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

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Abstract. The subject work covers the Belgrade wider area with a total area of about 2,000 km². 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 2733 m. Explicit paleontological findings of specialized analytists with determinations of macro- and microfauna and flora are presented both from Neogene formations and the older basin 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 км². Аутори су објединили капиталне геолошке и геофизичке податке обезбеђене површинским истраживањима и мултидисциплинарним елементима из 52 бушотине са дубинама између 33 и 2733 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 акифера. Од геофизичких података за бушотине дубље од 400 м коришћени су записи каротажних мерења, са маркерима на основу којих су извршена валидна стратиграфска раз-
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 sides of the Sava and Danube rivers. Within that, so-called the Belgrade Danube meander (Beogradska dunavsk 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 (Boë, 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 understand 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 paleorelief. 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; Andelković, 1960; Marinović, 1970, 1971, 1977; Nikolić, 1976; Maksimović et al., 1990; Pantić & Dulić, 1990; Radićević et al., 2010; Đumić et al., 2017; Đumić 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 stratigraphic-paleontological, structural and well-logging data), was the key motive for presenting these results to the wider professional and scientific public.

Having in mind that the studied area in the northern part is completely covered with Quaternary sediments, the paper especially emphasizes specific and original interpretations of the distribution and depth relationship of main stratigraphic units as well as their morphostructural features.

An overview of the geological background

The studied area is shown on the index (toponyms) map (Fig. 1). It is spatially limited by a quadrangle: Belegiš–Banatsko Novo Selo–V. Moštanica–Mala Ada (Brestovik). It is mainly covered by thinner or thicker Quaternary deposits of various genesis (alluvium, river-marsh sediments, river terraces, deluvial-proluvial deposits, loess-paleosol sequences, etc.), as evidenced by numerous data (e.g. ČIVKOVIĆ, 1966; MARKOVIĆ, 1985; NENADIĆ et al., 2011; GAUĐENYI et al., 2015; KNEŽEVIĆ et al., 2018b; TOLIĆ et al., 2014).

Below the Quaternary cover, there is a complex of Miocene and Pliocene sediments of different thickness formed during the evolution of the Pannonian Basin and its southern rim (continental-lacustrine deposits with volcanics of the Lower and Middle Miocene, marine and marine-brackish Middle Miocene and caspibrackish to freshwater sediments of the Upper Miocene to Pliocene). Due to the large number of papers regarding this, only those in which the authors dealt with various aspects of the predominantly Miocene of the area are listed chronologically (LUKOVIĆ, 1922; PAVLOVIĆ, 1922; LASKAREV et al., 1931; LASKAREV, 1949; WEICHER & OBRADOVIĆ, 1950; MARINOVIC, 1961, 1962, 1977, 1982; MILETIĆ-SPAJIĆ, 1961; MARINOVIC & KEMenci, 1969; STANGAČILOVIĆ, 1969; KRSTIĆ, 1973, 1985; STEVANOVIĆ, 1957, 1975, 1977; NIKOVIĆ, 1976; MILAKOVIĆ, 1986; MIHAJLOVIĆ & KNEŽEVIĆ, 1989; ŠUMAR & RUNDIĆ, 1992; VASKOVIĆ & MATOVIĆ, 1996; Dolić, 1997, 1998; KNEŽEVIĆ & GANIĆ, 2005, 2008; KRSTIĆ et al., 2012; SCHWARZHANSET et al., 2015; GANIĆ et al., 2016; ANBELKOVIC & RADOJOVIĆ, 2018; JOVANOVIĆ et al., 2019). The most important details and results of the mentioned research will be discussed in more detail in the following chapters of this paper.

