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Trans-border (north-east Serbia/north-west Bulgaria) correlations of the Jurassic lithostratigraphic units

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

Abstract. Herein, correlations of the Jurassic sediments from NE Serbia with those of NW Bulgaria are made. The following Jurassic palaeogeographic units: the Eastern Getic, the Infra-Getic and the Moesian Platform are included in the study. The East Getic was studied in the outcrops near Rgotina, where the sedimentation started in the Hettangian and continued during the Callovian–Late Jurassic and is represented by platform carbonates. The Infra-Getic is documented by the sections of Dobra (Pesača) and the allochtonous sediments near the Štubik. Very important for the Infra-Getic are the Late Jurassic volcano–sedimentary deposits of the Vratarnica Series, which crop out near Vratarnica Village. The Jurassic Moesian platform was studied in the sections near D. Milanovac and Novo Korito (Serbia) and in their prolongation in NW Bulgaria into the Gornobelotintsi palaeograben. Very important are the correlation in the region of Vrška Čuka (Serbia) and Vrashka Chuka (Bulgaria) – Rabisha Village (Magura Cave). A revision of the Jurassic sediments on the Vidin palaeohorst, which were studied in the Belogradchik palaeohorst, Gorno-Belotintsi palaeograben, Belimel palaeohorst and the Mihaylovgrad palaeograben, is made. The sedimentation on the Vidin palaeohorst started during different parts of the Middle Jurassic, and in the Mihaylovgrad palaeograben during the Hettangian (Lower Jurassic) where the sediments were deposited in relatively deeper water conditions. To south, the relatively shallow water sediments deposited on the Jurassic Vratsa palaeohorst on the southern board of the Mihaylovgrad palaeograben are described.

Key words: Jurassic, north-eastern Serbia, north-western Bulgaria, correlations, lithostratigraphic units.

Апстракт. Приказана је корелација јурских седимената североисточне Србије и северозападне Бугарске. У проучаваном подручју издвојене су следеће палеогеографске јединице: Источни Гетик, Инфра-гетик и Мезијска платформа. Источни Гетик је проучаван на изданцима у близини Рготине, где седиментација започиње од хетанжа, за време келовеј–горња јура таложе се платформни карбонати. Инфра-гетик је документован на профилима Добре (Песача) и алохтоним седиментима у близини Штубика. Главна карактеристика Инфра-гетика су горњојурско вулканско-седиментне творевине Вратарничке серије. Јурска Мезијска платформа је проучавана код Доњег Милановца и Новог Корита у Србији и Горнобелотинског рова у Бугарској. Урађена је корелација у области Вршке Чуке са обе стране границе и код села Рабиша (пећина Магура у Бугарској). Приказана је ревизија јурских седимената у Бугарској, код Видинског хорста, који су проучавани на Белоградчиском, Горње Белотинском, Белимелском и Михајловградском рову. Седиментација у Видинском хорсту започиње у различитим деловима средње јуре, а у Михајловградском рову за време хетанжа (доња јура) где се седиментација одвијала у релативно дубоководној средини. Јужно се одвијала плитководна седиментација на јурском Вратца гребену, на јужном крилу Михајловградског рова.

Кључне речи: Јура, североисточна Србија, северозападна Бугарска, корелација, литостратиграфске јединице.

[1] Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 24, 1113 Sofia, Bulgaria. E-mail: platon@lark.tu-sofia.bg

[2] Department of Geology, Faculty of Mining and Geology, University of Belgrade, Kamenička 6, P. O. Box 162, 11000 Belgrade, Serbia. E-mails: rabrenovic@verat.net; malesevic.nesa@gmail.com

[3] Department of Palaeontology, Faculty of Mining and Geology, University of Belgrade, Kamenička 6, P. O. Box 162, 11000 Belgrade, Serbia. E-mail: vrad@eunet.rs; brad@net.co.rs

Introduction

It is well known that the rock strata – sedimentary, igneous or metamorphic are organized in lithostratigraphic units based on macroscopically discernable lithologic properties or combination of lithologic properties and their stratigraphic relations. Often these units cross the state boundaries. However, it is the general practice that on geological maps, the lithostratigraphic units from the two sides of a state border are different and have different names. This is also the case with the Jurassic lithostratigraphic units on the two sides of the Serbian/Bulgarian state boundary. Our aim is to make correlations of the Jurassic lithostratigraphic units from the two sides of this state border. For the beginning, in the literature existing trans-border units (TCHOUMATCHENCO *et al*. 2006a, 2008) are correlated. With the present paper, this stage of the correlation in the north-east Serbia/north-west Bulgaria is finished. The second step, must be, after an analysis of all data, to replace the later names of the lithostratigraphic units by the earlier ones, other considerations being equal, following, in general, the principle of reasonable priority. In this way, the exigencies of the International Stratigraphical Guide (SALVADOR 1994; "Relation of Names to Political Boundaries") will be satisfied.

The Jurassic sediments within the framework of the study area of eastern Serbia and western Bulgaria enter the following large palaeogeographic units (TCHOUMATCHENCO *et al*. 2006a, 2008) (from west to east): the Getic (Dragoman Jurassic Pale horst in Bulgaria and Karpatikum in Serbia), divided into two sub-units – Eastern and Western Getic (TCHOUMATCHENCO *et al*. 2008) based on the presence (in Eastern Getic) or absence (in Western Getic) of Liassic sediments; the Infra-Getic Unit (Izdremets Jurassic Palaeograben in Bulgaria and Stara Planina–Poreč Unit in Serbia); the Moesian Platform. The purpose of this paper is the correlation of the Jurassic sediments across the state border in north-east Serbia and north-west Bulgaria.

The Serbian lithostratigraphic units have been described by D. Rabrenović, V. Radulović, N. Malešević and B. Radulović with the participation of P. Tchoumatchenco and of the Bulgarian, by P. Tchoumatchenco.

Jurassic Lithostratigraphic units

Nota Bene. The number in the description of the lithostratigraphic units corresponds to the number of the lithostratigraphic units in Figures 1, 2, 3; N - indicates that the beds are not nominated.

Getic Palaeogeographic Unit

The Getic is developed on the back-ground of the Serbo-Macedonian – Thracian Massif. During the Early Jurassic the whole territory represents dry land. In eastern Serbia in this unit enters large parts of the Carpatho–Balkan region of ANDJELKOVIĆ *et al*. (1996). In study area enters only the East Getic Unit, where the sedimentation in the vicinities of Rgotina started in the Early Jurassic.

Rgotina section (Figs. 1: Sb-1, 2). Here were deposited: **(N 1)** – sandstones with conglomeratic pebbles (Hettangian–Sinemurian); **(1)** – Rtanj brachiopod beds (ANDJELKOVIĆ *et al*. 1996): bioclastic limestones, marls (Pliensbachian, analogous to the Ozirovo Formation); **(N 2)** – grey sandstones (Toarcian–Aalenian); **(N 3)** – grey sandstones in the base intercalated by a bed of grey limestone (Bajocian); **(2)** – Rgotina Beds (ANDJELKOVIĆ *et al*. 1996; analogous to the Gulenovci Beds); in the base **(2a)** – alternation between reddish limestones and grey sandstones (Upper Bajocian–Bathonian) and **(2b)** – red limestones with some corals (Upper Bathonian–Lower Callovian; analogous to the Polaten Formation in Bulgaria); **(3)** – Basara Limestones (Andjelković *et al*. 1996): grey limestones with chert nodules (Middle Callovian; similar to the Belediehan Formation), on their base is exposed a bed **(3a)** with many *Macrocephalites* sp. (Lower Callovian; analogous to the Sokolov Venets Zoogenous Marker in Bulgaria); **(4)** – Vidlič limestones (ANDJELKOVIĆ *et al*. 1996): grey to blue, well bedded, limestones (Middle Callovian–Kimmeridgian (*p. p*.); analogous to the Javorets and Gintsi formations); **(5)** – Crni Vrh Limestones (ANDJELKOVIĆ *et al*. 1996): white to reddish reef and sub-reef limestones, with corals, gastropods, *etc*. (Tithonian–?Berriasian; analogous to the Slivnitsa Formation in Bulgaria).

Infra-Getic Palaeogeographic Unit

During the Jurassic, the Supra-Getic and the Getic units developed on the framework of the Thracian Massif, which had been separated from the other large palaeogeographic unit, the Moesian Platform, by the Infra Getic Unit with a relatively deep water sedimentation since the Hettangian. In the study area, the sediments of the Infra-Getic crop out in the region of the Dobra Village (Pesača River, *etc*.), the Štubik Village and the Vratarnica Village.

Dobra–Pesača (Figs. 1: Sb-2, 2) (VESELINOVIĆ 1975; ANDJELKOVIĆ 1975). **(N-4)** – quartz sandstones at the base with quartz conglomerates, locally with coal **(N-5)** (Lower Liassic); **(N-6)** – quartz, calcareous sandstones to sandy limestones with brachiopods and bivalves (Middle Liassic); **(N-7)** – quartz sandstones without fossils (Toarcian?); **(N-8)** – sandy limestones and clays (Aalenian–Bajocian).

Štubik (Figs. 1: Sb-3, 2) (ANDJELKOVIĆ 1975; ANDJELKOVIĆ *et al*. 1996). **(6)** – Štubik clastites: quartz, thick bedded, reddish to whitish sandstones (Aaleni-

Fig. 1. Sketch map of the locations of the Jurassic outcrops. Legend: **Bg-0,** Vrashka Chuka; **Bg-1,** Magura (Rabisha Village); **Bg-2,** Granitovo Village (Gradishte Peak); **Bg-3,** Belogradchik–Railway Station Oreshets; **Bg-4,** Belogradchik –TV Tower; **Bg-5,** Yanovets Village; **Bg-6,** Dolni Lom Village; **Bg-7,** Prevala – Mitrovtsi Villages; **Bg-8,** Gaganitsa Village; **Bg-9,** Gaganitsa Lake; **Bg-10,** Nikolovo Village (Shugovitsa River); **Bg-11,** Vratsa (Ledenika Cave); **Bg-12,** Kamenna Riksa – Vinishte Villages; **Bg-13,** Gorno Belotintsi Village (Nechinska Bara River); **Sb-1,** Rgotina Village; **Sb-2,** Dobra Village (Pesača River); **Sb-3,** Štubik Village; **Sb-4,** D. Milanovac Town; **Sb-5,** Vrška Čuka; **Sb-6,** Miroč; **Sb-7,** Vratarnica Village.

an–Bajocian (*p. p.*)) – Krajina (analogous to the Gradets Formation); **(7)** – Štubik *"Posidonya"* beds with two horizons with *"Posidonia"*: **(7a)** – First horizon with *"Posidonia" alpina* - fine grained sandstones; **(7b)** Thick bedded sandstones; **(7c)** – Second horizon with *"Posidonia" alpina* - grey marls and marly sandstones (Bajocian–Lower Callovian; no analogy in Bulgaria); **(8)** – Štubik limestones: grey, thick bedded limestones (Middle Callovian–Kimmeridgian; probably analogous to the Javorets Formation).

Vratarnica (Figs. 1: Sb-7, 2) (Andjelković 1975; Andjelković *et al*. 1996; Andjelković & Mitrović-Petrović 1992). **(9)** – Vratarnica volcanogenous-sedimentary series: argillites, marls, sandstones and rare calcarenites and limestones with calcareous olistolites (Late Tithonian–?Berriasian; no analogy in Bulgaria) (Figs. 4A–C).

