Biostratigraphy and microfacies of the pelagic carbonates across the Jurassic/Cretaceous boundary in eastern Serbia (Stara Planina–Poreč Zone)

Silviya Petrova¹, Dragoman Rabrenović², Iskra Lakova¹, Elena Koleva-Rekalova¹, Daria Ivanova¹, Lubomir Metodiev¹, Nenad Malešević²

¹ Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev Street, Bl. 24, 1113 Sofia; Bulgaria
e-mail: silviya_p@geology.bas.bg
² Department of Geology, Faculty of Mining and Geology, University of Belgrade, Kamenicka 6, P.O. Box 227, 11000 Belgrade, Serbia; e-mail: d.rabrenovic@gmail.com

(Accepted in revised form: November 2012)

Abstract. Integrated micropaleontological and microfacies studies on Tithonian and Berriasian pelagic carbonates of the Stara Planina–Poreč Zone (eastern Serbia) provided a new knowledge on the stratigraphic ages, depositional settings and lateral correlation with the Western Balkan Unit in Bulgaria. A total of forty calpionellid species, nineteen benthic foraminiferal species, and fourteen species of calcareous dinoflagellates have been identified in the Rosomač section in eastern Serbia. Calpionellid zones Chitinoidella, Crassicollaria, Calpionella, and Calpionellopsis have been recorded. Calcareous dinoflagellate zonation consists of Parastomiosphaera malmica, Colomisphaera fortis, and Stomiosphaerina proxima zones. The Rosomač Limestones are assigned to the Upper Tithonian and Lower Berriasian and the Ržana Clayey Limestone Beds to the Upper Berriasian. Seven distinct microfacies have been identified at the Rosomač section in eastern Serbia. Two of them, MF 1 calpionellid mudstones and MF 2 calpionellid wackestones, characterize the basinal depositional zone. Five microfacies belong to the slope facial zone, including the toe of the slope. These are: MF 3 Saccocoma wackestones, MF 4 wackestones with bioclasts, MF 5 intraclast-bioclastic grainstones, MF 6 bioclast-intraclastic floatstones, and MF 7 bioclast-intraclastic rudstones. Vertical microfacies distributions are directly correlated with the calpionellid and calcareous dinocyst zonations in sections in Serbia and Bulgaria. The pelagic carbonates in the Tithonian/Berriasian boundary interval were deposited under slope conditions at Rosomač section, and under basinal conditions at Barlya section in western Bulgaria.


Key words: Tithonian, Berriasian, eastern Serbia, calpionellids, calcareous dinoflagellates, microfacies, depositional setting.

INTRODUCTION

The Stara Planina–Poreč Zone in eastern Serbia represents an Alpine tectonic unit of regional implication that is a part of the Balkanikum in the sense of Andjelković (1996), and of the Carpatho–Balkanides in the sense of Kräutner and Krstić (2003). To north-east the Stara Planina–Poreč Zone was thrust over the Miroč–Fore Balkan Zone along the Stara Planina Frontal Line (Tchoumatchenko et al., 2011). The south-west border of the Stara Planina–Poreč Zone is the Vidič fault of primary importance in the tectonic division of eastern Serbia and western Bulgaria. To south-west of the Vidič fault is located the Getic–Srednogorie Zone. According to the recent tectonic map of Bulgaria (Dabovski et al., 2002; Dabovski and Zagorchev, 2009), the West Balkan Unit of the Balkan orogenic system is that tectonic unit passing through the Serbian–Bulgarian state border which is equivalent in definition, position, boundaries and rock successions with the Stara Planina–Poreč Zone. Tchoumatchenko et al. (2006a, b) considered this zone as the Infra–Getic Unit in terms of palaeogeography and presented a correlation of all Jurassic lithostratigraphic units in eastern Serbia and western Bulgaria. The enormous number of names for the same tectonic entities in the Carpatho–Balkanides proposed in Serbia, Romania...
and Bulgaria, enforcing Tchoumatchenco et al. (2011) to present inventory lists of the tectonic units positioned between the Moesian Platform and the Serbo–Macedonian Massif, including the Stara Planina–Poreč Zone and the Western Balkan Unit which are subject of this article.

Upper Jurassic and Lower Cretaceous pelagic carbonates in the Stara Planina–Poreč Zone in eastern Serbia are largely exposed from the Serbian–Bulgarian border in east at about 40-50 km to west at Visočka Ržana area (Fig. 1). The Upper Jurassic deep-water carbonates were divided (Andjelković et al., 1996) into the Kamenica Limestones (Callovian and Lower Oxfordian), Pokrovenik Limestones (Upper Oxfordian, Kimmeridgian and Lower Tithonian) and Rosomač Limestones (Upper Tithonian). Tchoumatchenco et al. (2006b) correlated the Upper Jurassic lithostratigraphic units in the Stara Planina–Poreč Zone with those in the Western Balkan Unit in Bulgaria. The Lower Cretaceous pelagic and hemipelagic carbonates include the Rosomač Limestones (Berriasian), Ržana Clayey Limestone Beds (Berriasian, Valanginian and Lower Hauterivian) and Ržana Marl Beds (Upper Hauterivian).

Tithonian and Berriasian clayey nodular limestones, micritic limestones and thin-beded clayey limestones in particular, crop out largely in the NE-SW strip from Visočka Ržana to the Serbian–Bulgarian border. In western Bulgaria the same sedimentary units continue into a 60 km long band of W-E trend that reaches the Iskar River Valley.

The purpose of this paper is to present calpionellid and calcareous dinoflagellate biostratigraphy and carbonate microfacies distribution of Upper Tithonian and Berriasian pelagic carbonates in the Stara Planina–Poreč Zone and to correlate them with the Western Balkan Unit in Bulgaria. Different depositional environments from both sides of the Serbian–Bulgarian border are deduced from the microfacies and microfossils recorded. A general trend is supposed in the deep-water sediments from proximal depositional settings in WNW to distal environments in ESE.

**Lithostratigraphy and Previous Biostratigraphy**

The section studied is located in the area of Rosomač Village (Pirot District, eastern Serbia) and covers the top of the Pokrovenik Limestones, the Rosomač Limestones and the basal 10 m of the Ržana Clayey Limestone Beds. Tchoumatchenco et al. (2006b) provided lithostratigraphic correlation at the Jurassic/Cretaceous boundary interval on both sides of the Serbian–Bulgarian border. Those authors revealed that the Pokrovenik Limestones are the same with the Gintsi Formation in Bulgaria, and the Rosomač and Ržana Limestones correspond to the Glozhene and Salash formations, respectively.

