermost part of the section is composed of stratified, gently folded chert of dark red color (Fig. 2), which are from 10 to 50 cm thick, in alternation with thin-bedded green siliceous claystone, tuffite and light silicified and recrystallised limestone. The chert is intersected by fractures, which are mostly filled with calcite, rarely with secondary quartz. Microlamination due to a higher concentration of ferruginous material is locally visible in the chert. The approximate average thickness of the layers composed of siliceous claystone is 5 cm, while the limestone layers reach a thickness of about 10 cm. The whole sequence is about 20 m thick (Fig. 2).

Four samples were taken from the chert at the locality Ovčar Banja, three of which gave positive results.

Sample NDJ 103. Chert collected 20 cm from the bottom of the section (Fig. 2). The radiolarian association is relatively well preserved and is represented by the following species: *Canesium lentum* BLOME, *Capnodoce crystallina* PESSAGNO, *Capnuchosphaera lenticulata* PESSAGNO, *Capnuchosphaera concava* DE WEVER, *Capnuchosphaera* sp. cf. *C. tricornis* DE WEVER, *Capnuchosphaera* sp. cf. *C. deweveri* KOZUR & MOSTLER, *Sarla* sp. aff. *S. vizcainoensis* PESSAGNO, *Spongotortilispinus carnicus* (KOZUR & MOSTLER), *Spongostylus tortilis* KOZUR & MOSTLER, *Pachus multinodosus* TEKIN, *Whalenella* ? *speciosa* BLOME, *Japonocampe* sp. and *Triassocampe* sp.

The radiolarian assemblage can be attributed to the early Norian due to the co-existence of *Capnodoce crystallina* PESSAGNO (latest Carnian/earliest Norian–early Norian, ? late middle Norian; TEKIN 1999), *Capnuchosphaera lenticulata* PESSAGNO (early Norian–late middle Norian, ? late Norian; TEKIN 1999), *Spongotortilispinus carnicus* (KOZUR & MOSTLER) (middle Carnian–early Norian; TEKIN 1999) and *Spongostylus tortilis* KOZUR & MOSTLER (late Ladinian–early Norian; TEKIN 1999).

Sample NDJ 102. Chert collected 1 m from the bottom of the section (Fig. 2). The abundant and versatile radiolarian association is represented by the following species: *Capnodoce* sp. cf. *C. anapetes* DE WEVER, *Capnodoce crystallina* PESSAGNO, *Capnuchosphaera concava* DE WEVER, *Capnuchosphaera* sp. cf. *C. lea* DE WEVER, *Capnuchosphaera theloides* DE WEVER, *Capnuchosphaera theloides minor* BRAGIN, *Capnuchosphaera triassica* DE WEVER, *Japonocampe nova* (YAO), *Japonocampe* sp. cf. *J. nova* (YAO), *Loffa* ? *mulleri* PESSAGNO, *Xiphothecella rugosa* (BRAGIN) and *Whalenella* sp.

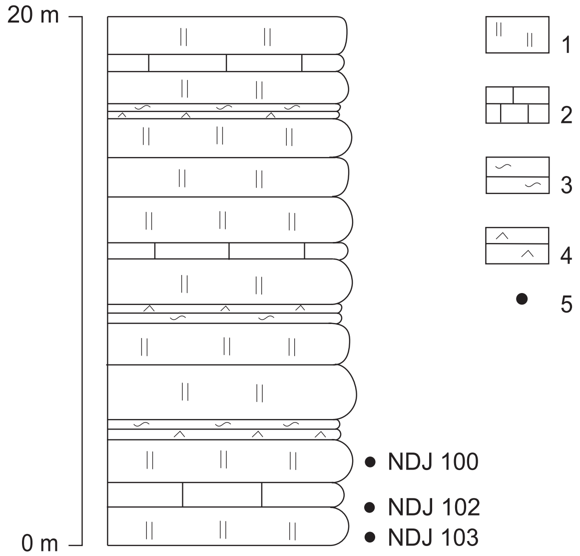

Fig. 2. Sample position and lithological log of the Ovčar Banja section. Legend: **1,** chert; **2,** limestone; **3,** silicified chert; **4,** tuff; **5,** radiolarian sample position.

The age is latest Carnian/earliest Norian–early Norian due to the co-occurrence of *Xiphothecella rugosa* (BRAGIN) (latest Carnian/earliest Norian–early Norian; TEKIN 1999), *Capnodoce crystallina* PESSAGNO (latest Carnian/earliest Norian–early Norian, ?late middle Norian; TEKIN 1999), *Capnuchosphaera triassica* DE WEVER (early Carnian–early Norian; TEKIN 1999), *Capnuchosphaera concava* De Wever (early Carnian–early Norian; TEKIN 1999).