Moesian Platform Palaeogeographic Unit

The Moesian Platform is a crustal block, located beyond the south-western margin of the European craton. It was divided during the Jurassic (according Patrulius *et al*. 1972; Sapunov *et al*. 1988) into three parts: the West and East Carbonate Moesian Platforms separated by the Central Moesian Basin. Herein, only the West Moesian Platform, the sediments of which crop out from the two sides of the Bulgarian/Serbian state border, is studied. To west, it is limited by the Infra-Getic Unit.

The **West Moesian Platform** is structured by the Vidin Horst and the Vratsa Horst separated by the Mihaylovgrad Graben (with its Gornobelotintsi–Novo Korito Branch – Basin (Graben)).

The **Vidin Horst** (Sapunov *et al*. 1988) is the north-western part of the West Moesian Platform and

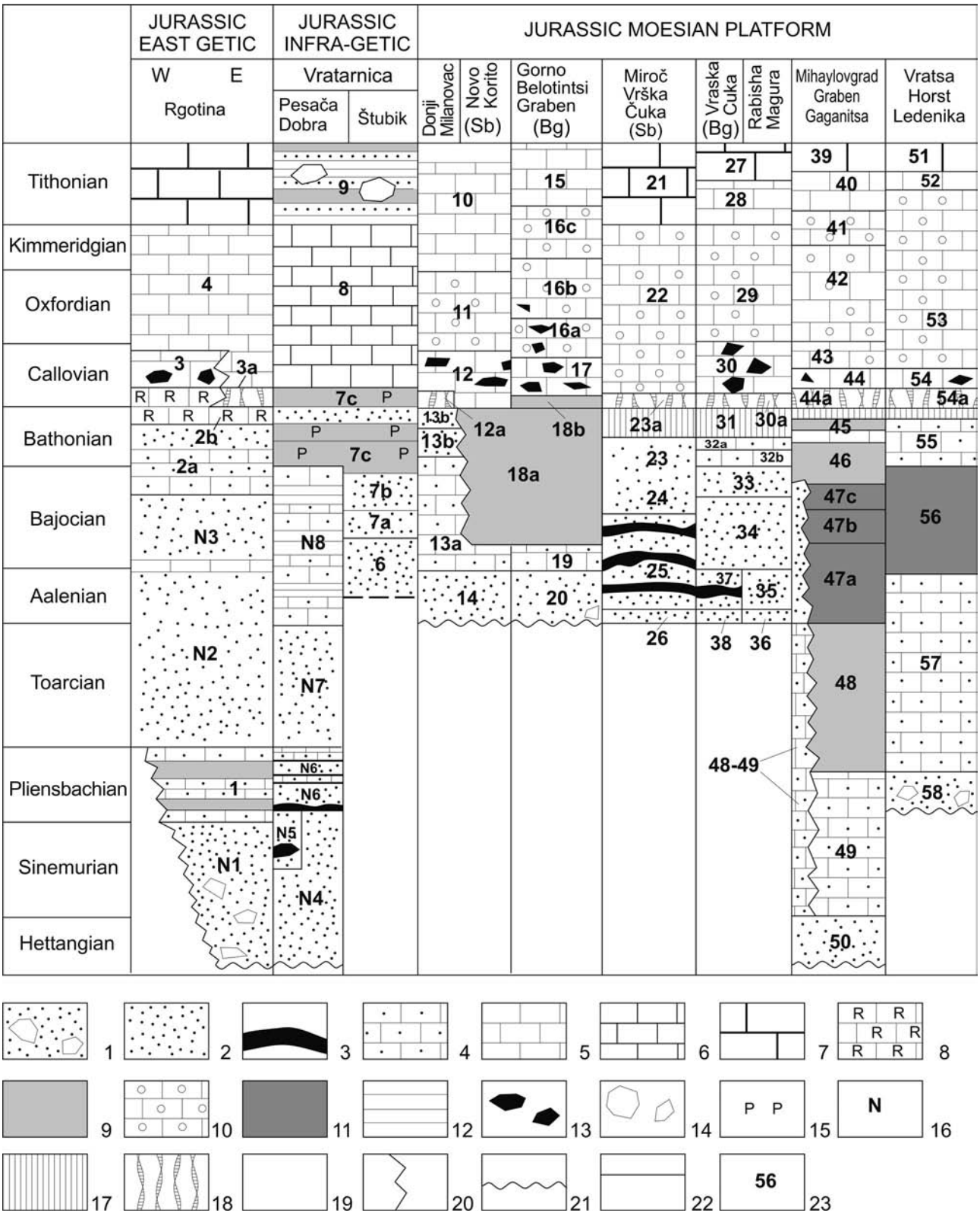

Fig. 2. Trans-border (north-east Serbia/north-west Bulgaria) correlation of the Jurassic lithostratigraphic units. Lithology: **1,** conglomerates and sandstones; **2,** sandstones; **3,** coal; **4,** sandy and bioclastic limestones; **5,** limestones; **6,** thin bedded limestones; **7,** thick bedded limestones; **8,** reddish limestones; **9,** clayey limestones; **10,** nodular and/or lithoclastic limestones; **11,** black shales; **12,** argillites; **13,** cherts nodules; **14,** olistolites; **15,** with "*Posidonia*"; **16,** non-nominated beds; **17,** submarine lack of sedimentation; **18,** zoogenous limestones; **19,** bioclastic and sandy limestones; **20,** horizontal transition; Lithostratigraphy: **21,** transgressive boundary; **22,** normal lithostratigraphic boundary; **23–56,** nominated lithostratigraphic units (explanation in the text).

is built up (from north to south) by the Gomotartsi Step, the Belogradchik Step, the Belotintsi Step, the Prevala Step and the Belimel Step.

The **Belogradchik Step** (SAPUNOV *et al*. 1988). During the Early Jurassic and the Aalenian, in the Belogradchik Step of the Vidin Horst entered the Miroč–Vrška Čuka Zone from NE Serbia and the Rabisha–Vrahska Chuka Zone from NW Bulgaria, which represented a dry land with a continental environment – a terrigenous, coal bearing formation. During the Bajocian, a large part was covered by sea water, in which existed a shallow, sublittoral environment with a sandy-pebbly bottom and agitated water with the sedimentation of oligomictic sandstones and conglomerates, covered by the aleuritic marls. To the north of Belogradchik Town, the sediments of the Bov Formation were subsequently eroded (under sub-marine condition) and the Callovian part of the Javorets Formation (micritic limestones) lied directly on the Lower Bathonian parts of the Polaten Formation.

Miroč Section (Figs. 1: Sb-6, 2) (ANDJELKOVIĆ & MITROVIĆ-PETROVIĆ 1992). **(21a–26a)** The sediments in the Miroč area are very similar to those of the Vrška Čuka area and will be described together with them.

Vrska Čuka Section (Figs. 1: Sb-5, 2). (21) Vratnac Limestones (ANDJELKOVIĆ *et al*. 1996): reef and sub-reef limestones (Tithonian); **(22)** – Greben ammonitic limestones (ANDJELKOVIĆ *et al*. 1996): clayey nodular limestones with cherts (Middle Callovian–Oxfordian–Kimmeridgian); in the base **(23a)** – sandy limestones with *Macrocephalites macrocephalus* (VESELINOVIĆ 1975; ANDJELKOVIĆ *et al*. 1996; analogous to the Bulgarian Sokolov Venets Marker (Lower Callovian)); **(23)** – Bujkovo sandstones (Bathonian); **(24)** – Staro Selo Beds (ANDJELKOVIĆ *et al*., 1996): yellow marine sandstones (Upper Bajocian–Bathonian); **(25)** – Vrška Čuka coal beds (ANDJELKOVIĆ *et al*. 1996): yellow sandstones, coal schists and coal (Aalenian–Bajocian); **(26)** – Vrska Čuka clastites (Aalenian; ANDJELKOVIĆ *et al*. 1996): quartz conglomerates and sandstones, lying discordantly over Permian rocks.

Vrashka Chuka (Bg-0) – Rabisha (Magura) (Bg-1) Sections (Figs. 1, 2, 3) (SAPUNOV & TCHOUMATCHENCO 1995b). In the Bulgarian part of the Vidin Horst were sedimented: **(27)** – the Magura Formation: massive, light, organogenic (with bivalves, gastropods) and biodetritic limestones (Upper Tithonian–lower part of the Berriasian); **(28)** – the Glozhene Formation: grey-whitish limestones (Middle Kimmeridgian–Tithonian); **(29) –** the Gintsi Formation: grey, lithoclastic to nodular limestones with many ammonites (Oxfordian–Kimmeridgian; **(30)** – the Javorets Formation: grey micritic limestones (Lower Callovian–Oxfordian); at the base, there are many ammonites, as a breccia; **(30a) –** individualized as the Sokolov Venets Zoogenous Marker; **(31a) –** syn-sedimentary break in the sedimentation (Upper Bathonian); **(32)** – the Polaten Formation, divided into two members: **(32a)** – the Dessivitsa Member: built up of sandy, biodetritical limestones with ferrous ooids and quartz pebbles (Lower Bathonian); **(32b)** – Vratnitsa Member: grey to grey-beige calcareous sandstones with single quartz conglomerate pebbles and sandy limestones (Lower Bathonian); Kichera Formation: **(33)** – Oreshets Member: sandstones, yellowish, clayey, calcareous (Upper Bajocian); **(34–35)** – coarse grained sandstones, in the basal part, conglomeratic – non-divided lower part of the Kichera Formation (analogous to the Granitovo and Kreshtenitsa Members (Aalenian–Bajocian); **(36)** – yellow sandstones and grey to dark-grey sandy shales with coal substance - continental coal-bearing sediments, analogous to the continental sediments of Vrashka Chuka (Aalenian–?Toarcian); from the Vrashka Chuka Section **(Bg- 0)**; **(37)** – the Vrashka Chuka Member of the Kichera Formation: the base is structured by sandstones, interbedded with clays; above follow three coal beds, followed by clays and sandstone (Aalenian**)**; **(38)** – the Kiryaevo Member of the Kichera Formation: alternation of sandstones and clays (Aalenian–?Toarcian). Substratum: Late Carboniferous Stara Planina granodiorites.

Granitovo Section (Figs. 1: Bg-2, 3). The section is situated to the north-east of the Granitovo Village, on the slope of Gradishte Hill - western part of the Sokolovo Venets Peak. Here crop out: **(27a)** – the Magura Formation: grey, organodetritic, thick-bedded limestones (Upper Tithonian–lower part of the Berriasian); **(28a)** – the Glozhene Formation: grey-white, well bedded limestones (upper part of the Lower–Middle–Upper Tithonian); the Gintsi Formation, divided into **(29a)** – "Upper nodular limestones": red nodular limestones (Upper Kimmeridgian–Lower Tithonian); in these sediments exist a west inclined fold (Fig. 4D), in many places, passes to a west-directed inverse fault (Fig. 4E), probably due to a sub-marine slump; **(29ab)** – "Grey quarry limestones": grey micritic limestones, intercalated by grey lithoclastic limestones (Oxfordian–Lower Kimmeridgian); **(29ac)** – "Lower nodular limestones": red to grey lithoclastic limestones, in some beds with many ammonites and belemnites (Middle Callovian–Lower Oxfordian); **(30a)** – the Sokolov Venets Zoogenous Marker of the Javorets Formation: calcareous zoogenic (ammonitic, belemnitic, *etc*.) breccia, upwards the ammonites became rarer (Lower Callovian?); **(31a)** – syn-sedimentary break in the sedimentation; the Bov Formation: **(31-1a)** – Verenitsa Member: grey aleuritic limestones with rare ammonites (lower part of the Upper Bathonian); **(31-2a)** – Gornobelotintsi Member: grey to brown aleuritic marbles with ammonites; the Polaten Formation: **(32a)** – the Desivitsa Member: grey bioclastic and sandy limestones (Lower Bathonian) and **(32b)** – the Vratnitsa Member: grey bioclastic and sandy limestones, in the base up to conglomerates (Upper Bajocian–Lower Bathonian); the Kichera Formation: **(33a)** – the Oreshets Member: yellow, medium grained sandstones

with calcareous cement (?Bajocian); **(34a)** – the Granitovo Member: reddish to brownish gravelitic sandstones with rare quartz pebbles, well rounded (Bajocian); **(35a)** – the Kreshtenitsa Member: white gravelitic sandstones (?Aalenian); **(36a)** – the Venets Member: probably continental sandstones and conglomerates (analogous to the Kiryaevo Member of the Kichera Formation and to the Vrška Čuka clastites (Aalenian–?Toarcian). Substratum: the Toshkovo Formation - Middle Triassic limestones.

