

Stratigraphic characteristics of Quaternary deposits on the left bank of the Sava River near Belgrade

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Abstract. Quaternary deposits on the banks of the Sava River in the Belgrade area have a significant thickness and they are represented by genetically different formations. The data about these sediments were obtained by exploration of two relatively shallow boreholes, RB 47/P-1 and RB 53/P-1, located on the left bank of the Sava River. Two genetic entities are distinguished: the lacustrine-palustrine deposits of Plio–Pleistocene age and alluvial deposits of Pleistocene and Holocene age. Deposits of the Plio–Pleistocene are clearly different, both lithologically and palaeontologically, from the overlying alluvial deposits. Lithologically similar fluvial deposits of the Pleistocene and Holocene age were distinguished according to their palaeontological characteristics, particularly by the presence of bivalve genera *Corbicula* and *Dreissena*.

Key words: Quaternary, stratigraphy, boreholes, left bank of the Sava River.

Апстракт: Квартарне наслаге обале Саве код Београда имају знатну дебљину и представљене су генетски разноврсним творевинама. Подаци о овим седиментима добијени су проучавањем две релативно плиће бушотине, RB 47/P-1 и RB 53/P-1, лоциране на левој обали Саве. Генетски, овде се могу издвојити две целине: језерско-барске творевине плиоцена-плеистоцена и алувијалне творевине плеистоцена и холоцена. Наслаге плиоцена-плеистоцена се литолошки и палеонтолошки јасно разликују од алувијалних наслага у повласти, док су за раздвајање литолошки сличних речних творевина плеистоцена и холоцена послужиле њихове палеонтолошке карактеристике, присуство шкољака рода *Corbicula* и *Dreissena*.

Кључне речи: квартар, стратиграфија, бушотине, лева обала Саве.

Introduction

The Sava River separates the administrative areas of New Belgrade and the old part of Belgrade, which, from geographic and geotectonic standpoints, represent the lowland areas of the Pannonian Plain (Pannonian Basin) and hilly areas of the Balkan Peninsula, respectively.

On the left bank of the Sava River, in the Belgrade area, the thickness of Quaternary sediments is about 30 m. The surface layers are mostly made up of Holocene alluvial sediments. Information on the older sed-

iments of both Quaternary and Neogene age cannot be obtained by field studies, but only by exploration borehole drilling.

According to previous research, data from the existing boreholes and water wells situated on the banks of the Sava River, but also in the areas of Ada Ciganlija, New Belgrade and Zemun, it is concluded that, in addition to significant thickness, the Quaternary sediments are also characterized by extensive spatial distribution (LASKAREV, 1938; STEVANOVIĆ, 1977; KNEŽEVIĆ et al., 1998; JEVREMOVIĆ & KUZMIĆ, 1999; NENADIĆ, 1997, 2003; NENADIĆ et al., 2009, 2010,

