

# Depth geological relations of the wider area of Belgrade - based on the wells and geophysical data

Đorđe Marinović, Ljupko Rundić



Дигитални репозиторијум Рударско-геолошког факултета Универзитета у Београду

[ДР РГФ]

Depth geological relations of the wider area of Belgrade - based on the wells and geophysical data | Đorđe Marinović, Ljupko Rundić | Annales geologiques de la Peninsule balkanique | 2020 | |

10.2298/GABP201030009M

<http://dr.rgf.bg.ac.rs/s/repo/item/0005819>

Дигитални репозиторијум Рударско-геолошког факултета Универзитета у Београду омогућава приступ издањима Факултета и радовима запослених доступним у слободном приступу. - Претрага репозиторијума доступна је на [www.dr.rgf.bg.ac.rs](http://www.dr.rgf.bg.ac.rs)

The Digital repository of The University of Belgrade Faculty of Mining and Geology archives faculty publications available in open access, as well as the employees' publications. - The Repository is available at: [www.dr.rgf.bg.ac.rs](http://www.dr.rgf.bg.ac.rs)

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/347545310>

# Depth geological relations of the wider area of Belgrade – based on the wells and geophysical data

Article in *Geoloski anali Balkanskog poluostrva* · December 2020

DOI: 10.2298/GABP201030009M

---

CITATIONS

0

---

READS

31

2 authors, including:



Ljupko Rundić

University of Belgrade

54 PUBLICATIONS 396 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



The evolution of Paratethys: the lost sea of Central Eurasia [View project](#)



Miocene Lake System in Serbia [View project](#)

## Depth geological relations of the wider area of Belgrade - based on the wells and geophysical data

ĐORĐE MARINOVIĆ<sup>1</sup> & LJUPKO RUNDIĆ<sup>2</sup>

**Abstract.** The subject work covers the Belgrade wider area with a total area of about 2,000 km<sup>2</sup>. The authors integrated the principal geological and geophysical data provided by surface works and multidisciplinary elements from the fifty-two wells with depths between 33 and 2,733 m. Explicit paleontological findings of specialized analysts with determinations of macro- and microfauna and flora are presented both from Neogene formations and the older basinal floor. In addition to conventional petrological descriptions of rocks, microscopic determinations of intrusive and extrusive magmatites were also cited. From the enclosed basin space, the mineralization of deep aquifers is also correlative positioned. From the geophysical data for wells deeper than 400 m, records of well logging measurements were used, with markers based on which valid stratigraphic delimitations were made. Seismic survey sections were the basis for spatial shaping of Neogene sedimentation and basin floor configuration. For in-depth geological interpretations, published and repository gravimetric and geomagnetic maps of different sizes and years were consulted. The authors focused primarily on factometric indicators without entering into variable and debatable theoretical schematizations, especially orogenically complex of subbasin tectonics, in dissonant relations with the younger disjunctive shaped configuration which is visually shown in the reference cross-sections both vertically and laterally.

### Key words:

*Stratigraphic elements,  
Neogene, Depth delimitations,  
Geophysical indicators,  
Structural-Paleogeographic  
interpretation.*

**Апстракт.** Предметна референца обухвата простор шире околине Београда укупне површине око 2.000 km<sup>2</sup>. Аутори су објединили капиталне геолошке и геофизичке податке обезбеђене површинским истраживањима и мултидисциплинарним елементима из 52 бушотине са дубинама између 33 и 2.733 m. Конкретни палеонтолошки налази специјализованих аналитичара са детерминацијом макро и микрофауне и флоре, презентовани су како из неогених формација тако и из басенске подине. Осим конвенционалних петролошких описа стена цитиране су и микроскопске детерминације интрузивних и екструзивних магматита. Из затвореног басенског простора корелативно су позициониране и минерализације дубинских аквифера. Од геофизичких података за бушотине дубље од 400 m коришћени су записи каротажних мерења, са маркерима на основу којих су извршена валидна стратиграфска раз-

<sup>1</sup> Radnička 41, 21000 Novi Sad, Serbia.

<sup>2</sup> University of Belgrade – Faculty of Mining and Geology, Department of Regional Geology, Kamenička 6, 11000 Belgrade, Serbia. Email: ljupko.rundic@rgf.bg.ac.rs

**Кључне речи:**

*Стратиграфски елементи,  
неоген, дубинска разграничења,  
геофизички показатељи,  
структурно-палеогеографска  
интерпретација*

граничења. Секције сеизмичких испитивања биле су основ за просторно обликовање неогене седиментације и конфигурације басенске подине. За дубинска геолошка тумачења консултоване су објављене и фондовске гравиметријске и геомагнетне карте разних година и размера. Аутори су се задржали првенствено на фактометријским показатељима не улазећи у променљиве и дискутабилне теоретске шематизације нарочито орогено сложене подбасенске тектонизације, у дисонантном односу са млађом, дисјунктивно обликованом неогеном конфигурацијом која је у референтној графици визуелно приказана и вертикално и латерално.

**Introduction**

The wider area of the city of Belgrade includes not only its central and highly urban part, but also all the peripheral settlements that stretch around that urban core from both side of the Sava and Danube rivers. Within that, so-called the Belgrade Danube meander (Beogradski dunavski ključ), in the narrower sense, means the area of Belgrade or its eastern rim that follows the course of the Danube river in the coastal part and low inner hills (Višnjica, Slanci, Veliko Selo) all the way to Mirijevo and Vinča. Once a marginal part of the Belgrade settlement and a space suitable for field trips and professional observations, it has a long tradition of geological research (BOUE, 1840). From that time, numerous studies have been done, hundreds of wells have been drilled and some generally known facts have been established. Many papers have been published about this after World War I (e.g. PAVLOVIĆ, 1922; LUKOVIĆ, 1922; LASKAREV et al., 1931). After World War II, the interest of the geological public spread to the other side of the Danube, and with the beginning of hydrocarbon exploration in Banat and beyond, the subsurface geology of the wider Belgrade area became even more relevant (MARINOVIĆ, 1959, 1961, 1962). For example, it was understood that the subsurface geological composition of that area is a reflection of the genesis and evolution of the Pannonian Basin, pronounced syn- and post-rift Neogene tectonics and block structure. This conditioned the existence of differences in a relatively small area, the formation of smaller or larger depressions as opposed to distinct structural elevations (NIKOLIĆ, 1976; STEVANOVIĆ, 1977). Neogene sediments heterochronously cover the pre-Neogene bedrock,

mimicking the configuration of the inherited paleo-relief. The Alpine-type tectonized structure is not identically oriented with the younger disjunctive shaped basin structure of Neogene. It is understood that parts of the more pronounced ruptures were reactivated during the Neogene (RUNDIĆ et al., 2019).

These facts influenced the authors of this paper to make the basic driving motto has been factometry, i.e. the desire to present the subsurface structures of the wider Belgrade area with much more details.

Thanks to geological-geophysical research as well as performed exploratory drilling, it has long been known that paleorelief or “old rocks” exposed on the surface of the terrain south of the Danube River, build the basis for the Neogene and Quaternary sediments up to 4000 m thick (e.g. PETKOVIĆ, 1951; ANĐELKOVIĆ, 1960; MARINOVIĆ, 1970, 1971, 1977; NIKOLIĆ, 1976; MAKSIMOVIĆ et al., 1990; PANTIĆ & DULIĆ, 1990; RADIVOJEVIĆ et al., 2010; DUNČIĆ et al., 2017; DULIĆ et al., 2019). Having all this in mind, as well as the existence of clear discordant relations between stratigraphic units and, in that sense, significant stratigraphic deviations in a smaller area (local unconformities, erosions, pronounced disjunctive tectonics, etc.), the presentation of our results will contribute to a better understanding of these processes.

Considering that nowadays it is difficult to get direct data related to exploratory drilling and geophysical research of the Neogene of Vojvodina, and that subsurface geological models are established mainly on the basis of re-interpretation of existing data and their further approximation, a huge database of geological documents (primarily strati-



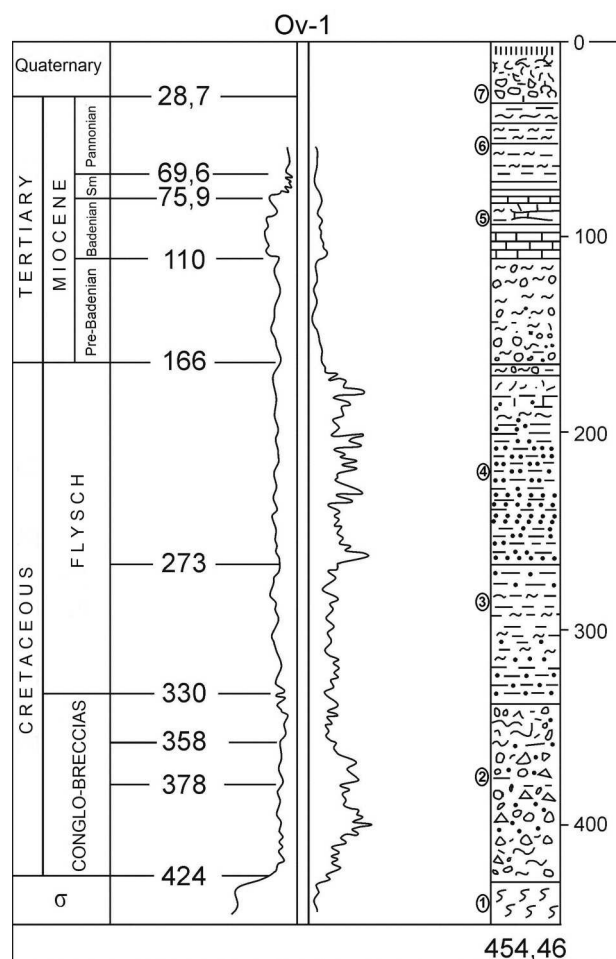
## Material and methods

The presentation of the depth geological structure of the Belgrade wider area is the result of the analysis of 15 deep wells on the Banat side of the Danube river (Fig. 1). In the southern part of studied area 37 mostly shallow wells were analyzed. It should be noted that in the given scale of the graphics (Figs. 1 and 10), not all the toponyms mentioned in the text nor shallow wells could be shown. The complete list of used wells can be found in the Table 1. The collected stratigraphic-paleontological data, performed well logging and seismic-geological correlations were analyzed by the first signed author (DM), as well as a part of the paleontological determination related to Neogene units in the presented deep wells. On the Banat side, the depth geological-stratigraphic demarcations are based on correlative markers of well logging (MARINOVIĆ, 1970, 1971 – see Fig. 2), harmonized with available paleontological, petrological and hydrochemical elements, transferred on the network of reflective seismic sections. On the Belgrade side, numerous literature-processed surface data have been supplemented by a selection of stratigraphically instructive wells and representative geological columns (by LjR). For the entire area, gravimetric maps of isogams (mgI) and vertical gradient (E) were used from the geophysical data – Funds of “Naftagas” (Novi Sad) and “Geozavod” (Belgrade), which were partially published (SIMIN, 1963; BILIBAJKIĆ et al., 1979; BILIBAJKIĆ, 1998). In addition, geomagnetic maps  $\Delta z$  anomalies ZMP 1954 (NIKOLIĆ & SIMIN, 1959) and the fund of the Za intensity section were used, except for the areas that were deleted from the competent authorities in due time.

Based on all of this, the first signed author constructed subsurface geological sections of the SW Banat (profiles I, II and III) as well as the map of Neogene base configuration ( $E = 100$  m), which covers an area of about 2,000 km<sup>2</sup>. The depth geological model defined in this way is supplemented with facts that refer to the subsurface and outcrop geological data of the wider area of Belgrade, that is south of the Danube river (LjR).

Determination of the stratigraphic affiliation of geological units from the Banat deep wells was

taken primarily from ČANOVIĆ & KEMENCI (1988) and other publications (e.g. PANTIĆ & ŠEĆEROV, 1975; PANTIĆ & DULIĆ, 1990; KNEŽEVIĆ et al., 1994). However, in order to avoid burdening the text with continuous repetition of the signatories of internal reports or works of the published paleontological and other data from the deep wells of Banat, in the chapter „Stratigraphic review“, the corresponding authors are grouped as follows: determination of Neogene microfauna - V. Marković, N. Gagić („Naftagas“, Novi Sad); determination of Mesozoic microfauna - M. Čanović („Naftagas“, Novi Sad) and Đ. Mihajlović („Geozavod“, Belgrade); determination of Neogene macrofauna - P. Janković, Đ. Marinović („Naftagas“,



**Fig. 2.** Synthetic stratigraphic section of the borehole Ov-1 (compiled by DM). The plotted diagram is one of the first geoelectric measurement in Serbia performed in 1950 with the Schlumberger apparatus (Zagreb team). Key (generally): 1, serpentinite; 2, conglu-breccia; 3, siltstone & claystone; 4, sandstone; 5, limestone; 6, marl, and 7, sand & gravel.

Novi Sad); determination of microflora – N. Pantić (Faculty of Mining and Geology, Belgrade), P. Šećerov and I. Dulić („Naftagas“, Novi Sad); petrographic analyzes - R. Kemenci („Naftagas“, Novi Sad); physical and chemical analyzes of water - A. Dekanj and A. Maksimčev („Naftagas“, Novi Sad); correlative stratigraphic distinctions - Đ. Marinović (Naftagas, Novi Sad). In the area south of the Sava and Danube rivers, the references are cited in Table 1.

## Stratigraphic review

### Pre-Tertiary basement

In the studied area, the pre-Tertiary basement makes the geological and stratigraphic units of Jurassic and Cretaceous age of different genesis.

### Jurassic

**The oldest Jurassic unit** is a series of dark to black tectonized clays and argiloshists with sand-siltstone intercalations permeated by quartz grains. It was found in the well Pč-1 (2,395–2,733 m) and can be correlated with similar deposits in the close vicinity, i.e. with black sericitized claystones with sandstone inserts found in the well Crepaja-1 (1,597–1,603 m) then, generally, with “shiny shales” (PANTIĆ, 1978), as well as with black sericitized thin-bedded claystones, siltstones and sandstones of the well Padina-1 (1,554.3–1,613.6 m). Based on the analysis of the palinospectrum (insight into the original report dated 28.06.1958 by N. Balteš) dominated by *Ophioglossum delectus* BOLKHOVITINA, *Cupressacites minor* (MALYAVKINA), *Protopiceacerina* BOLKHOVITINA, *Picea* sp., *Podozamites rotundus* BOLKHOVITINA, *Ginkgo praecuta* BOLKHOVITINA, *Leptochylus* sp., *Bennettitales delucidus* BOLKHOVITINA, *Lophotriletes* sp., *Selaginella* sp., *Bothrychium* sp., *Lycopodium* sp., etc. the **lower Jurassic - Lias (J<sub>1</sub>)** was determined (Figs. 3, 4).

Claystones and clayey siltstones with the association of dinoflagellate algae (*Nannoceratopsis* cf. *gracilis* ALBERTI and *Gonyaulacista* sp.), spores and pollen of the type *Ginkgoales* sp., *Cycadophytes* sp.,

*Konkispurites* sp. were drilled in the BNsj-1 well at a depth of 1901–1908 m (Fig. 6). Stratigraphically, these deposits correspond to the **upper Lias (J<sub>1</sub>)** (ČANOVIĆ & KEMENCI, 1988; PANTIĆ & DULIĆ, 1990).

On the other side of the Danube River, in the well G-1 (Grocka), in a depth interval from 1,300 to 1,378 m, the pelites with an abundance of radiolarians (*Mirifusus mediodilatatus* (RÜST) and *Pavicingula boesi* (PARONA), less often with spores and other palynomorphs were drilled (Š. Goričan, in KNEŽEVIĆ et al., 1994). Relatively recently, from dark red radiolarites from a depth of 1,378 m, the next radiolarians were identified: *Belleza decora* (RÜST), *Semihsum* sp. A, *Praewilliriedelum robustum* (MATSUOKA), *Mirifusus diana* s.l. (KARRER), *Spongocapsula palmerae* PES-SAGNO which corresponding to the **late middle Jurassic**, while from a depth of 1,400 m the younger Jurassic association of radiolarians was determined: *Parapodocapsa amphitreptera* (FOREMAN), *Cinguloturris carpatica* DUMITRICA, *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO), *Archaeodictyomitra minoensis* (MIZUTANI), *Protunuma japonicus* MATSUOKA & YAO, *Zhamoidellum ovum* DUMITRICA, *Hiscocapsa hexagona* (HORI). Biostratigraphically, it corresponds to the **Upper Jurassic (J<sub>3</sub>- middle Oxfordian to late Tithonian)** (ĐERIĆ et al., 2010) (Fig. 6).

The complex of **ultrabasic rocks (σ)** is represented by peridotites and serpentized peridotites (Figs. 2–4). They were found in the wells G1-1 (below 865 m) and G1-2 (below 835 m) in the north of the studied area where they form the Pre-Tertiary basement.

Somewhat further to south, in the Ov-1 well, compact peridotites at the bottom of the well and cracked serpentinites at higher levels were drilled in the interval 424–454,46 m (Figs. 2, 3). They belong to the massif of peridotite-pyroxene rocks. Morphologically, the top of the buried magmatite is located in the narrowest area of Ovča, and its the longitudinal depth root most probably in the belt of the main tectonic fault, in the area between the Sibnica and Tamiš rivers (Fig.3). An ultramafic complex was identified in the SA-2 well, between 352 and 531.5 m (KNEŽEVIĆ et al., 2018a). Peridotites and serpentized peridotites are degraded, tectonic deformed and intersected by a network of cracks. They are hydrothermally altered (Fig. 3).