In the base of Neogene formations, there are the older rocks mostly built of various post-Triassic formations (diabases, serpentinized peridotites, radiolarites, clays, argilosists, limestones, sandstones, spilites, andesites, etc.) about which there are published data as well (e.g. ĐIMITRIJEVIĆ, 1931; PETKOVIC, 1951; ANBELKOVIC, 1960, 1973, 1987; ČANOVIĆ & KEMenci, 1988, 1999; KNEŽEVIĆ et al., 1994; TOJIĆ, 1996; ĐERIĆ et al., 2010; ĐUNIĆ et al., 2017). The stratigraphic position of these sedimentary rocks in the area of southern Banat and the Belgrade hills was determined on the basis of different macro- and microfauna (e.g. PANTIĆ & ŠEČEROV, 1975; KNEŽEVIĆ et al., 1994; BRAGIN et al., 2011). The genesis, chemistry features and age of igneous rocks were determined through their spatial relationships and relations to the surrounding rocks or based on geochemical characteristics and isotopic geochronology (e.g. SOKOLET al., 2020).

**Fig. 1.** Geographic position of the studied area (left, white rectangle), and a close-up with the main toponyms which mark position of the studied boreholes (right). Key: white circle – studied deep boreholes; full lines – geological cross-sections (I, II, III).

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 (ĐM), 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 (MARINOVIC, 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 (mgl) 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 Δz anomalies ZMP 1954 (NIKOLIĆ & SIMIN, 1959) and the fund of the Ζα 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 km². 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. Gagic („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“, 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,

![Fig. 2. Synthetic stratigraphic section of the borehole Ov-1](compiled by ĐM). 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, congo-breccia; 3, siltstone & claystone; 4, sandstone; 5, limestone; 6, marl, and 7, sand & gravel'
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 thinly-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, Gingko praeucta Bolkhovitina, Leptochylus sp., Bennettitales delucidus Bolkhovitina, Lophotriletes sp., Selaginella sp., Bothrychium sp., Lycopolium sp., etc. The lower Jurassic - Lias (J1) was determined (Figs. 3, 4).

Claystones and clayey siltstones with the association of dinoflagellate algae (Nannoceratopsis cf. gracilis Alberti i Gonyaulacista sp.), spores and pollen of the type Ginkgoaules sp., Cycadophytes sp., Konkisporites 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 (J1) (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 (Rößt) and Paviciningula 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 (Rößt), Semihsuum sp. A, Praewilliriedelium robustum (Matsuoka), Mirifusus dianae s.l. (Karrer), Spongocapsula palmerae Pessagno which corresponding to the late-middle Jurassic, while from a depth of 1,400 m the younger Jurassic association of radiolarians was determined: Parapodocapsa amphitrecteria (Foreman), Cinguloturris carpatica Dumitrica, Eucyrtidiellum ptyctum (Riedel & Sanfilippo), Archaeodictyomitra minoes (Mizutani), Protunnana japonicus Matsuoka & Yao, Zhamoidellum ovum Dumitrica, Hisccapsa hexagona (Hori). Biostratigraphically, it corresponds to the Upper Jurassic (J3- middle Oxfordian to late Tithonian) (Đerić et al., 2010) (Fig. 6).

The complex of ultrabasic rocks (6) is represented by peridotites and serpentinized peridotites (Figs. 2–4). They were found in the wells GI-1 (below 865 m) and GI-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 masif 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 serpentinized peridotites are degraded, tectonic deformed and intersected by a network of cracks. They are hydrothermally altered (Fig. 3).

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 38m 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 ($K_B$) lying over the ultramafic rocks was discovered in the wells Ov-1 and SA-2. It is built of hard breccias, or conglö-breccias. The clasts originate mainly from ultramafites, predominantly angular pieces of serpentinitized peridotites (Fig. 3) tightly bound by cement that partially contains a high percentage of carbonates. The thickness of these breccias is from 94m 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 serpentinite breccias were discovered in well Bt 1-2 (Ljubičica-Leštane) where, in the interval of 28-38 m depth, they overlie the mass of serpentinized peridotites in which drilling was completed (92m) (Rundić et al., 2019).