Belogradchik–Railway Station Oreshets section (Figs. 1: Bg-3, 3) (SAPUNOV & TCHOUMATCHENCO 1995e). The section is located along the road Belogradchik–Railway Station Oreshets. Here are located the holostratotypes of the members of the Kichera Formation and of the Sokolov Venets Zoogenous Marker. **(27b)** – the Magura Formation (for SAPUNOV & TCHOUMATCHENCO 1995e – the Slivnitsa Formation): grey to whitish thick bedded limestones (Berriasian). It is covered by the Simeonovo Formation (NIKOLOV & RUSKOVA 1989) – Urgonian type limestones with many special "nodules" in them (Upper Hauterivian–Aptian). This type urgonian sediments is developed only in the region of the Oreshets Village, deposited in a very active environment, which existed especially on the Belogradchik Step (horst); **(28b)** – the Glozhene Formation: grey to whitish clearly bedded micritic limestones with nodules or discontinued beds of chert (upper part of the Lower Tithonian–Upper Tithonian); the Gintsi Formation is with three packets: **(29ba)** – "Upper nodular limestones": red nodular limestones (Upper Kimmeridgian–Lower Tithonian); in these sediments exist a west directed inverse fault (Fig. 4F), probably due to a sub-marine slump; **(29bb)** –"Grey quarry limestones": grey micritic limestones, intercalated by grey lithoclastic limestones (Oxfordian–Lower Kimmeridgian); **(29bc)** – "Lower nodular limestones": red to grey lithoclastic limestones, in some beds with many ammonites and belemnites (Middle Callovian–Lower Oxfordian); **(30ab)** – the Javorets Formation, here, it is represented by the Sokolov Venets Zoogenous Marker. The type section is situated here, along the road Belogradchik–Railway Station Oreshets (Fig. 5A), described by STEPHANOV (1961), rediscribed by SAPUNOV & TCHOUMATCHENCO (1995e) and by BELIVANOVA & SAPUNOV (2003). After STEPHANOV (1961), here are exposed two beds – No. 6–7. Bed 7 (the upper) (Fig. 4E): thickness 0.30 m, brown-red limestones with ferrous hydroxide ooids: *Macrocephalites macrocephalus* (SCHLOTHEIM) (abundant), *Hecticoceras hecticum* (REINECKE) (rare), *Choffatia spirorbilis* (BONCHEV & POPOV). Bed 6 (the lower): thickness 0.12 m, yellowish-red clayey limestones (Fig. 5B) with scattered ooliths and with large flat-spherical lenticular ferrous hydroxide nodules, up to 25 cm in diameter around Bathonian calcareous pieces or Callovian ammonites - *Macrocephalites macrocephalus* (SCHLOTHEIM) (frequent) and others ammonites. In the two beds, there are many Perisphinctidae, Phylloceratidae, Litoceratidae, *etc*.; **(31b)** – sub-marine gap in the sedimentation, between the Lower Bathonian and the redeposited Lower Callovian sediments. The Polaten Formation is divided into two members: **(32a)** – the Desivitsa Member: built of sandy, biodetritical limestones with ferrous ooids and quartz pebbles with many ammonites (SAPUNOV & TCHOUMATCHENCO 1995e); **(32b)** – the Vratnitsa Member: structured by grey to grey-beige calcareous sandstones with single quartz conglomerate pebbles and sandy limestones with many ammonites (SAPUNOV & TCHOUMATCHENCO 1995e). The upper and lower surfaces are transitional**.** In both of them, STEPHANOV (1961) found ammonites, which indicated the Lower Bathonian *Zigzag* Zone; The Kichera Formation: **(33b)** – Oreshets Member: yellow, medium grained sandstones with calcareous cement (?Bajocian); **(34b)** – the Granitovo Member: reddish to brownish gravelitic sandstones with rare quartz pebbles, well rounded (Bajocian); **(35b)** – the Kreshtenitsa Member: white gravelitic sandstones (?Aalenian); **(36b)** – the Venets Member: probably continental sandstones and conglomerates, (analogous to the Vrashka Cuka Member and Kiryaevo Member of Kichera Formation) (Aalenian and ?Toarcian). Substratum – the Toshkovo Formation (Middle Triassic limestones).

Gornobelotintsi–Novokorito Graben (Basin) (Belotintsi Step) (SAPUNOV *et al*. 1988). During the Early Jurassic, this was also an area of continental sedimentation. At the beginning of the Bajocian started the formation of a new graben with sandy sedimentation under conditions of a shallow sublittoral environment with a sandy bottom and agitated water during the beginning of the Bajocian – the Gornobelotintsi–Novo Korito Graben. At the end of the Bajocian–Bathonian–Early Callovian, in it existed the conditions of a deep sublittoral environment with a muddy bottom and slightly agitated water with the sedimentation of marls, interbedded by clayey limestones. During the Middle Callovian–Late Jurassic started a stage of bathymetric differentiation and pelagic micritic and nodular limestones were sedimented. In east Serbia, will be described the sediments near Milanovac–Novo Korito and in Bulgaria, the Belogradchik TV Tower, Yanovets, Dolni Lom and Gornobelotintsi sections in the Gornobelotintsi Graben are described herein.

Belogradchik TV Tower Section (Figs. 1: Bg-4, 3). The section is along the road to the TV Tower, but the Magura **(27c)** (Upper Tithonian–Berriasian) and the Glozhene **(28c)** (upper part of Lower–Middle–Upper Tithonian) Formations are covered by a forest and do not crop out. The Gintsi Formation is built up of three packets: **(29ca)** – "Upper nodular limestones" (Middle Kimmeridgian–Lower Tithonian); in these sediments there is an inverse fault, inclined to SW, probably due to a sub-marine slump; **(29cb)** – "Middle

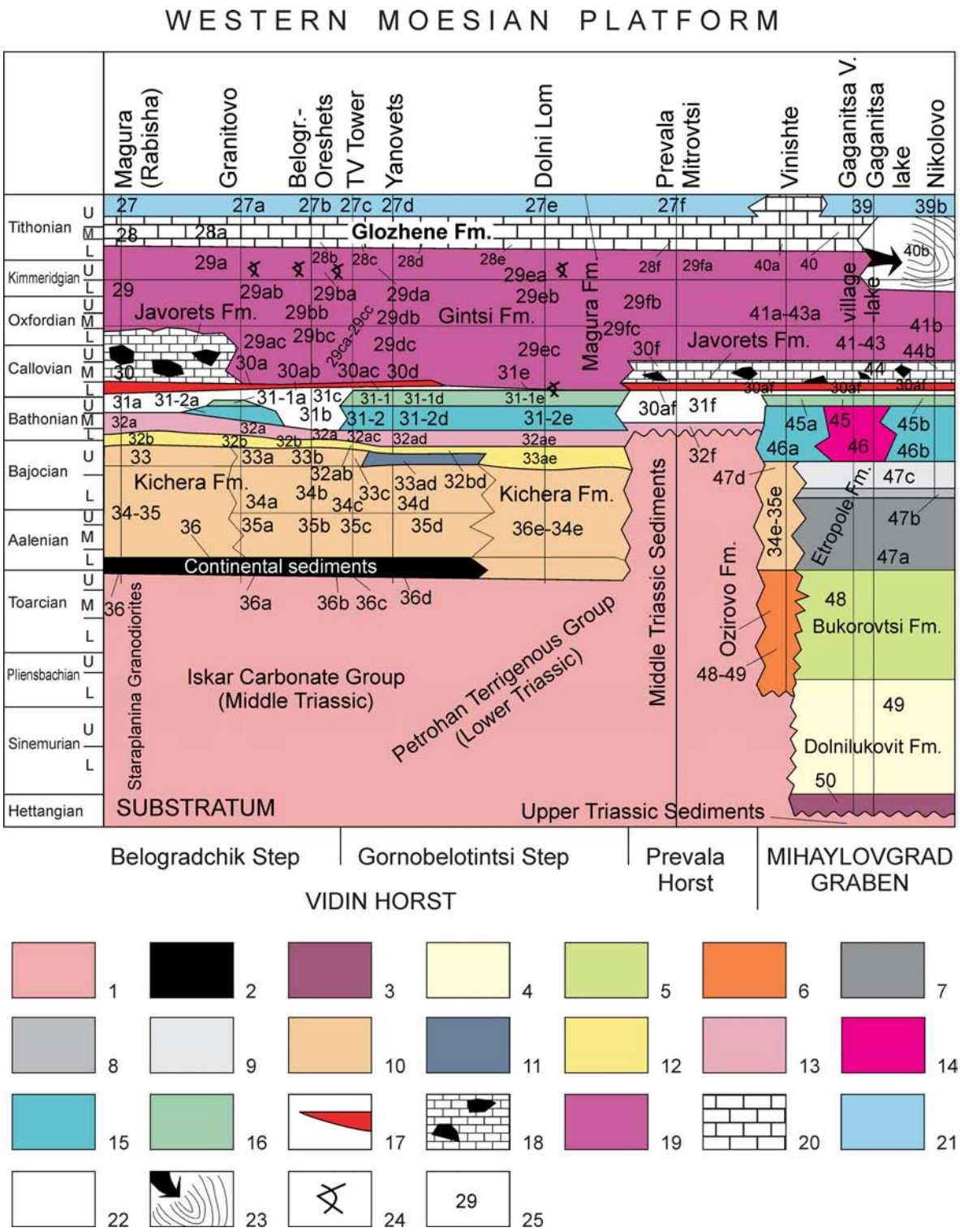

Fig. 3. Temporal-facial connections of the Jurassic lithostratigraphic units in NW Bulgaria (modified after TCHOUMATCHENCO 1978; SAPUNOV & TCHOUMATCHENCO 1995k, 1995l, 1995m; TCHOUMATCHENCO *et al.* 2011). Legend: **1,** Substratum (Triassic sediments); **2,** continental Jurassic sediments; **3,** Kostina Formation; **4,** Dolnolukovit Formation; **5,** Bukorovtsi Formation; **6,** Ozirovo Formation; Etropole Formation: **7,** Nefela Member; **8,** Stefanets Member; **9,** Shipkovo Member; **10,** Kichera Formation; Polaten Formation: **11,** Yanovets Member; **12,** Vratnitsa Member; **13,** Desivitsa Member; **14,** Polaten-Bov Formation; Bov Formation: **15,** Gornobelotintsi Member; **16,** Verenitsa Member; **17,** Sokolov Venets Marker of the Javorets Formation; **18,** Javorets Formation; **19,** Gintsi Formation; **20,** Glozhene Formation; **21,** Brestnitsa Formation; **22,** sub-marine break in the sedimentation; **23,** Shugovitsa Slump; **24,** Granitovo angular discordance; **25,** number under which the lithostratigraphic units are described in the text.

quarry limestones" with many cherts (Oxfordian–Lower Kimmeridgian); **(29cc)** – "Lower nodular limestones" (Middle Callovian–Lower Oxfordian): beige to white nodular micritic limestones; **(30ac)** – the Sokolov Venets Marker of the Javorets Formation, 2–3 cm, blackish to grey marls (?Lower Callovian); **(31c)** – sub-marine gap in the sedimentation; the Bov Formation: **(31-1)** – the Verenitsa Member: alternation between micritic beige limestones and beige–grey aleuritic marls (Upper Bathonian–lowermost Lower Callovian); **(31-2)** – the Gornobelotintsi Member: grey-greenish marls with rare calcareous intercalations (Middle–Upper Bathonian); the Polaten Formation: **(32ad)** – the Desivitsa Member: grey sandy limestones with crinoids (Lower Bathonian); **(32bd)** – the Vratnitsa Member: grey sandy limestones to calcareous sandstones with many ammonites, well-preserved, non-flattened, probably resedimented (Lower Bathonian – *Zigzag* Zone); the Kichera Formation: **(33c)** – the Oreshets Member: calcareous sandstones (purely exposed (Bajocian); **(34c)** – the Granitovo Member: reddish sandstones and conglomerates (Bajocian); **(35c)** – the Kreshtenitsa Member: white sandstones (?Aalenian); **(36c)** – the Venets Member: probably continental sandstones and conglomerates (Aalenian and ?Toarcian?). Substratum: the Toshkovo Formation - Middle Triassic limestones.