Sample NDJ 100. Chert collected 2 m from the bottom of the section (sl. 2). The radiolarian association is relatively well-preserved and represented by the following species: *Capnuchosphaera theloides* DE WEVER, *Capnuchosphaera theloides minor* BRAGIN, *Capnuchosphera tricornis* DE WEVER, *Sarla vetusta* PESSAGNO, *Spongotortilispinus carnicus* (KOZUR & MOSTLER), *Paronella* sp., *Capnuchosphaera* sp., *Japonocampe* ? sp., and *Whalenella* sp.

Based on the co-occurrence of *Capnuchosphera tricornis* DE WEVER (late Carnian–middle Norian; TEKIN 1999), *Sarla vetusta* PESSAGNO (latest Carnian/earliest Norian–late middle Norian, ? late Norian; DE WEVER *et al*. 1979; BRAGIN & KRILOV 1999, TEKIN 1999) and *Spongotortilispinus carnicus* (KOZUR & MOSTLER) (Carnian–early Norian; TEKIN 1999; BRAGIN 2007), the age of the fauna is late Carnian–early Norian.

Comparison

The majority of the species extracted from the samples taken from the section at the locality Ovčar Banja are widely known, primarily from the Triassic beds of the Mediterranean Region. Almost all of them occur in the Upper Triassic (Upper Carnian–Lower Norian) of southern Turkey (DE WEVER *et al*. 1979, TEKIN 1999) and southern Cyprus (BRAGIN 2007). The late Carnian to Early Norian radiolarians at the locality Ovčar Banja can be compared to the radiolarians in the volcano-sedimentary formation of the Rubik area in Albania (CHIARI *et al*. 1996, BORTOLOTTI *et al*. 2006), Greece and Sicily (DE WEVER *et al*. 1979), as well as to the Early Norian fauna of Slovakia (KOZUR & MOSTLER 1981). Some species, for example *Capnodoce anapetes*, *Capnodoce crystallina*, *Capnuchosphera theloides*, *Xiphothecella longa* and *Xiphothecella rugosa* were recorded in the Late Carnian of Transcaucasia (KNIPPER *et al*. 1997), the Upper Carnian–Lower Norian of Oman (OTSUOKA *et al*. 1992), the Upper Carnian–Lower Norian of the Far East of Russia (BRAGIN 1991) and Japan (SUGIYAMA 1997) and the Upper Carnian–Middle Norian of Mexico and Oregon (PESSAGNO *et al*. 1979, BLOME 1984).

Final remarks

The siliceous deposits from the Ovčar Banja locality consist of radiolarian cherts with clay, tuff and limestone interlayers. On the basis of the radiolarians, the analyzed cherts were deposited between the Late Carnian and the Early Norian. These sediments were also sheared off during the formation of mélange; they are, however, tectonically underneath the ophiolitic blocks described above. These large (km-size) slices of Triassic sediments are analoguous to similar occurrences in Greece ("Maliac" nappes). The late Carnian to Early Norian radiolarians at the locality Ovčar Banja can be compared to the radiolarians in the volcano-sedimentary formation of the Rubik area in Albania (CHIARI *et al*. 1996, BORTOLOTTI *et al*. 2006), Greece and Sicily (DE WEVER *et al*. 1979), as well as to the Early Norian fauna of Slovakia (KOZUR & MOSTLER 1981) and Cyprus (BRAGIN 2007).

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Резиме

Горњотријаске радиоларије из Овчарско-кабларске клисуре (ЈЗ Србија)

У оквиру западног појаса Вардарске Зоне истраживани су рожнаци у Овчарско-кабларској клисури (локалитет Овчар Бања). Локалитет се налази на путу Чачак–Пожега (сл. 1), око 2 km СИ од Овчар