The Lower Cretaceous ($K_J^1, K_J^{1.5}$), 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 Patrijlius, 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 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* (Murgas, Filipescu), *Colomiosphaera heliosphaera* (Vogler), *Globochaeta alpina* Lombard, and rare headbergels, textularis and frequent radiolarians were drilled. These rocks correspond to the Hauterivian–Barremian Stage (Čanović & Kemenic, 1988). Similar the deep-sea Lower Cretaceous sediments were found in the well Doz-1 (Dolovo) in 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., *Litho-
Fig. 6. The geological cross-section Grocka – Banatsko Novo Selo. For the rest of legend, see Fig. 3.

(Rundić et al. 2019), and in Cerak near Rakovica (BC-3, 42.3 m – Maslarević & Gagić, 1976). They discordantly underlie the various Miocene formations.

In the base of Tertiary, tectonized flysch-like the Upper Cretaceous sediments (Kp, K2-4) 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* (Quereau), *G. concavata* (Brotzen), *Marginotruncana coronata* (Boll), *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 nanoplankton were identified from sandstones and siltstones: *Prediscosphaera cretacea* (Arkhangelsky), *Watznaueria barnesae* (Black in Black and Barnes), *Eiffelithus eximius* (Stover), *Chiasmopygus littorarius* (Görka), *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).

**Tertiary**

**Miocene**

The early Miocene “pre-Badenian” (Pbt, Pbp) is the oldest Tertiary unit found in most of the men-

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

| 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-9       | 52                  | 43, Cr-Pg flysch            | 30.8 Bd, 29 Pn+Q                 | Knežević & Ganić, 2005 |
| 7. Novi Beograd  | PdUS-10      | 140                 | It is not drilled           | 72 Bd, 52 Sm, 30 Pn+Q            | Knežević & Ganić, 2005 |
| 8. Novi Beograd  | PdUS-11      | 84                  | 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 limestone            | 29 Sm, 21 Pn+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 - Ćukarica | DB-9 | 43                  | 24, Cr-Pg flysch            | 14 Sm+Q                          | Knežević et al., 2012 |
| 16. Ada Ciganlija - Ćukarica | DB-10 | 40                 | 21, Cr-Pg flysch            | 11 Sm+Q                          | Knežević et al., 2012 |
| 17. Branko 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                  | Lučković, 1922 |
| 19. Beograd - Skadarlija | BC-3 | 321                | 147, Cr sandstone          | 64.5 Clay, limestone             | Tomic, 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 sandstone          | Bd, 45 sand, 35 Leitha lim.      | Stevanović, 1977 |
| 22. Beograd - 25. May Museum / Batićeva Str. | B-11 | 33                 | 29, Cr Urgonian limestone | 9 PBd Slan. Ser, 7 Sm+Q          | Knežević & Kristić, 2015 |
| 23. Beograd - Dr. D. Mišović Hospital | B-1 A | 120                | It is not drilled           | 96 PBd Slan. Ser. 30 Bd+Sm+Q     | Knežević & Kristić, 2015 |
| 24. Beograd - Konjarnik | No name *Ko | 251                | It is not drilled           | 150, Bd schlir, 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 - Jablanica 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           | 136.3 PBd, Slan. Ser, 3.2 Bd     | Đolić, 1977 |
| 28. V. Mokri Lug | No name *VML | 310               | 7 300, 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 O n+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                 | 28, Serpentinite, 28 Breccias | 21 PBd, 8 Bd+Q                  | Rundić et al., 2019 |
| 32. Rakovica village | KGK-14 | 160                | It is not drilled           | 100 Pn+P+Q                      | Knežević, 1989 |
| 33. Resnik | KGK-13 | 130                | 118, j-Cr?                 | 83 Sm+Pn+P+Q                    | Knežević, 1989 |
| 34. Pinosava | KGK-15 | 97                 | 80, j-Cr?                  | 8 P+Q                           | Knežević, 1989 |
| 35. Vrčin | KGK-16 | 232                | It is not drilled           | 212 Sm+Pn+P+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+P+Q                      | Rundić, 1990 |
tioned 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 predominance of greenish and brown-red clays, gray-green gravelly sands and conglomerates, fragments of cherts, serpentine, carbonates, and carbonate concretions were observed (Fig. 3, 6). In the whole series, the remains of freshwater molluskan 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 determine (Dulic et al., 2010). Sporadically, smaller occurrence of coal 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. Por) Pr. et Til., Triatriopollenites quietus (Potonie), Monocolpopollenites tranquillus (Potonie) and spores Polypodiaceosporites maschiensis Murr., Leiotriletes mexoides (Knežević, 1969) with the accompanying association of microflora remains, the series corresponds to the Lower Miocene (Knežević et al., 1994). Close to Ovče, this series of oxidative genesis locally thickens towards the east on a visible morphorheological 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 reducing genesis (PČ-1). In two intervals between 2,339 and 2,381 m, the black to black-gray slightly marly siltstones with thinner transitional 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, Polypodiaceosporites sp., Laevigatosporites sp., Toriosporites sp., Tricolpopollenites sp., Ephedripites sp., Sulbritpoporellpollenites simplex, Triatriopollenites hiatus, Monocolpopollenites sp., etc. (det. I. Dulic - internal report of the Naftagas, unpublished).