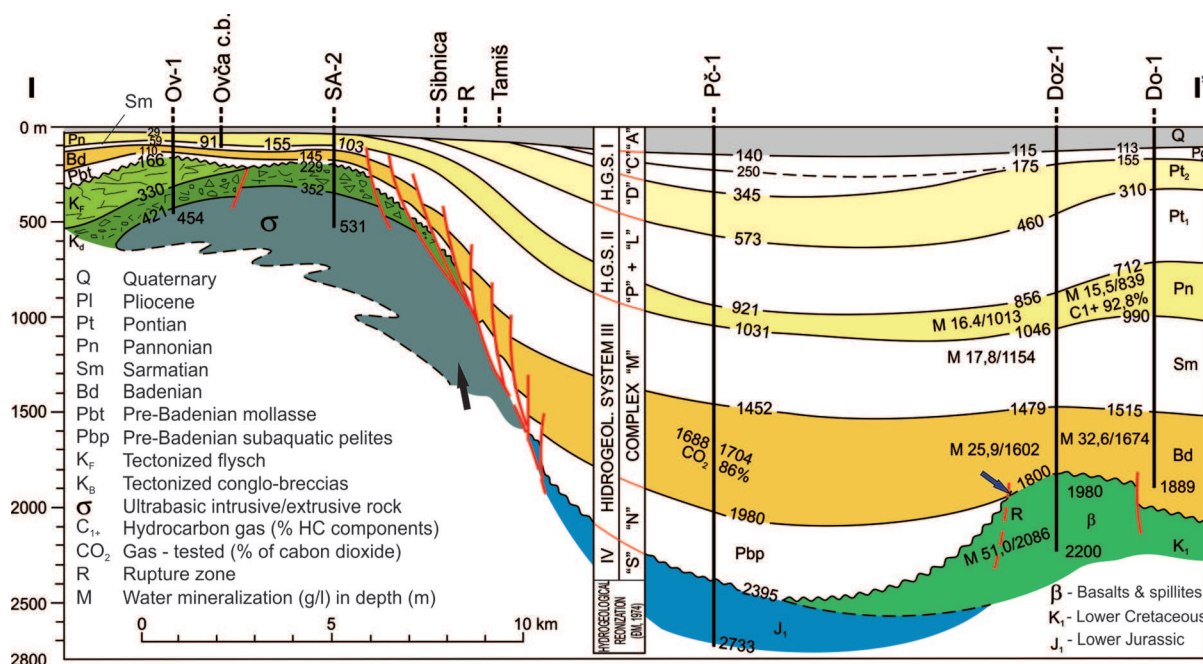


Fig. 3. The geological cross-section Ovča–Pančevo–Dolovo. The stratigraphic units and their boundaries are consistent with geoelectric logs. Comparative review of the nomenclature of depth hydrogeological reonization, according to MARINOVIĆ (1982).

Masses of similar serpentinized peridotites and serpentinites were discovered on the surface north and east of Avala Mt. (Ljubičica, Bubanj potok, Zuce). In the well Bt 1-2 (Ljubičica–Bubanj potok) below a 38 m thick series of younger rocks, serpentinites were drilled (RUNDIĆ et al., 2019 - Table 1). Similar observations about the appearance of these rocks at the mentioned sites have been mentioned before (e.g. MAROVIĆ & KNEŽEVIĆ, 1985; TOLJIĆ, 1996; TOLJIĆ & TRIVIĆ, 1997).

### Cretaceous

**The coarse clastite complex (K<sub>B</sub>)** lying over the ultramafic rocks was discovered in the wells Ov-1 and SA-2. It is built of hard breccias, or conglu-breccias. The clasts originate mainly from ultramafites, predominantly angular pieces of serpentinized peridotites (Fig. 3) tightly bound by cement that partially contains a high percentage of carbonates. The thickness of these breccias is from 94 m in the well Ov-1 (330–424 m) to over 120 m (229–352 m) in the well SA-2 (Fig. 5). In the Ov-1 well, this complex is covered by the tectonized flysch sediments.

On the Belgrade side, similar the compact serpentine breccias were discovered in well Bt 1-2 (Ljubičica–Bubanj potok) where, in the interval of 28–38 m depth, they overlie the mass of serpentinized peridotites in which drilling was completed (92 m) (RUNDIĆ et al., 2019).

**The Lower Cretaceous (K<sub>1</sub>, K<sub>1</sub><sup>1-5</sup>)**, principally with the characteristics of turbidite, in the segments of coarse-clastic flysch, was drilled in the well Om-1 (Omoljica) at a depth of 932–1,905 m (Figs. 4, 6). Spheres are rarely present in the deepest levels of the well (laminated siltstones below 1,740 m). Above that, in the depth interval from 1,566 to 1,569 m, the glauconite siltstones with diabase debris, interbedded with sandstones and marls with *Hedbergella infracretacea* (GLAESSNER) were found. Breccias similar the synsedimentary fragments contain algal remains of *Coptocamphilodon fontis* PATRULIUS, *Acroporella* sp. which would correspond to shallow facies of the Barremian–Aptian Stage (ČANOVIĆ & KEMENCI, 1988). In deeper levels (1,108–1,495 m), in the succession of siltstones, sandstones and partly laminated micrites, the presence of foraminifers (*Hedbergella* sp., *Lenticulina* sp., *Textularia* sp., etc.) and the sphere of *Globochaeta alpina* LOMBARD was recorded. In the



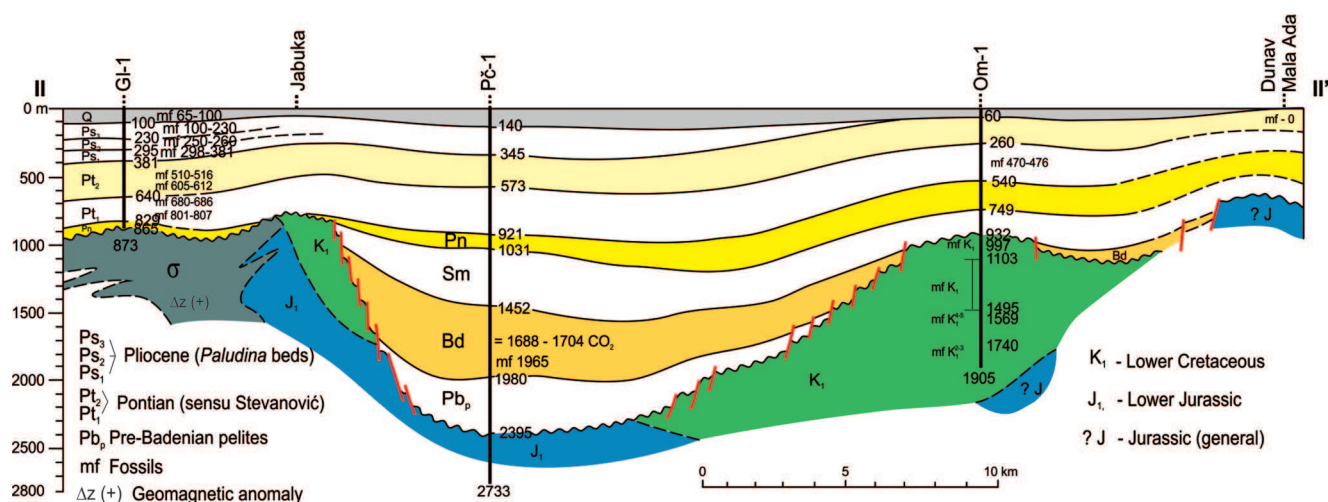


Fig. 4. The geological cross-section Glogonj–Pančevo–Danube (Mala Ada)–Brestovik. For the rest of legend, see Fig. 3.



Fig. 5. Detail of hard, reddish-gray and dark green conglomero-breccia probably of the Lower Cretaceous. Borehole SA-2 (334 m). Photo by Lj. Rundić

shallowest part, highly tectonized marls and siltstones are without paleontological markings, while the siltstone-sand breccias, micrites and biosparites (997–1,100 m) contain hydrozoas and detritus of indeterminate mollusks (ČANOVIĆ & KEMENCI, 1988).

In Banatsko Novo Selo, in the well BNs-1 (1,171–1,243 m), marly siltstones and biomicrites with *Tintinoporella carpatica* (MURGEANU-FILIPESCU), *Colomiosphaera heliosphaera* (VOGLER), *Globochaeta alpina* LOMBARD, and rare headbergels, textularians and frequent radiolarians were drilled. These rocks correspond to the Hauterrivian–Barremian Stage (ČANOVIĆ & KEMENCI, 1988). Similar the deep-sea Lower Cretaceous sediments were found in the well

Doz-1 (Dolovo) in a depth interval from 1,800 to 2,200 m (Fig. 6). They are made of hard siltstones, marls and micrites with a microfauna of radiolarians such as *Cenosphaera* sp., *Dictiomitra* sp., *Lithocampe* sp., etc. Among foraminifers, the pelagic *Hedbergella* sp. and benthic *Bigenerina* sp. and *Textularia* sp. were found. Among microplankton, the representatives of *Colomiosphaera* sp., *Heliosphaera* sp., *Cadosina-Stomiosphaera* association dominate as well as rare zoospores (*Globochaeta* ex. gr. *alpina*). At a depth of 1,980 m and at bottom of the well (2,200 m), synsedimentary spillites and submarine basalt outflows were registered. By correlation of logging markers, similar the Lower Cretaceous deposits (Barremian) were found in the well VI-1 (1,222–1,355 m) in Vladimirovac.

Apart from the surface, the Lower Cretaceous formations were previously found in some wells, for example, near Skadarlija in the centre of Belgrade (BC-3, 147–321 m; TOMIĆ, 2005), and close to the Faculty of Veterinary Medicine (VF) at a depth of 82 m (STEVANOVIĆ, 1977). Recent research and drilling near the Museum in Dedinje, the Urgonian limestones in the depth interval of 29–33 m have identified (B-11, KNEŽEVIĆ et al., 2015). At right bank of the Sava River, during the construction of the residential and business complex “Belgrade Waterfront”, the Urgonian limestones and sandstones were identified at depths between 60–94,7 m (B-1, KNEŽEVIĆ et al., 2017 – Fig. 7 and Table 1).

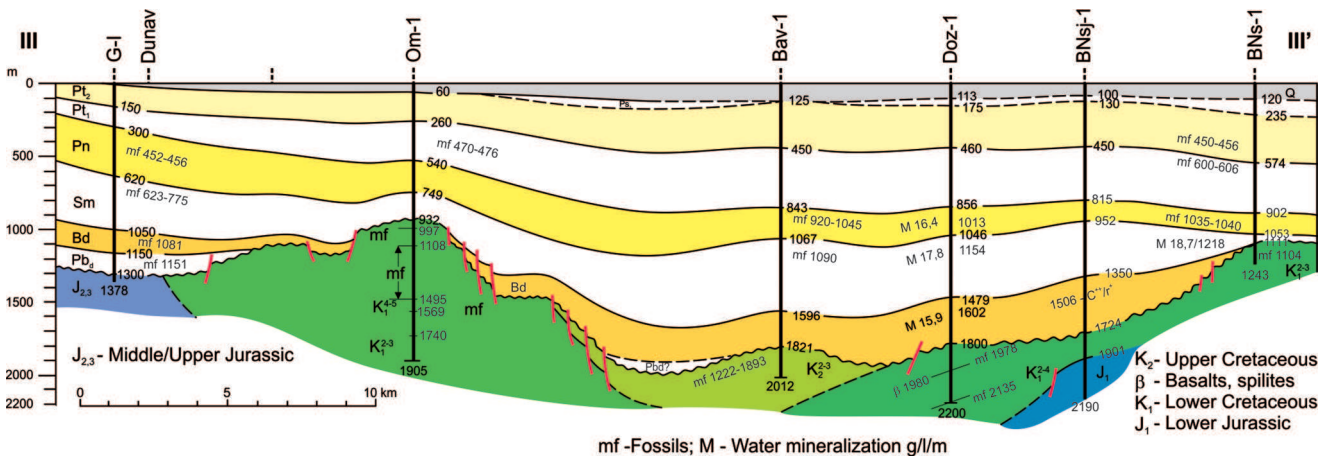


Fig. 6. The geological cross-section Grocka – Banatsko Novo Selo. For the rest of legend, see Fig. 3.

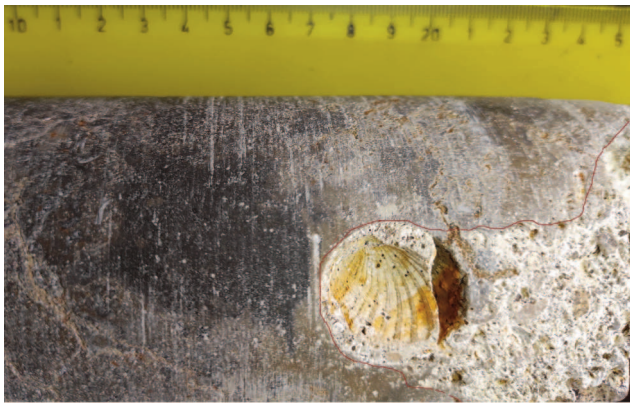


Fig. 7. Borehole B-1, “Belgrade Waterfront”. The light-gray, porous limestones of Sarmatian (right) overlie the dark-gray Urganian limestones (left) at depth of 60 m. It has been visible an imprint of the *Cerastoderma vindobonense* (Partsch-Laskarev) mollusk shell. Photo by Lj. Rundić

Stratigraphically undevided the Jurassic-Cretaceous formations were found in Resnik and Rakovica (KGK-13 and KGK-15) at 118 and 80 m, respectively (RUNDIĆ et al. 2019), and in Cerak near Rakovica (BC-3, 42.3 m – MASLAREVIĆ & GAGIĆ, 1976). They discordantly underliethe various Miocene formations.

In the base of Tertiary, tectonized flysch-like the **Upper Cretaceous sediments** ( $K_f, K_2^{2-4}$ ) built mainly of succession of sandstones, laminated marls and siltstones were documented. In the well Ov-1 (Ovča) they were observed between 166–330 m and interbedded by the sequences with organic “rot”

(Fig. 3). Similarly, they have been documented within the tectonized and partially eroded compressed synclinal depression near Bavanište (Bav-1, Fig. 6). From a depth of 1,823–1,825 m, a rich association of planktonic foraminifers was determined: *Globotruncana arca* (CUSHMAN), *G. tricarinata* (QUE-REAU), *G. concavata* (BROTZEN), *Marginotruncana coronata* (BOLLI), *Marssonella oxygona* (REUSS), *Dicarinella concavata* (BROTZEN), *Rosita fornicata* (PLUMMER), etc. The association also includes numerous globigerinids, lenticulins, textularians, rotalids, radiolarians and ostracods (det. M. Čanović – ČANOVIĆ & KEMENCI, 1988). In the depth interval 1,874–1,993 m, the calcareous nannoplankton were identified from sandstones and siltstones: *Prediscospahera cretacea* (ARKHANGELSKY), *Watznaueria barnesae* (BLACK in BLACK and BARNES), *Eiffelithus eximius* (STOVER), *Chiastozygus litterarius* (GÓRKA), *Tranolithus orionatus* REINHARDT, *Zygodiscus elegans* GARTNER, etc. which indicates the Upper Turonian–Senonian (det. Đ. Mihajlović- internal report of the Naftagas, unpublished).

On the Belgrade side, the Upper Cretaceous flysch sediments were drilled on Ada Ciganlija (DB-10, 21m; DB-9, 24m; DB-8, 60 m; DB-6, 80 m - KNEŽEVIĆ et al. 2012), near Branko’s bridge (UPD-1, 127 m - RUNDIĆ et al. 2011), in New Belgrade at the confluence of the Sava and the Danube rivers (PdUS-3, >126 m, PdUS-8, 43m and PdUS-13, 128 m - KNEŽEVIĆ & GANIĆ, 2005, 2008). Further to south, they were found in Leštane (Le-II) at 278 m (SPAJIĆ & DŽODŽO-TOMIĆ, 1973).

**Table 1.** Excerpt data of the Neogene basis and the represented Neogene cover of the Belgrade area.

No.	Location of well	Name of well	The well bottom (m)	Depth of Neogene basins (m)	Upper depth of Neogene units (m)	Reference
1.	Novi Beograd	PdUS-1	-	It is not drilled	42 Bd, 37 Pn, 31 Q	RUNDIĆ et al., 2011
2.	Novi Beograd	PdUS-2	127	44, Cr-Pg flysch	42 Bd, 36 Pn+Q	RUNDIĆ et al., 2011
3.	Novi Beograd	PdUS-3	126	It is not drilled	52 Bd, 38Sm, 22 Pn+Q	RUNDIĆ et al., 2011
4.	Novi Beograd	PdUS-5	84	It is not drilled	26 Bd+Q	RUNDIĆ et al., 2011
5.	Novi Beograd	PdUS-7	78	It is not drilled	72 Bd, 52 Sm, 30 Pn+Q	RUNDIĆ et al., 2011
6.	Ušće - Museum	PdUS-8	52	43, Cr-Pg flysch	30.8 Bd, 29 Pn+Q	KNEŽEVIĆ & GANIĆ, 2005
7.	Novi Beograd	PdUS-9	140	It is not drilled	72 Bd, 52 Sm, 30 Pn+Q	KNEŽEVIĆ & GANIĆ, 2005
8.	Novi Beograd	PdUS-10	142	It is not drilled	84 Bd, 55 Sm, 30 Pn+Q	KNEŽEVIĆ & GANIĆ, 2005
9.	Novi Beograd	PdUS-13	137	128, Cr-Pg flysch	93 Bd, 82 Sm, 31 Pn+Q	KNEŽEVIĆ & GANIĆ, 2005
10.	“Belgrade Waterfront”	B-1	94.7	60, Cr <sup>2</sup> limestone	29 Sm, 21Pn+Q	KNEŽEVIĆ et al. 2017
11.	Ada Ciganlija - spitz	DB-5	68	It is not drilled	32 Pn+Q	KNEŽEVIĆ et al. 2012
12.	Ada Ciganlija - spitz	DB-6	92	80, Cr-Pg flysch	65 Sm, Pn+Q	KNEŽEVIĆ et al. 2012
13.	Ada Ciganlija - spitz	DB-7	67	It is not drilled	65 Sm, Pn+Q	KNEŽEVIĆ et al. 2012
14.	Ada Ciganlija - spitz	DB-8	80	60, Cr-Pg flysch	40 Sm, Pn+Q	KNEŽEVIĆ et al. 2012
15.	Ada Ciganlija - Čukarica	DB-9	43	24, Cr-Pg flysch	14 Sm+Q	KNEŽEVIĆ et al. 2012
16.	Ada Ciganlija - Čukarica	DB-10	40	21, Cr-Pg flysch	11 Sm+Q	KNEŽEVIĆ et al. 2012
17.	Branko's Bridge - Beograd	UPD-1	130	127, Cr-Pg flysch	68 Bd, 60 Sm, 33 Pn+Q	RUNDIĆ et al., 2011
18.	Beograd - Dorćol	No name *EC	161	It is not drilled	97 Bd sandstone	LUKOVIĆ, 1922
19.	Beograd - Skadarlija	BC-3	321	147, Cr <sup>2</sup> sandstone	64.5 Clay, limestone	TOMIĆ, 2005
20.	Beograd - Karaburma fabric plant	B-1	180	138, Bd sandstone	124 sandy clay, 9 clay	“Geosonda” Report (unpublished)
21.	Beograd - Faculty of Veterinary Medicine	No name *VF	-	82, Cr <sup>2</sup> sandstone	Bd, 45 dand, 35 Leitha lim.	STEVANOVIĆ, 1977
22.	Beograd - 25. May Museum / Batićeva Str.	B-11	33	29, Cr <sup>2</sup> Urganian limestone	9 PBd Slan. Ser., 7 Sm+Q	KNEŽEVIĆ & KRSTIĆ, 2015
23.	Beograd - Dr. D. Mišović Hospital	B-1	120	It is not drilled	96 PBd Slan. Ser. 30 Bd+Sm+Q	KNEŽEVIĆ & KRSTIĆ, 2015
24.	Beograd - Konjarnik	No name *Ko	251	It is not drilled	150, Bd schlier., 30 Sm marl	STEVANOVIĆ, 1977
25.	Beograd - Žarkovo (Inst. Veterinary)	S-3	90.2	It is not drilled	76.9 Bd, 13.5 SM+Pn	STEVANOVIĆ, 1977
26.	Cerak - Jablanička Str.	BC-3	-	42.3, Cr-Pg flysch	11.3 Sm+Q	MASLAREVIĆ & GAGIĆ, 1976
27.	Veliko Selo	V-150	194	It is not drilled	13.6 PBd, Slan. ser., 3.2 Bd	DOLIĆ, 1977
28.	V. Mokri Lug	No name *VML	310	? 300, Cr-Pg flysch	72 Bd, 10,2 Sm+Q	SPAJIĆ & DŽODŽO-TOMIĆ, 1973
29.	Kumodraž	No name *Ku	333.6	It is not drilled	149 Bd, 69 Sm, 7 On+Q	SPAJIĆ & DŽODŽO-TOMIĆ, 1973
30.	Leštane	Le-II	400	278, Cr-Pg flysch	166 Bd, Sm+Pn	SPAJIĆ & DŽODŽO-TOMIĆ, 1973
31.	Bubanj potok	Bt 1-2	92	38, Serpentinite, 28 Breccias	21 PBd, 8 Bd+Q	RUNDIĆ et al., 2019
32.	Rakovica village	KGK-14	160	It is not drilled	100 Pn+Pt+Q	KNEŽEVIĆ, 1989
33.	Resnik	KGK-13	130	118, j-Cr?	83 Sm+Pn+Pt+Q	KNEŽEVIĆ, 1989
34.	Pinosava	KGK-15	97	80, j-Cr?	8 Pt+Q	KNEŽEVIĆ, 1989
35.	Vrčin	KGK-16	232	It is not drilled	212 Sm+Pn+Pt+Q	KNEŽEVIĆ, 1989
36.	Grocka	PG-6	110	It is not drilled	108 Pn+Q	RUNDIĆ, 1990
37.	Mala Moštanica	KG-28	210	It is not drilled	201 Pn+Pt+Q	RUNDIĆ, 1990

