Геолошки анали Балканског полуострва Annales Géologiques de la Péninsule Balkanique	72	63–69	Београд, децембар 2011 Belgrade, December 2011

DOI: 10.2298/GABP1172063B

Paraseqences in the Kotroman Formation, western Serbia

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Abstract. An attempt was made to describe two parasequences separated within the sediments of the Kotroman Formation at the Mokra Gora Village in western Serbia. The whole formation, of Albian–Cenomanian age, in some general characteristics corresponds to tidal flats, some of which were described in the literature (Larsonneur 1975), and the sediments were compared with ones from recent tidal flat environments. The heterogeneous composition of the Kotroman Formation influenced different authors to describe several non-synchronous and incomparable superpositioned packages. The parasequences were investigated in the attempt to correlate them with the stratigraphic age of the members. The parasequences were formed during the Albian transgression and represent a gradual deepening of the wider area. Well-developed flooding surfaces with significant deepening indicated retrogradational stacking of certain transgressive system tracts and reflect landward movement of the shoreline, indicating a gradual sea level rise.

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

Апстракт. У раду су описане две парасеквенце уочене у седиментима формације Котроман код Мокре горе у западној Србији. Цела формација, албско-ценоманске старости, у неким својим општим карактеритикама, одговара тајдалној равни, какве су већ описане у литератури (Larsonneur 1975), а њени седименти су упоредиви са творевинама рецентних тајдалних равни. Хетерогена грађа формације Котроман условила је да више аутора описује неколико различитих суперпозиционих пакета који се међусобно не могу поредити. У раду су описане парасеквенце и представљена је њихова стратиграфска припадност. Парасеквенце су формиране током албске трансгресије и настале су услед постепеног продубљавања на ширем простору. Површине плављења са маркатним продубљавањем указују на ретроградациони трансгресивни тракт и представљају последицу сталног издизања нивоа мора уз постепено померања обалске линије ка копну.

Кључне речи: Парасеквенце, Формација Котроман, палеонтологија, седиментологија, алб–ценоман, Мокра Гора, западна Србија.

Introduction

After a period of no deposition during the Aptian and the Albian, with a new transgressive cycle, land masses of Jurassic ophiolites (nowadays in western Serbia) were flooded with a shallow to moderately shallow sea. Although extensively eroded since, Cretaceous deposits that were formed during this transgressive cycle could be found on numerous outcrops in western Serbia. The most extensive exposure among these outcrops is located in the vicinity of Mokra Gora and occupies the Beli Rzav and Kamešina Valleys with their tributaries. The lower portion of these deposits near Mokra Gora Village was previously studied and described as the Kotroman Formation (Banjac *et al*. 2008 and references therein).

Previous Studies

The general consensus among the stratigraphic community was that the Mokra Gora deposits are Upper Cretaceous in age. However, much debate was involved to the question of the age of specific strati-

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graphic sections. The Mokra Gora deposits were first described by ŽUJOVIĆ (1893), as carbonates of Senonian age. The author sporadically mentioned numerous hippuritids and abundant fossil gastropod associations. The following works (ŽIVKOVIĆ 1905, 1907; PETKOVIĆ 1925; AMPFERER1928; MILOVANOVIĆ 1933) confirmed Mokra Gora deposits as Senonian in age, locating the whole sequence as analogues to the Gosau Beds in Austria. The determination was based on macrofossil fauna assemblages with: *Pyrgulifera pichleri, P. accinosa, P. lyra, P. striata, Glauconia kefersteini, G. renauxi, G. coquandi, Natica bulbiformis, N. lyrata, Hippurites gosaviensis, Radiolites lusitanicus*, etc. However, LÓCZY (1924) indicated that the sediments are Upper Cretaceous in age, more specifically Cenomanian, Turonian and Senonian, based on the macrofossil fauna: *Acanthoceras mantelli*, *Puzosia* aff. *gaudama*, *Biradiolites affilaensis*, etc. MILOVANOVIĆ (1935) just mentioned deposits from the Upper Cenomanian to the Upper Campanian age. MITROVIĆ (1966), MITROVIĆ *et al.* (1989), confirmed this age based on abundant echinid assemblages with numerous representatives of the *Epiaster* and *Hemiaster* genera.