Yanovets Section (Figs. 1: Bg-5, 3) (SAPUNOV & TCHOUMATCHENCO 1995f). Located at 2 km west of the Yanovets Village, Belogradchik community. The Magura **(27d)** (Upper Tithonian–Berriasian) and the Glozhene **(28d)** (Middle–Upper Tithonian) Formations are covered by a forest and do not crop out. The Gintsi Formation is built up of three packets: **(29da**) – "Upper nodular limestones" (Middle Kimmeridgian–Lower Tithonian); in these sediments, there is an inverse fault, inclined to the SW; **(29db)** – "Middle quarry limestones" with many cherts (Oxfordian–Lower Kimmeridgian); **(29dc)** – "Lower nodular limestones" (Middle Callovian–Lower Oxfordian): beige to white nodular micritic limestones; **(30d)** – the Sokolov Venets Marker of the Javorets Formation is covered by a talus gravity accumulation; the Bov Formation: **(31-1d)** – the Verenitsa Member: grey to greenish aleuritic marls, in alternation with rare beds of clayey limestones (Upper Bathonian–lowermost Lower Callovian); **(31-2d)** – the Gornobelotintsi Member: grey-greenish aleuritic marls (Middle–Upper Bathonian); the Polaten Formation: **(32ad)** – the Desivitsa Member: grey to dark grey aleuritic and biodetritic limestones, and in the base, irregular alternation between aleuritic, oolithic limestones and marls (Lower Bathonian); **(32bd)** – the Vratnitsa Member: grey coarse-grained biodetritic limestones with numerous quartz grains, passing into calcareous sandstones (uppermost Upper Bajocian–Lower Bathonian); **(33ad)** – the Yanovets Member: pink, crinoidal limestones with single fragments of bryozoans, echinids and oncolites; in the basal part, grey to grey-pinkish sandy limestones, with numerous pebbles of quartz or sandstones, built almost entirely by bryozoan fragments (Upper Bajocian); the Kichera Formation: **(34d)** – the Granitovo Member: red, coarse-grained sandstones with numerous quartz pebbles (Bajocian); **(35d)** – the Kreshtenitsa Member: light grey to whitish medium grained sandstones with planar cross-bedding in some beds (Aalenian); **(36d)** – the Venets Member: no outcrops. Substratum: reddish sandstones and conglomerates of the Lower Triassic Petrohan Terrigenous Group.

Dolni Lom Section (Figs. 1: Bg-6, 3) (SAPUNOV & TCHOUMATCHENCO 1995g). The section starts near the cemetery of Dolni Lom Village and continues across the quarry and the hill to west of the village. **(27e)** – the Magura Formation (Slivnitsa**,** SAPUNOV & TCHOUMATCHENCO 1995g): alternation between thick bedded and medium bedded micritic and biomicritic limestones (Upper Tithonian–Berriasian); **(28e)** – the Glozhene Formation: alternation between micritic thin and medium bedded limestones and, in the basal part, lithoclastic limestones (Lower–Upper Tithonian); the Gintsi Formation: **(29ea)** – "Upper Nodular limestones": grey to reddish nodular and lithoclastic limestones alternating with grey micritic limestones (Upper Kimmeridgian–Lower Tithonian); in this packet, there is an angular discordance; **(29eb)** – "Grey Micritic (Quarry) Limestones": micritic grey limestones in alternation with lithoclastic limestones containing grey chert (Oxfordian–Lower Kimmeridgian); **(29ec)** – "Lower Nodular Limestones": grey lithoclastic limestones alternating with micritic limestones (Middle Callovian–Oxfordian); these lithoclastic limestones are in angular contact with sediments of the Verenitsa Member; the Bov Formation: **(31-1e)** – the Verenitsa Member: alternation between grey-greenish aleuritic marls and grey micritic limestones, *Macrocephalites* sp. indet. (Upper Bathonian–Lower Callovian); **(31-2e)** – Gornobelotintsi Member: grey-greenish aleuritic marls, purely exposed (Upper Bathonian); the Polaten Formation: **(32ae)** – the Desivitsa Member: grey to dark-grey biodetritic limestones with chert nodules (Upper Bathonian); below, red to brown, oolithic, ferruginous limestones – "the Coarse Oolite Horizon" (STEPHANOV & TZANKOV 1970) (condensation of the Lower Bathonian *Zigzag* Zone and the Middle Bathonian *Subcontractus* Zone); **(33ae)** – the Vratnitsa Member: grey biodetritic, slightly sandy limestones (upper part of the Lower Bathonian – upper part of the Upper Bajocian); **(36e-34e**) – the Kichera Formation (not divided): grey–beige to whitish sandstones (?uppermost Upper Toarcian–lowermost part of the Upper Bajocian). Substratum: the Petrohan Terrigenous Group built of white to greenish sandstones with mica (Lower Triassic).

Novo Korito (Figs. 1: Sb-8, 2)–D. Milanovac (Figs. 1: Sb-4, 2) Sections (ANDJELKOVIĆ *et al*. 1996).

The sedimentation in the two areas was analogous during the Late Jurassic and the Callovian and differed only during the Middle Jurassic. Here was deposited the following sediments: **(10)** – Novokorito limestones: clayey biomicrites and dolomitic biomicrites with ammonites, *Saccocoma* and calpionelids - in the upper parts (Kimmeridgian–Tithonian) (analogous to the Glozhene Formation); **(11)** – Greben ammonitic limestones (ANDJELKOVIĆ *et al*. 1996): grey, clayey biomicrites to dolomitic limestones, nodular, with cherts (Middle Callovian–Oxfordian), analogous to the Bulgarian Gintsi Formation; **(12) –** Staro Selo beds: grey micritic limestones with cherts nodules (Callovian; analogous to the Bulgarian Javorets Formation); **(12a)** – Staro Selo beds: red and reddish ferrous limestones (0.20 m thick) with a rich association of ammonites - *Macrocephalites macrocephalus*, *etc*. (ANDJELKOVIĆ 1975; ANDJELKOVIĆ *et al*. 1996) (Lower Callovian, analogous to the Bulgarian Sokolov Venets Zoogenous Marker in this paper) and in Ribnica stream - grey-greenish clay and limestones with cherts with *Macrocephalites* (ANDJELKOVIĆ 1975). During the Middle Jurassic, a differentiation between the sections of D. Milanovac and Novo Korito commenced. In D. Milanovac **(Figs. 1: Sb-4, 2)** sedimented: **(13)** – the Staro Selo Beds (ANDJELKOVIĆ *et al*. 1996): in the upper part **(13b)** – yellow to reddish sandstones (Bathonian; no analogy in Bulgaria) and in the lower part **(13a)** – sandy oolithic limestones (Bajocian; analogous to the Vratnitsa Member of the Polaten Formation in Bulgaria); **(14)** – Staro Selo clastites (ANDJELKOVIĆ *et al*. 1996) – conglomerates and sandstones (Aalenian; analogous to the Kichera Formation). In the Novo Korito Section, during the Bajocian and the Bathonian, sedimented **(18a)** – grey-greenish aleuritic marls (locally with many *Zoophycos*) (horizontal analogue to the Bulgarian Gornobelotintsi Member of the Bov Formation).

Gornobelotintsi (Nechinska Bara River) Section (Fig. 1: Bg-13, 3) (SAPUNOV *et al*. 1988; SAPUNOV & TCHOUMATCHENCO 1995d). Here, the following Jurassic sediments were deposited: **(15)** – the Glozhene Formation: well-bedded micritic limestones (slightly lithoclastic in the base) (Middle–Upper Tithonian); the Glozhene Formation is covered by thick bedded limestones, which TCHOUMATCHENCO (2002) assigned to the Magura Formation with Berriasian age; in its uppermost parts. there are calcareous breccia-conglomerates; **(16)** – the Gintsi Formation: nodular and lithoclastic limestones in three packets: **(16c)** – the upper packet ("Upper nodular limestones"): reddish nodular and lithoclastic limestones (Middle–Upper Kimmeridgian – Lower Tithonian); **(16b)** – the middle packet: "Quarry limestones" - lithoclastic and micritic limestones (Middle and Upper Oxfordian–Lower Kimmeridgian); **(16a) –** the lower packet ("Lower nodular limestones"): grey nodular and lithoclastic limestones (Upper Callovian–Lower Oxfordian); **(17)** – the Javorets Formation: grey, medium bedded limestones interbedded by thin bedded clayey limestones (Middle Callovian); its lower boundary represents an angular disconformity, which is probably one of the manifestations of the Sokolov Venets Marker in the central part of the basin; **(18b)** – the Verenitsa Member of the Bov Formation: medium bedded micritic and clayey limestones in alternation with marls with *Macrocephalites* sp. (Lower Callovian); **(18a)** – the Gornobelotintsi Member of the Bov Formation: marls aleuritic (Bathonian – upper part of the Upper Bajocian); **(19)** – the Polaten Formation, Vratnitsa Member: sandy limestones and calcareous sandstones (Bajocian); **(20)** – the Kichera Formation (non-subdivided): whitish to yellowish quartz sandstones (Aalenian); it is possible that, in the lowermost part the sandstones, could be continental (analogous to the Venets Member).