By correlating of the logging diagrams (Mari-
mains (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 (MARINOVIC, 1977). Concerning the different Badenian facies in the studied area, also wrote KNEZEVIC et al. (1994), GAJIC et al. (2008) and ANDELKOVIC & RADOJOEVIC (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., Clamydis sp., Dentalium badense PARTSCH, etc.) and red algae Lithothamnionp sp. confirm the truemarine Badenian mixed character of the mentioned deposits (det. V. MARKOVIC & 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 molluscs 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 Cretaceous “colorful series” or Slanci Formation (PAVLOVIC, 1922; LUKOVIC, 1922; DOLIC, 1997; 1998; RUNDIC et al., 2013; SCHWARZHANS et al., 2015; MANDIC 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 (KNEZEVIC & 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 od Danube river, the Badenian deposits have been studied by several authors (e.g. SPAJIC & DZODZO-TOMIC, 1973; STEVANOVIC, 1975, 1977 and references therein; KNEZEVIC & 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 (RUNDIC et al., 2011) while near Branko’s bridge, on the Srem side, observed in the well UDP-1 at a depth of 68 m (Table 1). In Serdar Jola Street near the D. Mišović Hospital, in the well B-1 about 120 m deep, Badenian sands and sandy limestones were discovered at 30 m depth and are over 60 m thick (KNEZEVIC & KRSTIC, 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 (LUKOVIC, 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 (SPAJIC & DZODZO-TOMIC, 1973; STEVANOVIC, 1977 - Table 1). In the area of Ljubičica and Bubanj potok, they are already drilled at 8 m of depth (Bt 1-2) and are quite reduced in thickness and overlie the pre-Badenian mollase (RUNDIC 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), BNSj-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 terrain (Fig. 6). At the structural ridge of Omoljica, their thickness has been reduced to about 180 m. On the disrupted paleohorist of Banatsko Novo Selo (BNS-1), the reduced Sarmatian layers about 120 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 transi-
tion to a reduced-marine environment. In addition to the small benthic foraminifers (*Elphidium macel-lum* (Fichtel & Moll), *Elphidium hauerinum* (d’Or-bigny) *El. reginum* (d’Orbigny), *Quinqueloculina acneriana* d’Orbigny, *Porosonion granosum* (d’Or-bigny), *Ammonia* ex. gr. *Beccarii* (Linne), etc.) and numerous ostracods, these deposits contain the particular assemblages of bivalves and gastropods such as *Ervilia dissita* Eichvvald, *Pirenella picta* De-france, *Musculus sarmaticus* (Gatuev), *Cerastoderma 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 14x12mm. Determination and photo by D. 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, Ćukarica, Rakovica, Leštane, Resnik, Grocka (Mitróvić & 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 pylons 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 Ćukarica 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 Kumorža (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), Bavi-1 (843–1,067 m), BNs-1-1 (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 promulti-striatum* Jekelius, *Orygoceras fuchsi* Kittl, *Gyraulus cf. preponticus* Gorjanović-Kramberger, et al. There are also numerous ostracods such as *Lineocypris reticu-lata* Mehes, *Serbiella sagitossa* Krsitc, *Hungarocypris*
hieroglyphica Mehes, Amplocypris subacuta Zalanyi, Cyprideis heterostigma obessa Reuss, Hemicytheria loerentheyi Mehes, etc. (Marinović, D., 1970, 1977; Spašić, 1987; Rundić, 1990; Knežević et al., 1994, 1999).