**Eastern Serbia**

Description of formations in eastern Serbia herein studied is given according to Andjelković (1975, 1996), and Andjelković et al. (1996). The Pokrovenik Limestones (Fig. 2.1) consist of clayey limestones of red, pink, greenish and gray colours, very rich in ammonites. These *ammonitico rosso* type limestones were assigned to the Kimmeridgian and Lower Tithonian. The studied Tithonian part of the Pokrovenik Limestones includes platy and nodular pink and red in colour limestones. The upper boundary with the Rosomač Limestones is sharp, reflecting a change in the palaeogeographic conditions. The nektonic macrofossil association of the Pokrovenik Limestones includes mainly ammonites and rare belemnoids.
nites. Microfacies are characterized by predominance of *Saccocoma*, *Globochaete alpina* Lombard and calcareous dinocysts.

The Rosomač Limestones (Fig. 2.2) represent the deepest Upper Jurassic and Lower Cretaceous deposits in the Stara Planina–Poreč Zone of eastern Serbia. This lithostratigraphic unit consists of light gray, regularly bedded micritic limestones with thin interbeds or nodules of dark gray chert. The Rosomač Limestones at the studied section finish with a 20-cm thick chert bed. Among ammonites, Phylloceratina and Lytoceratina strongly predominate over Ammonitina. The same pattern was documented in the coeval Glozhene Formation (Komshtitsa section) in western Bulgaria by Sapunov et al. (1988). Microfacies are characterized by the calpionellid genera *Tintinnopsella*, *Crassicollaria* and *Calpionella*. The age of the Rosomač Limestones was considered as Late Tithonian and Early Berriasian by Andjelković et al. (1996). According to Rabrenović in Andjelković et al. (1996), findings of *Pseudosubplanites lorioli* (Zittel) and *Malbosiceras chaperi* (Pictet) in the Rosomač Limestones indicate the lowest Berriasian Jacobi Zone. *Calpionella alpina* and *Calpionella elliptica* were also reported.

Vašíček et al. (2009) provided data on the occurrence of calpionellids *Calpionellopsis oblonga*, *Tintinnopsella longa* and *Tintinnopsella carpathica* (palaeontological identifications by R. Radoičić) in Vladikina Ploća section within the topmost 5 m of the Rosomač Limestones. These calpionellids indicate a Late Berriasian age.

The Ržana Clayey Limestone Beds cover concordantly the Rosomač Limestones. The lower part of this formation consists of thin-bedded gray clayey limestones with dark gray chert nodules or interbeds. Rabrenović (in Andjelković et al., 1996, p. 158) presented a stratigraphic log of the Berriasian and Valanginian (Rosomač Limestones and Ržana Beds) in the Stara Planina–Poreč Zone near Rosomač Village. At 17-20 m above the base of the log, *Calpionellopsis oblonga* and *Tintinnopsella dacica* Filipescu & Dragastan were reported indicating a Late Berriasian age. The Lower Valanginian was
determined on the basis of *Busnardoites cf. campylo-toxius* (Uhlig) and *Calpionellites darderi* (Colom). In the Ržana Beds Andjelković (1975) reported the ammonite *Subthurnmannia boissieri* (Pictet) that indicates the Upper Berriasian Boissieri Zone. Vašček et al. (2009) assigned the Ržana Clayey Limestone Beds at Vladičina Ploča section to the Upper Valanginian and Hauterivian on the basis of ammonite Peregrinus, Radiatus, Loryi, Balearis and Ohni zones.

In the south-western end of the Stara Planina–Porčez Zone, a local fault represents its boundary with the Dobr Do–Grlište Zone (Fig. 1). There, the shallow-water Rsovci Limestones (Fig. 2.3) crop out thrustted over the Lower Cretaceous of the Stara Planina–Porčez Zone (Fig. 2.4). This nappe was designated as the Rsovci dislocation by Andjelković (1996).

**Western Bulgaria**

In the Western Balkan Unit, the ages of the Gintsi, Glozhene and Salash formations were determined on the basis of ammonites, calpionellids and calcareous dinocysts. Sapunov (1976, 1977) assigned the upper part of the Gintsi Formation to the Lower Tithonian (Hybonotum, Vimineus and Ponti ammonite zones) and the lower half of the Glozhene Formation to the Transitorius ammonite Zone with Microcanthum and Jacob subzones. Ammonite biostratigraphy of the Salash Formation (Mandov, 1971, 1976; Nikolov, 1995b; Petrova, 2009) demonstrated that it covers a time span from the Late Berriasian to the Late Hauterivian. The following zones were determined: Boissieri (Upper Berriasian), Pertransiens, Campylotoxus (Lower Valanginian), Verrucosum, Peregrinus, Furcillata (Upper Valanginian), and Radiatus, Loryi, Ligatus, and Balearis (Hauterivian).

Calpionellid zonation consisting of all zones from Chitinoidea up to Tintinnopsella divided in details the Upper Tithonian to Upper Valanginian interval at the Barlya and Gintsi sections (Lakova et al., 1999; Lakova and Petrova, 2013). Directly integrated to it is a calcareous dinocyst zonation of 13 zones from *C. fibrata* in the Oxfordian to St. echinata in the Upper Valanginian (Ivanova in Lakova et al., 1999; Ivanova in Lakova et al., 2007).

Easterly, in the area of the Iskar River Gorge, the pelagic and hemipelagic carbonates of the Glozhene and Salash formations pass both laterally and vertically to the turbiditic sandstone-limestone alternation of the Sarbenitsa Wedge (Mandov, 1972) of the Cherni Osam Formation (Nikolov, 1995a). Calpionellid biostratigraphy indicated as early Late Berriasian the age of this faunal transition (Petrova, 2010).

**MATERIAL AND METHOD**

For micropaleontological identification and micropetrographic observations 21 thin sections labeled Ro1 to Ro21 of the Rosomač section (Serbia) and 47 thin sections of the Barlya section (Bulgaria) have been studied. The limestones have been classified using the textural scheme of Dunham (1962), expanded by Embry and Klovan (1971). The microfacies and facies zones are here defined following the methodology of Flügel (2004). The thin sections examined are stored at the Geocollections of the Geological Institute, Bulgarian Academy of Sciences, Sofia.

**BIOSTRATIGRAPHY**

Three microfossil groups have been used in the biostratigraphic subdivision of the Rosomač section, namely calpionellids, calcareous dinoflagellates and benthic foraminifera. Basically, the rock succession has been divided into the following calpionellid zones and subzones (Fig. 3): Dobeni Subzone (Lower Tithonian), Crassicollaria Zone with Remanei and Massutiniana subzones (Upper Tithonian), Calpionella Zone with Alpina, Remaniella and Eiliptica subzones (Lower Berriasian), and Calpionellopsis Zone with Simplex and Oblonga subzones (Upper Berriasian).

**Calpionellid biostratigraphy**

The biostratigraphic zonation on calpionellids follows the schemes proposed in Bulgaria for the Western Balkan Unit by Lakova et al. (1999), and Lakova and Petrova (2013), and those for the Southern Carpathians (Pop, 1994, 1997) and Western Carpathians (Reháková and Michalík, 1997). Preliminary data on calpionellid occurrence across the Tithonian/Berriasian boundary in the Rosomač section were reported by Lakova et al. (2009). All representative and stratigraphically important calpionellid species are illustrated in Figs 4–6.