PEJOVIĆ & RADOIČIĆ (1971, 1973, 1974) and RADOIČIĆ (1984), placed the whole Mokra Gora series as the Cenomanian, Turonian and older Senonian. According to these authors, the sandy and marly carbonate portion of the local stratigraphic column, "tens of meters above the weathering crust" RADOIČIĆ (1984, p. 136.), is characterized by mid-Cenomanian microfauna: *Aeolisacus inconstans, Ovalveolina maccagnae* and *Rhapidionina laurinensis*. Therefore, the authors concluded that the lower-most, palaeontologically sterile basal section can be recognized as the Albian stage. The upper portion of the local stratigraphic column is represented by marly limestone with abundant ostreids, grypheas and inoceramids, as well as pelagic microfossils of the *Pithonella ovalis*, *Hedbergella-Ticinella* group, which indicate the lower Turonian stage. However, upper Cenomanian age was accepted after later revision of the beds with *Cisalveolina fraasi*, (RADOIČIĆ 1984, 1995).

The uppermost member of the stratigraphic column is represented with massive limestone bearing hippurites and gastropods of Turonian age.

The Albian–Cenomanian age of the Mokra Gora Series was confirmed in the works of BANJAC (1994, 1994a, 2000). The author reported mollusc fauna of Albian–Cenomanian and Turonian age, although some of the specimens, e.g., *Paraglauconia lujani*, is known from Aptian deposits. DULIĆ (2003), described it as the Albian–Cenomanian palynomorph association from the Mokra Gora Series. The same age was confirmed by JOVANOVIĆ *et al*. (2004) based on the microfauna assemblage, as well as BANJAC *et al*. (2007) based on the gastropod assemblage. RADOIČIĆ & SCHLAGINTWEIT (2007) at the Mokra Gora Series established a new species *Neomeris mokragorensis* of Albian age. It must be noted that lower portion of the stratigraphic column is described as deposits of Barremian age (NIRTA *et al.* 2008; MENA *et al.* 2008).

Lithostratigraphic members

Due to heterogeneous composition of the Mokra Gora Series, authors described several non synchronous and incomparable superpositioned packages. LÓCZY (1924) differentiated five packages. (1) The first one consists of conglomerates and sandy horizons with oolith iron nodules, (2) the second with marly to sandy limestone, (3) the third with shaly and sandy limestone. The fourth package (4) is represented by greyish to yellowish fragile marl with large molluscs and bivalve fossil specimens, whereas the fifth package (5) is represented by massive reef limestone. MILOVANOVIĆ (1933) also differentiated 5 packages: (1) basal, represented by conglomerate, reddish quartzite and iron rich bearing schist; (2) tabular marl and limestone, which gradually become sandy limestone and sandstone; (3) lower package of sandstone, sandy limestone and marls with abundant associations of gastropods and most commonly the genus *Pyrgulifera* and (4) upper package of sandy limestone and marl with associations of gastropods, bivalves and echinoids. The uppermost package (5) is represented with massive reef limestone with abundant rudist fauna. This subdivision was generally accepted in the works of DRAKULIĆ & DEDIĆ (1963) and FOTIĆ (1965).

PEJOVIĆ & RADOIČIĆ (1971, 1973, 1974), RADOIČIĆ (1984) described the biostratigraphic characteristics of the Mokra Gora Series, with three main levels: (1) the basal clastites, (2) carbonates with marls and (3) shallow water reef limestone. The lowermost level (1), transgressively overlying serpentine or a weathering crust, is represented by conglomerate, conglomeratic sandstone and sandstone lacking any fauna. The overall height is around 50 m. The authors emphasized the extremely heterogeneous composition and thickness of this level. The following level (2) was named by the authors as Carbonaceous or Pelagic beds, and bears two members of lower rank, *i.e*., (2a) sandstone, marl and carbonaceous deposits (150–200 m thick) and (2b) marly-carbonaceous deposits (150–200 m. thick). The uppermost level (3) consists of massive limestone with hippurits of Turonian age. A similar partition with three principal units was presented by MOJSILOVIĆ *et al*. (1978) and OLUJIĆ *et al*. (1986). NIRTA *et al.* (2008) and MENA *et al* (2008) explained the lithologic characteristics of the Mokra Gora Series, describing two units (named A and B), which reflect two main deepening-shallowing cycles. These units correspond to the levels 1 and 2, respectively, suggested by PEJOVIĆ & RADOIČIĆ (1971, 1973, 1974) and RADOIČIĆ (1984). The authors also mentioned, but did not study, the third unit (named C), which corresponds