Prevala Horst

Mitrovtsi–Prevala Sections (Figs. 1: Bg-7, 3) (SAPUNOV & TCHOUMATCHENCO 1995h). The section near the Mitrovtsi Village crops out as a cliff along the road Montana Town–Belogradchik, along the Ogosta River. The stratotype of the Desivitsa Member of the Polaten Formation crop out in the Desivitsa Valley between the villages Mitrovtsi and Prevala. **(27f)** – the Brestnitsa Formation; in the region of NW Bulgaria, it is connected in the horizontal direction with the Magura Formation; it is composed of whitish to beige massive biodetritic limestones (uppermost part of the Upper Tithonian–Berriasian); **(28f) –** the Glozhene Formation: represented by bright grey, grey-beige to dark grey micritic limestones (middle part of the Lower–Upper Tithonian); the Gintsi Formation; **(29fa)** – "Upper Nodular limestones": grey to reddish nodular and lithoclastic limestones alternating with grey micritic limestones (Upper Kimmeridgian–Lower Tithonian); in this packet there is an angular discordance; **(29fb)** – the "Grey Micritic (Quarry) Limestones": micritic grey limestones in alternation with lithoclastic limestones containing grey chert (Oxfordian–Lower Kimmeridgian); **(29fc)** – the "Lower nodular limestones": grey lithoclastic limestones alternating with micritic limestones (Middle Callovian–Oxfordian); **(30f)** – the Javorets Formation: grey, predominantly thin-bedded, micritic limestones with rare intercalation of lithoclastic limestones (Lower–Middle Callovian); **(30af)** – the Sokolov Venets Marker of the Javorets Formation (Fig. 5C): (a) – red to pink lithoclastic limestones; the lithoclasts are surrounded by red marly cement (thickness 80 cm); (b) – red to grey zoogenic (predominantly ammonitic) breccia - *Macrocephalites* sp. (20 cm); (c) – laminated red, ferruginous, calcareous marls - after Dr I. LAZAR (perssonal communication, 2011), they are stromatoid

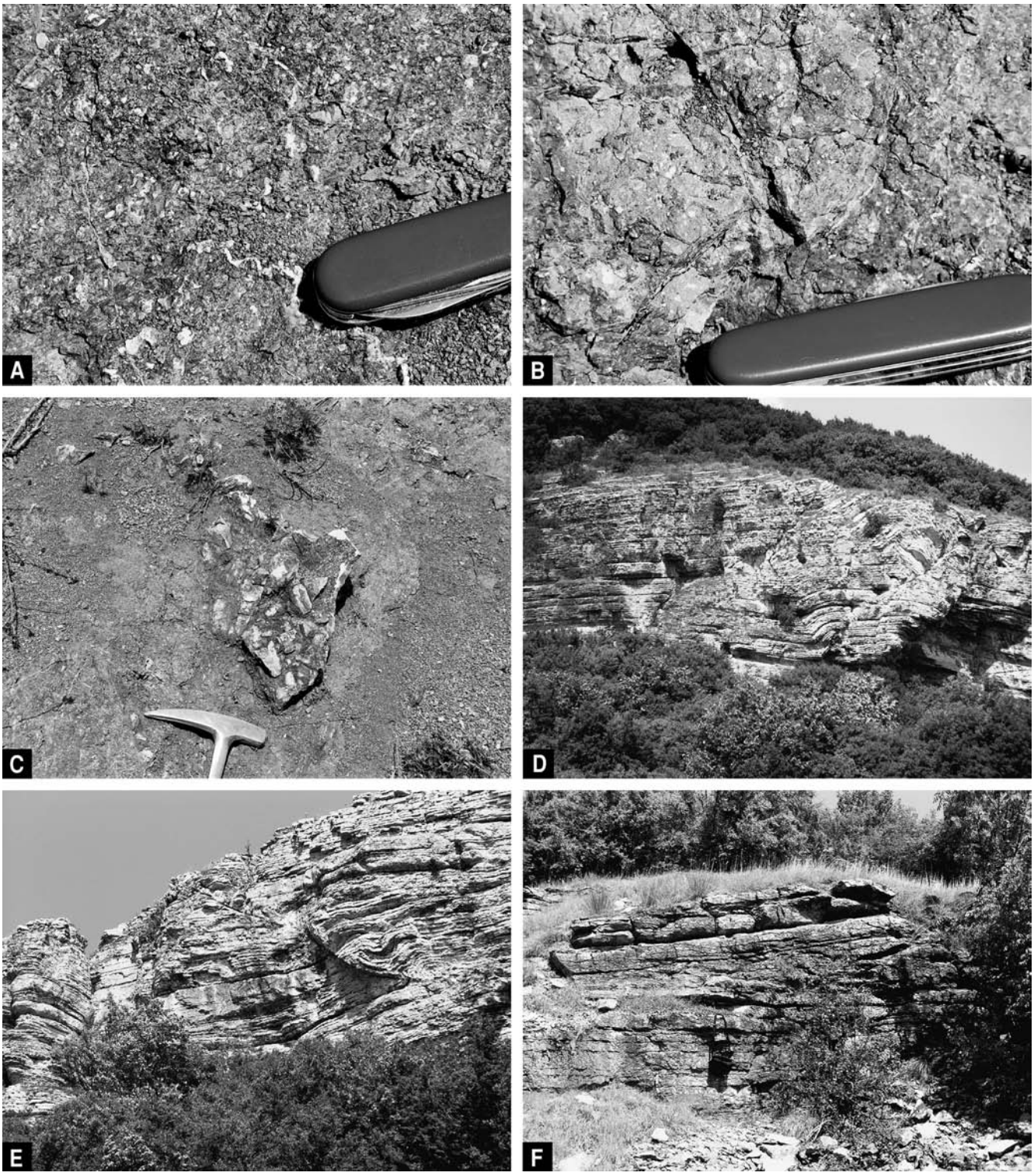

Fig. 4. **A,** Vratarnica Series, the "matrix" of the formation, near the road south of Vratarnica Village, Zaječar District; **B,** Vratarnica Series, olistolite of volcanogenous rock in the matrix, near the road south of Vratarnica Village, Zaječar District; **C,** Vratarnica Series, olistolite of coarse grained whitish limestone (analogous to the Crni Vrh Limestones of east Serbia or the Bulgarian Slivnitsa Formation) in the matrix, near the road south of Vratarnica Village, Zaječar District; **D,** Granitovo, Gradishteto Hill, syn-sedimentary fold in the upper part of the Gintsi Formation; **E,** Reverse fault in the upper part of the Gintsi Formation near Granitovo Village, Sokolov Venets Hill - in the upper part of the Gintsi Formation; **F,** reverse fault in the upper part of the Gintsi Formation, near the road Belogradchik–Railway Station Oreshets.

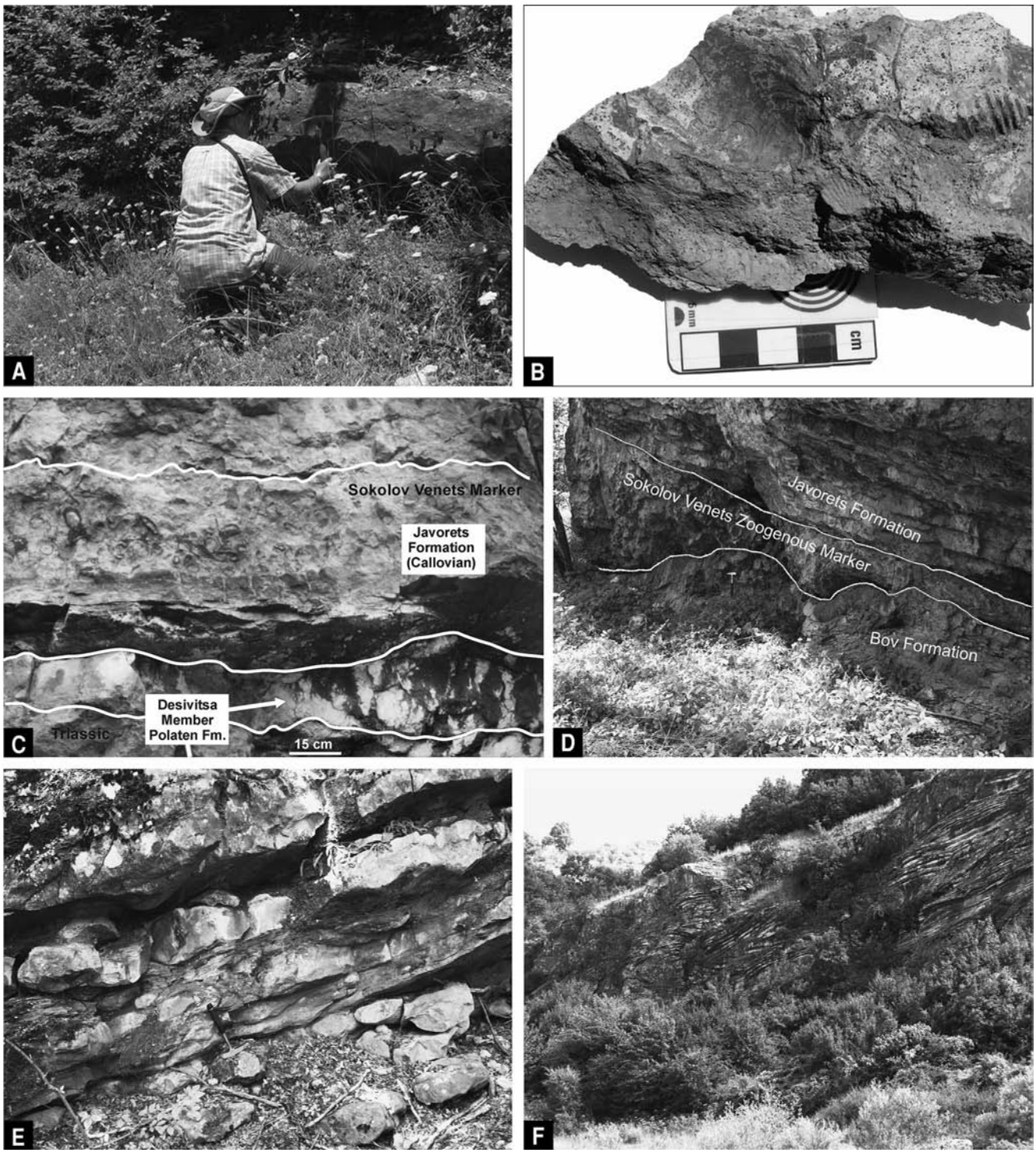

Fig. 5. **A,** Holotype section of the Sokolov Venets Zoogenous Marker, along the road Belogradchik–Railway Station Oreshets, general view and upper bed No 7; **B,** Holotype section of the Sokolov Venets Zoogenous Marker, along the road Belogradchik–Railway Station Oreshets, specimen from the lower bed No 6 – zoogenous breccia; **C,** Sokolov Venets Zoogenous Marker, view of the outcrop on the cliff by the road near Mitrovtsi Village, Montana District; **D,** Sokolov Venets Zoogenous Marker, view of the outcrop on the southern hill of the Gintski Venets (Cliff), near Gintsi Village, Sofia District, folded uppermost bed of the Bov (Polaten?) Formation; the sediments of the Sokolov Venets Zoogenous Marker fully fill the negative part of the ancient relief; in the right part of the photograph is seen the bed of the Polaten (Bov?) Formation overlaid by zoogenous breccia of the Sokolov Venets Zoogenous Marker; **E,** Desivitsa Member of the Polaten Formation in the Desivitsa Valley, near Prevala Village, Montana District; **F,** view of the Shugovitsa Slump; in the Shugovitsa River Valley, near Nikolovo Village, Montana District, the folds are in the Gintsi and the Glozhene Formations.

constructions; **(31f)** – sharp, irregular surface, probably the result of a sub-marine break in the sedimentation (Middle Bathonian–Lower Callovian); Polaten Formation: **(32af)** – the Desivitsa Member: red, ferruginous limestones (Lower Bathonian); in the Desivitsa Valley to the SE of Prevala Village is the stratotype of the Desivitsa Member (Fig. 5E), built by: (c) – violet-reddish micritic limestones with many ammonites (1.20 m); (b) – red to rose micritic limestones, in the basal part with irregular intercalation of red marls (3.30 m) and in the base with a dark zoogenous oolitic limestones (the "Prevala Beds", STEPHANOV 1966). This development of the Desivitsa Member – reddish marls and limestones are close to the Klaus Schichten from the Romanian and Serbian South Carpathian. Substratum: the Iskar Triassic Carbonate Group – the Cesmicka Formation (Lower Carnian).