## Tertiary

### Miocene

**The early Miocene “pre-Badenian” (Pbt, Pbp)** is the oldest Tertiary unit found in most of the mentioned wells. It is built of terrigenous-subaquatic

molasses and shows a discordant relationship to the older substratum, i.e. Upper Cretaceous flysch. It is described in detail and graphically presented from a lot of deep wells (e.g. MARINOVIĆ, 1959, 1961, 1962, 1977; MARINOVIĆ & KEMENCI, 1964). In the wells Ov-1 (110–166 m), SA-2 (145–229 m), and G-1 (1,150–1,300 m), multicolored clastites with a predomi-

nance of greenish and brown-red clays, gray-green gravelly sands and conglomerates, fragments of cherts, serpentinites, carbonates, and carbonate concretions were observed (Figs. 3, 6). In the whole series, the remains of freshwater molluscan fauna such as *Congeria* sp., *Limnaeus* sp., *Planorbis* sp., *Unio* sp. and ostracods (MARINOVIĆ, 1962), as well as fish fragments have been poorly preserved and difficult to determinate (DULIĆ et al., 2010). Sporadically, smaller occurrence of coaly clays or thinner layers of coal can be found. However, based on the analysis of the palynological spectrum in the G-1 well, in which the dominant pollen grains of conifers are *Pityosporites microalatus* (R. POT) PF. et TH, *Triatriopollenites quietus* (POTONIÉ), *Monocolpopollenites tranquillus* (POTONIÉ) and spores *Polypodiaceosporites maschiensis* MURR., *Leiotriletes mexoides* KED with the accompanying association of microflora remains, the series corresponds to the Lower Miocene (KNEŽEVIĆ et al., 1994). Close to Ovča, this serie of oxidative genesis locally thickens towards east on a visible morphostructural ridge. However, in the sunken part east of the system of stepped faults, within the Pančevo depression, there are significantly different pre-Badenian, the gray-black **sub-aquatic pelites (Pbp) of redoxing genesis (Pč-1)**. In two intervals between 2,339 and 2,381 m, the black to black-gray slightly marly siltstones with thinner transition zones into gray-black fine-grained, partially and clayey-marly sandstones were cored. A scarce Lower Miocene content of the small fern and pollen spores was found in them: *Polypodiaceosporites* cf. *spiniverrucatus*, *P.* cf. *lusaticus*, *Polyodiaceosporites* sp., *Laevigatosporites* sp., *Torioisporites* sp., *Tricolpopollenites* sp., *Ephedripites* sp., *Sulbtriporopollenites simplex*, *Triatriopollenites hiatus*, *Monocolpopollenites* sp., etc. (det. I. Dulić - internal report of the Naftagas, unpublished).

By correlating of the logging diagrams (Marinović, Maksimčev and Janković), the Lower Miocene interval was simultaneously extended by insight into sieve samples (Stratigraphic frame 1,980–2,395 m, the Naftagas fund), which indicates that the series reaches a thickness of over 400 m (central part on the Figs. 3 and 4).

On the right side of the Danube river, an early Miocene continental-lacustrine “colorful” series

permeated with volcanoclastites is known on the surface of the terrain and from numerous wells in Višnjica, Slanci, Veliko Selo and Torlak area (PAVLOVIĆ, 1922; STANGAČILOVIĆ, 1969; PAVLOVIĆ, 1976; DOLIĆ, 1997, 1998; KRSTIĆ et al., 2012; RUNDIĆ et al., 2013). In vicinity of the Slanci village, the well VP-150 up to 194 m deep, did not enter the bedrock of the basin and the pre-Badenian series was drilled at a depth of 13.6 m (DOLIĆ, 1997). In other parts of Belgrade, drilling has found the equivalents of this oldest Miocene unit, over which the sediments of the marine Badenian mostly lie discordantly. In the B-11 well (near the May, 25 Museum), the colorful Lower Miocene succession was found at a depth of 9 m and near to the D. Mišović Hospital (B-1) at the depth of 96 m (KNEŽEVIĆ & KRSTIĆ, 2015). In the Bt 1-2 well (Ljubičica–Bubanj potok) similar unit was found, where in 21 m depth, it lies under the Badenian carbonates (RUNDIĆ et al., 2019).

**Marine, archipelago-dispersed sediments of the Badenian (Bd)** transgressively cover stratigraphically different geological substrates. They were found in wells Ov-1 (76–110 m), SA-2 (112–145 m), G-1 (1,060–1,150 m), Bav-1 (1,596–1,821 m), Doz-1 (1,479–1,800 m), Do-1 (1,515–1,889 m), BNs-1 (1,350–1,724 m), Pč-1 (1,452–1,980 m). Shallowest below the surface (76 m), they were drilled in the Mesozoic ridge near Ovča where their thickness is only 35 m (Fig. 3), while on the sides of the morphostructures Gloganj–Jabuka, Omoljica, Banatsko Novo Selo and Vladimirovac they completely wedged out. They are the deepest observed in the Pančevo depression (1,980 m), where they transgressively and discordantly overlies the early Miocene rocks and reach up to 550 m thick. Near Bavanište (1,821 m), Dolovo (1,889 m) and Banatsko Novo Selo (1,724 m) they discordantly overlies the Upper Cretaceous or Lower Cretaceous deposits (Fig. 6). Based on very numerous fossil remains (mollusks, foraminifers, algae, etc.) three different type of the Badenian facies have been identified: a) Basin and the basinal-lagoon, b) coastal and the shallow water-reef and c) mixed one (MARINOVIĆ, 1977). Concerning the different Badenian facies in the studied area, also wrote KNEŽEVIĆ et al. (1994), GAJIĆ et al. (2008) and ANĐELKOVIĆ & RADIVOJEVIĆ (2018). Finding of planktonic and benthic foraminifers in the well Do-1 (1,575–1,690 m) such

as *Asterigerinata planorbis* (D'ORBIGNY), *Cibicides dutemplei* D'ORBIGNY, *C. ungerianus* D'ORBIGNY, *C. pseudoungerianus* CUSHMAN, *Globigerinoides* (= *Trilobatus*) *trilobus* (REUSS), *Glandulina laevigata* D'ORBIGNY, *Cibicides* (= *Heterolepa*) *dutemplei* (D'ORBIGNY), *Globulina gibba* D'ORBIGNY, *Borelis mello* (FICHTEL & MOLL), etc.), mollusks (*Lucina incrasata* DUBOIS, *Cardium* sp., *Anadara* sp., *Ostrea* sp., *Chlamys* sp., *Dentalium badense* PARTSCH, etc.) and red algae *Lithothamnion* sp. confirm the true marine Badenian mixed character of the mentioned deposits (det. V. Marković & M. Buljan – “Naftagas” Novi Sad). In terms of facies characteristics, in addition to various sandstones, marls and marly clays, typical reef limestones with an abundance of fossil algae, bryozoans, foraminifers and mollusks have been identified.

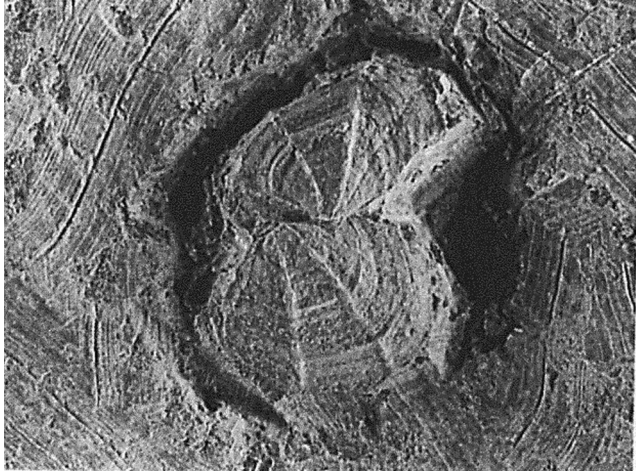
In the area of the Belgrade Danube meander, they were explored on the surface in Višnjica, Slanci and Veliko Selo and transgressively overlie the Lower Miocene “colorful series” or Slanci Formation (PAVLOVIĆ, 1922; LUKOVIĆ, 1922; DOLIĆ, 1997; 1998; RUNDIĆ et al., 2013; SCHWARZHANS et al., 2015; MANDIĆ et al., 2019). Near the confluence of the Sava and Danube rivers, in the wells PdUS-9 and PdUS-10, the Badenian sediments were drilled in the interval 72–84 m depth and were mostly built of the Leitha limestone and a small part of sandstone (KNEŽEVIĆ & GANIĆ, 2005, 2008). In the PdUS-13 well, the similar massive limestones are found at depth of 93–128 m and cover the Upper Cretaceous sandstones. On the Srem side, i.e. in New Belgrade, the Badenian deposits are also present in other wells as shown in Table 1.

In the area south of Danube river, the Badenian deposits have been studied by several authors (e.g. SPAJIĆ & DŽODŽO-TOMIĆ, 1973; STEVANOVIĆ, 1975, 1977 and references therein; KNEŽEVIĆ & GANIĆ, 2005; GANIĆ et al., 2016). They occupy a significant area near city center (Kalemegdan, Tašmajdan, Dorćol, Karaburma, Konjarnik, Kumodraž, Banjica, Rakovica, Torlak, etc.) or were proven in wells where they are covered by younger Miocene or Quaternary deposits. For example, in the well B-1 on Kalemegdan they were found at a depth of 23 m (RUNDIĆ et al., 2011) while near Branko's bridge, on the Srem side, observed in the well UDP-1 at a depth of 68m (Table 1). In Serdar Jola Street near the D. Mišović Hospital, in the well B-1 about 120 m deep, Badenian sands and sandy lime-

stones were discovered at 30 m depth and are over 60 m thick (KNEŽEVIĆ & KRSTIĆ, 2015). At Dorćol, near the Power plant, in the well EC with a total depth of 161 m, which did not drill the paleorelief, Badenian sediments were found at 97 m (LUKOVIĆ, 1922). In an unnamed well in Kumodraž (here marked as Ku – see Table 1), they were discovered at a depth of 149–333.6 m, while in Veliki Mokri Lug (VML) and Žarkovo (S-3) they were discovered from depths of 72 and 76.9 m to the end of the wells (SPAJIĆ & DŽODŽO-TOMIĆ, 1973; STEVANOVIĆ, 1977 - Table 1). In the area of Ljubičica and Bubanj potok, they are already drilled at 8m of depth (Bt 1-2) and are quite reduced in thickness and overlie the pre-Badenian mollase (RUNDIĆ et al., 2019).

**The marine-brackish sediments of the Sarmatian (Sm)**, built of sands, laminated marls, siltstones, clays and partly sandy limestones, were found in the following wells: Ov-1 (70–76 m), Ovča c.b. (91 m), SA-2 (103–112 m), Pč-1 (1,031–1,452 m), Doz-1 (1,046–1,479 m), Do-1 (990–1,515 m), G-1 (620–1,050 m), Om-1 (749–932 m), Bav-1 (1,067–1,596 m), BNs-1 (952–1,350 m), BNs-1 (1,053–1,111 m). Similar to the Badenian deposits, they have the smallest thickness in Ovča and appear below the surface of the terrain at 70 m. From there to the east, towards Bavanište and Dolovo, they sank significantly, thickened in the Pančevo depression and reached a thickness of 400–500 m (Fig. 3). It is similar in the area of Grocka in the extreme south of the studied area (Fig. 6). At the structural ridge of Omoljica, their thickness has been reduced to about 180 m. On the disrupted paleohorst of Banatsko Novo Selo (BNs-1), the reduced Sarmatian layers about 59 m thick, discordantly overlying the Lower Cretaceous paleorelief. Fossils are not numerous in the Sarmatian deposits, but their finding clearly indicates a change in the sedimentation regime and the transition to a reduced-marine environment. In addition to the small benthic foraminifers (*Elphidium macellum* (FICHTEL & MOLL), *Elphidium hauerinum* (D'ORBIGNY) *El. reginum* (D'ORBIGNY), *Quinqueloculina acneriana* D'ORBIGNY, *Porosonion granosum* (D'ORBIGNY), *Ammonia* ex. gr. *beccarii* (LINNE), etc.) and numerous ostracods, these deposits contain the particular assemblages of bivalves and gastropods such as *Ervilia dissita* EICHWALD, *Pirenella picta* DEFRANCE, *Musculus sarmaticus* (GATUEV), *Ceras-*

*toderma vindobonensis* (PARTSCH), *Cardium* (*Cerastoderma*) *transcarpaticum* GRISCHKIEVICH (Fig. 8) (MARINOVIĆ, 1970, 1977; KNEŽEVIĆ et al., 1994, 2018a; GAJIĆ et al., 2008).



**Fig. 8.** *Cardium* (*Cerastoderma*) *transcarpaticum* Grischkievich (Ov-1, 70 m). The natural size of the fossil is 14×12 mm. Determination and photo by Đ. Marinović.

Sarmatian deposits, widely represented in the area of the Belgrade Danube meander, are present on the surface in Karaburma, Mirjevo, and further to the southeast towards Vinča, Ritopek, Leštani and Grocka, about which there are previously published data (STEVANOVIĆ, 1977; SPAJIĆ, 1987; MIHAJLOVIĆ & KNEŽEVIĆ, 1989; ŠUMAR & RUNDIĆ, 1992; KNEŽEVIĆ & GANIĆ, 2008; RUNDIĆ et al., 2012). In addition, they are known from Prokop, Čukarica, Rakovica, Leštane, Resnik, Grocka (MITROVIĆ & RUNDIĆ, 1991; KNEŽEVIĆ et al., 1994, 2012, 2017; RUNDIĆ et al., 2019).

Close to the Sava and Danube rivers confluence, Sarmatian sands and sandy limestones were drilled in the wells PdUS-9 (52–72 m) near Branko's Bridge, PdUS-10 (55–84 m) near the Old Bridge and PdUS-13 (82–93 m) near the Ušće Palace (KNEŽEVIĆ & GANIĆ, 2005, 2008). Similar thickness of sediments and their depth position were found in the wells PdUS-3 (38–52 m) and PdUS-7 (52–72 m), UPD-1 (60–68 m) (RUNDIĆ et al., 2011). In the well B-1, near the Belgrade Tower ("Belgrade Waterfront"), it was determined that the Sarmatian sandy limestones about 30 m thick (29–60) transgressively overlie the Lower Cretaceous sandstones and limestones (KNEŽEVIĆ et al.,

2017). At the pylon of the Ada bridge, the wells DB-6, DB-7 and DB-8 (see Table 1) drilled Sarmatian crumbly, sandy limestones in the depth interval of 40–65m which discordantly overlie the Upper Cretaceous-Paleogene flysch (KNEŽEVIĆ et al., 2012). On the Čukarica side of the bridge, Sarmatian was drilled shallowly in the same relation to the mentioned flysch and was found in the wells DB-9 (14–24 m), and DB-10 (11–21 m) (KNEŽEVIĆ et al., 2012 – Table 1). In the part of the terrain around Leštane (Le-II) and Kumodraž (Ku), the Sarmatian carbonate sediments reach a significantly greater thickness (Table 1).

**Brackish and caspibrackish sediments of the Upper Miocene, Pannonian stage s. str. (Pn)**, known as the Lake Pannon deposits have a significant distribution. Lithologically, they are built of marls, sandy marls, siltstones and sands that were discovered in the following wells: Ov-1 (29–59 m), Ovča c.b. (30–70 m), SA-2 (35–93 m), Gl-1 (829–865 m), Pč-1 (921–1,031 m), Doz-1 (856–1,046 m), Do-1 (712–990 m), G-1 (300–620 m), Om-1 (540–749 m), Bav-1 (843–1,067 m), BNs-1 (845–952 m), and BNs-1 (902–1,053 m). The total thickness of these deposits in the depression south and north of Omoljica is more than 300 m with a decreasing trend of thickness towards Banatsko Novo Selo at about 150 m (Fig. 6). Near Ovča and Glogonj, they are reduced to only about 30 m (Figs. 3 and 5). They contain a rich and diverse fauna of mollusks, among which are predominantly represented: *Congeria banatica* R. HOERNES (Fig. 9), *C. ramphophora* BRUSINA, *Monodacna viennensis* PAPP, *Limnocardium promultistriatum* JEKELIUS, *Orygoceras fuchsi* KITTL, *Gyraulus* cf. *preponticus* GORJANOVIĆ-KRAMBERGER, et al. There are also numerous ostracods such as *Lineocypris reticulata* MEHES, *Serbiella sagitossa* KRSTIĆ, *Hungarocypris hieroglyphica* MEHES, *Amplocypris subacuta* ZALANYI, *Cyprideis heterostigma obessa* REUSS, *Hemicytheria loerentheyi* MEHES, etc. (MARINOVIĆ, 1970, 1977; SPAJIĆ, 1987; RUNDIĆ, 1990; KNEŽEVIĆ et al., 1994, 2018a; RUNDIĆ & MITROVIĆ, 2005; RUNDIĆ et al., 2011).