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

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 (Mišetić-Spašić, 1961; Krstić, 1973, 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 Ciganlija, 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: Pt1 and Pt2. In the wells around Pančevo, Bavaniste, 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 (Pt1) 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 caspibrackish mollusks (Paradacna abichi Hoernes, Didacna otiophorum Brusina) and ostracods (Leptocythere andrusovi Livental, Candona (Camptocypria) alata Zalanyi, Loxoconchis schwayeri Suzin, Hemicytheria pejinovicensis Zalanyi, Bacunella dorsoarcata Zalanyi, etc.) (Marinović, 1970, 1977; Knežević et al., 1994).

The younger level of Pontian (Pt2) 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 cornutocostata 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 (STEVA NOVIĆ, 1977; KNEŽEVIĆ, 1989 – Table 1). Both of the above-mentioned levels of the Pontian are well documented faunistically (RUNDIĆ, 1990; STEVA NOVIĆ, 1990; RUNDIĆ et al., 2019).

Pliocene

The Pliocene Paludina layers (PS1-3) 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 welllogging 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 riverare not present, while further to north they are present in the vicinity of Sremski Karlovi (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), Lithogyphus naticoides (PFEIFFER) and freshwater ostracods (Candona sp., Scottia sp., etc.). In the well GI-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 (NEVADIĆ et al., 2011; TOLIĆ et al., 2014; GAUDENYI et al., 2015; KNEŽEVIĆ et al., 2018b).

Structural-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 terrain 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 Kovilovo on the Banat side, to the northeast, encompassing the Jabuka and Glogonj massifs (Figure 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 subbasin projection on the reference map of the Neogene base configuration (Fig. 10). In the meander of the Zavojnička river, near Zuce, as well as east of Avala Mt. to the south, serpentinized 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. (al. 511), built of tectonized terrigenous flysch, including the lowest western and southern periclines, is marked by an anomalous geomagnetic minimum of a closed oval-funnel configuration, which indicates a depth absence of ultramafic 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 itscap built of flysch sediments there is no petrologically indeterminate magmatic pluton, or an ultramafic 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, wires 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 subbasin 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.

The presence of depth igneous channels from the basin floor of high convective heat transfer and intrabasin frequent the older Miocene effusive breakthroughs is shown on the map of geothermal gradients with closed anomaly 0,09 °C/m which is 40% larger than the area with the sunken Neogene sedimentary column with a dominantly conductive heat transfer on the eastern Banat side (Marinović, 2019). In this area, thanks to frequently volcanicogenic deposits within the Pre-Badenian continental-lacustrine series, the structural-tectonic elements originally adapted to the floor morphology, were altered by accompanying extrusions and additionally disturbed by a complex system of the parquet faults towards structural reorientations in the all directions. In that way, the intertwining of the primary structural fabric, the discordant sedimentary column disturbed by renewed extrusions (clasts, white and gray tuffs), was achieved, with possible synsedimentary pleats of lower intensity. Pre-Badenian anticlinal 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 disjunctively formed within the contour of Zvezdara south–Šumice–Marinkova bara–Miloševac–Jajinci–Razbojište–Kumodraž–Kaluderica (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-Omoljica 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 (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, in some places with discordantly arranged remains of clastic basal molasses, during the pre-Pontian over/ underflow 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 (Biljajčić, 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 anticlinal, 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 bor-
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.