Mihaylovgrad Graben (SAPUNOV *et al*. 1988) (Figs. 1, 2, 3)**.** This is a SW–NE negative palaeostructure, in which the Jurassic sediments show an integrated section from the Hettangian up to the end of the Early Cretaceous. To the east, it is connected transitionally with the Central Moesian Basin and to west, with the N–S oriented Infra-Getic Palaeogeographic Unit and in both of them existed analogous palaeogeographic conditions. The transgression started with the deposition of oligomictic sandstones, followed during the Pliensbachian by sandy bioclastic limestones deposited also in a shallow sublittoral environment, but with a calcareous bottom (Gresten facies – *grosso modo*). During the Aalenian and the Bajocian, in the Mihaylovgrad Graben existed a deep sublithoral environment when argilites of the facies "black shales with *Bositra–Possidonia alpina*" were deposited. During the Middle Callovian and the Late Jurassic, micritic limestones (Middle Callovian–Middle Oxfordian) were deposited, followed by nodular and lithoclastic limestones – "*ammonitico rosso* facies" (Late Oxfordian–Early Tithonian), lithoclastic and micritic limestones (Middle–Late Tithonian) and platform limestones (Late Tithonian–Berriassian).

The section Gaganitsa Village is the section where the complete development of the Jurassic sedimentation deposited in the central parts of the Mihaylovgrad palaeograben crop out. The Gaganitsa Lake section shows a lack of the upper part of the Gintsi Formation and the Glozhene Formation. The section Vinishte demonstrates the lateral changes connected with the board of the palaeograben and the section Nikolovo – the effect of a big slumping – the Shugavitsa Slump.

Gaganitsa Village Section (Figs. 1: Bg-8, 2, 3). In the vicinities of Gaganitsa Village (SAPUNOV & TCHOUMATCHENCO 1995i), in the central parts of the Mihaylovgrad Palaeograben, were deposited: **(39)** – the Brestnitsa Formation (NIKOLOV & KHRISCHEV 1965) – Slivnitsa Formation (after SAPUNOV & TCHOUMATCHENCO 1995i): light-grey to whitish, thick bedded limestones, often containing corals, bivalves, gastropods (*Nerinea*), *etc*. (Upper Tithonian–Berriasian); **(40)** – the Glozhene Formation: dark to light grey micritic limestones, locally lithoclastic in the base (Tithonian); **(41–43)** – the Gintsi Formation: nodular and lithoclastic limestones (Upper Callovian–Lower Tithonian); **(41)** – the "Upper nodular limestones: red nodular limestones (Upper Kimmeridgian–Lower Tithonian); **(42)** – the "Grey quarry limestones": grey micritic limestones, intercalated by grey lithoclastic limestones (Oxfordian–Lower Kimmeridgian); **(43)** – the "Lower nodular limestones": grey lithoclastic limestones (Middle Callovian–Oxfordian); **(44)** – the Javorets Formation: grey micritic, often clayey limestones with nodules of chert (Lower–Middle Callovian); **(30af)** – the Sokolov Venets Marker: grey aleuritic and oolitic limestones, containing numerous ammonitic fragments and glauconite (thickness 1.40 m) with *Hecticoceras (Brightia) nodosum* (BONARELLI), *H. (B.) tenuicostatum* ZEISS, *H. (B.) subnodosum* (DE TSYTOVITCH), *Choffatia villanoides* (TILL); the Bov Formation: **(45)** – the Verenitsa Member: alternation between greenish aleuritic marls and thin beds of micritic limestones (Upper Bathonian); **(46)** – the Bov/Polaten Formation: grey aleuritic marls in alternation with silicificated micritic limestones (analogous to the Gornobelotintsi Member) (Upper Bajocian–Bathonian); the Etropole Formation is divided into three members: **(47c)** – Shipkovo Member: dark grey to blackish shales (Lower Bajocian–Upper Bajocian); the **(47b) –** Nefela Member: dark clayey siltstones (Lower Bajocian); **(47a)** – the Stefanets Member: dark grey to black, slightly calcareous silty argillites (Aalenian – lower part of the Lower Bajocian); **(48)** – the Bukorovtsi Formation: slightly sandy clayey marls with rare interbeds of clayey limestones (Toarcian–Upper Pliensbachian); **(49)** – the Dolnilukovit Formation: dark-grey sandy to bioclastic limestones (lower part of the Lower Sinemurian – Upper Pliensbachian); **(50)** – the Kostina Formation: fine- to coarse-grained quartz sandstones (Hettangian).

Gaganitsa Lake Section (Figs. 1: Bg-9, 2, 3). This section is situated 3 km south-east from the Gaganitsa Village Section. Its sediments are the same as in the Gaganitsa Village Section, but differs from the latter by the fact that the thick bedded limestones with debris of corals, gastropods, *etc*. of the Brestnitsa Formation lie directly on the reddish clayey lithoclastic limestones of the middle packet of the Gintsi Formation; the uppermost part of the Gintsi Formation and the limestones of the Glozhene Formation are missing. The situation is the same in the east direction, on the Peak Ludeno and east wards. This is, after P.T., the effect of the Shugovitsa Slump; the missing parts of the section were slumped to north and now crop out as big folds in the Shugovitsa River Valley near the village of Nikolovo, Montana District, at a distance of 16 km**.**

Kamenna Riksa–Vinishte Section (Figs. 1: Bg-12, 3) (SAPUNOV & TCHOUMATCHENCO 1995k). The Juras-

sic sediments are poorely exposed in the section between Kamenna Riksa Village–Zabarge Hill–Viniste Village and the Kamiko Hill and the hills around it (to the north of Vinishte Village). Here, the Brestnitsa Formation is not developed and the Glozhene Formation is directly covered by the clayey limestones of the Salash Formation. **(40a)** – The Glozhene Formation: grey micritic limestones, partially with lithoclasts (Lower Tithonian–Berriasian); **(41a–43a)** – the Gintsi Formation: predominantly grey to pinkish lithoclastic limestones, intercalated by grey micritic limestones; **(44a)** – the Javorets Formation: grey, predominantly micritic limestones (?Middle Callovian – lower part of the Upper Oxfordian); **(30af)** – the Sokolov Venets Zoogenous Marker: limestones with ammonites and belemnites (Lower Callovian); The Bov Formation: **(45a)** – the Verenitsa Member (not far from here is situated the holostratotype): grey aleuritic more or less calcareous marls (uppermost Upper Bathonian (?) – Lower Callovian); **(46a)** – the Gornobelotintsi Member: grey aleuritic, clayey marls (Upper Bajocian–Upper Bathonian); **(47d)** – the Vratnitsa Member of the Polaten Formation: grey sandy limestones to calcareous sandstones with some brachiopods and belemnites (Upper Bathonian); **(34e–35e)** – the Kichera Formation (homogenous): white to pinkish, locally ferruginous oligomictic sandstones (Aalenian–Upper Bajocian); **(48–49)** – the Ozirovo Formation: grey to pinkish sandy limestones to calcareous sandstones, locally with rounded quartz pebbles, with bivalves, brachiopods and ammonites (Pliensbachian–Toarcian). The Ozirovo Formation is transgressive over the Upper Triassic sediments.

Nikolovo Section (Figs. 1: Bg-10, 3) (Sapunov & Tchoumatchenco, 1995k). The Lower and partly the Middle Jurassic sediments were studied in the drill cores of many bore holes. On the surface crop out the sediments since the upper parts of the Etropole Formation. In this section, the Jurassic sediments are very similar to the Jurassic sediments developed in the Gaganitsa Village Section. The difference between them lies in the fact that the sediments of the Glozhene Formations here are folded in a few horizontal to reversed folds **(40b)** (Fig. 5F) to reverse faults (Tchoumatchenco & Sapunov 1998), which slid on the surface, formed by the reddish lithoclastic limestones of the Gintsi Formation – the Shugovitsa Slump is probably the result of the slumping of these sediments from the region of the Gaganitsa Lake Section – the result of seismic shock.

Vratsa Horst (Sapunov *et al*. 1988). The dry land in a continental environment under conditions of erosion and denudation on the Vratsa Horst progressively diminished (destroyed during the Callovian) and was encountered by a shallow and moderately deep sublittoral environment with the sedimentation of sandy, bioclastic limestones (type of Gresten facies – *grosso modo*) during the Early and part of the Middle Jurassic (at the beginning of the Aalenian). During the end of the Aalenian and the Early, Middle and the early part of the Late Bajocian the conditions of a deep sublittoral environment dominated with the sedimentation of silty argillites (facies of black shale with *Bositra–Possidonya alpina*). At the end of the Late Bajocian and the Bathonian, sandy bioclastic limestone was deposited. During the Middle Callovian–Middle Oxfordian, micritic limestones were deposited, followed upwards by lithoclastic during the Middle Oxfordian–Tithonian. During the Latest Late Tithonian and the Berriasian, the conditions in the Vidin and Vratsa Horsts, and in the Mihaylovgrad (and in its branch, the Gornobelotintsi Graben) became more or less uniform and thick bedded, sometimes bioclastic limestones were deposited.

Ledenika Cave (Figs. 1: Bg-11, 2). On the Vratsa Horst the following sediments were deposited (Sapunov & Tchoumatchenco 1995c, n): **(51)** – the Brestnitsa Formation (Slivnitsa Formation, after Sapunov & Tchoumatchenco 1995c, n): massive, organogenous–biodetrital and biohermic, pelletal–oolithic limestones (Upper Tithonian–Lower Cretaceous); **(52)** – the Glozhene Formation: thick bedded limestones with biodetritus and lithoclasts (Middle Tithonian–Berriasian); **(53)** – the Ledenika Member of the Gintsi Formation (Sapunov *in* Nikolov & Sapunov 1977): thick bedded grey pelletal–oolithic limestones with numerous intercalations of lithoclastic limestones; they contain coral remains, echinoids spines, bivalves (Upper Oxfordian, *p. p*. –Lower Tithonian); **(54)** – the Javorets Formation: grey, micritic limestones with rare intercalation of lithoclastic limestones (Middle Callovian–lower part of the Upper Oxfordian *p. p*.); **(54a)** – the Sokolov Venets Organogenous Marker: grey, micritic limestones, rich in glauconite in the basal part – *Macrocephalites macrocephalus* (Schlotheim) and *Hecticoceras (Brightia) tuberculatum* (de Tsytovitch) (Lower–Middle Callovian); **(55)** – the Polaten Formation: grey sandy limestones, in the base, a bed of conglomerates (0.15 m) with pebbles of black shales (the Etropole Formation?) and Triassic limestones (Upper Bajocian–Bathonian); **(56)** – the Etropole Formation (nonsubdivided): black shales (Aalenian–Bajocian); **(57)** – the Ozirovo Formation: pink to reddish, ferruginous sandy limestones (Upper Pliensbachian–Aalenian); **(58)** – the Kostina Formation: grey, medium-bedded, quartz sandstones to gravel-stones (Lower Pliensbachian–Upper Pliensbachian *p. p*.)

Notes on the Jurassic lithostratigraphy in NW Bulgaria

In this paper, one of us (P. Tchoumatchenco) express some opinions on the lithostratigraphy of the Jurassic which slightly differ from the "official"

points of view of the Bulgarian lithostratigraghic interpretation, expressed, *e.g*., in SAPUNOV & METODIEV (2009) – " Jurassic Geology", Chapter 5.3 of the "Mesozoic Geology of Bulgaria" and in many others publications, of which P. TCHOUMATCHENCO is also a co-author. They will be studied in stratigraphical order.