Бање (7434755, 4861714). Карактеристични услојени рожнаци са силициозним глинцима и подређеним кречњацима откривени су на профилу широком око 70 m. Најнижи део профила састоји се од стратификованих, благо убраних рожнаца тамноцрвене боје, дебљине од 10 до 50 cm у смени са танкослојевитим зеленим силициозним глинцима, туфитима, туфовима и светлим силификованим и рекристаластим кречњацима. Рожнаци су испресецани жицама које су претежно испуњене калцитом, ређе секундарним кварцом. Слојеви силициозних глинаца су просечно дебљине око 5 cm, док слојеви кречњака достижу дебљину и од око 10 cm. Цео пакет је дебљине око 20 m. Према S. SCHMID (усмено саопштење) овај део формације меланжа не садржи офиолите него тријаске седименте који су вероватно били део пасивне маргине. Ове простране (km ред величина) пласе тријаских седимената су аналогне сличним појавама у Грчкој ("Maliac" навлаке). Из тријаских рожнаца локалитета Овчар Бања узорковане су три пробе које су дале позитивне резултате:

Проба НЂ 103, узоркована из најнижих делова профила, садржи релативно добро очувану заједницу радиоларија. Доње норичка старост одређена је на основу присуства врста *Capnodoce crystallina* PESSAGNO, *Capnuchosphaera lenticulata* PESSAGNO, *Spongotortilispinus carnicus* (KOZUR & MOSTLER) и *Spongostylus tortilis* KOZUR & MOSTLER.

Проба НЂ 102, узоркована из средишњих делова профила садржи бројну и разноврсну асоцијацију радиоларија горње карнијске до доње норичке старости. Одредба старости извршена је на основу присуства карактеристичних врста: *Xiphothecella rugosa* (BRAGIN) и *Capnuchosphaera triassica* DE WEVER.

Проба НЂ 100 узоркована је из средишњих делова профила. Присуство врста *Capnuchosphera tricornis* DE WEVER, *Sarla vetusta* PESSAGNO и *Spongotortilispinus carnicus* (KOZUR & MOSTLER) указује на горње карнијску до доње норичку старост рожнаца ове пробе.

Горње карнијске до доње норичке радиоларијске асоцијације локалитета Овчар Бања могу се поредити са асоцијацијама радиоларија вулкано-седиментне формације Рубик подручја у Албанији (CHIARI *et al*. 1996; BORTOLOTTI *et al*. 2006), Грчке и Сицилије (DE WEVER *et al*. 1979), као и доње норичком фауном Словачке (KOZUR & MOSTLER 1981) и Кипра (BRAGIN 2007).

PLATE 1

Late Carnian to Early Norian radiolarians from the Ovčar-Kablar Gorge

Fig. 1. *Capnuchosphaera theloides* DE WEVER, Sample NDJ 102, × 200.
Fig. 2. *Spongotortilispinus* ? *carnicus* (KOZUR & MOSTLER), Sample NDJ 100, × 350.
Fig. 3. *Spongotortilispinus carnicus* (KOZUR & MOSTLER), Sample NDJ 103, × 300.
Fig. 4. *Loffa* ? *mulleri* PESSAGNO, Sample NDJ 102, × 200.
Fig. 5. *Capnuchosphaera* sp., Sample NDJ 100, × 200.
Fig. 6. *Capnuchosphaera triassica* DE WEVER, Sample NDJ 102, × 200.
Fig. 7. *Capnodoce* sp. cf. *C. anapetes* DE WEVER, Sample NDJ 102, × 200.
Fig. 8. *Capnodoce crystallina* PESSAGNO, SampleNDJ 103, × 200.
Fig. 9. *Pachus multinodosus* TEKIN, Sample NDJ 103, × 200.
Fig. 10. *Japonocampe* sp., Sample NDJ 103, × 200.
Fig. 11. *Japonocampe nova* (YAO), Sample NDJ 102, × 200.
Fig. 12. *Xiphothecella rugosa* (BRAGIN), Sample NDJ 102, × 100.
Fig. 13. *Japonocampe* ? sp., Sample NDJ 100, × 200.