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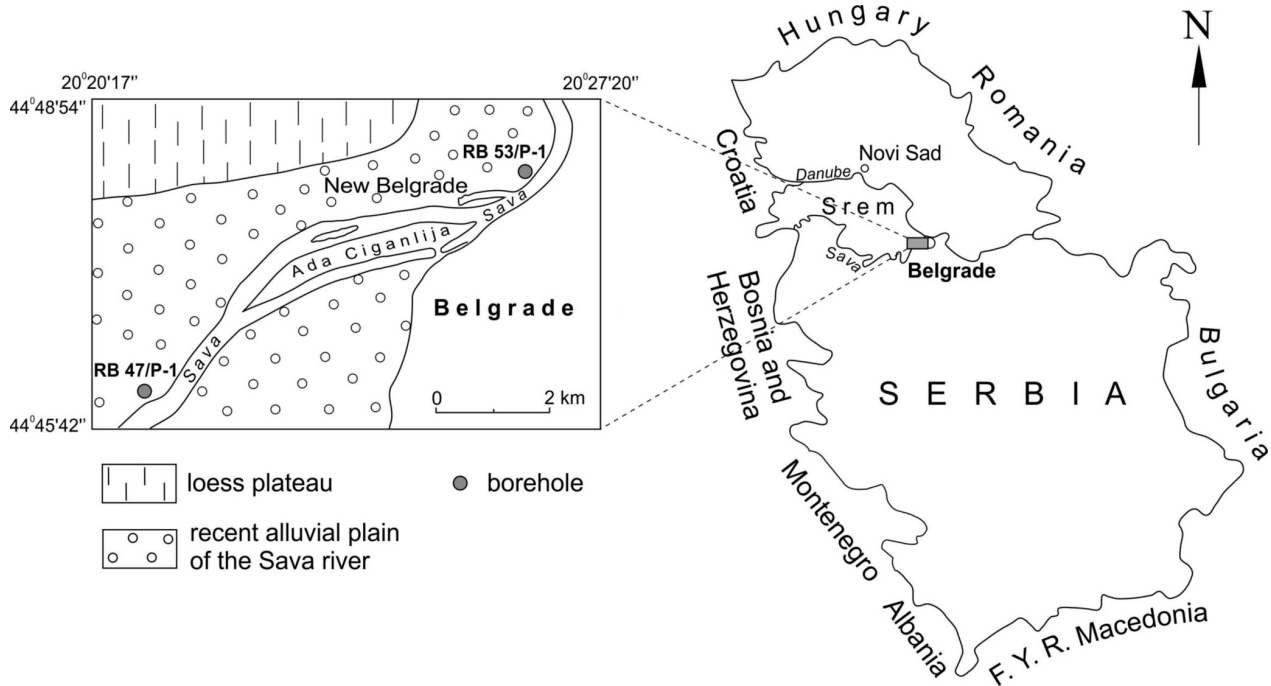


Fig. 1. Geographic position of the investigated area.

2011, 2015, 2016; NENADIĆ & GAUDENYI, 2013; NENADIĆ & BOGIĆEVIĆ, 2014).

A more complete picture of stratigraphic characteristics of Quaternary sediments was attained using the data obtained from the boreholes RB47/P-1 and RB 53/P-1, which were bored along the left bank of the Sava River in 2016/17. It may be concluded that both the immediate and the broader areas include various genetic types of the continental Quaternary sediments, originating as products of geodynamic processes under specific paleogeographic conditions.

Although the boreholes in the investigated area did not reach considerable depth (the deepest was 28.0 m), precise position, thickness, lithological and palaeontological composition of the Quaternary deposits has been clearly defined for each borehole. Geographic positions of the boreholes are presented in Fig. 1 (GPS coordinates RB53/P-1: 44°48'34" N; 20°26'38" E, altitude 76.08; RB47/P-1: 44°45'48" N 20°20'33" E, altitude 75.55).

New data on the Quaternary deposits of this area provide a more complete picture on the existing stratigraphic units, their interrelationships and contacts with the underlying sediments, in this case of the Neogene age. The new data set for Quaternary deposits on the Sava banks reported in this paper improves our understanding of the Quaternary stratigraphy and paleogeography in Central and Southeastern Europe.

Stratigraphic characteristics of deposits

According to the data from the borehole cores RB47/P-1 and RB53/P-1, deposits of the Neogene and

Quaternary age can be identified in the investigated area (Fig. 2).

Neogene

The Neogene deposits underlie Quaternary sediments in the borehole RB 53/P-1, from the depth of 27.7 m to the bottom of the hole. They are represented by deposits of Late Miocene (Pannonian) age made up of grey marly clay with ostracod microfauna and rare fossil molluscs: *Gyraulus praeponticus* (GORJANOVIĆ-KRAMBERGER), *Congeria banatica* HÖERNES, *Limnocardium* sp. etc. At the contact with the Quaternary sediments, these deposits are greyish-yellow and contain lenses of calcium carbonate.

Quaternary

Based on genesis, superposition and age of the Quaternary deposits, and by using the data obtained from the boreholes RB47/P-1 and RB53/P-1, two types of the Quaternary deposits can be identified in the valley of the Sava River in Belgrade:

1. lacustrine-palustrine sediments of Plio-Pleistocene age and
2. alluvial sediments of Pleistocene-Holocene age.