South of the Sava and the Danube rivers, the Pannonian white and gray marls and silts have a large surface distribution in the area of the city of Belgrade. They underlie the Quaternary alluvial, proluvial, loess or loess-like sediments, and overlie the older Miocene units (MILETIĆ-SPAJIĆ, 1961; KRSTIĆ, 1973,



**Fig. 9.** Pannonian marl with *Congeria banatica* R. Hoernes and other mollusks (SA-2, 55 m). Photo by Lj. Rundić

1985; KNEŽEVIĆ et al., 1994; RUNDIĆ et al., 2011). It was also noticed that along the Sava stepped fault, on the left bank of the Sava river, were sunk to depths of over 50 m (RUNDIĆ et al., 2011; KNEŽEVIĆ et al., 2012). On the right bank of the Sava river, they are often visible on the surface or shallowly below the Quaternary (RUNDIĆ et al., 2011). In the well B-1 ("Belgrade Waterfront"), the Pannonian gray marls drilled below the Quaternary anthropogenic and alluvial deposits between 21–29 m of depth (KNEŽEVIĆ et al., 2017). Similar Pannonian sediments have been found in other shallow wells in the area of Beli Potok, Vrčin, Zaklopača, Begaljica and Grocka where they have a much greater thickness (e.g. KNEŽEVIĆ, 1989, 1990; RUNDIĆ, 1990) (Table 1)

In the area of the Great War Island and the confluence of Sava and Danube rivers, Pannonian gray marls were drilled in the wells PdUS-9 (30–52 m) near Branko's bridge, PdUS-10 (30–55 m) near the Old bridge and PdUS-13 (31–82 m) near the Ušće Palace (KNEŽEVIĆ & GANIĆ, 2005, 2008). A similar thickness was found in the wells PdUS-3 (22–38 m) and PdUS-7 (30–52 m) (RUNDIĆ et al., 2011). In Ada Cigan-

lija, near the Ada bridge, they were found in wells DB-6, DB-7 and DB-8 in the depth interval of 21–65 m where they overlie Sarmatian limestones (KNEŽEVIĆ et al., 2012). In New Belgrade, they were drilled directly below the Quaternary deposits at a depth of more than 30 m in wells DB-4 and DB-5 where they reached up to 40 m thick (KNEŽEVIĆ et al., 2012).

**The Upper Miocene - Pontian stage** (sensu STEVANOVIĆ, 1990) is divided into two parts: Pt<sub>1</sub> and Pt<sub>2</sub>. In the wells around Pančevo, Bavanište, Dolovo and Banatsko Novo Selo, it reaches a total thickness between 600–700 m (Pč-1, Bav-1, Doz-1, BNSj-1, BNS-1), while on the Ovča structural ridge it is completely missing (Figs. 3, 5 and 6). The older level of the **Pontian (Pt<sub>1</sub>)** consists of brackish sands, marls and siltstones discovered in the following wells: Gl-1 (640–829 m), Pč-1 (573–921 m), Doz-1 (460–856 m), Do-1 (310–712 m), G-1 (150–300 m), Om-1 (260–540 m), Bav-1 (450–843 m), BNSj-1 (450–845 m), and BNS-1 (574–902 m). Biostratigraphically, the older Pontian was proved on the basis of the findings of caspi-brackish mollusks (*Paradacna abichi* HOERNES, *Didacna otioforum* BRUSINA) and ostracods (*Leptocythere andrusovi* LIVENTAL, *Candona (Camptocypria) alata* ZALANYI, *Loxoconchs schweyeri* SUZIN, *Hemicytheria pejinovicensis* ZALANYI, *Bacunella dorsoaricata* ZALANYI, etc.) (MARINOVIĆ, 1970, 1977; KNEŽEVIĆ et al., 1994).

The younger level of **Pontian (Pt<sub>2</sub>)** concordantly overlies the older Pontian and determined in the following wells: Gl-1 (381–640), Pč-1 (345–573), Doz-1 (175–460), Do-1 (155–310), G-1 (0–150), Om-1 (60–260), Bav-1 (125–450), BNSj-1 (130–450), and BNS-1 (235–574). It can be seen that in the part of the trench-depression it reaches a thickness of over 300 m (Fig. 6). Lithologically, it is represented by sands and sandy clays with admixtures of coal and coal clays. Numerous fossils indicate a freshwater lake environment (e.g. *Paradacna okrugići* BRUSINA, *Caladacna steindachneri* BRUSINA, *Limnocardium ochetophorum* BRUSINA, *Zagrabica* sp., *Pisidium* sp., *Candona (Camptocypria) balcanica* ZALANYI, *Candona (Pontoniella) lotzyi* ZALANYI, *Leptocythere cornuto-costata* SCHWEYER, etc.).

In the wider Belgrade area, the Pontian sediments are known from M. Moštanica, Avala, Zuce and Vrčin, and especially from Rakovica and the so-

called Beli Potok trench (STEVANOVIĆ, 1977; KNEŽEVIĆ, 1989 – Table 1). Both of the above-mentioned levels of the Pontian are well documented faunistically (RUNDIĆ, 1990; STEVANOVIĆ, 1990; RUNDIĆ et al., 2019).

### **Pliocene**

**The Pliocene Paludina layers (PS<sub>1-3</sub>)** were determined only on the Banat side of the studied area. All the three levels of Paludina layers were discovered in Glogonj and the Pančevo depression (Gl-1, 100–381 m and Pč-1, 140–345 m). In Glogonj, the oldest horizon corresponds to the layers with *Viviparus pannonicus* NEUMAYR (295–381 m), the middle horizon marks the *V. bifarcinatus* (BIELZ) zone in the depth of 230–295 m, and the youngest one horizon with the index species *V. altecarinatus* BRUSINA was found in a depth interval 100–230 m. Near Dolovo only older levels were found (Doz-1, 115–175; Do-1, 113–155 m) (Figs. 3, 4 and 6). Further to south, towards Omoljica, they completely disappear and also missing north from Ovča. They were delimited by well logging and the presence of morphologically different gastropods of the genus *Viviparus* and other freshwater-lacustrine and completely freshwater molluscs (*Viviparus pannonicus* NEUMAYR, *V. bifarcinatus* (BIELZ), *V. cf. altecarinatus* BRUSINA, *Melanopsis lanceolata* M. NEUMAYR, *Valvata* sp., *Lyrcea* sp., *Unio* sp., *Nerodontha* sp.) (JANKOVIĆ, 1970, 1977; MARINOVIĆ et al., 2016; MARINOVIĆ, 2017). “Paludina layers” in Belgrade and its surroundings south of the Danube river are not present, while further to north they are present in the vicinity of Sremski Karlovci (e.g. RUNDIĆ et al., 2016).

### **Quaternary**

Quaternary deposits of different genesis represent the youngest unit of basin filling in the area of SW Banat, i.e. the Belgrade city area. In the mentioned wells in Banat, they reach a total thickness of over 140 m (Pč-1) in the Pančevo depression. In the south, towards Omoljica, their thickness is reduced to only 60 m and further towards the Danube river (G-1) they have a very small thickness. On the morphostructural ridge Belgrade - Ovča they discordantly overlie the

Pannonian marls (Fig. 3). Lithologically, these are various terrestrial, fluvial-swamp sands, gravels and gravel clays with the remains of fossil gastropods and bivalves (*Pisidium rugosum* NEUMAYR, *Viviparus* cf. *diluvianus* (KUNTH), *Lithoglyphus naticoides* (PFEIFFER) and freshwater ostracods (*Candona* sp., *Scottia* sp., etc.). In the well Gl-1 (Glogonj) at a depth of 100 m, the base of the Quaternary was defined based on the findings of *Viviparus* cf. *diluvianus* (KUNTH).

Above that, fluvial-eolian loess-paleosol sequences cover most of the study area on both sides of the Danube and Sava rivers (NENADIĆ et al., 2011; TOLJIĆ et al., 2014; GAUDENYIET al., 2015; KNEŽEVIĆ et al., 2018b).

### **Structural-tectonic and paleogeographic interpretation**

The structural-tectonic interpretation of primarily Neogene evolution of the Belgrade wider area is based on combined geological-geophysical data (correlations of well logging data and paleontological-stratigraphic elements transferred on the network of reflective-seismic sections, gravimetric and geomagnetic maps, etc.). South of the Sava and the Danube rivers, an abundant literature data and available surface outcrops have been supplemented by selected geological columns from the field and an instructive stratigraphic profiles of wells.

Literature data on the presence of pre-Neogene formations in complex tectonic relations, which are present in the surface around Belgrade vicinity, together with magmato-volcanogenic intrusions and extrusions of limited size, are not necessary or possible to repeat here. Therefore, on the constructed map (Fig. 10), their outer contours with minor changes as far as the size of the map allowed, are approximately framed according to the regional map by MILOVANOVIĆ & ĆIRIĆ (1968).

In order to emphasize the important depth structural configuration, the map avoids plotting literary-numerous variants (mostly assumed) of mutually inconsistent faults of different conceptions, names, directions and mutual relations. The routes of the reference mentioned faults fit in organized directions of denser, relatively short curved uniform equidistant distances. The large fault systems are recognizable



by distinctly condensed isopaches of the main fractured directions, in principle, an overall disjunctively shaped neotectonic structures.

Taking into account all the above-mentioned, three main structural units were separated in the investigated area: Belgrade-Banat Morphostructural Ridge (BBMR), Pančevo-Danube Neogene Depression (PDND) and the West Banat Neogene Belt with the edge of regional the Srem depression (WBNB).

**The Belgrade-Banat morphostructural ridge (BBMR)**, in this article, is defined by the eastern side from Crepaja in the north, the lower course of the Tamiš river and the Danube riverbed to Ritopek, and then across Vrčin further to the south. The western border is marked by a fragmented rim of regional the Srem Neogene depression, which continues from Moštanica, Surčin and the Zemun polje, through Kobilovo on the Banat side, to the northeast, encompassing the Jabuka and Glogonj massifs (Fig. 10, central part of the map).

In the central part of BBMR, the geomagnetic impact is most pronounced along the axis: Horst-massif Glogonj-Velika humka-Jabučki rit-Railway station of Ovča-Mirjevo-Mali Mokri Lug-Ljubičica-Zuce and further to Kasapovac. The specified route determines the belt of pre-Cretaceous penetration of ultrabasic magmatites of the Cimmerian tectogenesis, graphically shown as a sub-basin projection on the reference map of the Neogene base configuration (Fig. 10). In the meander of the Zavojnica river, near Zuce, as well as east of Avala Mt. to the south, serpentized peridotites on the surface are in a reverse west-vergent relation to the Cretaceous deposits they cover (MARKOVIĆ, 1985). From the closed maximum geomagnetic anomaly of Zuce, through Jajinci to Kanarevo brdo, the rectilinear lineament to the south decreases sharply, and somewhat milder in the parallel direction Banjica-Senjak, with the transverse segment Kanarevo brdo-Banjica (Belgrade center). These points to the routes of compensatory-connected the depth faults of Dinarides orientation with a dropped southwest wing.

To understanding the area of Avala Mt., in the shortest form, it is necessary to combine two mutually complementary geological-geophysical approaches. The first one is that the dome-shape formed Avala Mt. (alt. 511), built of tectonized terrigenous flysch, including the lowest western and southern

periclinal, is marked by an anomalous geomagnetic minimum of a closed oval-funnel configuration, which indicates a depth absence of ultrabasic massive. Another approach is to slightly decrease the gravimetric values, generally a parallel orientation, south of the center of the Beli Potok Neogene trench and the previously mentioned Zuce, including at the morphologically dominant massif of Avala Mt. It means that below its cap built of flysch sediments there is no petrologically indeterminate magmatic pluton, or an ultrabasic rock of older Alpine magmatite of meridional orientation. Contrary, it is an oval-transverse intrusive occurrence (acceptable literary as a lacolite) in principle of acidic composition, certainly from younger tectonic stage. It corresponds to granite-granodiorite, or similar magmatic differentiations. This is supported by the once established occurrences of post-Cretaceous penetration of neutral or neutral-acid apophyses, veins and phylonites, both at the Avala Mt. massif itself and in the surrounding wider area, partly with a contact changes, or even later hydrothermal mineralization in Šuplja stena and Džever kamen (GUDOVIĆ, 1875; DIMITRIJEVIĆ, 1931; STEVANOVIĆ, 1977).

A positive gravimetric anomaly of the E-NE direction is expressed from the elbow of Zavojnica river. On surface in the area of Boleč mehana and Babin vis, the opposite inclinations of Sarmatian sediments are noticeable, which is indicative of the existence of a deep vault that sinks around Ritopek towards Ivanovo in Banat.

South of the great meander of Danube river, a gravimetric anomaly of a closed oval configuration stands out, with a maximum increment below Slanci. However, the geomagnetic influence from Mirjevo, i.e. the axis of the deep fault to the east, is in a trend of continuous decrease, indicative of the deficit of ultrabasic masses, within the not deeply sunken, an objectively turbidite and Cretaceous flysch sub-basin structure. On the northeastern wing of the morphostructure, within the well V-150, the basin bedrock was not reached to a depth of 194 m, nor was the deepest well up to 219 m in that area (DOLIĆ, 1997). According to the constructed map here, it would be on a vault at a depth of about 200 m.

To the presence of depth igneous channels from the basin's floor of high convective heat transfer as well as older Miocene effusive breakthroughs is in-

licated by higher geothermal gradients (MARINOVIĆ, 2019) to the closed anomaly of 0,09 °C/m which is near 40% larger than the gradients of area with the sunken Neogene sedimentary column with a dominantly conductive heat influence on the eastern, Banat side. In this area, thanks to renewed volcanogenic deposits within the pre-Badenian continental-lacustrine series partly with cross-sedimentation (STEVANOVIĆ, 1975; MILAKOVIĆ, 1986; ĆIRIĆ, 1992), the morphostructural elements originally adapted to the floor changes were altered by accompanying extrusions and additionally disturbed by synchronous pleats with fault occurrences, up to local reorientations in relation to the original structure. Pre-Badenian antiformal complex with its discordant Badenian cover, along the stepped fault gradually sinks into the Pančevo depression, and through Mirjevo it is connected to the Belgrade structural units by a shallow saddle (Fig. 10).

**The Mokri lug Neogene subdepression** is discontinuously formed within the contour of Zvezdara south–Šumice–Marinkova bara–Miloševac–Jajinci–Razbojište–Kumodraž–Kaludžerica (generally, south-east from Belgrade center, Fig. 10). On the basis of combined geological columns from the surface and from wells (STEVANOVIĆ, 1977; SPAJIĆ, 1987) very variable thicknesses of stratigraphic members were interpreted in ranges: pre-Badenian 50–350 m, discordantly Badenian 180–200 m, Sarmatian 150–200 m, Pannonian and Pontian (partly eroded) 50–180 m but, in the center of the subdepression, according to the map, with a total average thickness of about 550 m. In the direction to Vinča, it is connected to the west-Omljica structural saddle in Banat by a small faulted structural depression. The discordant basin floor is built by the Upper Cretaceous flysch sediments (Le-II, 278 m) with a longitudinal belt of ultrabasic magmatites (SPAJIĆ & DODŽO-TOMIĆ, 1973; SPAJIĆ, 1987).

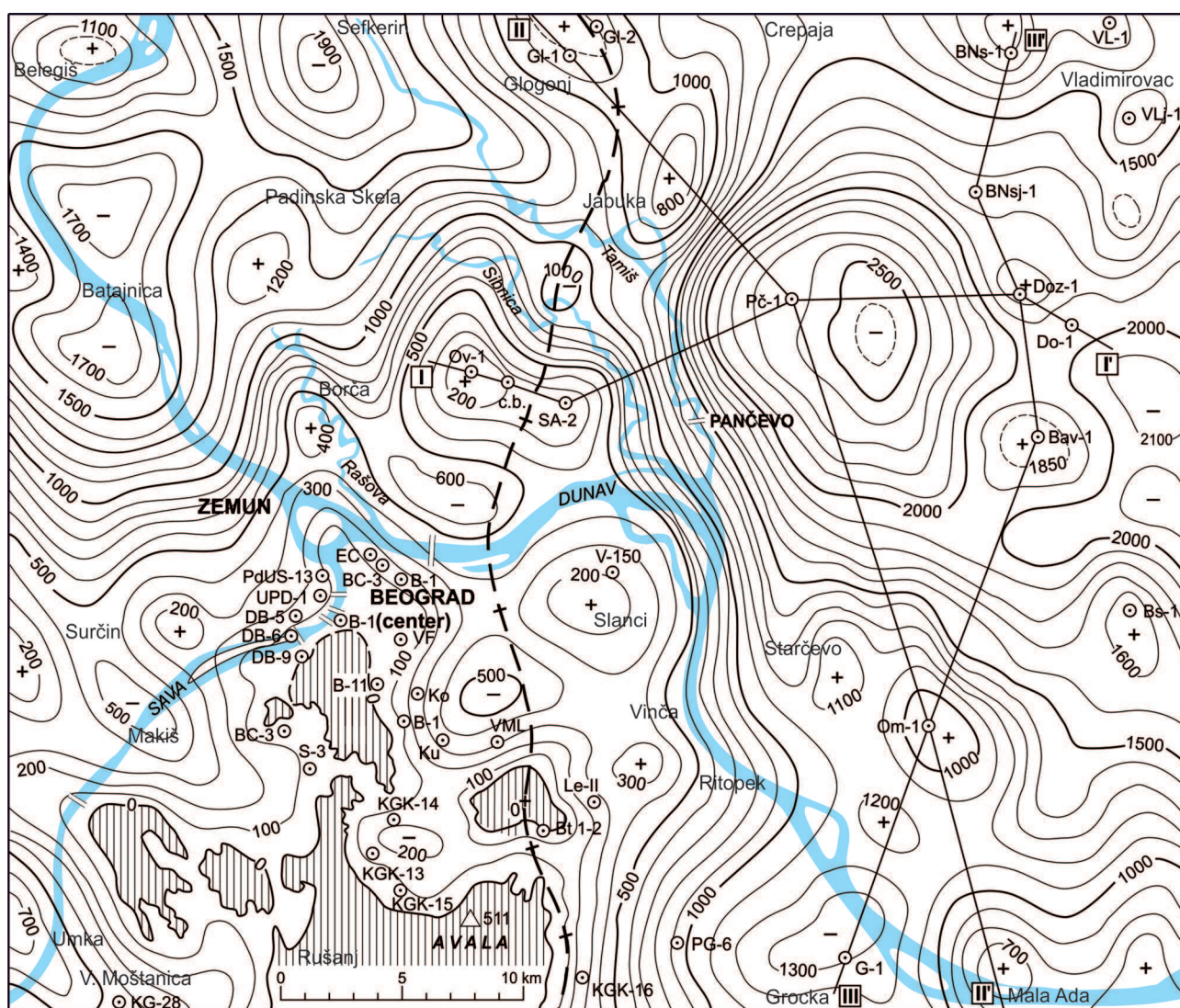
With the structural threshold of Torlak–Rakovica village, the subdepression is limitedly connected with the narrowed Beli Potok trench of E–W direction and a reduced sedimentary column from the Pre-Badenian to Pontian age (here, the projected depth up to 250 m), and over the northern foothills of Mt. Avala, from Zuce and Čot (STEVANOVIĆ, 1977), it was paleogeographically connected to the Vrčin–

Zaklopača wider area i.e. the western rim of the Grocka trench-depression (Fig. 10) (KNEŽEVIĆ, 1989; KNEŽEVIĆ et al., 1994; RUNDIĆ, 1990; RUNDIĆ et al., 2019).