to level 3 of massive limestone with hippurites suggested by PEJOVIĆ & RADOIČIĆ (1971, 1973, 1974).

Within an analysis of the Cretaceous deposits of western Serbia, JOVANOVIĆ *et al.* (2004) separated three levels.

The first is basal terrigenous sandy series with nodular biomicrite. The biocomponent is represented with rare fragments of microflora and microfauna in addition to mollusc detritus. The frequent charophyts and ostracods of the same age indicate the presence of an intermittent freshwater environment at the same period. Rich fossil assemblages can be found in the uppermost section of the Kotroman Formation.

The next level is the Pelagic Series, composed of thin-bedded marly limestone. These are fine laminated biomicrite with an abundant alevritic fraction and centimetre thick beds of bioclastic marl, bioclastic packstone, sometimes with accumulations of thin shell fragments. They are commonly alternating with thin marly layers.

The third level, uppermost portion of the Mokra Gora Series, consists of massive carbonates with hippurits and gastropods of Turonian age.

The first of the aforementioned, the so-called Basal terrigenous sandy series, was described by Banjac *et al*. (2008), and proposed as the Kotroman Formation. The Formation consists of clastic deposits 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 the upper limit is a blunt transition to the so-called Hemipelagic Series. Three separate members were distinguished in the Kotroman Fm.: the Kamišna Mb, the Uroševići Mb and the Jatare Mb.

Kamišna Member

At the investigated locality, the Kamišna Member is not exposed at its whole thickness. In its lower segment, transgressive extra-formational oligomict conglomerate can be observed. Fragments of serpentinite and chert are deposited within a sandy or silty matrix.

Iron-rich, dark green chamosite ooides and serpentinite particles can be frequently found in the conglomerate fragments. The grains are cemented with calcareous or clay-ironstone cement. The described sediments correspond to the gravel initially deposited below the low-water tide level (LARSONNEUR 1975).

In the upper parts of the stratigraphic column, these sediments increasingly interchange with iron-rich sandstone characterized by well-rounded pyritised grains and fragments of serpentine, without any fossils. The deposits gradually transform to sandstone containing more than 25 % fine-grained rock fragments, predominantly pyroxene and spinel clasts. This coarse- to fine-grained loose dark grey sandstone is present in the main portion of the Basal Member. Small cherty fragments as well as sand particles of different sizes are bound by clayey or limonitic red or brown cement.

The described sediments correspond to gravelly sand which was deposited on about the low-water tide level (LARSONNEUR 1975).