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).

Fig. 10. The map of Neogene basis configuration (isopache E = 100 m) constructed based on available well data. The dashed line marks an apical axis of the Cimmerian phase of ultramafic rocks (by DM). Vertical hatching marks the simplified pre-Neogene contours (according to Milovanović & Ćirić, 1968 and modified with new data).
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 BBMG. In that area, the largest morphostructural unit is the Pančevo Neogene depression (Fig. 10, central and NE part). It has oval contours of 20x15 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 BBMG 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 floor of the eastern BBMG 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.

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The Grocka trench depression, measuring 10x5 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, thicken inversely to the SW and S, more than 300 m and together with the caspibrackish Pannonian sediments up to 700 m. The marginal facies of the Pontian on the SW flanks of the subdepression 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-glaucnonite 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 interdepression horst massifs of Jabuka and Glogonj, as the mentioned before, the invasive overflow was achieved at the beginning of Pannonian. 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–Vrbovsko 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 intradepression fracture, with depths of about 500 m, is noticeable on the stretch Bežaniša gornje polje–Zemun polje, with NE joining the just mentioned lineament Borča (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 uncovered area towards Nova Pazova is gradually shifting to a parallel lineament, the beginning of which is visible in the NW within the 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 (Ivkonović et al., 1966), the serpentinites and serpentinized peridotites 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 38m, 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. Andreković & Milojević, 1969; Toljčić, 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; Toljčić 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 Šupljia 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 congo-breccias (KB) 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 (92m) (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 & Kemenči, 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 re-
mains 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 (Dulić et al., 2010). A similar molasses formation has been found in dozens of wells in the wider vicinity of Belgrade under the name of Slanačka serija (= Slanci formation) (Dolić, 1997; Rundič et al., 2013; Knežević & Kristić, 2015).

Due to the lack of good chronostratigraphic benchmarks, it is not easy to give a close stratigraphic 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 mollasse belongs to the Lower Miocene. Herein, it corresponds to the Egenburgian-Ottnangian-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 reduxing 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 (Polypodiacea) 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 mohostructures 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 denivation of the existing relief. Good examples are the Badenian and Sarmatian 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 mohostructures, 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–Mala Ada (Brestovik). 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-Sand 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. Pančevo, Sefkerin) which have significantly thick Neogene deposits (1,900–2,600 m). It should be noted that the mechanism of their origin 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 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 D. Marinović 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 aquifier 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 (Mišević, 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 Do-1 with a depth of 839 m, has a lower mineralization, specifically 15.5 g/l. A 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 ac-
cordance with a modern marine waters (Šarković, 1973). Finally, water from the Miocene lagoon with an ambiently 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 caspibrackish cardids (Marinović, 2017).