**Chitinoidea Zone (Longicollaria dobeni Subzone)**

is found in the upper part of the Pokrovenik Limestones (Ro1). The chitinoidelean association consists of *Longicollaria dobeni*, *Dobeniella colomi*, *Daciella banatica*, *Daciella damubica* and *Daciella svinitensis* (Fig. 3).

The Boneti Subzone and Praetintinnopsella Zone have not been determined in this study. Their characteristic index-species were resedimented in the Remanei Subzone.

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*Fig. 3.* Age, lithology, calpionellid and calcareous dinocysts biostratigraphy and vertical distribution of the calpionellid and dinocyst species of the Rosomač section.
Crassicollaria Zone is distinguished in the top of Pokrovenik Limestones and the lower half of Rosomač Limestones. Most of the zone is represented by the lower Remanei Subzone (Ro2–Ro7). Only Ro8 and Ro9 belong to the Massutiniana Subzone.

Remanei Subzone occurs in the top of the Pokrovenik Limestones and the lower third of Rosomač Limestones. Calpionellid association consists of Tintinnopsella carpathica, Tintinnopsella remanei and Crassicollaria intermedia. Two species, characteristic of the Boneti Subzone.
and the Praetintinnopsella Zone, namely their index-species *Chitinoidella boneti* and *Praetintinnopsella andrusovi*, also occur. Their presence in the upper parts of Remanei Subzone is due to resedimentation of intraclasts. A group of chitinoidellids that is characteristic of the Boneti Subzone, e.g. *Borziella slovenica*, *Dobeniella bermudezi*, *Chitinoidella elongata* and *Chitinoidella ferasini* have been found reworked in this subzone in samples Ro4 and Ro5. At the top of Remanei Subzone, the FO of *Crassicollaria massutiniana* has been recorded.

**Massutiniana Subzone** has been found in the mid Rosomač Limestones. The calpionellid association consists of *Calpionella grandalpina*, *Calpionella alpina*, *Tintinnopsella carpathica*, *Crassicollaria intermedia*, *Crassicollaria massutiniana*, *Calpionella elliptalpina*, *Crassicollaria brevis*, *Crassicollaria parvula* and *Crassicollaria colomi*. The latter three crassicollarian species appeared in the upper part of the subzone. In sections of the Western and Southern Carpathians, Reháková and Michalík (1997) and Pop (1994, 1997) defined a peculiar Colomi Subzone at the top of Crassicollaria Zone.

**Calpionella Zone.** The Tithonian/Berriasian boundary has been traced between Ro9 and Ro10 samples. The LOs of *Crassicollaria intermedia*, *Crassicollaria massutiniana*, *Crassicollaria brevis*, *Calpionella grandalpina* and *Calpionella elliptalpina* have been recorded in Ro9. The explosion of small spherical *Calpionella alpina* occurs in Ro10. The upper half of the Rosomač Limestones and the lowermost 2 meters of the Ržana Beds correspond to the Lower Berriasian Calpionella Zone.

**Alpina Subzone** covers the upper half of Rosomač Limestones (Ro10–Ro13). *Calpionella alpina*, *Tintinnopsella carpathica*, *Crassicollaria parvula* and *Crassicollaria colomi* represent the calpionellids in the lower part. Upwards in the subzone, *Calpionella minuta* and *Tintinnopsella doliphormis* successively appeared.

**Remanei Subzone** corresponds to the base of Ržana Beds (Ro14). All calpionellids from the Alpina Subzone continued here, except *Crassicollaria colomi*. The Remanei Subzone is recognized at the FOs of Remaniella duranddelgai and Remaniella colomi.

**Elliptica Subzone.** Upwards in the Ržana Beds (Ro15 and Ro16), Elliptica Subzone is characterized by the coeval FOs of *Calpionella elliptica* and the large form of *Tintinnopsella carpathica*. *Crassicollaria parvula*, *Tintinnopsella doliphormis* and *Calpionella minuta* from the underlaying subzones still occur.
longa, Tintinnopsella subacuta, Lorenziella hungarica, Remaniella cadischiana and Borzaiella atava. The base is traced at the FO of Calpionellopsis simplex. Crassicollaria parvula disappeared in the lower part of this zone. The large form of Tintinnopsis carpathica, Remaniella colomi and Remaniella catalanoi from the lower subzones are also present. The LO of Calpionella elliptica is recorded in the Simplex Subzone. Oblonga Subzone (Ro20 and Ro21) is defined at the FO of Calpionellopsis oblonga and Calpionellopsis sp. A. One single atypical specimen of ?Calpionellopsis oblonga in the sample Ro17 (Fig. 5.30) has not been
used for biostratigraphy as it occurs together with the first Calpionellopsis simplex. The calpionellid association is quite diverse consisting of Calpionellopsis simplex, Calpionellopsis sp. A, Calpionellopsis sp. B, Tintinnopsis carpathica (large form), Tintinnopsis longa, Tintinnopsis subacuta, Lorenziella hungarica, Remaniella cadischiana, Remaniella borzai, Sturiella dolomitica, Borzaeiella atava and Calpionella minuta.

Calcareous dinoflagellate cyst biostratigraphy

Calcareous dinocyst zonation here described (Fig. 3) follows previously defined successions of interval zones in the Balkan Zone of Bulgaria (Ivanova, 1994, 1997; Ivanova in Lakova et al., 1999; Ivanova et al., 2006), Nowak (1968) in Poland, Řehánek (1992) and Reháková (2000a, b) in Slovakia, Reháková et al. (2011) in Ukraine. Calcareous dinocyst associations of the Rosomač section are shown in Fig. 7.

Stomiopsphaerina proxima Zone Řehánek (1992). In Bulgaria the zone was established by Ivanova in Lakova et al. (1997) in both the Upper Tithonian and Lower Berriasian. Thus, Řehánek’s (1992) proposal to place the Tithonian/Berriasian boundary at the FO of Stomiopsphaerina proxima is not applicable. The FOs of Crustocadosina semiradiata olzae and Stomiopsphaera alpina are recorded in this zone. This is a relatively long-ranging zone covering uppermost part of the Upper Tithonian and the whole Berriasian except its very top.

Benthic foraminifera

Despite occurring only at certain levels of the Rosomač section, some benthic foraminiferal genera and species have been determined (Fig. 8): Protopen Oreoplois ultragranulatus (Gorbachik), Patellina turriculata Diesi & Massari, Patellina subcretacea Cushman & Alexander, Paalzowella feifeli seiboldi Latze, Spirillina polycla (Gümbel), Verneulinoides neocomiensis (Mjatliuk), Textularia cf. bettensaedi Bartenstein & Oertli, Vaginulina arguta Reuss, Pseudonodosaria cf. brandi (Tappan), Feurtilia grasilis Neagu & Cimaru, Conorboides cf. hoikeri (Bartenstein & Brand), Dentalina cf. communis d’Orbigny, Turritiglomina? anatolica Altiner, Rettori, Zaninetti & Martini,
Istriloculina emiliae Neagu, Moesiloculina danubiana Neagu, Andersenolina cf. molesta (Gorbatchik) as well as indetermined species: Guttulina sp., Spiroloculina sp., Ophthalmidium sp., Glomospirella sp., Epistomina sp.