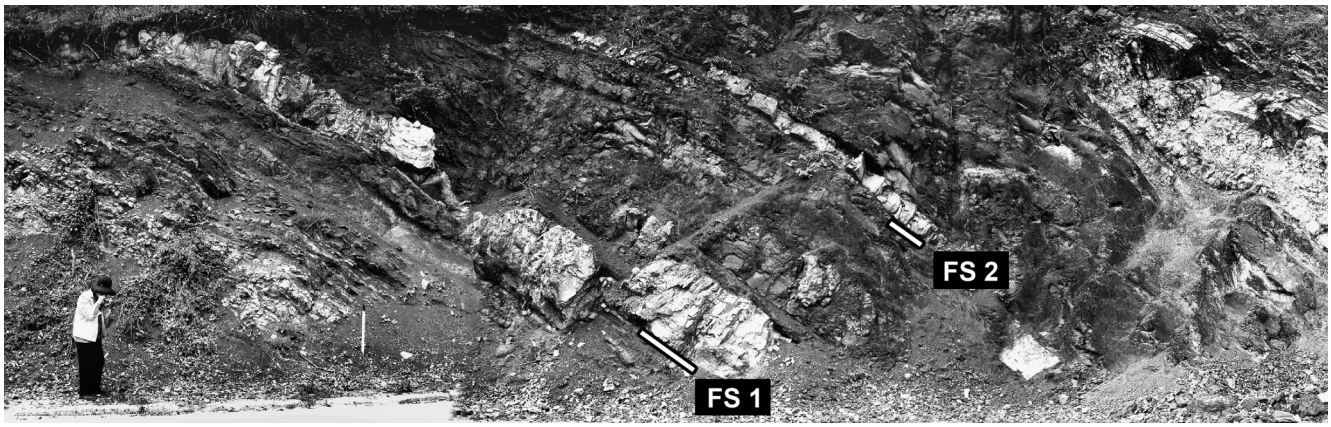

Fig. 1. Parasequences at the Kotroman locality. Legend: FS1 - Flooding surface 1, FS2 - Flooding surface 2.

Parasequences

An attempt was made to describe the two parasequences separated within the Uroševići Member of the Kotroman Fm. Their base is the upper portion of the Kamišna Mb. while they are overlain by the Jatare Mb. The whole Kotroman Fm. in some general way corresponds to a tidal flat, some of which were described in literature (LARSONNEUR 1975), and the sediments were compared with those from the environment of recent tidal flats. It must be noted that the low latitude (less than 30° N) position of the area during the Upper Cretaceous influenced not only the presence of siliciclasite, but also of carbonates with characteristics of the carbonate shelf system of the whole formation. The section with the described parasequences is shown in Fig. 1.

The iron-rich sandstone dominates in the upper portion of the Kamišna Mb. However nodular clastic limestone interbedded with yellowish thin marl occurs in this portion. The nodular limestone is represented by biomicrite, floatstone and wackestone, enclosed in an intimate mixture of clay and carbonate. Clasts of serpentine, pyroxene and quartz mixed with scarce mollusc shell fragments are found in a fine grain microsparite and clayey matrix. Extremely small crystals of quartz, pyrite and hematite can frequently be found in these deposits.

The quantity of the bioclastic fragments increases in the upper horizons, and rock gradually changes to bioclastic wackestone, packestone and floatstone, with sometimes large clasts. The characteristics of the rock resemble storm beds. The bioclasts are represented with numerous fragments of gastropods, bivalvs, and ostracods. 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* and *Cedrus* can be found.

The iron-rich sandstone of the upper portion of the Kamišna Mb. represents shallow water facies. It corresponds to biogenic sand and biogenic fine sand which was deposited about the high-water tide level (LARSONNEUR 1975).

Uroševići Member – Parasequence 1

Within the Uroševići Mb., two parasequences have been described, with an attempt to correlate them with stratigraphic age of the member (BANJAC *et al*. 2008).

The lowermost sediment of the Uroševići Mb. (within Kotroman Fm.) is represented with an almost one meter thick bed of sandy reddish nodular limestone with bivalve and gastropod shell fragments. Its lower boundary represents the flooding surface (FS1) that marks the base of a parasequence with abrupt contact. Sandy reddish nodular limestone lying directly on top of relatively shallow iron-rich sandstone located below the surface. The frequent appearance of small-scale erosion can be observed at this surface (Fig. 2).

In the following portion of the stratigraphic column, nodular limestone is frequently interbedded with thin layers of marl and siltstone.

The thin section of the reddish nodular limestone indicated bioclastic wackestone with frequent fossil shell fragments. Samples from the upper portion of these deposits revealed packestone, floatstone, rudstone and rarely fine-grained sandstone. The fossil content is represented with mollusc fragments, in some places with abundant gastropod and bivalve accumulations found in the cm-scale lenses of calcirudite and calcarenite. The mollusc shells frequently contain geopetal fillings. These beds also contain rare ostracode remnants, as well as gyrogonyts and charophyte remnants, which indicate intermittent fresh water influxes. In addition, the algae *Radiocicelapses* sp. and *Hemicyclamina sigali* MAYNC can be found.