Conclusions

- The Belgrade city area includes a segment of two morphologically touchable 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 depthly, it differs the subbasin unit affected by an intensive orogenic-fractured tectonization of the Alpine cycle, and, the discordant geological cover; disjunctively and compactly 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 pre-Senonian laccolitic intrusions of acidic magmatic differentiation Avala Mt. The presence of ultrabasite is excluded.
- Based on geomagnetic indicators, in this paper, for the first time, the route of ultrabasic break-throughs 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–Mirkovo–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, depressions and antiform structural units 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: Moštanička (SW corner of the map), Makiš (a bay of the Batajnica depression), Krsnjáča (Belgrade Danube River area), Beli Potok (foothills of Avala Mt.) and Batski Brestovac (open to the NE).
- In the meander of the Danube river, there is the Slanci antiform and the smaller one, Babin Vis. On the Banat side, the horst massifs Ovča, Jabuka and Glogonj stand out. The morphostructural row Batsko Novo Selo–Vladimirovac–Dolovo–Bavanište, somewhat separates the Pančevo depression from the Skorenovac–Smokerevo 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 antiform structures of Mala ada (Brestovik) and Orešac (outside the map).
- Below the Belgrade center, there is a structural polyfacial antiform, partly reefly row Čubura–Kalemegdan–Borča (extended to Padinska skela), then a shorter structural nose from Čukarica to Bežanija, and the separated periclinales of Ostružnica in the direction of Jakovo and Surčin.
- The oldest Neogene sediments of limited contours are lacustrine-subaquatic, multi-colored heterooclatic 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 (Badeñian, Sarmatian) are discordantly overlying the different rocks, over which they lie heterochronously. Three types can be separated: the basinal-lagoon, coastal-reefly 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 ambiental 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 discorances.

- 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 palentologically 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 palentologically 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 palentological elements of the aquifer, including lateral infiltrations into the reservoir on which the stratigraphic aquifer relies.

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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 контактa јужног обода Панонског басена, с једне, и унутрашњих Динарида у ширем смислу, са друге стране. Овде обухвaћeno подручје заузимa укупну површинu око 2.000 km².
У оквиру Панонског басена, геохронолошки и дубински, могу се разликовати две крупне целине: а) пренеогена основa (подбасенска целина) изграђена од различитих мезозојских стена тектонски интензивно орогено и разломно обликованиh током старије алпског циклуса, и б) Неогена и квартерна запуна басена - дискордантни геолошки покров, дисјунктивно и компакционo обликован током неогеног периода.
У оквиру подбасенске целине, најстаријe стена су црни, шкриљави серицитски пелити који, на основу присутне палинолошке асоцијацијe, одговарају старијој јури (горњи лијас - доњи доњегер). Утврђени су у Панчевачкој депресији (Pč-1, 2.395-2.733 m).
Серпентинисани перидотити харцбургитског типа, утврђени су непосредно испод неогеног застора (Глогоњ), затим испод грубокластичног кредног покрова (Овча) и на потезу Љубича-Бубањ поток, где је запажено обиље фрагмената и класти од серпентинита, рожнаца и других стена несумњиво из старије кредне етаже. На терену показују западно-вергентни однос према млађој, флишној крети.
Анализом геомагнетних показатељa, у овом раду се, по први пут, приказује конкретна траса ултрабазничних пробојa. На приложенoј карти конфигурацијe базе неогена, уткртана је као подбасенска дубинска пројекција апикалне осе, генералног правца C–J (Глогоњ–Велика хумка–Јабучки рит–железничка станица Овча–Мирјево–Мали мокри луг–Љубичица–Зуце).
На основу прикупљениh геолошко-геофизичкиh податакa, утврђено јe да на Авали нису присутне ултрабазичне стени. Напротив, постоjи реална могућност присуства лаколитске интрезие киселог типа којa је старијa од сенонa.
Преко поменутиh ултрамафита, утврђено јe да лежи комплекс грубих кластита (бушотини Ov-1 и SA-2). Изграђен јe од тврдих, компактних бреча и конгло-бреча дебљине и преко 120 m. У стратиграфском смислу, одговарају вероватно наслагамa доње кредне етаже.
Орогено тектонизовани подбасенски геолошки стуб Београдско-банатске морфоструктурне греде (ББМГ), генералног меридијанског правца, пренеогено је разломљен у блок системе различитих оријентациjе, и додатно модификовао на разуђену конфигурациjу подине басена.
Током неогена, сложеним разломним зонамa и слабије израженим раседним системимa, обликоване су депресионе и антиформне структурне целине различитог правца. Најизразитиjе раседне зоне, делом са реактивираним пренеогеним подбасенским разломимa, и токови мање изражених раседања, на карти конфигурациjе подине неогена су уочљиве по правциjамa различитo згуснутих изопахa (сл. 10).
На проучаваном терену, међу морфоструктурним јединицамa истичu се веће депресиe попут Панчевачке, Сефкеринске, Батајничке и Грочанске, сa мањом субдепресиjом Мокри Луг. Структурни ровови су: Моштанци (Ј3 угао карте), Макиш (залив Батајничке депресиjе), Крњача (београдско подунавље), Бели поток.
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 продужења 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), ограничен на контуру, 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 м). У бушотинама код Овче и Гроцке (Oв-1, 110–166 м; SA-2, 145–229 м и G-1, 1.150–1.300 м) дебљина им је мања. Међутим, на дну панчевачкој депресији утврђени су и посебно издвојени, синхрони, битно различити сиво-црни субакватични пелити редукционе генезе дебљине око 415 м (бушотина Рč-1, 1.980–2.395 м) и ово представља посебно важан допринос овог рада.