Small benthic foraminifers predominate such as Patellina turriculata, P. subcretacea, Paalzowella feifeli seiboldi, Spirillina polygyrata, S. tenuissima, Turriglomina? anatolica, Istriloculina emiliae, and Moesiloculina dan-
ubiana. Assemblages with Patellina, Paalzowella and Spirillina are generally considered as indicating deep-water depositional settings (Bucur, 1992). Dysaerobic conditions of the sea floor are suggested by occurrence of small Spirillina among the benthic foraminiferal assemblage (Cobianchi et al., 1999).

MICROFACIES AND FACIAL ZONES

On the basis of the microfacies analysis of the limestones from the Rosomač and Barlya sections, three facial zones are distinguished, namely the basinal, toe-of-slope, and slope zones.

The basinal zone represents the background pelagic sedimentation in a deeper-water environment. The main microfacies that characterize the zone are microfossil-bearing mudstone (MF 1), microfossil-bearing clayey mudstone (MF 1a), and microfossiliferous wackestone (MF 2), with prevalence of calpionellid mudstone and wackestone.

MF 1. The mudstones of this microfacies are composed predominantly of calcareous micrite matrix (up to 90%). The allochems are represented mainly by pelagic microfossils: calpionellids, calcareous dinocysts (Fig. 9.1), calcified sponge spicules and radiolarians, Globochaete alpina, ostracods and sporicid benthic foraminifers. Rare fragments of aptychi also occur. This microfacies is observed in both Rosomač and Barlya sections.

MF 1a. The additional MF 1a also consists of pelagic microfossils (less than 10%) but the micrite matrix besides carbonate contains some clayey admixture. This microfacies occurs only in the upper part of the Barlya section in the Salash Formation where microfossil-bearing clayey mudstones alternate with microfossil-bearing mudstones and microfossiliferous wackestones.

MF 2. Microfossiliferous wackestones contain pelagic components ranging between 10 and 25–30% included into calcareous micrite matrix. The main allochems are diverse pelagic microfossils such as calpionellids, calcareous dinocysts, radiolarians, and Globochaete alpina, but also calcified sponge spicules (Fig. 9.2), ostracods and benthic foraminifers. There are variable proportions of the occurrence of these microfossils, but calpionellids are the indicative component (Figs 10–12). Aptychi and ammonite bioclasts are scarce as well as echinoid fragments and intraclasts composed of micrite containing pelagic microfossils. This microfacies occurs in both studied sections.

The slope zone, including the toe-of-slope zone, is recognized by the presence of wackestones that are intercalated with gravity-induced deposits representing a mix of pelagic and platform-derived material. The main microfacies are: microfossiliferous wackestone (MF 2) and Saccocoma wackestone (MF 3), both typical of background sedimentation; fine bioclast-fossiliferous wackestones (MF 4), peloidal and intraclast-bioclastic grainstones (MF 5), bioclast-intraclastic floatstone (MF 6), and bioclast-intraclastic rudstones (MF 7), the latter four microfacies characterizing transported and redeposited sediments.

MF 2. The description of the microfossiliferous wackestones situated on the slope is the same as in the deeper basinal zone.

MF 3. Saccocoma wackestones consist of 30–40% allochems and matrix that frequently contains dissolution seams and zones (swarms), enriched in insoluble components such as clay minerals locally pigmented by Fe-oxhydroxides. Besides the various and abundant Saccocoma fragments, calcified radiolarians, sponge spicules and calcareous dinocysts are also observed (Fig. 9.3). Globochaete alpina, benthic foraminifers, aptychi and single calpionellids are recognized. Micrite
peloids are occasionally presented. This microfacies is typical of the lower parts of the sections studied (Gintsi Formation and Pokrovenik Limestones).

**MF 4.** In the wackestones comprising fine bioclasts and microfossils, the amount of allochems reaches a maximum of 40% and the calcareous matrix is over 60%. The bioclasts (Fig. 9.4) are mostly of sizes less than 1.0 mm, strongly recrystallized (probably with original aragonite composition) and unrecognizable. Rare micrite peloids and fine micrite intraclasts can be observed. The following microfossils are determined: calpionellids, *Globochaete alpina* (Fig. 9.4), calcified radiolarians and...
sponge spicules, calcareous dinocysts, ostracods, benthic foraminifers and aptachi. This mud-supported microfacies indicates the slope and the toe-of-slope zones where it alternates with grain-supported limestones (grainstones) in the Rosomač section.

**MF 5.** Grainstones are presented by peloidal and intraclast-bioclastic varieties. They contain two types of cement (jointly about 40%). The first type is drusy that fills the pore spaces between allochems (Figs. 9.5–6) and the second type represents syntaxial overgrowth on echinoderm bioclasts. The micrite is poorly sorted in some small pores. The allochems are about 60% (grain-supported texture) and the main constituents are micrite peloids (up to 0.2 mm) (Fig. 9.5), intraclasts and bioclasts, both of sizes less than 2.0 mm, rarely more. The intraclasts and bioclasts are relatively well-rounded. Some intraclasts are composed only of micrite (mudstones) but others are micrite wackestones that contain pelagic microfossils, (e.g. calpionellids, *Globochaete alpina*, calcified radiolarians, sponge spicules and calcareous dinocysts). The bioclasts are quite diverse and mainly of shallow-water origin (fragments of crinoids, echinoids, thick-walled shells, corals, algae, and *Crescentiella morronensis* (Crescenti) (Fig. 9.6). Aptychi and strongly recrystallized bioclasts also exist. Benthic foraminifers are common. The grainstones of this microfacies are typical of the middle part of the Rosomač section (toe-of-slope facies zone).

**MF 6.** Bioclast-intraclastic floatstone consists of well-preserved micrite matrix. The allochems constitute up to 25% of the rock volume. The intraclasts (Fig. 9.7) predominate over the bioclasts. The main type of intraclasts is microfossiliferous wackestone (of variable sizes, but bigger than 2.0 mm) that contains calpionellids, calcified sponge spicules, radiolarians, *Globochaete alpina* and calcareous dinocysts. The shallow-water bioclasts are mainly represented by crinoidal, shell, algal and recrystallized fragments. A single bioclast (7.0 × 6.0 mm) contains the encrusting micro-problematicum *Bacinella irregularis* Radoičić. Various benthic foraminifers can be seen. This microfacies occurs only in the Rosomač section.