The microfauna assemblage consists of codiacean grains and *Radoicicelapses sterni* RADOIČIĆ, *Nezzazatinella* cf. *picardi* (HENSON), *Hemicyclamina sigali* MAYNC, *Salpingoporella urladanasi* CONRAD, PEYBERNES & RADOIČIĆ, *Aeolisacus* sp. and *Glomospira* sp. The macrofauna is represented by gastropod fragments (*Cassiope* sp.).

Samples from the upper portion of the parasequence revealed an increase of fine-grained sandstone, gradually transforming to lithic sandstone. Clasts are represented with quartz, chert, pyroxene, serpentine, peridotite and siliceous rocks in spary cement or a microsparitic matrix. Birds-eye structures as well as fenestrated fabrics, which can be observed in the thin section, indicate a shallow environment with sporadic exposure to open air, i.e., deposition at the high water tide level. The general characteristics of the fine-grained sandstone shows a gradual shallowing which is terminated with a sudden contact. Relatively deeper nodular limestone is situated on top of the shallow fine-grained sandstone located below the surface. Small scale erosion can be observed at this surface (FS2), similar to one at the previous flooding surface (FS1).

Fig. 2. Flooding surface at the top of the Kamišna Mb.

Uroševići Member – Parasequence 2

The lower portion of the second parasequence is represented with an approximately 20 cm thick bed of nodular limestone with mollusc shell fragments. Its lower boundary is designated as a second flooding surface (FS2) that marks the base of the second parasequence. The nodular limestone of this parasequence is fossiliferous packestone and wackestone with peloidal and biogenic intraclasts in a micritic and microsparitic matrix.

In the upper portion of the parasequence, the nodular limestone alternates with ophiolithic coarse-grained reddish sandstone.