Морски и морско-брачични седименти (средњи миоцен - баден и сармат), дискордантно и хетерорхонто налазе се преко различите подине. Издвојена су три типа развица: басенско-лаңгуноски, прибалко-спрудни и мешовити. Сваки појединична је специфичне лиготафикалне карактеристике и фосилну асоцијацију. У Панчевачкој депресији баден је набушен тек на 1.452 м дубине и има велику дебљину (око 530 м). Слично је и око Долова где дубоко залеже преко доњокретног палеорељефа (бушотина Do-1). Наступање испод површине, баденски седименти су набушени код Овче (76 м) где им је дебљина само 35 м, док на боковима хорстова Омољица и Банатско Ново Село потпуно искиљивају. Као и баден, сармат је најтажи око Овче (свега неколико метара) и појављују се плитко испод површине (70 м). У панчевачкој депресији односно Долову и Баваништу, знатно је потонуо и задебљао и достиже између 400–500 метара дебљине. Слично је и у Грочанском и максе, на крајњем југу терена, где достиже дебљину преко 400 м. Насупрот томе, на структурном гребену Омољица, сармат је редукован (око 180 м), а на раседнутом палеохорсту Банатско Ново Село (бушотина BNs-1) има дебљину око 60 м, и дискордантно налазе се преко доњокрећног палеорељефа на дубини од 1.111 м. 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, Лештанима и др. где имају мању дебљину осим у ретким случајевима (Гроцка, бушотина G-1 – заједно преко 500 м).

Најмлађи миоценски брачичко-језерски (каспибрачични) седименти некадашњег Панонског језера (панон и понт) имају знатно распространење и укупну 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, достиже укупну дебљину преко 900 м, а утврђени су на дубинама испод 1.000 метара (Рч-1, Doz-1, Bav-1, BNs-1). У правцу Омољице и даље ка Дунаву доста су редуковани (< 700 м), код Глогоња имају дебљину око 500 метара док су на потонулој греди у Овчи знатно редуковани (око 30 м).

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

Квартарни седименти различите генезе представљају најмлађу јединицу басенске испуше. У панчевачкој депресији добија укупну дебљину преко 140 m (Pč-1). У правцу југа, према Омољици дебљина им се значајно смањује. Код Гроцке (G-1) имају симболичну дебљину. У бушотини Gl-1 (Глогоњ), на дубини од 100 m, дефинисана је база квартара на основу наласка *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 91 m, има минерализацију 16,46 g/l (Милојевић, 1960), а вода са источне стране панчевачке депресије, из корелативно блиског панонског колектора дубине 1013 m, има готово идентичну минерализацију 16,40 g/l (бушотина Doz-1, Шарчевић, 1973). Слично томе, вода из баденских колектора бушотина Doz-1 и Do-1 (Долово) дубина 1602 и 1674 m, имају минерализацију сагарбовану 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 каспибричних кардида (Мариновић, 2017).

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