To the north of the discovered tectonized Mesozoic massifs of the Belgrade hills, below the morphologically disparate urban area, **the Badenian shallow-water ridge of Čubura-Tašmajdan–Kalemegdan (Belgrade center)** point up, with its especially southern extensions. In that area where the Lower Cretaceous rocks build the Neogene basis (KNEŽEVIĆ & KRSTIĆ, 2015, during the pre-Pontian overflow-outflow episodes, the various sections of the thinned, originally more complete sedimentary column were partially or completely eroded. This refers to the entire area of the flange-separated paleorelief of complex geometry, where the cover built of the Neogene sediments are generally less than 100 m thick, i.e. there are wedge-shaped, lenticular and very thin layers which was noticed by several authors (e.g. STEVANOVIĆ, 1977; KNEŽEVIĆ & GANIĆ, 2005, 2008; KNEŽEVIĆ et al., 2015, 2017; RUNDIĆ et al., 2011).

Based on gravimetric measurements, especially the map of vertical gradients (BILIBAJKIĆ, 1998), the extension of mentioned structural ridge does not dominate from Kalemegdan towards Zemun, but continues along the Great War Island along the western side of the Rašova river towards Kovilovo, with a pronounced Borča antiformal, depth of 400–500 m. Literally accepted the “Donji Grad–Danube fault” (LASKAREV, 1949), has its northwestern extension on the Banat side, specifically along the eastern coast of Rašova river, to the intersection with the segment of the regional fault NW of the BBMG border, forming the SW side of the **structural trench Veliko Blato–Krnjača** as shown on the map (Figure 10, central part, north of the Danube).

**The Ovča morphostructure** is slightly inclined towards the structural saddle of the Višnjica part of the Belgrade Danube meander, and especially more strongly along the NW pericline, i.e. along the length of the fault diagonally formed of its northern flank, approximately along the southern coast of Sibnica river. From there, the majority of the pre-Badenian content of the structure builds a pass towards the more stable morphohorsts of Jabuka and Glogonj.



**Fig. 10.** The map of Neogene basis configuration (isopache  $E = 100$  m) constructed based on available data. The dashed line marks an apical axis of the Cimmerian phase of ultramafic rocks (by ĐM). Vertical hatching marks the simplified pre-Neogene countours (according to MILOVANOVIĆ & ČIRIĆ, 1968 and modified with new data).

On the western side of BBMR, from Čukarica and below Ada Ciganlija, there is a structural nose of northwestern orientation, with a subbasin antiform at a depth of about 200 m. By it closes the structural-arched space of the Belgrade geomorphological amphitheater in the area of Bežanija on the southwest side.

**The Makiš Neogene paleo-gulf depression**, in the structural sense, represents the ultimate rim of the Batajnica depression. It is a part of the tectonic trench formed between the fault system Bežanija gornje polje–Kneževac–Kijevo on the NE side, and the fault in the direction Surčin–Železnik–Orlovača

along the SW side, with here predicted Neogene substrate at about 500 m depth (SW part of the map, around the Sava river).

Finally, south of the Upper Cretaceous-Paleogene Ostružnica flysch horst-massif of orogenic meridian tectonics, a Neogene structural trench was formed, in the NW–SE direction, which has a depth of about 700 m between Umka and M. Moštanica and the extreme Miocene paleogeographic rim towards Sremčica (the extreme SW part of map).

**The Pančevo-Danube Neogene Depression (PDND)** extends east of the described BBMR. In that area, the largest morphostructural unit is the Pan-

čevo Neogene depression (Fig. 10, central and NE part). It has oval contours of 20×15 kilometers, with a bottom of about 2,600 m. The outer contour is somewhat elongated from Kačarevo to the north towards Crepaja, and to the south it has a trend of turning towards Bavanište. The western boundary is marked by a complex Neogene fault system, which connects from Crepaja to the eastern flank of the Jabuka horst massif to the already described the large longitudinal fault of the eastern BBMR boundary. On its SW side, the depression is characterized by the inner half-trench bay of Starčevo. The eastern boundary of the depression was determined by the morphostructural series of the sub-basin horst-massifs Banatsko Novo Selo–Dolovo west–Bavanište NW (Bav-1, Fig. 6). In the south, it is bordered by the Omoljica horst-massif.

The Neogene bedrock in central part of the depression is formed by tectonized, early Jurassic, dark to black pelites (sericite clays) (below 2,395 m in the well Pč-1), thicker than the drilled 338 m, without the presence of ultrabasic magmatites with determined direction towards Crepaja (Cp-1, 1,597 m). Along the length of the western and eastern sides, they are building a sub-basin basis predominantly of tectonized the Lower Cretaceous deposits with penetrations or synsedimentary basic magmatites and superpositionally limited the Upper Cretaceous flysch (Bav-1, Fig. 6). The Neogene depression in Pančevo should not be equated with the eastern trench of depression Dolovo selo–Skorenovac–Smederevo (further east, outside the map outlines), which is, with its NW segment to the interdepression threshold Dolovo west–Bavanište northwest (Bav-1) included in the constructed map.

These oldest Neogene sediments in the center of the depression are about 550 m thick. They were formed in extremely reduced, subaquatic conditions, which is especially emphasized in this paper due to significant differences in relation to heterogeneous, a predominant oxidative molasse of the surrounding areas. Badenian marine sediments, with the largest thickness up to 600 m, completely cover the reducing bottom molasses within the deepest sunken parts of the depression. On the sides of the depression, including the belt of the interdepression threshold (Bav-1, Doz-1, BNs-1), they hetero-

geneously lie directly above the sub-basin tectonized floor, but not covering the peripheral peaks of Omoljica, Jabuka and Banatsko Novo Selo. Marine-brackish Sarmatian, of generally transgressive continuity, east of the Jabuka horst massif abruptly thickens to the center of the depression (about 500 m), significantly covering the Omoljica horst, and sparsely (about 60 m) the extreme NE peripheral plateau of Banatsko Novo Selo (BNs-1).

The lacustrine, mostly marly caspi-brackish Pannonian-Pontian sediments, together of the greatest thickness (more than 900 m), are generally directed to centre with a pronounced trend of thinning towards the western edges of the depression, and in the zone with stepped faults, with complete extinction of the Pontian complex. The limnic-fluvial „Paludina layers“ (Pliocene) developed only north of the central part of the depression. Their thickness is about 400 m (Glogonj) with differentiated superposition members at the crossroads of the Pančevo and Sefkerin depressions. Quaternary swamp-loess and aeolian sediment in the central and SE parts of the depression, variably reaches a thickness of 150 m.

**The Grocka trench depression**, measuring 10×5 km, is elongated along the SW–NE axis, from Vrčin, to the crossover of the Omoljica horst massif and the Mala Ada (Brestovik) morphostructure on the Danube, up to about 1,300 m deep (extreme S and SE part of the map). Along the NE extension of trench, about 10 km long, it sinks abruptly towards the morphostructure of Bavanište selo. The basin bedrock is built by tectonic belts with the meridian direction of the upper Jurassic-lower Cretaceous complex (near Bavanište and with the Upper Cretaceous flysch), entirely without indications of ultrabasic magmatites.

The Neogene oxidation molasses of uncertain contours near Grocka up to 200 m thick (KNEŽEVIĆ et al., 1994), are covered by discordantly younger, the marine Badenian sediments, which thin along the SW rim and surrounding horst structures. The marine-brackish Sarmatian from the deeper sunken NE sides, thickens inversely to the SW and S, more than 300 m and together with the caspi-brackish Pannonian sediments up to 700 m. The marginal facies of the Pontian on the SW flanks of the subdepres-

sion wedged out from Grocka towards Zaklopača, and from Brestovik near the Danube river towards Begaljica, and significantly thicken on the NE extension of the subdepression trench from Banatski Brestovac to Bavanište. The relatively thin Quaternary cover has not been specifically studied.

During the Neogene tectonics, two depressions were formed on the northwestern side of BBMG: Sefkerin depression, west of the Tamiš river and the Batajnica depression, partly on the extreme SW part of the Banat Danube course and partly on the Srem side of the Danube course around Batajnica (NW part of the map).

**The Sefkerin depression** stretches from Opovo in the NW and Jabučki rit in the SE, about 25 kilometers long and about 10 km wide, with a maximum depth of about 1,900 m. Between the Jabuka horst and the NW flank of the Ovča massif, it is connected to the Pančevo depression by a structural saddle, and in the area of Besni fok–Padinska skela there is a wider communication with the Batajnica depression (Fig. 10). The basin bedrock along the NE flank of the depression is built by the already considered ultrabasites with a cover built of the Lower Cretaceous clastites. Under the central part of the depression, the tectonized Cretaceous flysch is prognostically represented. Based on increased geomagnetic influences, especially towards the Belegiš horst, younger Lower Cretaceous complexes are indicative, possibly with the iron-glaucanite clastites.

In this area, the older Miocene sediments are smaller in thickness compared to the Pančevo depression, but with an increased clay-marl complex, especially within the Pannonian–Pontian time, and an increased thickness of sandy-clay of Pliocene deposits. Above the inter-depression horst massifs of Jabuka and Glogonj, as the mentioned before, the ingressive overflow was achieved at the beginning of Pannonian time. From the Vrbovsko towards the top of the Belegiš horst on the Srem side, the total thickness of Neogene sediments decreases to about 1,100 m. The structural threshold towards the NE part of the Batajnica depression was interpreted at a depth of 1,500 m (the extreme NW part of the map).

**The Batajnica depression** was interpreted on the basis of the already cited combined gravimetric

and reflective-seismic indicators, harmonized with the data of exploration wells in eastern Srem. Within the covered area, east of the Ugrinovac–Surčin fault (visible on the map) and the morphostructural ridge Borča–Kovilovo–Vrbovski rit, on both sides of the Danube river it reaches depths of about 1,700 m. The internal dimensions average 20×10 km (western part of the map). A diagonal intra-depression fracture, with depths of about 500 m, is noticeable on the stretch Bežanija gornje polje–Zemun polje, that has NE extension to just mentioned the Borča lineament (west stream of Rašova)–Kovilovo.

Between Padinska Skela and the eastern periclinal of the Belegiš morphostructure, the depression is structurally associated with the Sefkerin depression. West of Novi Banovci, the peripheral parts of the depression are shallower and more complex depth configurations. The unincluded area towards Nova Pazova gradually shifting to a parallel lineament, the beginning of which is visible in the NW part of map, with depth-geological relations that are outside the studied topic.

## Discussion

The wider Belgrade area has been the subject of geological studies for more than a century. In that sense, the earlier authors, each in their own way, contributed to the knowledge of the geological characteristics of this area. However, the impression remains that these are mostly segmented works that dealt with individual aspects of structural-stratigraphic relations and possible relations of Miocene deposits towards the older rocks (e.g. PAVLOVIĆ, 1922; LUKOVIĆ, 1922; NIKOLIĆ, 1976; STEVANOVIĆ, 1977; DOLIĆ, 1997). In Belgrade and its surroundings, it has been known for a long time that the Jurassic-Cretaceous rocks are present both on the surface and in some wells. For example, at the Basic Geological Map, sheet Belgrade 1: 100,000, younger Jurassic limestones, marls and clays have a relatively small distribution in the SW part of the map, while the Cretaceous carbonate and flysch deposits are more widespread (MARKOVIĆ et al., 1984). At the Basic Geological Map, sheet Pančevo 1: 100,000 (IVKOVIĆ et al., 1966), the serpentinites and serpentinitized peri-

dotites and Upper Cretaceous flysch deposits are presented as oases or smaller, elongated belts in the extreme SW part of the sheet. They have NW–SE direction on surface, and so they move to the western area of the sheet Smederevo, 1: 100,000 (PAVLOVIĆ et al., 1977). It is interesting that in the well Bt 1-2 (Bubanj potok, north of Avala) under a thin Neogene cover already at a depth of 38 m, similar ultramafites were discovered (RUNDIĆ et al., 2019). Cretaceous magmatism and its phenomena in the wider vicinity of Avala Mt. have already been described (e.g. ANĐELKOVIĆ & MILOJEVIĆ, 1969; TOLJIĆ, 1996, 2016).

At the beginning, without pretending to talk more about the affiliation of rock deposits from the basin bedrock to certain large tectonic units (see MLADENOVIĆ, 1991; DUNČIĆ et al., 2017; TOLJIĆ et al., 2018, 2019) because we dealt more with the rocks filling the basin, we note that based on the depth demarcations and the mutual relationship between the units, we were able to quite accurately locate **the depth, subsurface route of the ultramafic distribution** in this area (a north-south dashed line, Fig. 10). In this work, it is fully factometrically documented and has a clear subsurface extension in the direction plotted on the map (Glogonj–Velika humka–Jabučki rit–railway station of Ovča–Mirjevo–Mali Mokri Lug–Ljubičica–Zuce and further along to Šuplja Stena–Kasapovac). This route within the Banat sub-basin belt up to 10 km wide apically determines the main depth distribution of intrusive ultrabasic magmatites, whose root follows the geomagnetic deficit of the eastern edge of the belt and as such is, for the first time, clearly marked and graphically shown on geological cross-sections I and II (Figs. 3 and 4).

Secondly, based on the mutual superpositional relations in the wells, the character of the boundary between the Jurassic sub-basin sediments and other rocks, it is evident that dark-black, tectonized clays and argiloshists in the well Pč-1 (2,395–2,733 m) represent the rocks of **the oldest Jurassic age (Lias)**. They have visible the processes of alteration of minerals (e.g. sericitization of feldspar), which indicate a certain hydrothermal effects.

Third, the stratigraphic range of the complex of coarse clastites, i.e. **breccias and congl-breccias (K<sub>B</sub>)** lying over ultramafites in wells (Ov-1 and SA-

2) is also quite clear. The clasts originate mainly from ultramafics, predominantly angular pieces of serpentinized peridotites tightly bound by cement that partially contains a high percentage of carbonates. The thickness of these breccias is from 90 m in the well Ov-1 (330–424) to over 120 m (229–352) in the well SA-2. In the Ov-1 well, this complex is covered with the tectonized Upper Cretaceous flysch sediments. No fossil remains were found in it. Since they are superpositionally located above the ultramafites and whose fragments they contain as well as they are overlying by the tectonized Upper Cretaceous flysch, their stratigraphic position probably corresponds to the Lower Cretaceous deposits or the so-called Para-flysch.

On the Belgrade side, similar the compact serpentinite breccias were discovered in well Bt 1-2 (Ljubičica–Bubanj potok) where, in the interval of 28–38 m depth, they cover a mass of serpentinized peridotites in which drilling was completed (92 m) (RUNDIĆ et al., 2019).

Regarding the depth geological structure of the Neogene-Quaternary cover, it was determined that the oldest Miocene units lie discordantly over the heterochronous pre-basin bedrock. **These are continental-lacustrine deposits of double-natured genesis.** This highly interesting geological unit of defined stratigraphic affiliation (Lower Miocene), has been established in some wells much earlier (e.g. MARINOVIĆ, 1959, 1961, 1962; MARINOVIĆ & KEMENCI, 1969; DOLIĆ, 1997, 1998). In the wells Ov-1 (110–166 m), SA-2 (145–229 m), and G-1 (1,150–1,300 m), in multicolored clastites with dominance of greenish and brown-red clays, gray-green gravelly sandstones and conglomerates, with fragments of chert, serpentinite, Mesozoic carbonates and carbonate concretions, there are not many fossil remains or, when found, they are poorly preserved and difficult to determine the remains of freshwater mollusk fauna and ostracods (MARINOVIĆ, 1962), fish fragments and pollen grains (DOLIĆ et al., 2010). A similar molasses formation has been found in dozens of wells in the wider vicinity of Belgrade under the name of Slanci serie (= Slanci formation) (DOLIĆ, 1997; RUNDIĆ et al., 2013; KNEŽEVIĆ & KRSTIĆ, 2015).

Due to the lack of good chronostratigraphic benchmarks, it is not easy to give a close strati-

graphic determination to this continental series of oxidative genesis. Still, other geological characteristics as well as lithostratigraphic correlation between similar continental-lacustrine small basins in Serbia, indicate the mentioned molasse belongs to the Lower Miocene. Herein, it corresponds to the Egenburgian–Ottangian–Karpatian regional stages i.e. time equivalents of the Aquitanian and Burdigalian stages in general Miocene division (MARINOVIĆ, 1959, 1961, 1962; DOLIĆ, 1997).

Especially interesting is the stratigraphically synchronous series of a completely different genesis, which was determined within the Pančevo depression. **Pre-Badenian, gray-black sub-aquatic pelites (Pbp) of reducing genesis (Pč-1, depth interval 1,980–2,395 m, see Fig. 3)** reach a thickness of over 400 m. A scarce content of small fern spores (Polypodiaceae) was found in them, which indicates the Lower Miocene age. In our opinion, this hitherto unseparated a fine-grained molasses series represents the time equivalent of the previously described the Miocene molasses of oxidative genesis. We think that its separation as a particular unit represents an important contribution of this paper.