Lacustrine-palustrine sediments of Pliocene-Pleistocene age

These deposits are found in the borehole RB47/P-1, where only their upper level is present in the depth

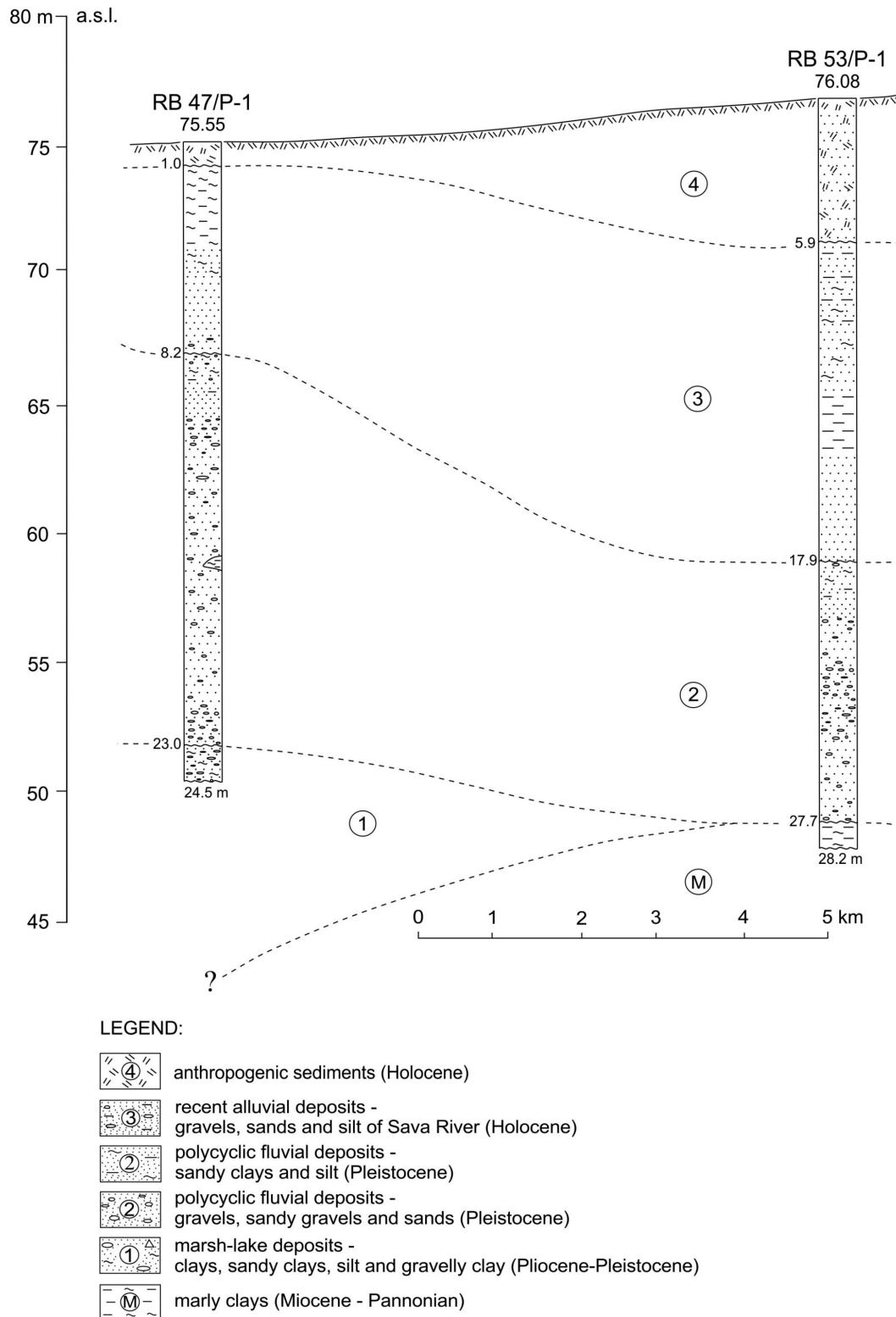


Fig. 2. Correlation of stratigraphic sections of boreholes RB 47/P-1 and RB 53/P-1.