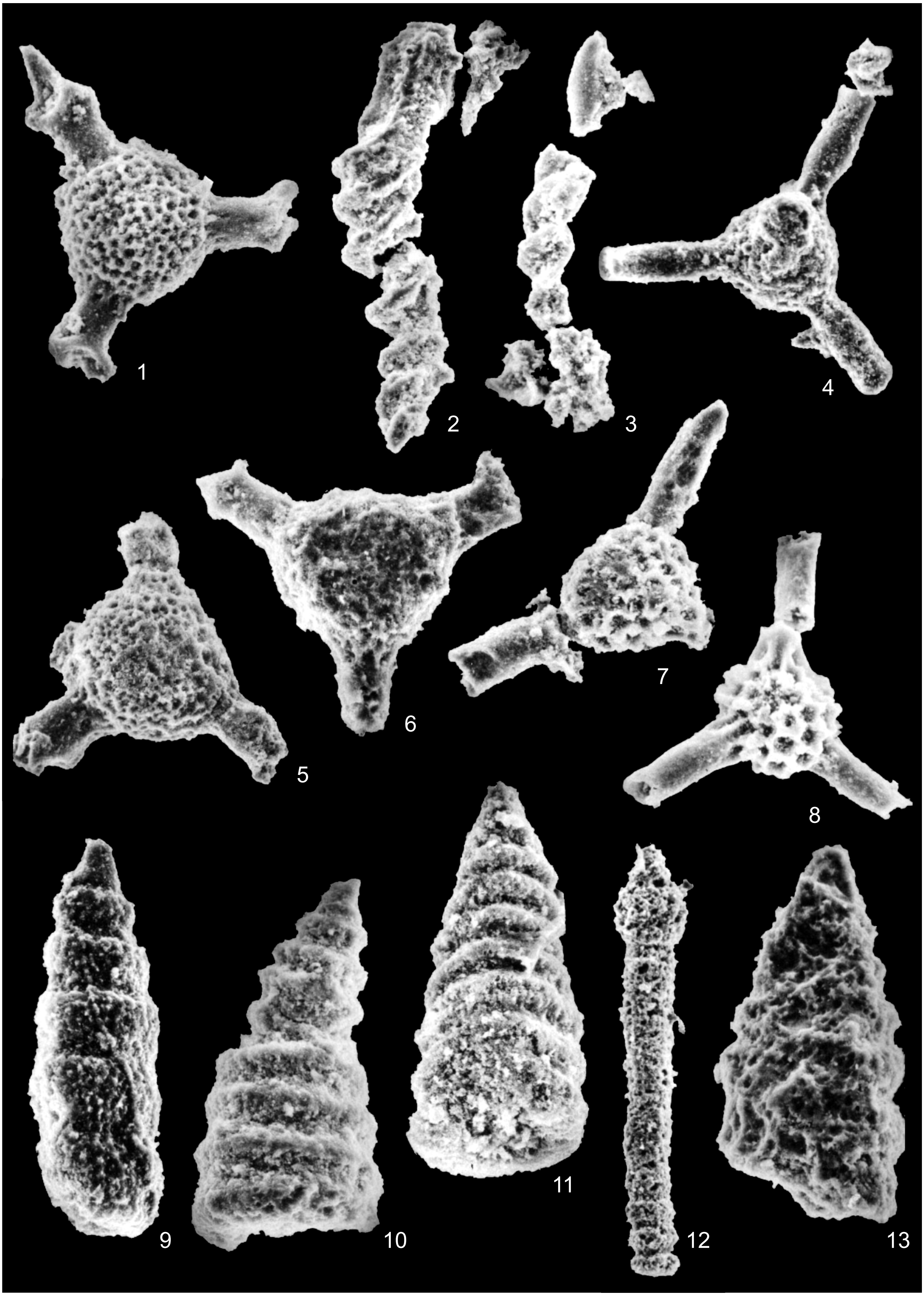
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PLATE 2

Late Carnian to Early Norian radiolarians from the Ovčar-Kablar Gorge

Fig. 1. *Capnuchosphaera theloides minor* BRAGIN, Sample NDJ 100, × 200.

Fig. 2. *Capnuchosphaera concava* DE WEVER, Sample NDJ 102, × 200.

Fig. 3. *Capnuchosphaera* sp. cf. *C. tricornis* DE WEVER, Sample NDJ 103, × 200.

Fig. 4. *Triassocampe* sp., Sample NDJ 103, × 200.

Fig. 5. *Japonocampe* sp. cf. *J. nova* (YAO), Sample NDJ 102, × 200.

Fig. 6. *Whalenella* sp., Sample NDJ 102, ×200.

Fig. 7. *Whalenella* ? *speciosa* BLOME, Sample NDJ 103, ×200.

Fig. 8. *Spongostylus tortilis* KOZUR & MOSTLER, Sample NDJ 103, × 350.

Fig. 9. *Canesium lentum* BLOME, Sample NDJ 103, × 200.