**MF 7.** Bioclast-intraclastic rudstone is composed of micrite matrix as locally the micrite is recrystallized to microsparite. The allochems (about 65%, clast-supported texture) are very diverse – intraclasts, peloids, bioclasts and microfossils. The intraclasts are more common than bioclasts. Intraclasts (usually varying in size from one to several mm) are mainly represented by microfossiliferous wackestone that contain calcified radiolarians, sponge spicules, calcareous dinocysts, *Globochaete alpina*, ostracods, sporadic calpionellids as well as single juvenile ammonites. Some large intraclasts are surrounded by stylolites and dissolution seams. The micrite peloids do not exceed 0.2 mm. Bioclasts, rarely bigger than 2.0 mm, are of both shallow-water and pelagic fossils. Shallow-water bioclasts are mostly of crinoids but also of sporadic echinoid, bryozoan and thick-walled shell fragments (Fig. 9.8). The pelagic bioclasts are of aptychi and *Saccocoma*. Benthic foraminifers are diverse. This microfacies is poorly sorted. It is characteristic only of the Rosomač section.

**DISCUSSION**

**Biostratigraphic correlations**

Calpionellid and calcareous dinoflagellate zonations in this study indicate that the top of the Pokrovenik Limestones corresponds to the Lower/Upper Tithonian boundary interval and the Rosomač Limestones belong to the Upper Tithonian and Lower Berriasian (Fig. 3). The sampled lower part of the RZana Clayey Limestone Beds corresponds to the upper Lower Berriasian and Upper Berriasian. The boundary between the Pokrovenik and Rosomač Limestones lies within the Remanie Subzone and *P. malmica* Zone, i.e. in the middle part of the Upper Tithonian. The lithostratigraphic boundary between the Rosomač Limestones and RZana Clayey Limestone Beds is in the Remaniella Subzone and *St. proxima* Zone, in the upper part of the Lower Berriasian.

Although the Rosomač Limestones differ from their correlative Glozhene Formation in Bulgaria in being deposited in shallower environment, the calpionellids are enough in quantity and well preserved. This makes indication of calpionellid zones and subzones reliable. However, the rate of sedimentation of the Rosomač Limestones is rather low. It is ca. twice lower than that of the Glozhene Formation, which in turn equals 6–7 mm/ka. The sampling density is rather insufficient to trace precisely the zonal/subzonal boundaries on calpionellids but it is dense enough to demonstrate that the deposition of the Rosomač Limestones covers the same time interval as the Glozhene Formation in Bulgaria, i.e. Late Tithonian and Early Berriasian.

A noteworthy feature of the section studied is a hidden stratigraphic unconformity in the top of the Pokrovenik Limestones. Calpionellid Dobeni Subzone is overlain by the Remanie Subzone (samples Ro1 and Ro2). Thus, the Boneti Subzone and the Praetintinnopsella Zone are absent from the section. Lithoclasts containing numerous *Chitinoidella boneti* as well as *Dobeniella bermudezi* and *Chitinoidella elongata* have been observed throughout the Remanie Subzone. It is an indication that elsewhere in the region pelagic sediments of the early Late Tithonian (Boneti Subzone) were deposited, then destroyed, transported and redeposited in younger sediments. Similarly, the calcareous dinocysts *Colomisphaera tenuis* has been recorded only in the *Colomisphaera fortis* Zone but not in lower levels.

In contrast, the calpionellid and calcareous dinocyst vertical distributions, bioevents and zonations in the Barlya section of western Bulgaria indicated a continuous sedimentation in the Late Tithonian, around the Gintsi/Glozhene formations boundary (Lakova et al., 1999; Lakova and Petrova, 2013). There, the background sedimentation typical of the basinal zone has been revealed on the basis of the presence of only basinal microfacies and pelagic microfossils (Fig. 12).

Calpionellid and calcareous dinoflagellate zonations of the Tithonian and Berriasian pelagic carbonates in the Western Balkan Unit of Bulgaria used for fine subdivision of the Gintsi, Glozhene and Salash formations (Ivanova in Lakova et al., 1999; Lakova and Petrova, 2013) have been applied to counterparts of those forma-
Fig. 8. Benthic foraminifers of the Rosomač section; samples Ro1–Ro3 from the Pokrovenik Limestones, samples Ro4–Ro13 from the Rosomač Limestones, and samples Ro14–Ro21 from the Ržana Beds.

10. *Spirillina tenuissima* (Gümbel), Ro5, Upper Tithonian.
11–12. *Andersenolina* cf. *molesta* (Gorbatchik), Ro12, Lower Berriasian.
15. *Guttulina* sp., Ro2, Upper Tithonian.
17. *Glomospirella* sp., Ro2, Upper Tithonian.
27. *Feurtilia gracilis* cf. *d’Orbigny, Ro5, Upper Tithonian.
28. *Protopenoplistus ultragrandula* (Gorbachik), Ro11, Lower Berriasian.

Depositional environments

The nodular limestones of the Gintsi Formation (Bulgaria) and Pokrovenik Limestones (Serbia) refer to the *rosso ammonitico* facies. It is traditionally defined as composed of condensed pelagic red nodular limestones (Martire, 1992). Usually, this facies is formed on submarine highs or pelagic platforms with increased water currents at water depths from approximately 100 m down to 300 m (Lukeneder, 2011).

In Bulgarian and Serbian sections the nodular limestones (Gintsi Formation and Pokrovenik Limestones) are composed mainly of *Saccocoma* wackestones (MF 3). In the lower part of the Gintsi Formation these wackestones are intercalated with gravity-flow deposits – peloid-bioclast-intraclastic grainstones and rudstones (unpublished data of E. Koleva-Rekalova). They contain resedimented shallow and deeper water materials such as echinoderm and thick-walled shell bioclasts, bryozoans and algal fragments, and *Cresentiella morronensis* (Crescenti). Micrite peloids and intraclasts composed of micrite limestones with pelagic microfossils and scarce peloid limestones occur as well. MF 3 resembles MF 5 and MF 7 microfacies defined in the present study. This alternation demonstrates that the limestones were formed on the slope facial zone. Since there are no data on the existence of submarine highs or pelagic platforms in the studied region it can be supposed that the nodular limestones of the upper part of the Gintsi Formation were also deposited under slope conditions (Fig. 12). The same probably refers to the nodular limestones of the Pokrovenik Limestones in Serbia (Fig. 10). *Saccocoma* is an indicative fossil for the Upper Jurassic nodular limestones. Some authors, (e.g. Ivanova et al., 2006; Lakova et al., 2007; Reháková et al., 2011), defined a peculiar *Saccocoma* microbiofacies in nodular limestones containing planktonic crinoids.

The pelagic limestones of the Glozhene Formation and Rosomač Limestones correspond to the Biancone/Maiolica limestones that are common Upper Tithonian to Lower Cretaceous facies in the pelagic successions of the Western and Central Europe. This facies represents a background pelagic sedimentation in a deeper-water environment, and it usually does not contain resedimented shallow-water clasts (Kukoč et al., 2012). According to Lukeneder (2011) such pelagic limestones were formed at water depths from approximately 100 m down to 500 m.