range from 23.0 m to 24.5 m, i.e. to the bottom of the borehole, so their exact thickness is not known. According to the available published data, the thickness of these sediments in the area of Ada Ciganlija is approximately 18.0 m, on the left bank of the Sava Ri-

ver the thickness decreases, while in the area of Zemun it dramatically increases to more than 100 m (KNEŽEVIĆ et al., 1998; NENADIĆ, 1997, 2001, 2003; NENADIĆ et al., 2009, 2010, 2011, 2015, 2016; NENADIĆ & BOGIĆEVIĆ, 2014).

Lithologically, the oldest Quaternary deposits in the Sava River valley are composed of heterogeneous gray-brown, gray, brown-reddish clays (mainly greasy and hard), sandy clays, clayey sands, gravelly clays, etc. Occurrences of ooliths and lenses of manganese and iron oxides are common, sometimes even in greater quantity, when sediments acquire dark brown-gray colour. In certain places they contain lenses and concretions of calcium carbonate (KNEŽEVIĆ et al., 1998; NENADIĆ, 1997, 2003; NENADIĆ et al., 2001).

In the investigated boreholes these sediments are represented lithologically by gray-green silts, varicoloured gravelly silts and clays, with manganese and iron oxides and calcium carbonate concretions. They are palaeontologically sterile, i.e. they contain no fossils, except in the area of Zemun (KNEŽEVIĆ et al., 1988; NENADIĆ, 2003; NENADIĆ et al., 2009), where these deposits contain only rare gastropod genera *Lymnaea* and *Planorbis*.

It is assumed that these layers were deposited in palustrine-lacustrine environment. They are found only in certain places on the river island Ada Ciganlija and almost everywhere along the left bank of the Sava River, where their thickness significantly increases (KNEŽEVIĆ et al., 1998).

In the Sava River valley in Makiš, on Ada Ciganlija and along the left bank of the river in New Belgrade, these deposits discordantly overlie the Miocene sediments of the Paratethys (mostly marls of Pannonian age), while in the area of Zemun, they lie over lacustrine deposits of Pliocene age (KNEŽEVIĆ et al., 1998; NENADIĆ, 1997, 2001, 2003; NENADIĆ et al., 2009, 2010, 2011, 2015, 2016).

The age of these sediments cannot be precisely determined due to the lack of palaeontological evidence. However, according to their lithostratigraphic position and superposition, it is assumed that they were formed in the Late Pliocene and Early Pleistocene.

Alluvial sediments of Pleistocene–Holocene age

Alluvial deposits of Quaternary age (according to data from the investigated boreholes) consist of two cycles of alluvial sedimentation:

- *older cycle*, so-called polycyclic deposits of the Early–Middle Pleistocene age and
- *younger cycle*, i.e. recent alluvial sediments of the Sava River.

Lower–Middle Pleistocene fluvial polycyclic deposits

The most widespread Pleistocene deposits in the riparian area of the Sava River in Belgrade are fluvial polycyclic deposits. In the earlier published papers they were known as the “Makiš beds” or “beds with *Corbicula fluminalis*” (LASKAREV, 1938; STEVANOVIĆ, 1977).

On the right bank of the Sava River, they usually discordantly overlie Miocene or, to a lesser extent, pre-

Neogene sediments, and in some places they are deposited over lacustrine-palustrine layers of Plio–Pleistocene age. On the left bank of the Sava River, they cover thick lacustrine-palustrine Plio–Pleistocene deposits, and near the confluence of the Sava and Danube Rivers they overlie Upper Miocene (Pannonian) marls (KNEŽEVIĆ et al., 1998; NENADIĆ, 2003; NENADIĆ et al., 2015).

The Pleistocene deposits make up the most part of the Quaternary deposits in the investigated boreholes, with thicknesses that vary between 10.0 and 15.0 m. Lithologically, they are represented mostly by the brown-yellow and gray sands, gravelly sands and sandy gravels, silty sands, with intercalations of silts and clays.

