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

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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-кимеријске *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 кимерија *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 преflиш 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

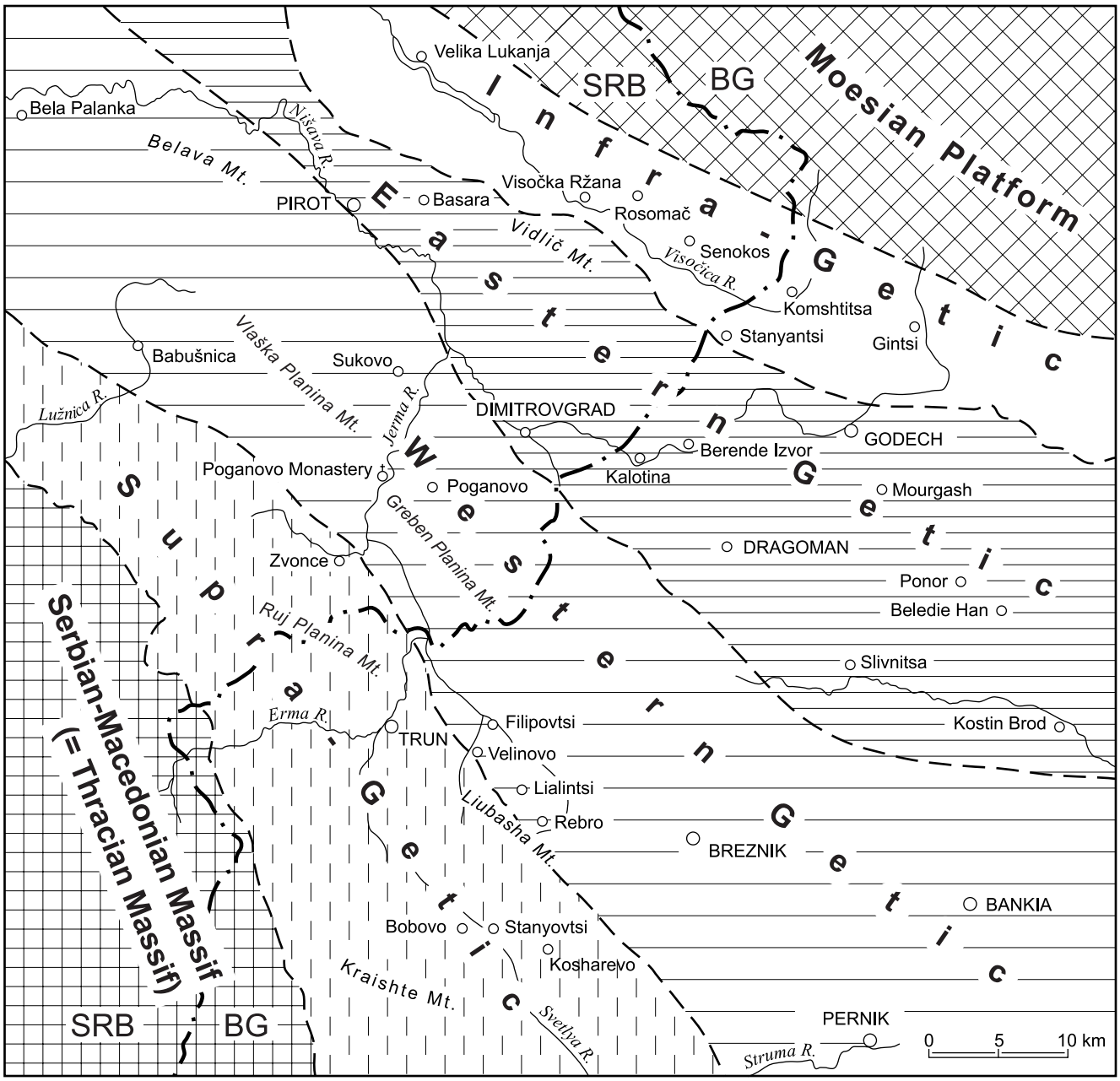

Fig. 1. Main Jurassic palaeogeographic units in south-eastern Serbia and in south-western Bulgaria.

et al. 1985). To the west from the Getic "carbonate paraplatform", 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-