The microfacies study reveals that the Glozhene Formation is mainly composed of microfossiliferous wackestone (MF 2) and rarely of microfossil-bearing mudstones (MF 1). Their main constituents are pelagic microfossils such as calpionellids, calcified sponge spicules, calcified radiolarians, *Globochaete alpina*, calcareous dinocysts, foraminifers and ostracods in variable
proportions. Calpionellids appear as an indicative component and often the limestones containing calpionellids are designated as calpionellid microfacies (Ivanova et al., 2006; Lakova et al., 2007; Reháková et al., 2011). In the lower part of the Glozhene Formation there is a relative abundance of Globochaete alpina Lombard. Flügel (2004) referred pelagic lime mudstone and wackestone with calpionellids to as “SMF 3-calp.” which is typical of the basinal zone. Accordingly, studied microfossiliferous wackestones and microfossil-bearing mudstones rich in calpionellids were formed in a basinal setting. Transported shallow-water clasts are absent except single echinoderm fragments of insignificant sizes. Locally, in the microfossiliferous wackestones are observed intraclasts of micrite limestones containing pelagic microfossils. Most probably their formation is connected to activity of bottom currents.

The Rosomač Limestones are lithostratigraphic counterpart of the Glozhene Formation. This succession consists of microfossiliferous wackestones (MF 2) that are intercalated with bioclast-intraclastic rudstones (MF 7) and fine bioclast-fossiliferous wackestones (MF 4) in the lower part, and with peloidal and intraclast-bioclastic grainstones (MF 5) and fine bioclast-fossiliferous wackestones (MF 4) in the upper part. The micropetrographic characteristics of the microfossiliferous wackestones is the same as that of the Glozhene Formation. The indicative microfossils are calpionellids. However, interbeds that occur are composed of pelagic microfossils and bioclasts, transported shallow-water bioclasts, and intraclasts of mainly microfossiliferous wackestones. The shallow-water bioclasts in the rudstones (MF 7) are represented predominantly by fragments of crinoids and echinoids, bryozoans and thick-walled shells. The intraclasts and bioclasts in the rudstones are rounded to subrounded and variable in size (from 1.0 to 20.0 mm), chaotically arranged and poorly sorted. Such deposits of mixed pelagic and eroded and transported shallow-water materials are regarded as gravity debris flows (Lowe, 1982; Einsele, 1991; Kukoč et al., 2012). They alternate with background pelagic deposits and are characteristic of the slope facies zone (Flügel, 2004). The shallow-water allochems are more diverse in the grainstones: fragments of crinoids, echinoids, thick-walled shells, recrystallized bioclasts, corals, algae, and Crescentiella morronensis. They also contain pelagic microfossils and intraclasts consisting of wackestones with pelagic microfossils. The bioclasts and intraclasts are well-rounded and usually less than 2.0 mm. These lithologies were also deposited by gravity-flow processes such as grain flows under slope conditions, but typically associated with the toe-of-slope zone (Flügel, 2004). In the Upper Jurassic–Lower Cretaceous sections in Europe numerous examples were reported of gravity-flow deposits associated with pelagic and hemipelagic limestones: the Cieszyn Limestone, Outer Carpathians, Poland (Matyszukiewicz and Słomka, 1994); the Barmstein Limestone (Schlagintweit and Gawlick, 2007), the Tressenstein Limestone (Schlagintweit and Gawlick, 2007), the Tressenstein Limestone (Schlagintweit and Ebel, 1999), and the Rettenstein Debris Flow (Auer et al., 2009) in the Northern Calcareous Alps; the Mateiaş Limestone in the Southern Carpathians, Romania (Bucur et al., 2010); and the Lower Cretaceous carbonate gravity-flow deposits in the Internal Dinaride, Slovenia (Kukoč et al., 2012).

In view of the above stated considerations, it seems that during the Late Tithonian and Early Berriasian the Western Stara Planina in Bulgaria (Glozhene Formation) was an area of in situ (basinal) sedimentation whereas the Stara Planina–Poreč Zone in eastern Serbia (Rosomač Limestones) represented a depositional setting of re-sediments (debris and grain flow) and pelagic deposits formed under slope and toe-of-slope conditions.
Fig. 10. Lithological log of the Rosomač section (East Serbia) with age, composition of rocks, microfacial zones, microfacies types, indicative fossils, sedimentological texture and abundance of pelagic and resedimented allochems.
The Salash Formation is composed of alternation of microfossil-bearing mudstones (MF 1), microfossil-bearing clayey mudstones (MF 1a) and marls. The microfossils (less than 10%) are of pelagic origin: calpionellids, calcareous dinocysts, calcified sponge spicules and radiolarians, *Globochaete alpina*, ostracods and benthic foraminifers. They suggest a basinal setting. The Ržana Beds that are stratigraphic counterpart of the Salash Formation are composed mainly of microfossil-bearing mudstones (MF 1) and microfossiliferous wackestones (MF 2). The microfossils are the same as determined in the Glozhene Formation and can also be referred to the basinal zone. As an exception, in the upper part of the Rosomač section among microfossil-bearing mudstones is recognized a bioclast-intraclastic floatstone (MF 6) that shows existence of the gravity induced debris flow. Besides pelagic microfossils and micrite intraclasts containing pelagic microfossils, shallow-water bioclasts of crinoidal, shell, algal, *Bacinella* and recrystallized fragments are determined as well. One explanation is that shallow-water components reached the basin as occasional debris flow and another is that the slope sedimentation setting returned.

**CONCLUSIONS**

The Ržana Clayey Limestone Beds in the Stara Planina–Poreč Zone of eastern Serbia are equivalent in sedimentology, stratigraphic position and age (Late Berriasian, Valanginian and Early Hauterivian) with the Salash Formation in Bulgaria. The overlying Ržana Marl Beds (Late Hauterivian–Early Barremian) correspond to the Mramoren Formation in western Bulgaria. Since the Late Barremian, shallowing of the depositional setting in the Stara Planina–Poreč Zone started. The Slavinja Sandstone Beds and the Gradštše Orbitoline Limestone Beds deposited till the Aptian. No correlative formations of the latter two lithostratigraphic units were found in western Bulgaria.

The transition from accumulation of clayey nodular limestones (Pokrovenik Limestones) to deposition of micritic limestones (Rosomač Limestones) in the Stara Planina–Poreč Zone occurred in the Late Tithonian (Remanei Subzone and *P. malmica* Zone). The beginning of hemipelagic carbonate sedimentation of clayey limestones and marls with ammonites (Ržana Clayey Limestone Beds) started in the late Early Berriasian (Remaniella Subzone and *St. proxima* Zone).

The stratigraphic succession at the top of Pokrovenik Limestones at Rosomač section was disturbed in missing the lowest Upper Tithonian, i.e. the Boneti Subzone and the Preatintinnopsella Zone. The latter were deposited elsewhere, and later were transported and redeposited as lithoclasts in the Remanei Subzone. This Lower/Upper Tithonian boundary in western Bulgaria was documented by non-interrupted sedimentation and a gradual transition between the Gintsi and Glozhene formations.