Cyclic alternation of typical riverbed deposits (gravels, sands) and sediments of flood phase (silts and rarely clays) is observed in these boreholes. A regular multi-phase gradation of grain size has been formed, with coarser material in the lower and finer material in the upper parts.

The percentage of coarser material is larger around the river itself (investigated boreholes), especially on the right riverbank, and it decreases northwards, below the Srem loess Plateau in the direction of Zemun Polje and Batajnica (KNEŽEVIĆ et al., 1988; NENADIĆ, 2003; NENADIĆ et al., 2001, 2009, 2015, 2016). In these deposits in the wider area of southeastern Srem, two cycles of alluvial sedimentation are observed: the *older cycle*, in which sands and gravels predominate (polycyclic phase) and the *younger cycle*, made up primarily of silts (fluvial-palustrine deposits). In the Sava River valley in Belgrade, younger layers of this complex have been eroded, and they are discordantly overlain by alluvial deposits of the Sava River (NENADIĆ, 2003).

Pleistocene fluvial deposits contain fossil molluscs, predominantly: *Viviparus boeckhi* (HALAVATS), *Corbicula fluminalis* (MÜLLER), *Microcolpia daudebartii acicularis* (FÉRRUSAC), *Esperia esperi* (FÉRRUSAC), *Lithoglyphus naticoides* (PFEIFFER), *L. fuscus* (PFEIFFER), *Holandriana holandri* (PFEIFFER), *Theodoxus transversalis* (PFEIFFER), *T. danubialis* (PFEIFFER), *Bithynia tentaculata* (LINNAEUS), *Unio crassus* (PHILIPSON), *Pisidium amnicum* (MÜLLER), etc. (KNEŽEVIĆ et al., 1998; NENADIĆ, 2003). An unidentifiable vole tooth and bone fragments of large mammals have been found in these deposits, too.

The lower level of these deposits is usually represented by coarser clastites with very rare faunal remains, most commonly the species *Viviparus boeckhi* and fragments of unionids (GAUDENYI et al., 2013). The biostratigraphical-palaeontological criterion for setting the boundary between the Pleistocene and recent fluvial deposits is the presence of species *Corbicula fluminalis* (MÜLLER), *Viviparus boeckhi* (HALAVATS), and ostracods *Candona neglecta* SARS, *Ilyocypris bradyi* SARS and *Scottia browniana* (JONES).

In accordance with recent studies and the revised guide species, such as *Corbicula fluminalis* (MÜLLER), *Viviparus boeckhi* (HALAVATS) and *Esperiana esperi* (FÉRRUSAC), the Pleistocene fluvial deposits that contain the above mentioned species have been dated as the Lower–Middle Pleistocene (NENADIĆ et al., 2009; NENADIĆ & GAUDENYI, 2013, 2014; GAUDENYI et al., 2015; NENADIĆ et al., 2015, 2016).

Alluvial deposits of Holocene age

Recent fluvial deposits represent the youngest stratigraphical unit in the alluvial package in the boreholes RB 47/P-1 and RB 53/P-1. They cut all older Quaternary sediments, and mostly overlie fluvial polycyclic sediments of Pleistocene age. Deposition of recent alluvial sediments precedes the episode of erosion of younger levels of the Pleistocene fluvial deposits, so in the investigated boreholes younger horizons of these deposits (known as fluvial-palustrine sediments) are missing, but they can be observed in the areas of Bežanija and Zemun (KNEŽEVIĆ et al., 1998; NENADIĆ, 2003; NENADIĆ et al., 2009).

Recent fluvial deposits consist of riverbed sediments (sandy gravels and sands) and sediments of floodplain (silts and sandy silts). Lithological units of riverbed sediments, sands and gravels with lenses of sandy silts, are alternating vertically. Lithostratigraphical column in both boreholes ends with floodplain sediments, gray-brown sandy silts, silts and gray-brown sandy-silty clays.