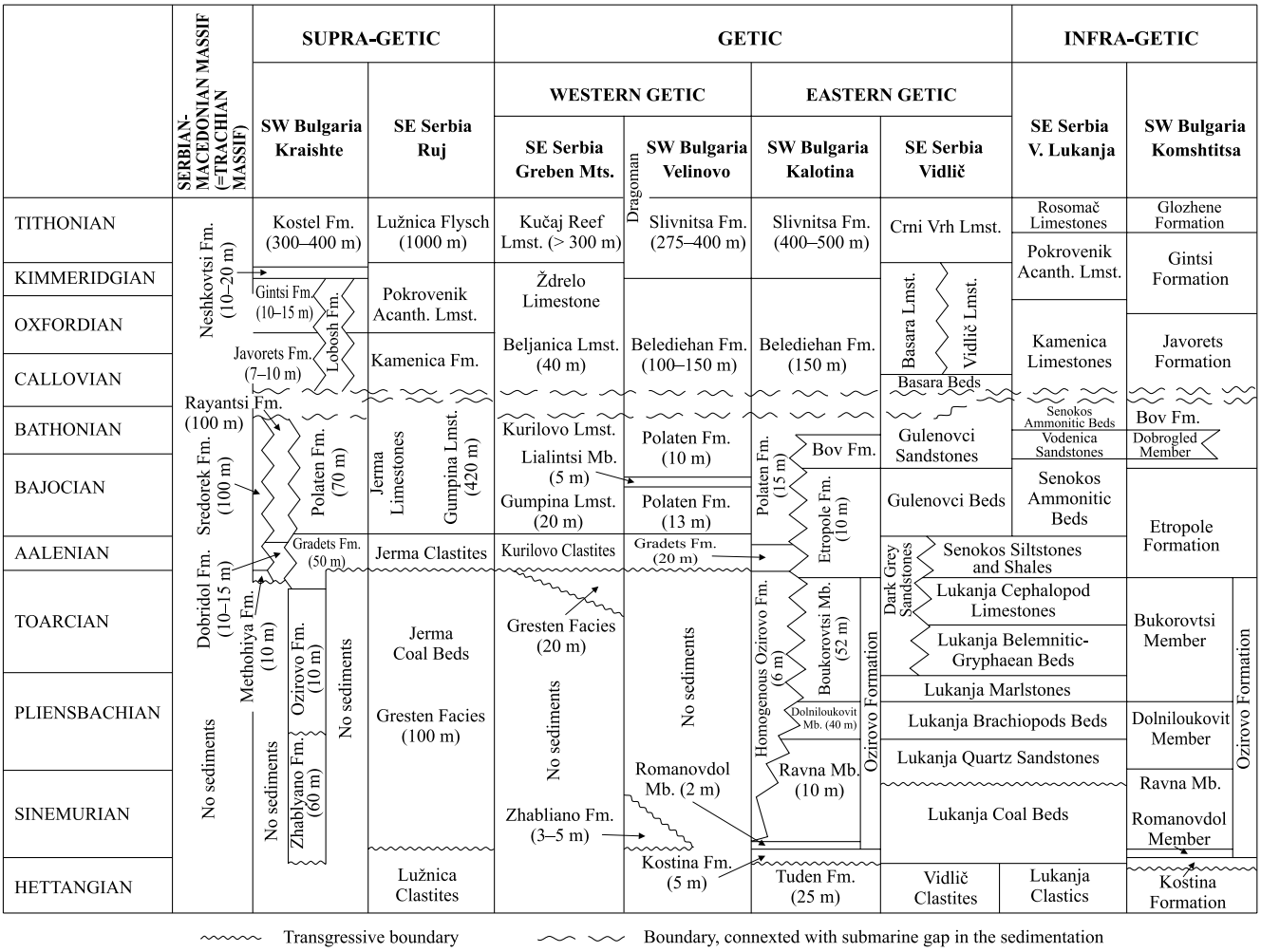

Fig. 2. WIELLER's Diagram of the Jurassic sediments in the Supra-Getic, Getic and Infra-Getic in south-eastern Serbia and south-western Bulgaria.

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 Cre-

taceous 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 кимериџа *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 гиначе 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.