The Rosomač Limestones in Serbia were deposited under slope conditions, including the toe-of-slope zone, whereas the correlative Glozhene Formation in Bulgaria formed in deeper basinal zone. At least four impulses of shallow-water material supply have been recorded in the Rosomač Limestones which are traditionally considered as the deepest sediments in the Stara Planina–Poreč Zone. A possible source of shallow carbonate intraclasts and bioclasts were the Rsovci Limestones from the neighbouring Dobri Do–Grlište Zone, at present thrustmed over the Ržana Marl Beds of the Stara Planina–Poreč Zone along the Rsovci dislocation (Fig. 2.3–4).

The rate of sedimentation of the micritic limestones and the marl-limestone alternation is twice greater in western Bulgaria than in eastern Serbia.

A general bathymetric trend in the pelagic basin of the Stara Planina–Poreč Zone and the Western Balkan Unit could be reconstructed from the present microfacies data. In eastern Serbia, deposition occurred in the slope zone...
Fig. 12. Lithological log of the Barlya section (West Bulgaria) with age, composition of rocks, distribution of main microfossils, bioclasts, dolomite crystals and intraclasts, microfacies types, indicative fossils, sedimentological texture, abundance of pelagic and resedimented allochems, and calpionellid and calcareous dinocysts biostratigraphy.

while in western Bulgaria purely basinal background pelagic carbonates were deposited without shallow-water ingredients. To the west of the Rosomač section, shallow-water carbonates of the Rsovci Limestones indicate more proximal conditions. Further to the east in Bulgaria, the alternation of micritic limestones, clayey limestones and marls of the Salash Formation are laterally substituted by the peripheral flysch deposits of the Cherni Osam Formation. Thus, the proximal parts of the basin during the Berriasian should be searched in the westernmost end of the Stara Planina–Poreč Zone in Rsovci area, and the distal environments are to be found in the easternmost part of the Western Balkan Unit at the Iskar River Valley.

Acknowledgements

This study was carried out under the auspices of the bilateral research project between Bulgarian and Serbian Academies of Sciences “Trans-border stratigraphic correlations of the Western Stara Planina Mts in western Bulgaria and eastern Serbia”. This is a contribution to the activities of the Berriasian Working Group of the ISCS (International Subcommission of Cretaceous Stratigraphy). The authors are grateful to Prof. Daniela Reháková, Comenius University of Bratislava, for valuable comments and useful suggestions.

APPENDIX 1. LIST OF MICROFOSSIL SPECIES

Calpionellids

Borzaiella atava Grün & Blau, 1996
Borziella slovenica (Borza, 1969)
Chitinoiella boneti Doben, 1963
Chitinoiella elongata Pop, 1997
Chitinoiella sp. 2 Sallouhi, Boughdiri & Cordey, 2011
Daciella banatica Pop, 1998
Daciella danubica Pop, 1998
Daciella svinetensis Pop, 1998
Dobieniella bermudezi (Furrazola-Bermúdez, 1965)
Dobieniella colomi (Borza, 1966)
Dobieniella dorati (Borza, 1966)
Praetintinnopsella andrusovi Borza, 1969
Calpionella alpina Lorenz, 1902
Calpionella elliptalpina Nagy, 1986
Calpionella elliptica Cadisch, 1932
Calpionella grandalpina Nagy, 1986
Calpionella minuta Houša, 1990
Calpionellopsis oblonga (Cadisch, 1932)
Crassicollaria brevis Remane, 1962
Crassicollaria colomi Doben, 1963
Crassicollaria intermedia (Durand-Delga, 1957)
Crassicollaria massutiniana (Colom, 1948)
Crassicollaria parvula Remane, 1962
Lorenziella hungarica Knauer & Nagy, 1964
Remaniella borzai Pop, 1994
Remaniella cadischiana (Colom, 1948)
Remaniella catalanoi Pop, 1996
Remaniella colomi Pop, 1996
Remaniella duranddelgai Pop, 1996
Remaniella ferasini (Catalano, 1965)
Sturiella dolomitica Grün & Blau, 1996
Tintinnopsis carpathica (Murgeanu & Filipescu, 1933)
Tintinnopsis doliformis (Colom, 1939)
Tintinnopsis longa (Colom, 1939)
Tintinnopsis remanei Borza, 1969
Tintinnopsis subacuta (Colom, 1948)

Calcareous dinocysts

Cadosina fisca fisca Wanner, 1940
Cadosina parvula Nagy, 1966
Crustocadosina semiradiata semiradiata Wanner, 1940
Crustocadosina cf. semiradiata semiradiata Wanner, 1940
Crustocadosina semiradiata olzae Nowak
Carpitomiosphaera tithonica Nowak, 1968
Colomisphaera carpathica (Borza, 1964)
Colomisphaera fortis Réhánek, 1982
Colomisphaera lapidosa (Vogler, 1941)
Colomisphaera tenuis (Nagy, 1966)
Parastomiosphaera malmica (Borza, 1964)
Stomiosphaera alpina (Leischner)
Stomiosphaera moluccana Wanner, 1940
Stomiosphaera proxima Réhánek, 1987

Benthic foraminifera

Verneulinoideae neocomiensis (Mjåtliuk)
Textularia cf. bennetstaedti Bartenstein & Oertli
Dentalina cf. communis d’Orginny
Spirillina polygyrata Gümbel
Spirillina tenassiima (Gümbel)
Andersenolina cf. molesta (Gorbatchik)
Moestiloculina damhiana Neagu
Istriloculina emiliei Neagu
Turriglomina? analitica Altiner, Rettori, Zaninetti & Martini
Patella luriculata Dieni & Massari
Patella subcretacea Cushman & Alexander
Patellicardia fejeli fejelidi Lutze
Vaginulina arguta Reuss
Pseudonodosaria cf. brandi (Tapan)
Feurtilia grassi Neagu & Cîrnaru
Protopeneroplis ultragranulata (Gorbachik)

APPENDIX 2. DESCRIPTION OF MICROFACIES IN SAMPLES (ROSMAC SECTION)

Ro1. Spicule-radiolarian-Saccocoma wackestone. Matrix – 65%, allochems – 35%. Matrix is composed of well preserved micrite. There are thin calcite veins and a dissolution zone. Allochems – Saccocoma fragments predominate. Calcified radiolarians and sponge spicles also are well represented. Calcareous dinocysts and Globochaeta alpina are rare. There are single foraminifers and aptychi.

Ro2. Spicule-peloidal wackestone. Matrix – 60%, allochems – 40%. The micrite of the matrix is locally recrystallized to microsparite. There are some thin calcite veins. Allochems – micrite peloids (of sizes under 0.2 mm) slightly prevail over calcified sponge spicles. Calcified radiolarians, calcareous dinocysts, foraminifers and Globochaeta alpina are very rare.

Ro3. Globochaeta alpina wackestone. Matrix – 70%, allochems – 30%. The micrite is comparatively well preserved. Indistinct dissolution seams and zones can be recognized. Allochems – Globochaeta alpina predominates. Other allochems as calcified sponge spicles, radiolarians, calcareous dinocysts, foraminifers and aptychus fragments are rare.