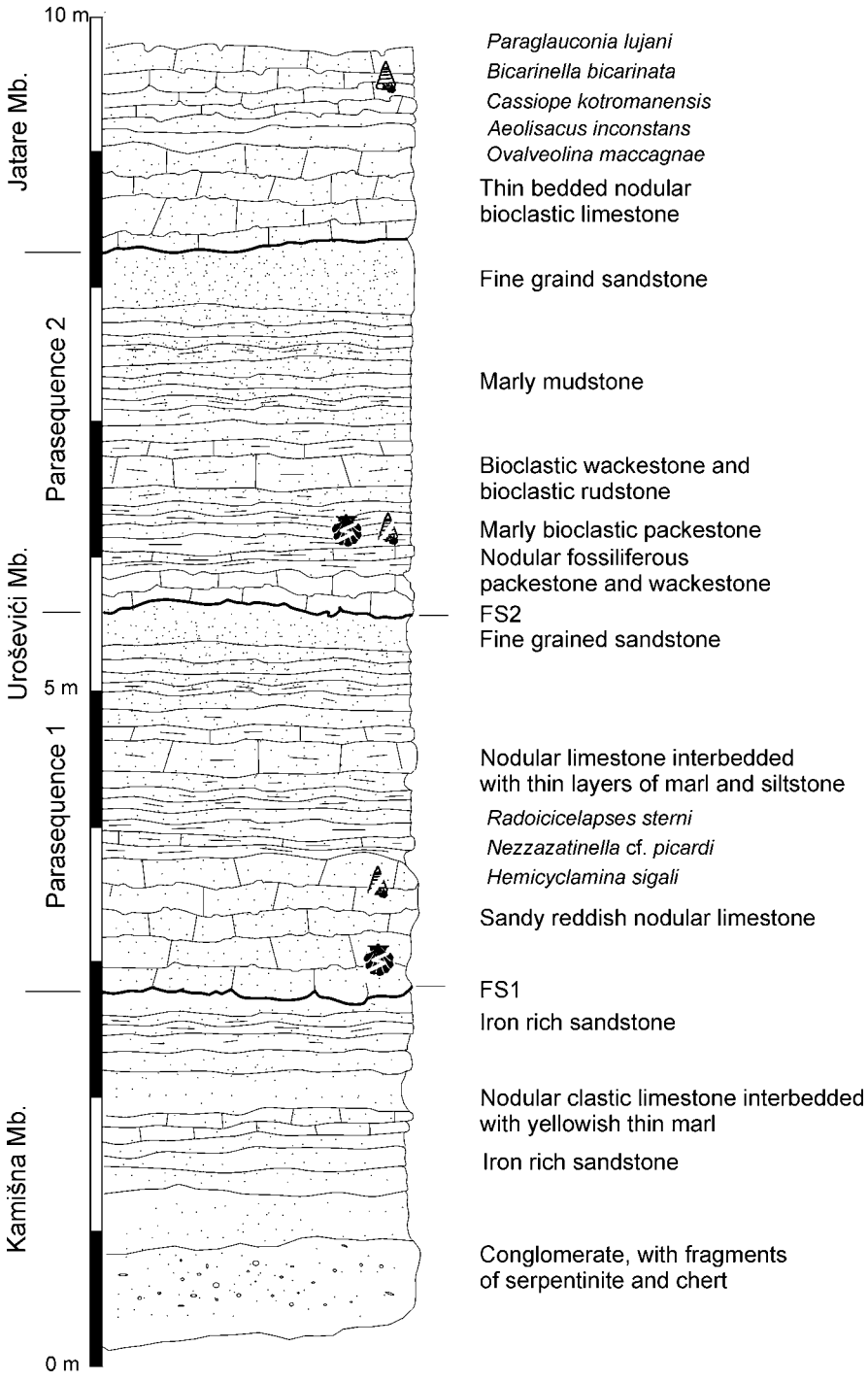

Fig. 3. Stratigraphic column with the described Parasequences.

Marly bioclastic packestone creates the next level in the parasequence. Gastropod or bivalve shells can frequently be found, especially in the marly beds between the thicker limestone beds. At some levels, there is a transition to wackestone, *i.e.*, biomicrite with unsorted angular shell fragments deposited within a microcrystalline calcite matrix. Besides shell fragments, charophyte girogonits and ostracods can be found, indicating intermittent fresh water influx. It is followed by decayed, lumpy limestone that is characterized by the presence of thin mollusc shell fragments. It is predominantly biomicrite with sporadic foraminifera and abundant iron matter. At some places within these limestone beds, the shell accumulations indicate storm beds. Bioclastic wackestone, as well as bioclastic rudstone can also be found at this portion of the parasequence. In the upper portion, a blunt transition to marly mudstone can be observed.

Fine-grained sandstone represents the uppermost portion of this parasequence. The described sediments correspond to biogenic gravelly sand to biogenic sand which was deposited between low and high water tide levels. (LARSONNEUR 1975).

Jatare Member

The fine-grained sandstone of the Uroševići Mb. is overlain by thin-bedded nodular bioclastic limestone belonging to the third member, the Jatare Mb. Calcareous and silty marlstones in some places contain abundant microfauna associations, which are represented by: *Aeolisacus inconstans* RADOIČIĆ, *Ovalveolina maccagnae* DE CASTRO and *Rhapidionina laurinensis* DE CASTRO. Macrofauna was discovered at numerous localities, sometimes forming coquina beds. It is represented by mollusc fragments: bivalvs *Amphidonte conicum* (SOWERBY), *Ostrea callimorphe* COQUAND and *O. cunabula* SEELEY, and the gastropods *Pseudomesalia teniucostata* (HACOBJAN), *P. multicostata* (HACOBJAN), *Pirenella* cf. *levadhiae* KOLLMANN, *Paraglauconia lujani* (DE VERNEUIL & COLOMB), *Bicarinella bicarinata* (PČELINCEV) and *Cassiope kotromanensis* BANJAC. Thin-bedded nodular bioclastic limestone with the

aforementioned association of fauna corresponds to sediments deposited at a subtidal shelf or outer shelf with increased carbonate production. In the upper portion, they gradually transfer to the thin-bedded, marly limestone of the so-called hemipelagic series.

Conclusions

An attempt was made to investigate the presence of parasequences in the Cretaceous deposits known as the Kotroman Formation according to type locality and type section at the Kotroman Village in western Serbia.