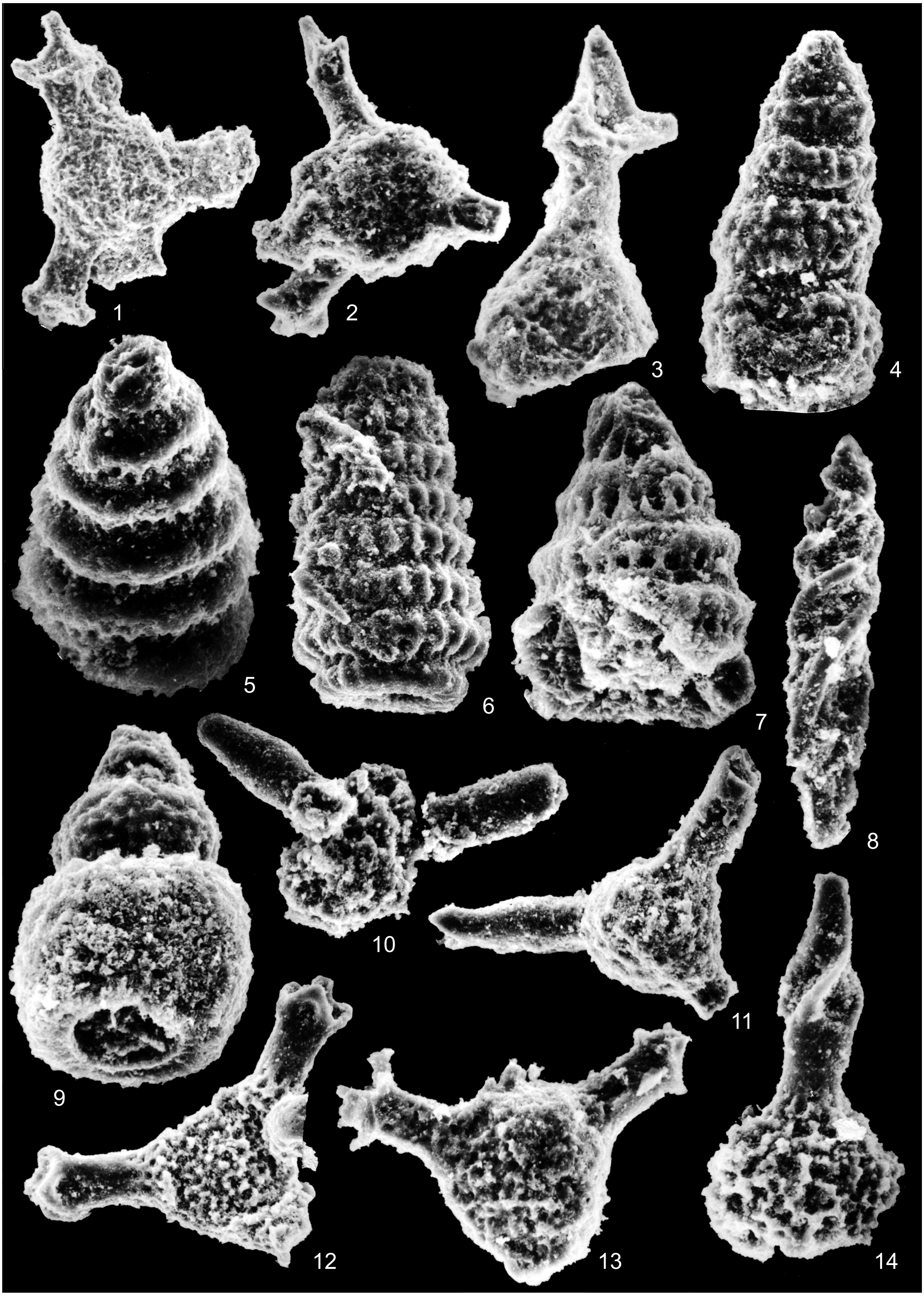
Fig. 10. *Capnodoce crystallina* PESSAGNO, Sample NDJ 103, × 200.

Fig. 11. *Capnodoce crystallina* PESSAGNO, Sample NDJ 103, × 200.

Fig. 12. *Capnuchosphaera concava* DE WEVER, Sample NDJ 103, × 200.

Fig. 13. *Capnuchosphaera* sp. cf. *C. tricornis* DE WEVER, Sample NDJ 103, × 200.

Fig. 14. *Capnuchosphaera* sp. cf. *C. deweveri* KOZUR & MOSTLER, Sample NDJ 103, × 200.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Sulser, H. 1996. Notes on the taxonomy of Mesozoic Rhynchonellida. *In*: Cooper, P. & Jin, J. (eds.), *Brachiopods*, 265–268. Balkema Press, Rotterdam.

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ГЕОЛОШКИ АНАЛИ БАЛКАНСКОГА ПОЛУОСТРВА
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