Kostina Formation (SAPUNOV *in* SAPUNOV *et al*. 1967). It is used as in the original paper – quartz sandstones (Hettangian, some time up to the Lower Pliensbachian).

Ozirovo Formation (SAPUNOV *in* SAPUNOV *et al*. 1967). Herein it is used as in the original paper; later it was named "Homogenous Ozirovo Formation", without subdivision into members. Hence, it is the Ozirovo Formation in the holostratotype (NACHEV *et al*. 1963). In this meaning, the Ozirovo Formation has a spotted distribution and is a very important palaeogeographic marker; it was deposited in shallow water conditions in a sublittoral area, often with the formation of iron-bearing sediments in the limestones (upper part of the Hettangian–Toarcian). It enters into the Malaplanina carbonate group.

Dolnilukovit Formation (SAPUNOV 1983). It was introduced as a member of the Ozirovo Formation. Here, it is used as an independent lithostratigraphic formation, built of bioclastic dark grey limestones. In some localities, it contains a few lithostratigraphic members: the Ravna, Romanovdol and Teteven members. Maximal range: Sinemurian–Toarcian. This Formation was sedimented in more quiet and deep localities in the Early Jurassic Basin. It enters into the Mala Planina carbonate group.

Bukorovtsi Formation (SAPUNOV *in* SAPUNOV *et al*. 1967). Here, is restituted its original meaning as an independent lithostratigraphic formation, as was created by SAPUNOV (1967). The Formation is built of clayey limestones and marls (Upper Pliensbachian–Toarcian or the lower part of the Aalenian). The Bukorovtsi Formation was sedimented in quiet and relatively deep environments. It enters into the Mala Planina carbonate group.

Etropole Formation (SAPUNOV *in* SAPUNOV *et al*. 1967). Black shales and argillites (similar to the "Black Shales with Possidonia" in the Southern Alps). In the study area, it is divided into three members: the Shipkovo, Nefela and Stefanets Members. They enter into the Chernivit terrigenous group.

Shipkovo Member (SAPUNOV & TCHOUMATCHENCO 1989). Grey-blackish aleuritic argillites with sideritic concretions (uppermost part of the Lower Bajocian).

Nefela Member (SAPUNOV & TCHOUMATCHENCO 1989). Grey-blackish clayey aleurolites with sideritic concretions (upper part of the Lower Bajocian–lower part of the Upper Bajocian).

Stefanets Member (SAPUNOV & TCHOUMATCHENCO 1989). Grey-blackish aleuritic argillites with sideritic concretions (Aalenian–lower part of the Lower Bajocian).

Kichera Formation (STEPHANOV & TZANKOV 1970). Bright sandstones and conglomerates (Aalenian–Upper Bajocian). In the study area, it is divided into the following members: the Oreshets Member, Granitovo Member, Venets Member, Kiryaevo Member and Vrashka Chuka Member.

Oreshets Member (STEPHANOV & TZANKOV 1970). Brownish-beige non-calcareous to feebly calcareous sandstones (middle and upper parts of the Upper Bajocian).

Granitovo Member (STEPHANOV & TZANKOV 1970). Brown-reddish sandstones and conglomerates (Lower Bajocian–lower part of the Upper Bajocian)**.**

Venets Member (TCHOUMATCHENCO 1978). Grey-pinkish conglomerates, gravelitic sandstones, pinkish clays (probably horizontal transition into the Kiryaevo Member) (?Aalenian).

Kiryaevo Member (TCHOUMATCHENCO 1978). Continental sandstones and conglomerates (lower part of the Aalenian).

Vrashka Chuka Member (TCHOUMATCHENCO 1978). Alternation between clays, coals and sandstones (Aalenian – ?uppermost part of the Toarcian).

Polaten Formation (STEPHANOV 1966). In northwestern Bulgaria, it is divided into three members: the Yanovets, Vratnitsa and Desivitsa members. They enter into the Mala Planina carbonate group.

Yanovets Member (TCHOUMATCHENCO 1978). Based on pinkish limestones and calcareous sandstones (Upper Bajocian).

Vratnitsa Member (STEPHANOV 1966). It is built of calcareous sandstones to sandy limestones. The lectostratotype is described by TCHOUMATCHENCO (1978) (upper part of the Lower Bajocian–lower part of the Bathonian).

Desivitsa Member (STEPHANOV 1966). TCHOUMATCHENCO (1978) gave to these sediments the range of Formation which SAPUNOV & TCHOUMATCHENCO (1986) accepted for them, the range of one marker – the Desivitsa Oolite Marker. Herein, the original meaning of the beds of the Polaten Formation, *i.e*., above the Vratnitsa Member and below the Bov Formation, in which exists a local Oolite marker in the lower parts of the Desivitsa Member, is returned. It is not logic to have in the Polaten Formation in NW Bulgaria, in the base, a Vratnitsa Member, an Oolite Marker and the Polaten Formation. In the Desivitsa Valley, where these sediments are better developed, in the base exist a bed with oolites and above it, red micritic limestones and marls (Fig. 5E), which are the most important part of this Member. This is the reason for the return to the wider meaning, which was introduced by TCHOUMATCHENCO (1978) (middle part of the Lower Bathonian–lower part of the Upper Bathonian). These sediments were deposited in a shallow part of the basin, with relatively strong water movement. The Desivitsa

Member of the Polaten Formation is the probable equivalent of the Klaus Schichten in the Southern Carpathians.

Bov Formation (SAPUNOV 1969). It is characterised by clayey limestones and marls (maximal range Upper Bajocian–Middle Callovian). Often it is divided in two members: the Gornobelotintsi and Verenitsa Members**.**

Gornobelotintsi Member (SAPUNOV & TCHOUMATCHENCO 1989): grey-greenish aleuritic marls (Bathonian–upper part of the Upper Bajocian).

Verenitsa Member (TCHOUMATCHENCO 1978): medium-bedded micritic and clayey limestones in alternation with marls with *Macrocephalites* sp. in the upper part (Lower Callovian – Bathonian).

Javorets Formation (NIKOLOV & SAPUNOV 1970). The Formation is based on micritic limestones with chert concretions (Middle Callovian–Oxfordian). Elsewhere in the basal part of this Formation, a horizon exists with zoogenous breccia-conglomerates, herein individualized as an independent lithostratigraphic unit, with the range of a lithostratigraphic marker, the Sokolov Venets Zoogenous Marker. It enters into the West-Balkan Carbonate Group.

Sokolov Venets Zoogenous Marker (Соколов Венец зоогени репер – new unit) (0.42 m thick in the holostratotype) (named after the peak Sokolov Venets, situated 3.5 km to the NNE of Belogradchik Town). The type section is situated along the road Belogradchik–Oreshets Railway Station (Fig. 4E), described by STEPHANOV (1961), rediscribed by SAPUNOV & TCHOUMATCHENCO (1995e) and by BELIVANOVA & SAPUNOV (2003). Here the description is also after STEPHANOV (1961). "Bed 7. Thickness 0.30 m; brown-red limestones with ferrous hydroxide ooids: *Macrocephalites macrocephalus* (SCHLOTHEIM) (abundant), *Hecticoceras hecticum* (REINECKE) (rare), *Choffatia spirorbilis* (BONCHEV & POPOV). Cover: lithoclastic, pinkish limestones (the Gintsi Formation). Bed 6. Thickness 0.12 m; yellowish-red clayey limestones with scattered ooliths and with large flat-spherical lenticular ferrous hydroxide nodules up to 25 cm in diameter around Bathonian calcareous pieces or Callovian ammonites: *Macrocephalites macrocephalus* (SCHLOTHEIM) (frequent) and others ammonites. In the two beds, there are many *Perisphinctidae*, *Phylloceratidae*, *Litoceratidae*, *etc*." The fossils were probably resedimented in the horizontal direction from the Verenitsa Member of the Bov Formation. In this sediment, the Callovian Stage was proven for the first time in Bulgaria by BONCHEV & POPOV (1935), substratum (Lower Bathonian *Zigzag* Zone): sub-marine hard ground, erosional surface over the Desivitsa Member: sandy, biodetritical limestones with ferrous ooids. Cover: sharp boundary with red nodular limestones containing *Hecticoceras* (Middle Callovian). Previous uses: "Macrocephalites beds" (BONCHEV & POPOV 1935) and "Red oolitic Callovian limestones" (ATANASOV & ALEXIEV 1956; ATANASOV 1957). Regional aspect: in the section near the Television Tower of Belogradchik, the substratum of the Sokolov Venets Zoogenous Marker is represented by alternation of marls and micritic limestones - the Verenitsa Member of the Bov Formation; cover: beige micritic lithoclastic limestones – the Gintsi Formation. The Sokolov Venets Marker is composed of a few centimetres of dark grey marly limestones. This marker is distributed in the Western, Central and East Stara Planina, the Pre-Balkan and in West Bulgaria. In some localities, it represent an erosional surface between the Polaten Formation and the cover of the Gintsi Formation (Staro selo, region of Pernik, western Bulgaria (TCHOUMATCHENCO *et al*. 2010a, 2010b), between the Polaten Formation and the Belediehan Formation (TCHOUMATCHENCO *et al*. 2010a), between the Polaten Formation and the turbidite Cerniosam Formation (in Konyava Planina Mt., demonstrated by I. Zagorchev), or between the Polaten and the Lobosh Formation (TCHOUMATCHENCO *et al*. 2010a). More complicated is the situation in the area of Godech, to north-west of Sofia, near the Villages Gintsi and Komshtitsa. BELIVANOVA & SAPUNOV (2003) wrote that "The section of the Gintsi Cliff, District of Sofia is an uninterrupted Bathonian–Callovian section". This is demonstrated in their figs. 1 and 2 and proven by the ammonitic data, the results of a microfacies study (samples 1, 2) and the analysis of the faunal spectra. This situation is true for the north Gintsi Venets (Cliff) and partly, for the south Gintsi Venets (Cliff), where the beds are concordantly. Interestingly, BELIVANOVA & SAPUNOV (2003) do not comment on the paper of TCHOUMATCHENCO & SAPUNOV (1998), in which the folded upper beds of the Polaten (or Bov?) Formation is demonstrated, and they comment only on this part of the section where it is represented by two horizontal beds, lower (called in the Komshtitsa Section, the Polaten Formation by TCHOUMATCHENCO *et al*. (2001) and the Bov Formation by BELIVANOVA & SAPUNOV (2003)) and the upper "Niveau condensé à ammonites" with indications of the "Z. à *Gracilis* (s/Z. à *Michalskii*)". BELIVANOVA & SAPUNOV (2003) indicated that in the "Bov Formation" is collected *Clydoniceras* cf. *discus* (J. SOWERBY 1813) (Upper Bathonian, upper part) the *C. discus* Zone and the upper bed, the Yavorets Formation – dark grey micritic limestones, in which, from the very base of the packet, is found *Macrocephalites cannizaroi* (GEMMELLARO 1868) (Lower Callovian), *Grossouvria* sp. (Callovian) and *Macrocephalites* spp. (Lower Callovian). The determination of these ammonites is out of doubt. However, in the south Gintsi Venets (Cliff), these two beds in horizontal direction change over a short distance (in 2–3 meters) (Fig. 5B). The lower bed became folded (TCHOUMATCHENCO & SAPUNOV 1998; refigured in TCHOUMATCHENCO *et al*. 2010a, Fig. 4D), and the upper bed (with the Callovian

ammonites) became thick, up to 1.80 m. This bed fully filled the negative parts of the folded lower bed (Fig. 5D). What is demonstrated in Figure 5d? At the end of the Bathonian, the beds were folded (the cause is unknown, probably slumping of the Bathonian sediments), then the negative folds were fully filled by current accumulations from the Lower Callovian sediments, which were the result of erosion and redeposition of sediments containing ammonites and other fossils (especially from the Lower Callovian part of the Bov Formation). In the vicinities of Komshtitsa Village (at the piedmont of the Elenine Vrah), the Sokolov Venets Zoogenous Marker was structured by a zoogenous breccia or locally, by an intraformational conglomerate (TCHOUMATCHENCO *et al*. 2010b, Fig. 4F). In the Nechinska Bara Valley, near Gorno Belotintsi Village, Montana District, the Sokolov Venets Marker is expressed only by an angular discordance (SAPUNOV & TCHOUMATCHENCO, 1998; SAPUNOV & TCHOUMATCHENCO, 1995d). In addition, a local discordance between the Verenitsa Member and the Gintsi Formation is expressed in the Dolni Lom Village section (SAPUNOV & TCHOUMATCHENCO 1995g). The substratum of the Sokolov Venets Zoogenous Marker is with different ages: Lower Bathonian in the type section, in western Bulgaria, *etc*.; Upper Bathonian in the Gintsi Village sections, in the Komshtitsa section, *etc*.; Lower Callovian in the Belogradchik TV Tower section, in the Nechinska Bara Valley section, in the Dolni Lom section, *etc*. and depends on the energy of the sub-marine erosion (after STEPHANOV 1961 – emersion and transgression). The Sokolov Venets Marker is analogous to the Middle Callovian Sultanci Formation in the bore holes in the area of Provadiya Town, eastern Bulgaria.