Other Miocene units that make up the basin fill-in (Badenian, Sarmatian, Pannonian, Pontian, Pliocene *Paludina* layers) are quite well known. However, in the studied area, they have been completely spatially and temporally correlated by this research. Namely, the map of Neogene thicknesses presented here, indicates a system of morphostructures built of small or larger depressions separated by structural saddles and elevations which, logically, gradually pass into each other. **The disjunctively shaped space and the resulting structural relationships** have led to the formation of several significant depressions (e.g. Pančevo, Sefkerin, Batajnica, Grocka) and horsts structures (Omoljica, Jabuka–Glogonj, Banatsko Novo Selo, etc.) whose existence explains quite different stratigraphic relationships in depth and the present lithostratigraphic content in certain segments of this area. This has led to the fact that the relations between the Miocene units are not in accordance and there are phenomena of local discordances due to the differential sinking of “blocks” (structures), erosion and denivelation of the existing relief. Good examples are the Badenian and Sar-

matian sediments in Ovča, which are very shallowly located, thinned and have a thickness of several to twenties meters, while in neighboring the Pančevo depression they are downlifted to considerable depths and have a much greater thickness (up to 500 m each). In contrast, on structural elevations or smaller horsts, some Miocene units are very often completely eroded and remain present only on the flanks of these structures (e.g. Omoljica or Jabuka where Badenian is eroded and the Sarmatian or Pannonian deposits directly overlie the Lower Cretaceous rocks - Fig. 4). On the disrupted paleohorst of Banatsko Novo Selo (BNS-1), the reduced Sarmatian sediments about 60 m thick, discordantly overlie the Lower Cretaceous paleorelief at a depth of 1,111 m.

A more detailed attempt to interpret the geodynamics of the Belgrade area during the Neotectonic time was presented by ĆIRIĆ (1992). By the author, the Neogene period is characterized by radial tectonics. Some fault systems are inherited from the Mesozoic and reactivated during the Neogene and some others are the product of Neotectonic activity. All of these resulted in the author editing a sketch for a Neotectonic map and showing the main elements, types of faults, volcanic phenomena and Neogene terrains with different degrees and dynamics of sinking. Among other things, he singled out a few faults important for the formation of Neotectonic morphostructures, such as the Sava and Danube faults (this second one is also mentioned by LASKAREV, 1949). So-called the Vinča fault (a right longitudinal strike-slip fault of the NW–SE direction) formed in the Mesozoic and reactivated during the Neogene, which separates this area from the Velika Morava trench at east, is especially important (Fig. 6, ĆIRIĆ, 1992).

Here we would like to note that, regardless of a certain contribution of the mentioned paper, the fact is that the fault systems presented are not based on clear factometric or geophysical data. By our research and by construction of the Neogene thickness map and determined structures formed on the basis of wells data, it can be observe in principle the existence of certain faults with significantly corrected direction, size and character of movements (e.g. the Sava fault has a different orientation and the Danube fault has different prolongation).

An important structural unit on the map is **the Pančevo depression**, located east of the described morphostructural ridge and the longitudinal row of sunken horsts of Banatsko Novo Selo–Bavanište. It has a depth up to 2,600 m and N-S direction (Fig. 10). The observed sharp tectonic boundary of the Pančevo depression towards BBMR on the west side, which has a winding general direction of N-S and marked by the flows of the Tamiš and Sibnica rivers, corresponds to a system of normal, lystric faults (Figs. 3, 4 and 10). Our stratigraphic-geomagnetic data indicate the sediments of the Pančevo depression formed in the early Miocene syn-rift phase (initial rifting), over which the Middle Miocene sediments of the rift maximum (Badenian–early Sarmatian) and the post-rift, the middle Sarmatian sediments were deposited all the way to the Pontian time (Figs. 3–6).

About the existence of a system of depressions (basins) in southern Banat has been recently reported by DULIĆ et al. (2019). Among other things, the authors single out the Pančevo Basin, which is one in a series of the so-called pull-apart basins formed during the Miocene and whose sediment thickness exceeds 3,700 m. They are genetically related to a complex system of longitudinal faults of the Dinaridic direction along which the space for the creation of more parallel basins was opened. According to the authors, these south Banat basins represent a part of a wider, southern chain of pull-apart basins developed along the so-called Moravian Corridor. The mechanism of formation of these structures is related to stresses along regional, longitudinal faults (DULIĆ et al., 2019).

Our research has shown that in a relatively small area it is possible to single out several relatively deep local depressions (e.g. Sefkerin, Pančevo) which have significantly thick Neogene deposits (1,900–2,600 m). It should be noted that the mechanism of their origin in the early Miocene must certainly be viewed in the broader context of the entire southern rim of the Pannonian Basin. Terminologically, for the mentioned area, we are of the opinion that it is more convenient to use the term depression than basin (e.g. Pančevo depression).

Finally, apart from the mentioned historical-geological and structural-tectonic evolution of the

wider Belgrade city area, the aspect of applicability and use of certain lithostratigraphic units of SW Banat and beyond is especially interesting i.e. their depth hydrogeological zoning.

**Four hydrogeological systems** (HGS I-IV, see Fig. 3) and within them 10 separate complexes (A-S), have been defined as the authorized work by Đ. Marinić at 1974 and it was published for professional public eight years later (MARINOVIĆ, 1982). Essentially, this zoning defines how and to what extent mineralization and aquifer types change within the basin. This means that the contained mineralizations of water do not depend on the depth, but primarily on the position of the certain layer in relation not only to the contact floor package but also to the structural lateral sides, on which the cover collector eventually relies.

As can be seen in the presented profile I, the water from Ovča from the Sarmatian/Pannonian contact with a depth of 91 m has a mineralization of 16.46 g/l (MILOJEVIĆ, 1960), and the water even from the eastern side of the Pančevo depression, from the correlatively close Pannonian collector depth of 1,013 m, has an almost identical mineralization of 16.4 g/l (Doz-1). Correlatively slightly younger Pannonian layer of the well Doz-1 with a depth of 839 m, has a lower mineralization, specifically 15.5 g/l. Stratigraphically determined Sarmatian deposits of the well Doz-1 from a depth of 1,154 m, contain a correspondingly increased mineralization of 17.85 g/l which is close to the mentioned values from Ovča, i.e. from the Sarmatian/Pannonian contact. Waters from the Badenian reservoirs of the wells Doz-1 and Do-1, depth 1,602 and 1,674 m, have mineralization according to the intra-Badenian “age” by increasing the mineralization from 25.9 to 32.6 g/l, which is in accordance with a modern marine waters (ŠARKOVIĆ, 1973). Finally, water from the Miocene lagoon with an ambientally high mineralization of 51 g/l – was laterally infiltrated into a fissured collector of the Lower Cretaceous rocks (Fig. 3). It is worth mentioning that e.g. waters from the Pontian sediments (HGS-I, complex D) in Kikinda from depths of 1,100–1,400 m, have a mineralization of 4–6 g/l, which is the same as the mineralization of the level of significant reduction of caspi-brackish cardids (MARINOVIĆ, 2017).



## Conclusions

- The Belgrade wider area includes a segment of two morphologically adjacent geotectonic units - the inner Dinarides *s. lato*, and the southern rim of the Pannonian Basin, without considering the regional geotectonic interpretations.

- Within the Pannonian Basin, geochronologically and deeply, it differs the sub-basin unit affected by an intensive orogenic-fractured tectonization of the Alpine cycle, and, the discordant geological cover, disjunctively and compactionally formed during the post-Paleogene time.

- Within the sub-basin structure, the oldest rocks are a black, schist like, sericited pelites that are palynologically determined as the Early Jurassic (late Lias-early Doggerian), without the content of ultrabasic magmatites.

- Serpentinized peridotites of the harzburgite type were drilled directly below the Neogene cover (Glogonj), then under the Cretaceous agglomerates (Ovča) as well as in the area of Ljubičica-Bubanj Potok, with an abundance of serpentinite fragments, cherts and other rocks, comparatively the early Cretaceous age. On the surface, they are already known from the valley of the Zavojnica river, Zuce and the eastern sides of Avala Mt. in a thrust, west-vergent relationship with the Cretaceous flysch.

- By the analysis of the combined geophysical data it is confirmed the possibility of the existence, the post-Senonian laccolitic intrusions of acidic magmatic on Avala Mt. The presence of ultrabasic is excluded.

- Based on geomagnetic indicators, in this paper, for the first time, the route of ultrabasic breakthroughs is presented. On the attached map, it is specifically plotted as a sub-basin depth projection of the apical axis with a general direction of N-S (Glogonj-Velika humka-Jabučki rit-the Ovča railway station-Mirjevo-Mali Mokri Lug-Ljubičica-Zuce).

- Orogenically tectonized the sub-basin's geological column of BBMG, generally of meridional orientation, is broken into block systems of different orientation during pre-Neogene. Besides, it is additionally modified to the disjointed basin floor configuration as the base of a heterochronous Neogene cover.

- During the Neogene, by complex fracture zones and less pronounced fault systems, the depressions and antiformal structural units with mutually different orientations were formed. The most pronounced fault belts, partly with reactivated pre-Neogene depth faults, and the zones of less pronounced faults, on the constructed map (Fig. 10) are visible in the directions and lengths by differently condensed isopaches. Drawing of these faults is unnecessary.

- Among the formed morphostructural units, the main depressions stand out: Pančevo, Sefkerin, Batajnica and Grocka, with a smaller sub-depression of Mokri Lug. The structural trenches are: Moštanica (SW corner of the map), Makiš (a bay of the Batajnica depression), Krnjača (Belgrade Danube River area), Beli Potok (foothills of Avala Mt.) and Banatski Brestovac (open to the NE).

- In the meander of the Danube river, there is the Slanci antiformal and the smaller one, Babin Vis. On the Banat side, the horst massifs Ovča, Jabuka and Glogonj stand out. The morphostructural row Banatsko Novo Selo-Vladimirovac-Dolovo-Bavanište, somewhat separates the Pančevo depression from the Skorenovac-Smederevo depression, the western extension of which is visible on the attached map. The Omoljica horst-massif, with a smaller unit Starčevo-Ivanovo has a southeastern extension towards the antiformal structures of Mala ada (Brestovik) and Orešac (outside the map).

- Below the Belgrade wider center, there is a structural polyfacial antiformal, partly reefly row Čubura-Kalemegdan-Borča (extended to Padinska Skela), then a shorter structural nose from Čukarica to Bežanija, and the separated periclines of Ostružnica in the direction of Jakovo and Surčin.

- The oldest Neogene sediments of limited contours are lacustrine-subaquatic, multi-colored heteroclastic molasses (interbedded by volcanoclastics), in principle of oxidative genesis. This reference promotes the black and gray black, pelitic molasses of reducing genesis, so far drilled only at the bottom of the Pančevo depression, 415 m thick.

- The marine and semi-marine sediments (Badeian, Sarmatian) are discordantly overlying the different rocks, over which they lie heterochronously. Three types can be separated: the basinal-lagoon,

coastal-reef and mixed one. Each of them has specific lithofacial characteristics and fossil content.

- The late Miocene brackish-lacustrine sediments (Pannonian and Pontian *s. str.*) were developed according to the same ambient principle, but without the peculiarities of the lagoon and reef type. In accordance with the permanently mobile tectonic oscillations, according to the disparate geometry of the floor, the different overflow-outflow relations were achieved, including with intraserial discordances.

- The Pliocene lacustrine-fluvial sediments ("Paludina beds"), were deposited just north of the Surčin–Borča–Tamiš River–Pančevo–Bavanište line. In Glogonj, all the three fossil complexes have been paleontologically documented (based on phylogenetic relations of the genus *Viviparus*).

- Quaternary sediments in the Pančevo depression are estimated to be up to 150 m thick. It is goodly correlative with the Glogonj locality, where they have been paleontologically determined to a depth of 100 m.

- To all the above, for the practical reasons of usage, it can be added that in the whole Vojvodina basin area, the hydrochemical characteristics of water do not depend on depth, but primarily on the paleoecological elements of the aquifer, including lateral infiltrations into the reservoir on which the stratigraphic aquifer relies.

## Acknowledgments

The authors are grateful to N. MALEŠEVIĆ (technical support of GABP) for help during the figures preparation. Special thanks go to S. ĆORIĆ (Geological Survey of Austria) and an anonymous reviewer for their helpful suggestions that improved the final version of the manuscript. Lj. Rundić is grateful to the Ministry of Education, Science and Technological Development of the Republic of Serbia for supporting this research.

## References

ANĐELKOVIĆ, M. 1960. Paleogeografija i tektonika jednog dela Unutrašnjih Dinarida (Šumadijska i zapadnosr-

bijanska zona) [Paläogeographie und tektonike in-esteiles der Innerdinariden (Sumadija - und west serbische Zone)– in Serbian, German summary]. *Geološki anali Balkanskoga poluostrva*, 27: 103–152.

ANĐELKOVIĆ, M. 1973. Geologija mezozoika okoline Beograda [Geology of Mesozoic of the vicinity of Belgrade–in Serbian]. *Geološki anali Balkanskoga poluostrva*, 38: 1–136.

ANĐELKOVIĆ, M. 1987. Jura [Jurassic]. In: ANĐELKOVIĆ, M. (Ed.). Geologija sire okoline Beograda [Geology of the surroundings of Belgrade– in Serbian]. Zavod za regionalnu geologiju i paleontologiju, Rudarsko-geološki fakultet Beograd, 1: 68–86.

ANĐELKOVIĆ, M. & MILOJEVIĆ, N., 1969. Starost mezozojskog vulkanizma i faze njihovog stvaranja u okolini Beograda, sa osvrtom na magmatizam Šumadijske zone [The age of Mesozoic volcanism and the phases of their creation in the vicinity of Belgrade, with reference to the magmatism of the Šumadija zone – in Serbian]. *Zapisnici SGD za 1964*, 65–74.

ANĐELKOVIĆ, F. & RADIVOJEVIĆ, D. 2018. Doprinos poznavanju facijalne raznovrsnosti badenskih sedimenata Beograda [A contribution to the knowledge of facial diversity of the Badenian sediments of Belgrade – in Serbian]. *XVIII kongres geologa Srbije, Vrnjačka Banja*, 232–236.

BILIBAJKIĆ, P. 1998. Nova saznanja i potencijalne mogućnosti srpske naftonosne provincije [New knowledge and potential possibilities of the Serbian oil-bearing province – in Serbian]. *XIII Kongres geologa Jugoslavije, Herceg Novi*, IV: 841–858.

BILIBAJKIĆ, P., BILIBAJKIĆ, D., JANČIĆ, T. & MLADENOVIĆ, M. 1979. Prilog tumačenju geostrukturnih karakteristika Jugoslavije na osnovu regionalnih gravimetrijskih i geomagnetnih ispitivanja, s posebnim osvrtom na jugoslovenski deo Panonskog basena [A contribution to the interpretation of the geostructural characteristics of Yugoslavia on the basis of regional gravimetric and geomagnetic tests, with special reference to the Yugoslav part of the Pannonian Basin – in Serbian]. *III načni skup znanst. Sav. za naftu JAZU, Zbornik radova, knj. I, Novi Sad 1977*, 27–44.

BOUE, A. 1840. *Esquisse geologique de la Turquie D'Europe*. Imprimerie de Bourgogne et Martinet, Paris, 128 pp.

BRAGIN, N., BRAGINA, L., DJERIĆ, N. & TOLJIĆ, M. 2011. Triassic and Jurassic Radiolarians from Sedimentary Blocks of Ophiolite Mélange in the Avala Gora Area (Belgrade

- Surroundings, Serbia). *Stratigraphy and Geological Correlation*, 19 (6): 631–640.
- ČIRIĆ, B. 1992. Geodinamika beogradskog područja u neotektonsko doba [Geodynamics of the Belgrade area in the Neotectonic time – in Serbian]. *Zapisi SGD – jubilarna knjiga 1891-1991*, 103–120.
- ČANOVIĆ, M. & KEMENCI, R. 1988. *The Mesozoic of the Pannonian Basin in Vojvodina (Yougoslavia): Stratigraphy and Facies, Magmatism, Paleogeography*. Matica Srpska, Novi Sad, 339 pp.
- ČANOVIĆ, M. & KEMENCI, R. 1999. Geologic setting of the Pre-Tertiary basement in Vojvodina (Yugoslavia). Part II: The north part of the Vardar zone in the south of Vojvodina. *Acta Geologica Hungarica*, 42: 427–449.
- DIMITRIJEVIĆ, B. 1931. Avala: petrografsko-mineraloška studija sa kartom R 1: 50.000. [Avala: a petrographic-mineralogical study with map at scale 1: 50.000– in Serbian]. *Posebno izdanje SKA, LXXXV, Prir. mat. spisi*, 23–30.
- DOLIĆ, D. 1997. Lake Miocene near Belgrade. *Geološki anali Balkanskoga poluostrva*, 61 (2): 15–49.
- DOLIĆ, D. 1998. Odnos nasleđa Paratetisa i miocenskih jezerskih formacija u Srbiji [The relationships of Paratethyan and Miocene lake deposits in Serbia – in Serbian, English summary]. *XIII Kongres geologa Jugoslavije, Herceg Novi*, 2: 373–382.
- DULIĆ, I., GAJIĆ, V., RAŠKOVIĆ, M. & VUČKOVIĆ, B. 2010. Neotektonska aktivnost u jugozapadnom Banatu [Neotectonic activity in southwestern Banat – in Serbian]. *Proceedings of 15th Serbian Geological Congress, Belgrade, Abstracts*, 151.
- DULIĆ, I., GAJIĆ, V., BOGIĆEVIĆ, G., MARJANOVIĆ, S. & PERIŠIĆ, K. 2019. Pull-Apart Basins of Southern Banat (South-eastern Part of the Pannonian Basin). *Proceedings of 6th. Croatian Geological Congress, Zagreb, Abstract book*, 60–61.
- DUNČIĆ, M., DULIĆ, I., POPOV, O., BOGIĆEVIĆ, G. & VRANJKOVIĆ, A. 2017. The Campanian-Maastrichtian foraminiferal biostratigraphy of the basement sediments from the southern Pannonian Basin (Vojvodina, northern Serbia): implications for the continuation of the Eastern-Vardar and Sava zones. *Geologica Carpathica*, 68: 130–146.
- ĐERIĆ, N., GORIČAN, Š., GERZINA, N. & KRUNIĆ, O. 2010. Jurassic Radiolarians From the Grocka Borehole (Belgrade Area). *Proceedings of 15th Serbian Geological Congress, Belgrade*, 152–153.
- GAJIĆ, V., DULIĆ, I., DUNČIĆ, M. 2008. Biostratigrafija i paleoekologija srednjeg miocena jugozapadnog Banata. [Biostratigraphy and paleoecology of the middle Miocene of Banat – in Serbian]. *XVII kongres geologa Srbije, knjiga apstrakata*, 121–125.
- GANIĆ, M., RADOVIĆ, P., RUNDIĆ, Lj., BRADIĆ, K. & KNEŽEVIĆ, S. 2016. Traces of Drilling Predation in the Upper Badenian (Middle Miocene) Mollusks from the Rakovica Stream (Belgrade). *Geologia Croatica*, 69 (2): 173–180.
- GAUDENYI, T., NENADIĆ, D., STEJIĆ, P., JOVANOVIĆ, M. & BOGIĆEVIĆ, K. 2015. Stratigraphic revision of the Quaternary material from the vicinity of Belgrade and the Serbian segment of the Tisza valley analyzed by V.D. Laskarev, *Quaternary International*, 357: 93–109.
- GUĐOVIĆ, J. 1875. Izveštaj o starim rudnicima ispod Avale i njene okoline [Report on the old mines below Avala Mt. and its surroundings– in Serbian]. Ministry of Mining, the Principality of Serbia, Beograd, 1–8.
- IVKOVIĆ, A. 1975. Osnovna geološka karta SFRJ 1: 100 000. Tumač za list Pančevo L34-114. [Basic Geological Map of SFRJ 1:100000. Explanatory Booklet for the Sheet Pančevo – in Serbian]. Savezni geološki zavod, Beograd.
- IVKOVIĆ, A., VUKOVIĆ, A., NIKOLIĆ, J., KOVAČEVIĆ, D., PALAVEŠTRIĆ, Lj., PETROVIĆ, Lj., JOVANOVIĆ, O., TRIFUNOVIĆ, I. & SEBINOVIĆ, Lj. 1966. Osnovna geološka karta SFRJ 1:100000, List Pančevo L34-114 [Basic Geological Map of SFRJ 1:100000, sheet Pančevo – in Serbian]. Savezni geološki zavod, Beograd.
- JANKOVIĆ, P., 1970. Paludinski slojevi Vojvodine. [Paludina beds of Vojvodina – in Serbian]. *VII kongres geologa SFRJ, Zagreb*, 1: 103–115.
- JANKOVIĆ, P. 1977. Paludinski slojevi [Paludina beds]. In: PETROVIĆ K. (Ed.). *Geologija Srbije, Stratigrafija Kenozoik [Geology of Serbia, Stratigraphy - Cainozoic – in Serbian]*. Zavod za regionalnu geologiju i paleontologiju, RGF, 327–330.
- JOVANOVIĆ, G., VRABAC, S. & ČORIĆ, S. 2019. Stratigraphy revision of Upper Badenian of Rakovica stream near Belgrade (Central Paratethys, Serbia). *Geološki anali Balkanskoga poluostrva*, 81 (1): 11–30.
- KNEŽEVIĆ, S. 1989. Prinove iz ponta belopotockog rova [New specimens from the Pontian of Beli Potok trough – in Serbian, with an English summary]. *Geološki anali Balkanskoga poluostrva*, 53: 373–384.
- KNEŽEVIĆ, S. 1990. Prilog poznavanju neogenih sedimentata okoline Beograda (stratigrafski prikaz bušotine