The investigations of the sediments at the Kotroman locality imply two parasequences within the Uroševići Mb.: Parasequence 1 and Parasequence 2. The parasequences were formed during the Albian transgression and represent a gradual deepening of the wider area. Well-developed flooding surfaces with prominent deepening, indicated to retrogradational stacking of certain transgressive system tract and reflect the landward movement of a shoreline. The beds overlying the Uroševići Mb. indicate a new rise in the relative sea level. They are represented by thin-bedded nodular bioclastic limestone belonging to the Jatare Mb.

The insufficient data does not allow the results to be compared with the eustatic sea level curve (HAQ *et al.* 1987). It can only be approximately estimated (based on fossil age) that the described parasequences belong to the earliest Supercycle of the Upper Zuni A set (UZA 1).

Acknowledgments

We are very thankful to PLATON TCHOUMATCHENCO (Geological Institute, BAS, Sofia), as well as an anonymus critic who reviewed the paper. The work was supported by the Ministry of Education and Science of the Republic of Serbia (Project No. 176015).

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Резиме

Парасеквенце формације Котроман, западна Србија

У седиментима формације Котроман код Мокре горе у западној Србији истражене су и описане две парасеквенце, формиране током албске трансгресије и настале услед постепеног продубљавања на ширем простору. Цела формација, албско ценоманске старости, по својим општим карактеристикама, одговара тајдалној равни, какве су већ описане у литератури (Larsonneur 1975), а њени седименти могу да се упореде са творевинама рецентних тајдалних равни.

Хетерогена грађа формације Котроман условила је да више аутора описује неколико различитих суперпозиционих пакета. У већем броју старијих радова (Živković 1905, 1907; Petković 1925; Ampferer 1928; Milovanović 1933) наводи се стратиграфска припадност сенону, док се касније јавља мишљење о припадности албу, ценоману и турону (Milovanović 1935; Mitrović 1966; Mitrović *et al.* 1989; Pejović & Radoičić 1971, 1973, 1974; Radoičić 1984). У већини савремених радова наводи се припадност алб-ценоману (Banjac 1994, 1994a, 2000; Dulić 2003; Jovanović *et al*. 2004; Banjac *et al*. 2007; Radoičić & Schlagintweit 2007), а само изузетно и припадност старијим катовима (Nirta *et al.* 2008; Mena *et al.* 2008).

У оквиру члана Урошевићи формације Котроман, издвојене су две парасеквенце формиране током албске трансгресије на ширем простору. Основу им чине пешчари и конгломерати члана Камешина, таложени у условима плитке воде. Изнад њих се запажа јасна површина плављења (FS1) која означава драстичан прекид у седиментацији и почетак прве парасеквенце.

Прва парасеквенца обележена је квргавим кречњацима, са честим фрагментима фосила, који се местимично смењују са финозрним пешчарима. Фрагменти љуштура мекушаца који се налазе у седименту често садрже геопеталне испуне. Понекад се у седименту налазе и фрагменти остракода као и гирогонити и остаци харофита.

Друга парасеквенца обележена је као и претходна, јасном површином плављења (FS2), изнад које се налазе квргави кречњаци, пакстон и вакстон са фрагментима фосилне фауне у микритској основи. У вишим деловима јавља се грубозрни црвенкасти пешчар. Парасеквенца се завршава јасном површином плављења којом је одвојена од танкослојевитих квргавих кречњака члана Јатаре.

Јасно дефинисане површине плављења на горњој и доњој граници сваке парасеквнце са маркатним продубљавањем током развоја парсеквенце указују на ретроградациони трансгресивни тракт и постепено померање обалске линије у правцу копна. Танкослојевити квргави кречњаци који леже преко горње границе члана Урошевићи, указују на ново издизање нивоа мора.

Скроман обим података није нам дозволио поређење резултата са кривом промене нивоа мора (Haq *et al.* 1987). Могуће је само приближно предпоставити на основу старости детерминисане палеофауне да описане парасеквенце припадају најстаријем суперциклусу сета Upper Zuni A 1 (UZA 1).