Ro4. Bioclastic-intraclastic rudstone. Matrix – 40%, allochems – 60%. The micrite is locally recrystallized to microsparite. A well-rounded intraclast, 22.0 × 8.0 mm in size, is detached from the matrix with dissolution seams and stylolites. Diverse allochems represent bioclasts, microfossils, peloids and intraclasts. Bioclasts are of sizes less than 2.0 mm. Predominant bioclasts are crinoids. There are rare Saccocoma fragments and spherical sections of sea urchin spikes. Some small bioclasts resemble bryozoans. Shell fragments are in an insignificant amount, but aptychi are more common. Microfossils are calcified radiolarians, sponge spicles, foraminifers, calcareous dinocysts, Globochaeta alpina and ostracods. Micrite peloids are of sizes less than 0.2 mm. The intraclasts are of microfossil-bearing wackestone. The micrite contains rare calcified sponge spicles, radiolarians, foraminifers, calcareous dinocysts, ammonitellas and Globochaeta alpina. Shell and aptychus fragments are less common. The limestone is an example of debris flow – it is composed of shallow and deeper water components.

Ro5. Spicule-radiolarian wackestone. Matrix – 70%, allochems – 30%. Micritic matrix is well-preserved. There is a thicker dissolution zone. Predominant allochems are calcified radiolarians and sponge spicles. Other allochems are: foraminifers, gastropods, calcareous dinocysts, Globochaeta alpina, ostracods and aptychus fragments.

Ro6 as Ro5. Spicule-radiolarian wackestone.

Ro7. Fine-bioclastic-Globochaeta alpina wackestone. Matrix – 70%, allochems – 30%. The matrix is recrystallized to microsparite only in some places. The stylolites and dissolution seams and zones exist. In the periphery of the thin section, one part is seen that is composed of black organic matter. Globochaeta alpina predominates. Other allochems are: rare calcified radiolarians, sponge spicles, calcareous dinocysts, calpionellids, ostracods, foraminifers, Saccocoma and aptychus fragments. Single recrystallized bioclasts are present of sizes less than 1.0 mm.

Ro8. Calpionellid-spicule-radiolarian wackestone. Matrix – 65%, allochems – 35%. The micrite is well-preserved, only locally recrystallized to microsparite and rarely to sparite. The main allochems are calcified radiolarians, sponge spicles and calpionellids. Rare foraminifers, calcareous dinocysts, Globochaeta alpina, Saccocoma and aptychi are also recognized. Micritic peloids of sizes under 0.2 mm are less common.

Ro9. Spicule-radiolarian-calpionellid wackestone. Matrix – 70%, allochems – 30%. The matrix is well-preserved. Single dissolution zones and calcite veins exist. Allochems – there is a relative increase of calpionellids. Calcified radiolarians and sponge spicles are also common. Rare foraminifers, calcareous dinocysts and Globochaeta alpina are seen. Fragments of ammonite shells and aptychi are rare (one aptychus being of sizes 9.0 × 1.0-0.5 mm). Single small bioclasts smaller than 0.2 mm are phosphatized.

Ro10. Globochaeta alpina-calpionellid wackestone. Matrix – 70%, allochems – 30%. The micrite is well-preserved. Allochems are dominated by calpionellids and Globochaeta alpina. Calcified radiolarian and sponge spicles also exist. Rare foraminifers, ostracods, calcareous dinocysts and aptychus fragments are recognized.

Ro11. Intraclast-bioclastic grainstone. Cement and micrite – 40%, allochems – 60%. The cement is of two types. The first is drusy type and fills the pores. The second is syntaxial cement that grows on crinoids. The micrite is preserved only in some small pores. Biosilts slightly prevail over the intraclasts. Biosilts are of size below 2.0 mm, rarely bigger. There are crinoidal and shell fragments. Coral, bryozoan and recrystallized bioclasts also can be recognized. Rare aptychi and single foraminifers exist. Crescentiella morronensis and algae are common. Micritic intraclast predominate over the peloidal ones. Some intraclasts are only of micrite while others contain single microfossils such as calpionellids, Globochaeta alpina, calcified radiolarians and sponge spicles.
Ro12. Fine-bioclastic-calpionellid wackestone. Matrix – 60%, allochems – 40%. The matrix is well-preserved, of dark colouration. Single stylolates and dissolution zones are seen. Fe-oxides spots can be seen locally. Allochems – calpionellids relatively predominate. Recrystallized bioclasts are less common and have a size below 0.5 mm. Crinoid and aptychus fragments are rare. Single micritic peloids occur, smaller than 0.2 mm. A micritic intraclast, containing rare microfossils can be seen. Its size is 4.0 × 3.0 mm and it is encrusted. Calcified radiolarian, sponge spicules, ostracods, Globochaete alpina and calcareous dinocysts are visible.

Ro13. Peloidal grainstone. Cement and micrite – 40%, allochems – 60%. The cement is mainly drusy type – it fills pores. Syntactical overgrowths on crinoid fragments are rare. The micrite is preserved only in small pores. Allochems – micrite pellets of size below 0.2 mm predominate. Rare micritic intraclasts occur of size between 0.2 and 0.4 mm. Some contain single calpionellids, Globochaeta alpina and calcified sponge spicules. Bioclasts are less common and of sizes less than 0.4 mm. These are mainly crinoid and shell fragments. Completely recrystallized bioclasts also exist. Some small bioclasts are silicified. The foraminifers are common.

Ro14. Calpionellid wackestone. Matrix – 75%, allochems – 25%. The matrix is well-preserved. Fe-oxides spots and thin calcite veins exist. Predominant allochems are the calpionellids. There are rare calcified sponge spicules, Globochaeta alpina and aptychus fragments.

Ro15. Calpionellid mudstone. Matrix – 90%, allochems – 10%. The micrite matrix is well-preserved and is of dark colouration may due to be presence of clay minerals. In some places Fe-oxides spots are recognized. Allochems – calpionellids relatively predominate. Calcified sponge spicules, Globochaeta alpina and calcareous dinocysts are rare. There are sporadic foraminifers and aptychi.

Ro16, Ro17, Ro18 and Ro20 as Ro15. Calpionellid mudstone.

Ro19. Calpionellid-bioclast-intraclastic floatstone. Matrix – 75%, allochems – 25%. Micrite matrix is well-preserved. Dissolution seams and thin calcite veins are visible. Allochems – the intraclasts slightly predominate. There is a large intraclast (7.0 × 6.0 mm) that contains the encrusting microproblematicum Bacinella. Smaller micritic intraclasts are also represented. Crinoidal, shell, algal and recrystallized bioclasts can be seen of sizes less than 2.0 mm. There are various foraminifers. Calpionellids and calcified sponge spicules also exist. Calcified radiolarians, Globochaeta alpina and calcareous dinocysts are sporadic.

Ro21. Calpionellid wackestone. The allochem amount slightly increases to 15%.

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