- KGK-16 kod Vrčina [A contribution to the study of Neogene sediments in Beograd area (stratigraphic column of hole KGK-16 at Vrčin) – in Serbian, with an English summary]. *Geološki anali Balkanskoga poluostrva*, 54:181–197.
- KNEŽEVIĆ, S. & GANIĆ, M. 2005. Miocenski sedimenti kod ušća Save u Dunav na Novom Beogradu [Miocene sediments near the Sava – Danube confluence in New Belgrade – in Serbian]. *Proceedings of the 14th Congress of geologists of Serbia & Montenegro, Abstract book, Novi Sad*, 65.
- KNEŽEVIĆ, S. & GANIĆ, M. 2008. Skica za geologiju Velikog ratnog ostrva na ušću Save u Dunav [Geological survey of River Island “Veliko ratno ostrvo” at the confluence of rivers Sava and Danube – in Serbian]. *Zapisi SGD za 2007*, 101–112.
- KNEŽEVIĆ, S. & KRSTIĆ, N. 2015. Slanačka serija na zapadu Beograda, u dedinjskom saobraćajnom tunelu [Slanci series west of Belgrade, in the Dedinje traffic tunnel – in Serbian]. *Zapisi SGD za 2014*: 25–32.
- KNEŽEVIĆ, S., RUNDIĆ, Lj. & GANIĆ, M. 2012. The subsurface geology along the route of the new bridge at Ada Ciganlija Island (Belgrade, Serbia). *Geološki anali Balkanskoga poluostrva*, 73: 9–19.
- KNEŽEVIĆ, S., RUNDIĆ, Lj. & GANIĆ, M. 2017. “Beograd na vodi”: geološki uslovi terena “Savskog amfiteatra” [“Belgrade Waterfront”: geological conditions of the Sava amphitheater area – in Serbian and English]. *Zapisi SGD za 2017*, 83–88.
- KNEŽEVIĆ, S., SPAJIĆ, O., PAVLOVIĆ, M., ERCEGOVAC, M. & PETROVIĆ, M. 1994. Stratigrafska proučavanja tercijarnih naslaga u bušotini G-1 (Grocka). [Stratigraphic study of the Tertiary sediments from the G-1 well, Grocka – in Serbian]. *Geološki anali Balkanskoga poluostrva*, 58 (1): 31–49.
- KNEŽEVIĆ, S., GANIĆ, M. & RUNDIĆ, Lj. 2018a. Stratigraphic review of SA-2 well in Ovča, Belgrade. *XVII Kongres geologa Srbije*, 1: 144–148.
- KNEŽEVIĆ, S., NENADIĆ, D., RADULOVIĆ, B., BOGIĆEVIĆ, K., & ZARIĆ, J. 2018b. Stratigraphic characteristics of Quaternary deposits on the left bank of the Sava River near Belgrade. *Geološki anali Balkanskoga poluostrva*, 79 (1): 21–30.
- KRSTIĆ, N. 1973. *Biostratigraphy of the Congerian beds in the Belgrade region on the basis of Ostracoda*. Monographs, Vol. 4, Inst. Geol. Min. Expl. Investig. Nuclear Miner. Raw Mater., Belgrade, 1–158.
- KRSTIĆ, N. 1985. Ostracoden im Pannonien der Umbegung von Belgrad. In: Papp A. et al. (Eds.). *Chronostratigraphie und Neostatotypen, Miozän M6, Pannonien*. Akadémiai Kiadó, 103–143.
- KRSTIĆ, N., SAVIĆ, Lj. & JOVANOVIĆ, G. 2012. The Neogene Lakes on the Balkan Land. *Geološki anali Balkanskoga poluostrva*, 73: 37–60.
- LASKAREV, V. 1949. Arteski bunar u selu Ovči [Sur un puits artésien a Ovča, pres Belgrade – in Serbian with French summary]. *Geološki anali Balkanskoga poluostrva*, 17:11–14.
- LASKAREV, V., PETKOVIĆ, V. & LUKOVIĆ, M. 1931. Geološka karta okoline Beograda, 1: 25 000. [Geological map of the Belgrade surroundings, 1: 25,000]. Geološki institut kraljevine Jugoslavije, Beograd.
- LUKOVIĆ, M. 1922. Facije drugog mediteranskog kata u okolini Beograda [Facies of the II Mediterranean Series around Belgrade – in Serbian]. *Geološki anali Balkanskoga poluostrva*, 7:22–41.
- MAKSIMOVIĆ, B., VUČIĆ, S., ČANOVIĆ, M., DENIĆ, M., KURBALIJA, J., STARČEVIĆ, M., MUTIĆ, S. & TRKULJA, N. 1990. Prilog geotektonskoj rejonizaciji tercijarne podloge Vojvodine [A contribution to the geotectonic reonization of the tertiary base of Vojvodina – in Serbo-Croatian]. *Nafta* 41: 65–70.
- MANDIĆ, O., RUNDIĆ, Lj., ČORIĆ, S., PEZELJ, D., THEOBALT, D., SANT, K. & KRIJGSMAN, W. 2019. Age and mode of the Middle Miocene marine flooding of the Pannonian Basin - constraints from Central Serbia. *Palaios*, 34 (2): 71–95.
- MARINOVIĆ, Đ. 1959. Naftonosna struktura Lokve [Oil bearing structure of Lokve – in Serbian, English abstract]. *Nafta*, 10, 333–344.
- MARINOVIĆ, Đ. 1961. Jedan osvrt na geološke prilike jugoistočnog dela Panonskog basena [Eine Übersicht der Geologischen verhältnisse in den südöstlichen teilen des Pannonish enbeckens – in Serbian]. *III Kongres geologa Jugoslavije*, 1: 239–257.
- MARINOVIĆ, Đ. 1962. Regionalni pregled geologije i tektonike naftonosnih područja Vojvodine [A regional review of geology and tectonics of oil - bearing areas of Vojvodina – in Serbian]. *Referati V savetovanja geologa FNRJ*, 1: 253–266.
- MARINOVIĆ, Đ. 1970. Sintezni stratigrafski stub Vojvodine [A synthesized stratigraphic column of Vojvodina – in Serbo-Croatian]. In: MARINOVIĆ, Đ. & BOŠKOV-ŠTAJNER, Z. (Eds.). *Stratigrafska pripadnost naftnih i plinskih*

- nalazišta SFR Jugoslavije [*Stratigraphic affiliation of oil and gas deposits of SFR Yugoslavia* – in Serbo-Croatian]. VII Kongres geologa SFRJ, Zagreb, 1: 79–94.
- MARINOVIĆ, Đ. 1971. Synthetized stratigraphic column of Vojvodina, annex no. 5. In: BOŠKOV-STEINER, Z. & MARINOVIĆ, Đ. (Eds.). *Stratigraphy of oil and gas fields in the territory of Yugoslavia*. Nafta, 22: 524–532.
- MARINOVIĆ, Đ. 1977. Miocen na osnovu dubinskih bušotina [Miocene based on deep wells – in Serbian]. In: PETKOVIĆ, V. (Ed.). *Geologija Srbije, Stratigrafija – Kenozoik* [*Geology of Serbia, Stratigraphy - Cainozoic* – in Serbian]. Zavod za regionalnu geologiju i paleontologiju. Rudarsko-geološki fakultet, Beograd, 294–303.
- MARINOVIĆ, Đ. 1982. Prikaz opštih geoloških i hidrogeoloških prilika u SAP Vojvodini; hidrogeološki sistemi kao osnova za hidrogeološku rejonizaciju Vojvodine [An overview of general geological and hydrogeological conditions in SAP Vojvodina; hydrogeological systems as a basis for hydrogeological reonization of Vojvodina – in Serbian]. *Zbornik referata VII jugoslovenskog simpozijuma o hidrogeologiji*, 3/3: 5-26, 43–45, Novi Sad.
- MARINOVIĆ, Đ. 2017. Karta baze postkardidskog neogena Vojvodine-Srbija [Map of the base of the post-Cardium Neogene in Vojvodina (Serbia) – in Serbian and English]. *Zapisi SGD za 2015*: 1–26.
- MARINOVIĆ, Đ. 2019. Karta geotermkih gradijenata Vojvodine-Srbija [The map of the geothermal gradients of Vojvodina-Serbia – in Serbian and English]. *Zapisi SGD za 2018*: 21–45.
- MARINOVIĆ, Đ. & KEMENCI, R. 1969. Vulkanogeno sedimentne tvorevine i njihov stratigrafski položaj u neogenu Vojvodine [Volcanogenic sedimentary formations and their stratigraphic position in the Neogene of Vojvodina – in Serbian]. *Zapisi SGD za 1964-1967*: 93–103.
- MARINOVIĆ, Đ., RUNDIĆ, Lj. & KNEŽEVIĆ, S. 2016. Subsurface distribution model of the “Post-Cardids” Neogene of Vojvodina (northern Serbia). *RCMNS Interim Colloquium, May 20-24, 2016 Zagreb*, Abstract, 38–39.
- MARKOVIĆ, M., PANDŽIĆ, J., PAVLOVIĆ, R. & ČUPKOVIĆ, T. 1997. Strukturne karakteristike i neotektonska aktivnost jugoistočnog dela Panonskog basena [Structural characteristics and neotectonic activity in the south-eastern part of the Pannonian basin – in Serbian]. *DIT-Naftagas*, 25: 5–33.
- MARKOVIĆ, B., OBRADINOVIĆ, Z., VESELINOVIĆ, Z., ANĐELKOVIĆ, J., STEVANOVIĆ, P. & RAKIĆ, M. 1984. Osnovna geološka karta SFRJ 1:100000, List Beograd L34-113 [*Basic Geological Map of SFRY 1:100000, Sheet Beograd*]. Savezni geološki zavod, Beograd.
- MARKOVIĆ, B. 1985. Osnovna geološka karta SFRJ 1:100000. Tumač za list Beograd L34-113 [*Basic Geological Map of SFRY 1:100000. Explanatory booklet for the sheet Belgrade* – in Serbian]. Savezni geološki zavod, Belgrade.
- MAROVIĆ, M. & KNEŽEVIĆ, S. 1985. Neotektonika jednog dela Šumadije i severozapadne Srbije [Neotectonics of a part of Šumadija and northwestern Serbia – in Serbian]. *Geološki anali Balkanskoga poluostrva*, 49: 221–252.
- MAROVIĆ, M., DJOKOVIĆ, I., PEŠIĆ, L., RADOVANOVIĆ, S., TOLJIĆ, M. & GERZINA, N. 2002. Neotectonics and seismicity of the southern margin of the Pannonian Basin in Serbia. *EGU Stephan Mueller Spec. Publ. Ser.*, 3: 277–295.
- MAROVIĆ, M., TOLJIĆ, M., RUNDIĆ, Lj. & MILIVOJEVIĆ, J. 2007. *Neoalpine tectonics of Serbia*. Serbian Geological Society, 1–82, Belgrade.
- MASLAREVIĆ, Lj. & GAGIĆ, N. 1976. Sarmatski sediment Cerka na teritoriji Beograda [Sarmatian sediments of Cerak, the Belgrade area – in Serbian]. *II skup sedimentologa Jugoslavije*, Beograd, 73–86.
- MIHAJLOVIĆ, Đ. & KNEŽEVIĆ, S. 1989. Krečnjački nanoplankton iz badenskih i sarmatskih naslaga Višnjice i Karaburme (Beograd) [Calcareous nannoplankton from the Badenian and Sarmatian deposits at Višnjica and Karaburma in Belgrade – in Serbian]. *Geološki anali Balkanskoga poluostrva*, 63: 373–383.
- MILAKOVIĆ, B. 1986. Osvrt na pitanje subjezerskog vulkanizma neogenih basena Jugoslavije [A short review of the issue of sub-lacustrine volcanism of the Neogene basins of Yugoslavia – in Serbian]. *XI Kongres geologa Jugoslavije*, 2: 405–418.
- MILETIĆ-SPAJIĆ, O. 1961. Prinove za poznavanje panonskih (donjekongerijskih) slojeva okoline Beograda (Zaklopača, Begaljica, Vrčin). [Novels to the knowledge of the Pannonian (Lower Congerian) strata around Belgrade (Zaklopača, Begaljica, Vrčin) – in Serbian with German abstract]. *Geološki anali Balkanskoga poluostrva*, 28: 247–263.
- MILOJEVIĆ, N. 1960. Prilog za poznavanju naftnih voda Vojvodine [Oil waters in Vojvodina – in Serbian, English summary]. *Geološki anali Balkanskoga poluostrva*, 27: 429–443.
- MILOVANOVIĆ, B. & ĆIRIĆ, B. 1968. Geološka karta Srbije 1: 200.000 [*Geological map of Serbia 1: 200.000* – in Ser-

- bian]. Zavod za geološka i geofizička istraživanja, Beograd.
- MITROVIĆ, S. & RUNDIĆ, Lj. 1991. A contribution to the study of the Sarmatian in Belgrade area. *Geološki anali Balkanskoga poluostrva*, 55 (2): 67–73.
- MLADENOVIĆ, M. 1991. Rasprostranjenje ofiolitskog pojasa u podlozi tercijarnog Panonskog basena [Distribution of the ophiolite belt in the bedrock of Tertiary of the Pannonian Basin – in Serbian]. *Zapisi SGD za 1987-1989*: 241–246.
- NENADIĆ, D., GAUDENYI, T., BOGIĆEVIĆ, K. & GULAN, Z. 2011. The Lower Quaternary boundary in the southeastern Srem (North Serbia). *Bulletin of the Natural History Museum*, 4: 23–36.
- NIKOLIĆ, M. 1976. Vojvodina. In: PETKOVIĆ, V. (Ed.). *Geologija Srbije, Tektonika* [Geology of Serbia, Tectonics – in Serbian], Zavod za regionalnu geologiju i paleontologiju, RGF, 373–388.
- NIKOLIĆ, D. & SIMIN, D. 1959. Geologija Banata na osnovu novijih geofizičkih ispitivanja i dubokih bušenja [Geology of Banat based on recent geophysical research and deep drilling – in Serbian]. *Vesnik*, 17: 49–59.
- PANTIĆ, N. 1978. Paleopalinozoological studies of the „Schistes Lustres“ of the Swiss Alps and investigation of the Mesozoic „Schistes Lustres“ of the Balkan Peninsula. *Glas SANU, CCCVI, Natur. Sci.*, 43: 125–135.
- PANTIĆ, N. & ŠEĆEROV, P. 1975. Les études paleopalinozoologiques des sédiments Crétacés au fond des formations Néogènes du bassin Pannonien de Voïvodina (Paleopalinozoška proučavanja krednih sedimenata u podini neogenih tvorevina Panonskog basena u Vojvodini). *Geološki anali Balkanskoga poluostrva*, 39: 135–142.
- PANTIĆ, N. & DULIĆ, I. 1990. Palinomorfe mlađeg lijasu iz bušotine BNSJ-1 (Banatsko Novo Selo) [Upper Liassic palynomorphs from borehole BNSJ-1, Banatsko Novo Selo – in Serbian]. *Geološki anali Balkanskoga poluostrva*, 39: 199–216.
- PAVLOVIĆ, P. 1922. Geološki sastav Beogradskog dunavskog ključa [La composition géologique du "Beogradski Ključ" – in Serbian]. *Geološki anali Balkanskoga poluostrva*, 7(1): 1–13.
- PAVLOVIĆ, Z. 1976. Hronološki razvoj tercijarnog magmatizma u području Šumadije [The chronological development of the Tertiary magmatism in the area of Šumadija – in Serbian]. *VIII Kongres geologa Jugoslavije*, 1: 231–244.
- PAVLOVIĆ, Z., MARKOVIĆ, B., ATIN, B., DOLIĆ, D., GAGIĆ, H., MARKOVIĆ, O., DIMITRIJEVIĆ, M. & VUKOVIĆ, M. 1977. Osnovna geološka karta SFRJ 1:100000, List Smederevo L34-126 [Basic Geological Map of SFRY 1:100000, Sheet Smederevo]. Savezni geološki zavod, Beograd.
- PETKOVIĆ, K. 1951. Kako je Avala dobila svoj današnji oblik i zašto se ističe u reljefu okoline [How Avala got its present shape and why it stands out in a surrounding relief – in Serbian]. *Nauka i privreda*, 4: 3–9.
- RADIOJEVIĆ, D., RUNDIĆ, Lj. & KNEŽEVIĆ, S. 2010. Geology of the Čoka structure in northern Banat (Central Paratethys, Serbia). *Geologica Carpathica*, 61 (4): 341–352.
- RUNDIĆ, Lj. 1990. Upper Pannonian Ostracoda from borehole PG-6 (Grocka) and KG-28 (Mala Moštanica), general Belgrade area. *Geološki anali Balkanskoga poluostrva*, 54: 295–308.
- RUNDIĆ, Lj. & MITROVIĆ, S. 2005. Biostratigrafija i paleoekologija miocena iz bušotine PG-8, Begaljica, okolina Beograda [Biostratigraphy and paleoecology of the Miocene from the PG-8 well, Begaljica, Belgrade area – in Serbian]. *Proceedings of the 14th Congress of geologists of Serbia & Montenegro, Novi Sad*, 108–109.
- RUNDIĆ, Lj., DOLIĆ, D. & KNEŽEVIĆ, S. 2013. Continental-Lacustrine Lower Miocene of the Belgrade City Area (Serbia): state of art. *Proceedings of the 5th Intern. Workshop on Neogene of Central and SE Europe, Varna*, 55.
- RUNDIĆ, Lj., GANIĆ, M., KNEŽEVIĆ, S. & SOLIMAN, A. 2011. Upper Miocene Pannonian sediments from Belgrade (Serbia): new evidence and paleoenvironmental considerations. *Geologica Carpathica*, 62 (3): 267–278.
- RUNDIĆ, Lj., KNEŽEVIĆ, S., KUZMIĆ, V. & KUZMIĆ, P. 2012. A new data on geology of the archeological site at Vinča (Belgrade, Serbia). *Geološki anali Balkanskoga poluostrva*, 73: 21–30.
- RUNDIĆ, Lj., VASIĆ, N., ŽIVOTIĆ, D., BECHTEL, A., KNEŽEVIĆ, S. & CVETKOV, V. 2016. The Pliocene Paludina Lake of Pannonian Basin: new evidence from northern Serbia. *Annales Societatis Geologorum Poloniae*, 86 (2): 185–209.
- RUNDIĆ, Lj., GANIĆ, M., KNEŽEVIĆ, S., RADIOJEVIĆ, D. & RADONJIĆ, M. 2019. Stratigraphic implications of the Mio-Pliocene geodynamics in the area of Mt. Avala: new evidence from the Torlak Hill and Beli Potok (Belgrade, Serbia). *Geologia Croatica*, 72 (2): 109–128.
- SCHWARCHANS, W., BRADIĆ, K. & RUNDIĆ, Lj. 2015. Fishotoliths from the marine-brackish water transition from the Middle Miocene of the Belgrade area, Serbia. *Paläontologische Zeitschrift*, 89 (4): 815–837.