The Sokolov Venets Zoogenous Marker can be correlated with the Lower Callovian sediments with many ammonites in the area of Rosomač–Senokos (Stara Planina Mts.), near D. Milanovac (**23a** in the present paper) (ANDJELKOVIĆ 1975), *etc*.

What is the cause of the formation of the Sokolov Venets Zoogenous Marker? We agree with the notion of NACHEV (2010) that at the end of the Bathonian in the "Balkanids", there were many hesitant movements with a tendency of general swallowing. One of us (P.T.) thinks that the post-Bathonian erosion was the most developed during the early Callovian and at this time, the Bathonian–Lower Callovian sediments of the Bov Formation (Verenitsa Member), which are well preserved in the section of the Belogradchik–T.V. Tower, were completely destroyed to the north-west (in the holostratotype of the Sokolov Venets Zoogenous Marker). Probably during the early Callovian, the north part of a syn-Early Callovian fault, crossing the seabed near the present day Belogradchik, was elevated and the sediments destroyed, and their ammonites resedimented in the sediment of the Sokolov Venets Zoogenous Marker. The aspect of this marker is different in different localities: in some localities, it is represented by an erosional surface, where there was only elevation of the area, and in other, where the erosion was weaker, after the erosion followed stage of deposition of sediments of Sokolov Venets Zoogenous Marker. It is interesting that the new sedimentation started in many localities during the Middle Callovian and in others later, during the Early or the Late Kimmeridgian.

Gintsi Formation (NIKOLOV & SAPUNOV 1970) – nodular and lithoclastic limestones; in NW Bulgaria, they are divided into three unformal packets; the upper packet ("Upper nodular limestones") – reddish nodular and lithoclastic limestones (Middle–Upper Kimmeridgian–Lower Tithonian); the middle packet ("Quarry limestones") – lithoclastic and micritic limestones (Middle and Upper Oxfordian–Lower Kimmeridgian); the lower packet ("Lower nodular limestones") – grey nodular and lithoclastic limestones (Middle–Upper Callovian–Lower Oxfordian). It enters into the West-Balkan Carbonate Group.

Glozhene Formation (NIKOLOV & SAPUNOV 1970) – well bedded micritic limestones (slightly lithoclastic in the base) (Middle–Upper Tithonian–Berriasian). It enters into the West-Balkan Carbonate Group.

Brestnitsa Formation (NIKOLOV & KHRISCHEV 1965) – the Formation is structured by bright grey to grey-whitish limestones, thick bedded, often with corals, rudists, *etc*. (Upper Tithonian–Berriasian, (after some authors up to the Barremian). It enters into the West-Balkan Carbonate Group.

Magura Formation (NIKOLOV & TZANKOV 1996) – it is based on whitish to grey-beige thick bedded, shallow water limestones, in many localities containing corals, gastropods and bivalves. They also contain some calpionellids (Upper Tithonian–Berrisaian). It enters into the West-Balkan Carbonate Group.

Slivnitsa Formation (ZLATARSKI 1885) – it is based on bright thick-bedded limestones, in some locality with many corals and gastropods. It contain some calpionellids in its upper parts (Upper Tithonian–Berriasian; after some colleagues up to the Hauterivian). It enters into the West-Balkan Carbonate Group.

N. B.

These three lithostratigraphic units are with the same or very similar lithological characteristics and with almost the same stratigraphical position. The problems for the delimitation of their area of distribution are, to a high percent, subjective. Their outcrops are separated one from others by younger sediments and it is question of personal opinion whether one outcrop is connected with another or not. The discussion was opened by the paper of TCHOUMATCHENCO & SAPUNOV (1986). At this time, we did not know that in East Serbia, the Vratarnica Series of ANDJELKOVIĆ (1975) existed, and by analysis of the geological liter-

ature (known to this moment in Bulgaria), P.T. came to the decision that the Slivnitsa Formation is connected in the region of Vrashka Chuka with the Brestnitsa Formation. This idea was adopted by his colleague, Ivo Sapunov, and it was published by Tchoumatchenco & Sapunov (1986). In many of the sheets of the geological map of Bulgaria on the scale 1:100 000, concerning NW Bulgaria, this idea was adopted and on them is indicated the presence of the Slivnitsa Formation, but in the neighbouring map, for the same rocks, the Brestnitsa Formation was adopted. Later, Nikolov & Tzankov (1996) created for analogic rocks, a new lithostratigraphic formation – the Magura Formation. Finally, his (of P.T.) present day opinion is that the Slivnitsa Formation is developed only in western Bulgaria and is separated from the same rocks in NW Bulgaria and NE Serbia by the volcano–sedimentary rocks of the Vratarnica Formation ("Series") (Figs. 1, 2 and 3) of Andjelković (1975), Andjelković *et al*. (1996), Andjelković & Mitrović-Petrović (1992). His last opinion is that the Magura Formation is connected with the Brestnitsa Formation, but in text I, the idea of Ruskova & Nikolov (2009) is followed because it is a predominantly a Lower Cretaceous problem, *i.e.*, that they are separate lithostratigraphic bodies.

Syn-sedimentary discordances

In the Jurassic sediments of NW Bulgaria exist two regional syn-sedimentary discordances:

Sokolov Venets Discordance – in the subsided parts of the basin, it is expressed only by an angular discordance (without erosion of the substratum and new sedimentation – Nechinska Bara, Dolni Lom). In the moderately elevated region, the discordance is fossilized by few centimetre deposits – Belogradchik TV Tower, Teteven, *etc*. In the more elevated area was effectuated an erosion and subsequent accumulation of calcareous breccia-conglomerate, Belogradchik–Oreshets, Gintsi–Komshtitsa; the substratum is spotted; the erosion goes up to the Lower Bathonian beds, Belogradchik–Oreshets, Kremikovtsi, *etc*. In western Bulgaria, the result is a lack of sedimentation going up to the Early Kimmeridgian (Kremikovtsi – Sofia District), Staro Selo (Pernik District) or to the Late Kimmeridgian (Konyava Planina Mt.; a phenomenon demonstrated to me by I. Zagorchev).

Granitovo Discordance – as result of a seismic shock during the Late Kimmeridgian, in the sediments of the upper part of the Gintsi Formation, in the area of Belogradchik, a fold formed (Fig. 4D), which passed into an overthrust with NW vergency (Figs. 4E, F). In the Mihaylovgrad Paleograben, the result of this seismic shock was the formation of the Shugovitsa Slump (Fig. 5F). It commences in the region of the Gaganitsa Lake area and goes to the north of the Shugovitsa Valley, near Nikolovo Village. It is interesting that here the vergency of the folds and overthrusts are opposite to the fold-over thrust in the area of Belogradchik with north vergency and transport of material from south to north.

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Резиме

Међугранична (североисточана Србија/северозападна Бугарска) корелација јурских литостратиграфских јединица

На геолошким и тектонским картама Србије и Бугарске приказане су различите структуре ограничене само на националне територије. У овом раду извршена је корелација јурских седимената североисточне Србије и северозападне Бугарске. Издвојене су следеће палеогеографске јединице: Источни Гетик, Инфра-гетик и Мезијска платформа. Источни Гетик је проучаван на изданцима у близини Рготине, где седиментација започиње од хетанжа, а за време келовеј– горња јура таложе се платформни карбонати. Инфра-гетик је документован на профилима Добре (Песача) и алохтоним седиментима у близини Штубика. Инфра-гетик карактеришу горњојурско вулканско–седиментне творевине Вратарничке серије. Јурска Мезијска платформа је проучавана код Доњег Милановца и Новог Корита у Србији и Горнобелотинског рова у Бугарској. Приказана је корелација јурских седимената у области Вршке Чуке, са обе стране границе и код села Рабиша (пећина Магура у Бугарској). Урађена је ревизија јурских седимената у Бугарској, код Видинског хорста, који су проучавани на Белоградичком, Горње Белотинском, Белимелском и Михајловградском рову. Седиментација у Видинском хорсту започиње у различитим деловима средње јуре, а у Михајловградском рову за време хетанжа (доња јура), где се седиментација одвијала у релативно дубоководној средини. Јужније, на јурском Вратском гребену, на јужном крилу Михајловградског рова, одвијала се плитководна седиментација.

У јурској литостратиграфији СЗ Бугарске описане су следеће формације, које се нешто разликују од оних приказе од стране САПУНОВА И МЕТОДИЈЕВА (2009):

Костинска формација (хетанж, понекад до доњег плензбаха); Озировска формација (горњи део хетанжа–тоар); Дољолуковичка формација (доња јура); Букуровска формација (горњи плензбах–тоар–део алена); Ентрополска-7 формација, која је подељена на три члана: Шипковски (највиши део доњег бајеса), Нефелски (највиши део доњег бајеса–доњи део горњег бајеса) и Стефански (ален–доњи део доњег бајеса); Кичерска формација је подељена је у чланове: Орешечки (средњи и горњи део горњег бајеса), Гранитовски (доњи бајес–доњи део горњег бајеса), Венечки (?ален), Кирјевски (доњи део алена) и Врашко Чукски (ален–највиши део тоара); Полетенска формација је подељена у три члана: Јановечки (горњи бајес), Вратнички (горњи део доњег бајеса–доњи део бата), Десевички (средњи део доњег бата–доњи део горњег бата; ?еквивалент Клауским слојевима); Бовска формација је подељена на два члана: Горнобелотински (бат–горњи део горњег бајеса) и Веренски (доњи келовеј–бат); Јаворечка формација (средњи келовеј–оксфорд), у бази ове формације уведена је литостратиграфска јединица – Соколовско–веначки зоогени репер; Гиначка формација (средњи–горњи келовеј–доњи оксфорд); Гложанска формација (средњи–горњи титон–беријас); Брестничка формација (горњи титон–беријас; према неким ауторима до барема); Магурска формација (горњи титон–беријас) и Сливничка формација (горњи титон–беријас).

У јурским седиментима СЗ Бугарске постоје две син-седиментне дискорданције: Соколовско–веничка и Гранитовска.