- SIMIN, D. 1963. Gravimetrijska karta Vojvodine, Mačve i Pomoravlja, R 1: 500.000 [The Gravimetric map of Vojvodina, Mačva and Pomoravlje, 1: 500000 – in Serbo-Croatian]. *Nafta*, 9-10: 255–260.
- SOKOL, K., PRELEVIĆ, D., ROMER, R., BOŽOVIĆ, M., Van den BOGAARD, P., STEFANOVA, E., KOSTIĆ, B. & ČOKULOV, N. 2020. Cretaceous ultrapotassic magmatism from the Sava-Vardar Zone of the Balkans. *Lithos*, 354–355: 105268.
- SPAJIĆ, O. 1987. Sarmatski kat, Panonski kat. [Sarmatian & Pannonian Stage]. In: ANĐELKOVIĆ, M. (Ed.). *Geologija šire okoline Beograda*, knj.1, Geologija i geodinamika [Geology of the wider surroundings of Belgrade, book 1, Geology and geodynamics– in Serbian], Zavod za regionalnu geologiju i paleontologiju, Beograd, 195–221.
- SPAJIĆ, O. & DŽODŽO-TOMIĆ, R. 1973. Stratigrafska analiza miocenskih sedimenata iz hidrogeoloških istražnih bušotina okoline Beograda [Biostratigraphische analyse der Miozänischen sedimenten aus der hydrogeologischer forschung-bohrungen aus der umgebung Belgrads– in Serbian and German]. *Geološki anali Balkanskoga poluostrva*, 38: 167–182.
- STANGAČILOVIĆ, D. 1969. Submarinski vulkanizam u tortonu Beogradskog dunavskog ključa. [Submarine volcanism in the Tortonian of the Belgrade Danube Cape – in Serbian]. *Zapisi SGD za 1964*, 233–238.
- STEVANOVIĆ, P. 1959. Prinove za stratigrafiju i tektoniku neogena na teritoriji Beograda [Neu Beiträge zur Stratigraphie und Tektonik der Neogenablagerungen in der Stadt Belgrad– in Serbian, German summary]. *Zapisi SGD za 1957*, 7–19.
- STEVANOVIĆ, P. 1975. Stratigrafski položaj tercijarnih eruptivnih stena u okolini Beograda. [Stratigraphic position of the Tertiary eruptive rocks in the vicinity of Belgrade – in Serbo-Croatian]. *JAZU knj.41, Acta Geologica*, VIII/25: 453–468.
- STEVANOVIĆ, P. 1977. Miocen Beograda, Beogradskog dunavskog ključa i Posavine [Miocene of Belgrade, Belgrade Danube Ključ and Posavina]. In: PETKOVIĆ, V. (Ed.). *Geologija Srbije, Stratigrafija–Kenozoik* [Geology of Serbia, Stratigraphy - Cainozoic– in Serbian]. Zavod za regionalnu geologiju i paleontologiju, RGF,2/3: 113–145.
- STEVANOVIĆ, P. 1990. Die pontische halbbrackische Molluscenfauna aus Serbien und Bosnien. In: STEVANOVIĆ, P., NEVESSKAJA, L.A., MARINESCU, F.I., SOKAČ, A. & JÁMBOR, Á. (Eds.). *Chronostratigraphie und Neostatotypen: Pontien* (1989). JAZU–SANU, Zagreb–Beograd, 462–536.
- ŠARKOVIĆ, M. 1973. Geohemijske karakteristike slojnih fluida, nafte i gasnih ležišta II dela Panonskog basena i njihovo korišćenje pri istraživanju [Geochemical characteristics of strata fluids, oil and gas deposits in the SE part of the Pannonian Basin and their use in research– in Serbian]. Matica Srpska, odeljenje za prirodne nauke, 1–118, Novi Sad.
- ŠUMAR, M. & RUNDIĆ, Lj. 1992. Contribution to the study of the Sarmatian at Ritopek village near Belgrade. *Geološki anali Balkanskoga poluostrva*, 56 (2): 201–208.
- TOLJIĆ, M. 1996. Neotektonski sklop Avale (Srbija) [The Neotectonic Pattern of Mount Avala (Serbia) – in Serbian, English abstract]. *Geološki anali Balkanskoga poluostrva*, 60 (1): 147–157
- TOLJIĆ, M. 2016. Tectonic evolution of the European margin and Neotethys suture zone in the region of Belgrade (Northern Šumadija-Serbia). *WSEAS Transactions on Environment and Development*, 12: 268–277.
- TOLJIĆ, M. & TRIVIĆ, B. 1997. Prilog poznavanju gornjokrednih deponata okoline Beograda [Contribution to the study of Upper Cretaceous deposits of Belgrade environs– in Serbian and English abstract]. *Geološki anali Balkanskoga poluostrva*, 61 (1): 115–124.
- TOLJIĆ, M., NENADIĆ, D., STOJADINOVIĆ, U., GAUDÉNYI, T. & BOGIĆEVIĆ, K. 2014. Quaternary tectonic and depositional evolution of eastern Srem (northwest Serbia). *Geološki anali Balkanskoga poluostrva*, 75: 43–57.
- TOLJIĆ, M., MATENCO, L., STOJADINOVIĆ, U., WILLINGSHOFER, E. & LJUBOVIĆ-OBRAĐOVIĆ, D. 2018. Understanding fossil forearc basins: Inferences from the Cretaceous Adria-Europe convergence in the NE Dinarides. *Global and Planetary Change*, DOI10.1016/j.gloplacha.2018.01.018
- TOLJIĆ, M., STOJADINOVIĆ, U. & KRSTEKANIĆ, N. 2019. Vardar Zone: New insights into the tectono-depositional subdivision. *Proceedings of the 2nd Congress of geologists of Bosnia and Herzegovina, Laktaši*, 60–73.
- TOMIĆ, V. 2005. Hidrogeologija flaširane vode Beograda [Hydrogeology of bottled water in Belgrade– in Serbian]. *Zapisi SGD za 2001*: 101–104.
- VASKOVIĆ, N. & MATOVIĆ, V. 1996. The Tertiary Volcanic Rocks from Mt. Avala. *Geološki anali Balkanskoga poluostrva* 60 (1): 391–414.
- WEICHER, C. & OBRAĐOVIĆ, S. 1950. Starost slojeva Avale sa gledišta mikropaleontologije (Zur Deutung des Alters der Schichten auf der Avala vom Standpunkte der Mikropaläontologie – in Serbian, German summary). *Glasnik Prirodnjačkog Muzeja*, A, 3: 81–93.

## Резиме

### Дубински геолошки односи на ширем подручју Београда: базирано на бушотинским и геофизичким подацима

Шири простор града Београда представља важну геолошку целину смештену у зони контакта јужног обода Панонског басена, с једне, и унутрашњих Динарида у ширем смислу, са друге стране. Овде обухваћено подручје заузима укупну површину око 2.000 km<sup>2</sup>.

У оквиру Панонског басена, геохронолошки и дубински, могу се разликовати две крупне целине: а) пренеогена основа (подбасенска целина) изграђена од различитих мезозојских стена тектонски интензивно орогено и разломно обликованих током старије алпског циклуса, и б) Неогена и квартарна запауна басена – дискордантни геолошки покров, дисјунктивно и компакционо обликован током неогеног периода.

У оквиру подбасенске целине, најстарије стене су црни, шкриљави серицитски пелити који, на основу присутне палинолошке асоцијације, одговарају старијој жури (горњи лијас – доњи догер). Утврђени су у Панчевачкој депресији (Рџ-1, 2.395–2.733 m).

Серпентинисани перидотити харцбургитског типа, утврђени су непосредно испод неогеног застора (Глогоњ), затим испод грубокластичног кредног покрива (Овча) и на потезу Љубичица–Бубањ поток, где је запажено обиље фрагмената и класти од серпентинита, рожнаца и других стена несумњиво из старије кредне етаже. На површини су од раније познати из долине Завојничке реке, Зуца и источних падина Авале. На терену показују западно-вергентни однос према млађој, флишној креди.

Анализом геомагнетних показатеља, у овом раду се, по први пут, приказује конкретна траса ултрабазичних пробоја. На приложеној карти конфигурације базе неогена, уцртана је као подбасенска дубинска пројекција апикалне осе, генералног правца С–Ј (Глогоњ–Велика хумка–Јабучки рит–железничка станица Овча–Мирјево–Мали мокри луг–Љубичица–Зуце).

На основу прикупљених геолошко-геофизичких података, утврђено је да на Авали нису присутне ултрабазичне стене. Напротив, постоји реална могућност присуства лаколитске интрузије киселог типа која је млађа од сенона.

Преко поменутих ултрамафита, утврђено је да лежи комплекс грубих кластита (бушотине Ов-1 и SA-2). Изграђен је од тврђих, компактних бреча и конгло-бреча дебљине и преко 120 m. У стратиграфском смислу, одговарају вероватно наслагама доње креде јер су у супрепозиционом односу испод тектонизованог горњокредног флиша.

Орогено тектонизовани подбасенски геолошки стуб Београдско-банатске морфоструктурне греде (ББМГ), генералног меридијанског правца, пренеогено је разломљен у блок системе различите оријентације, и додатно модификован на разуђену конфигурацију подине басена.

Током неогена, сложеним разломним зонама и слабије израженим раседним системима, обликоване су депресионе и антиформне структурне целине различитог правца. Најизразитије раседне зоне, делом са реактивираним пренеогеним дубинским разломима, и токови мање изражених раседања, на карти конфигурације подине неогена су уочљиве по правцима и дужинама различито згуснутих изопаха (сл. 10). Из тог разлога, доцртавање разломних траса није било потребно.

На проучаваном терену, међу морфоструктурним јединицама истичу се веће депресије попут Панчевачке, Сефкеринске, Батајничке и Грочанске, са мањом субдепресијом Мокри Луг. Структурни ровови су: Моштаница (ЈЗ угао карте), Макиш (залив Батајничке депресије), Крњача (београдско подунавље), Бели поток (предгорје Авале) и Банатски Брестовац (отворен према СИ).

У Београдском дунавском кључу, налази се антиформа Сланци и мања, Бабин вис. На банатској страни, нарочито се истичу хорст-масиви Овча, Јабука и Глогоњ. Морфоструктурни низ Банатско Ново Село–Владимировац–Долово–Баваниште, разграничава Панчевачку депресију од депресије Скореновац–Смедерево чији је западни продужетак видљив на приложеној



карти. Омољички хорст-масив, са мањим јединицама Старчево-Иваново има ЈИ продужење према антиформним структурама Мала ада (Брестовик) и Орешац (изван оквира карте).

Испод ширег центра Београда, налази се антиформни структурни и полифацијални (делом спрудотворни) низ Чубура-Калемегдан-Борча (продужно до Падинске скеле), затим краћи структурни нос од Чукарице до Бежаније, и раздвојени периклинални Остружнице на правцу Јаково и Сурчин.

Најстарији неогени седименти (доњи миоцен), ограничених контура, су разнобојне лимничко-субакватичне хетерокластичне моласе (прослојене вулканитима), у принципу оксидационе генезе. Откривене су на површини у ширем подручју Београда јужно од Дунава (нпр. Сланци, бушотина VP-150, дебљина моласа је око 200 m). У бушотинама код Овче и Гроцке (Ov-1, 110-166 m; SA-2, 145-229 m и G-1, 1.150-1.300 m) дебљина им је мања. Међутим, на дну панчевачке депресије утврђени су и посебно издвојени, синхрони, битно различити сиво-црни субакватични пелити редукиционе генезе дебљине око 415 m (бушотина Рč-1, 1.980-2.395 m) и ово представља посебно важан допринос овог рада.

Морски и морско-бракични седименти (средњи миоцен - баден и сармат), дискордантно и хетерохроно налажу преко различите подине. Издвојена су три типа развића: басенско-лагунски, приобално-спрудни и мешовити. Сваки појединачно има специфичне литофацијалне карактеристике и фосилну асоцијацију. У панчевачкој депресији баден је набушен тек на 1.452 m дубине и има велику дебљину (око 530 m). Слично је и око Долова где дубоко залеже преко доњокредног палеорељефа (бушотина Do-1). Најплиће испод површине, баденски седименти су набушени код Овче (76 m) где им је дебљина само 35 m, док на боковима хорстова Омољица и Банатско Ново Село потпуно искињавају. Као и баден, сармат је најтањи око Овче (свега неколико метара) и појављују се плитко испод површине (70 m). У панчевачкој депресији односно Долову и Баваништу, знатно је потонуо и задебљао и достиже између 400-500

метара дебљине. Слично је и у грочанској депресији, на крајњем југу терена, где достиже дебљину преко 400 m. Насупрот томе, на структурном гребену Омољица, сармат је редукован (око 180 m), а на раседнутом палеохорсту Банатско Ново Село (бушотина BNs-1) има дебљину око 60 m, и дискордантно належе преко доњокредног палеорељефа на дубини од 1.111 m. У делу терена јужно од Саве и Дунава, баденске и сарматске наслаге су широко заступљене на површини али су добро проучене и у плитким бушотинама на Калемегдану, Ташмајдану, Дорћолу, Вишњици, Карабурми, Кумодражу, Великом Мокром Лугу, Раковици, Торлаку, Лештанимаи др. где имају мању дебљину осим у ретким случајевима (Гроцка, бушотина G-1 - заједно преко 500 m).

Најмлађи миоценски бракично-језерски (каспибракични) седименти некадашњег Панонског језера (панон и понт) имају знатно распрострањење и укупно велику дебљину. Обично леже конкордантно преко сарматских наслага или, пак, дискордантно преко ултрамафита и кредних седимената око Јабучког и Глогоњског хорста. У околини Баваништа и Долова, достижу укупну дебљину преко 900 m, а утврђени су на дубинама испод 1.000 метара (Рč-1, Doz-1, Bav-1, BNs-1). У правцу Омољице и даље ка Дунаву доста су редуковани (< 700 m), код Глогња имају дебљину око 500 метара док су на потонулој греди у Овчи знатно редуковани (око 30 m).

Плиоценски, речно-језерски седименти (*Палудински* слојеви) утврђени су само на банатској страни проучаваног простора, северно од линеамента Сурчин-Борча-р. Тамиш-Панчево-Баваниште. Сва три нивоа палудинских слојева (на основу присуства различитих морфолошких облика филогенетског низа рода *Viviparus*) откривена су код Глогња и у Панчевачкој депресији (бушотине Gl-1, 100-381 m и Рč-1, 140-345 m), док су око Долова откривени само старији нивои (Doz-1, Do-1).

Квартарни седименти различите генезе представљају најмлађу јединицу басенске испуне. У панчевачкој депресији достижу укупну дебљину преко 140 m (Рč-1). У правцу југа, према Омољици дебљина им се значајно смањује. Код

Гроцке (G-1) имају симболичну дебљину. У бушотини G1-1 (Глогоњ), на дубини од 100 m, дефинисана је база квартара на основу налазка *Viviparus cf. diluvianus* (KUNTH).

Подповршинска геолошка грађа ширег подручја Београда још једном указује и на важност примене тзв. хидрогеолошких система (HGS I-IV), ауторизованих још 1974. године од стране Ђ. Мариновића, а публикованих нешто касније (Мариновић, 1982). Они јасно дефинишу хидрогеолошка својства појединих стратиграфских јединица, а с тим у вези, и минерализацију воде у њима. На пример, вода из Овче са контакта сармат/панон дубине 91m, има минерализацију 16,46 g/l (Милојевић, 1960), а вода са источне стране панчевачке депресије, из корелативно блиског панонског колектора дубине 1.013m, има готово идентичну минерализацију 16,40 g/l

(бушотина Doz-1, Шарчевић, 1973). Слично томе, воде из баденских колектора бушотина Doz-1 и Do-1 (Долово) дубина 1.602 и 1.674 m, имају минерализацију саображену интрабаденској „старости“ са повећањем минерализације од 25,9 на 32,6 g/l – сагласно савременим морским водама. Додатно, вода из миоценске лагуне, амбијентално високе минерализације (51 g/l), бочно је инфилтрирана у пукотински колектор од доњокредних наслага. Није на одмет додати да нпр. воде из понтских седимента (HGS I, комплекс D) у Кикинди из дубина 1.100–1.400 m, имају минерализацију између 4–6 g/l колика је и минерализација нивоа битне редукције каспи-бракичних кардида (Мариновић, 2017).

*Manuscript received October 30, 2020*

*Revised manuscript accepted November 26, 2020*