In these deposits following species of molluscs were found: *Dreissena polymorpha* (PALLAS), *Viviparus viviparus* (LINNAEUS), *Unio pictorum* (LINNAEUS), as well as forms that occur in older Pleistocene sediments, such as: *Litoglyphus naticoides* (PFEIFFER), *L. fuscus* (PFEIFFER), *Microcolpia daudebartii acicularis* (FÉRRUSAC), *Theodoxus danubialis* (PFEIFFER), *T. transversalis* (PFEIFFER), *Holandriana holandri* (PFEIFFER), etc. Since the mollusc species *Dreissena polymorpha* is much less common in the fluvial deposits of Pleistocene age of the Sava riparian area, its significantly more abundant in the recent alluvial deposits, thus marking the boundary between lithologically similar Holocene and Pleistocene alluvial deposits.

Recent alluvial deposits are underlain by anthropogenic sands, whose thickness varies between 1.0 and 5.9 m (according to data from boreholes).

Discussion

In the areas of Ada Ciganlija, New Belgrade, Zemun and Makiš, recent research (KNEŽEVIĆ et al., 1998; NENADIĆ, 2003; NENADIĆ et al., 2009) revealed the presence of geological deposits that overlie the Neogene deposits and lie below Pleistocene fluvial polycyclic sediments. In the earlier literature these

beds were referred as the “Makiš beds” or “beds with *Corbicula fluminalis*” (LASKAREV, 1926, 1938; STEVANOVIC, 1977). However, the deposits were not identified as a separate stratigraphic unit of the Quaternary age, but were defined as “weathering crust” of the Neogene (Pannonian and Pontian) deposits of the Paratethys (ŽIVKOVIĆ 1976). Since 1990s, these deposits have been recognized as a separate unit, due to their extreme thickness, which sometimes exceeds 100 m, and their specific lithological-palaeontological features, of transitional, Plio–Pleistocene age (KNEŽEVIĆ et al., 1988).

Thickness of these sediments rapidly increases from the Sava River riparian area to the Srem loess plateau (Bežanijska Kosa and Zemun loess). Extreme thickness of these sediments has been registered in the Bežanija graveyard (near Kvantaš market), where the described deposits are over 100 meters thick and reach to the bottom of the drilled borehole (260 m), so their real thickness in this part of the area has only been assumed (KNEŽEVIĆ et al., 1998; NENADIĆ, 2003). Since they contain no fossils, biostratigraphical methods can not be used for age determination. As they underlie the upper parts of Lower Pleistocene sediments and overlie Pliocene deposits (in the area of Zemun) it has been assumed that they were deposited during Late Pliocene (Romanian)–Early Pleistocene (KNEŽEVIĆ et al., 1998; NENADIĆ, 2003; NENADIĆ et al., 2009).

In the other parts of the Pannonian Basin (Slavonija, Bačka, southern Banat) these deposits correspond to the layers of biostratigraphical zone with *Viviparus vukotinovi* (youngest horizon of the lacustrine Paludina beds) and “beds with *Viviparus boeckhi*” (NENADIĆ, 2003).

These deposits are widespread in the neighboring areas and are usually considered to be of Late Pliocene age, as, for example, on the Vukovar Plateau in Croatia (BAČANI et al., 1999) or in the southern parts of the Moldavian Plateau (GHENEA, 1970). Fluvial deposits were also common in Plio–Pleistocene: in Slovenia (Krško basin) non-carbonate sands and gravels of the oldest (fourth) terrace of the Sava River (VERBIĆ et al., 2000); in Romania (Dacian Basin) (Late Romanian–Early Pleistocene) deposits with mammal remains: *Mammuthus borsoni* (HAYS), *Anancus arvernensis* (CROIZET & JOBERT), *Mammuthus meridionalis* (NESTI) (ENCIU & BALTEANU, 2002).

Fluvial deposits of the Pleistocene age (fluvial polycyclic deposits or “beds with *Corbicula fluminalis*”) have been the subject of investigation related to Hydrogeological survey of Belgrade for a long time now (LASKAREV, 1938; STEVANOVIC, 1977; ŽIVKOVIĆ, 1976; RAKIĆ, 1977a; KNEŽEVIĆ et al., 1998; NENADIĆ, 2003). In the Sava River Valley they have been partly eroded and covered by recent alluvial sediments of this river, while in Bežanijska Kosa and Zemun, they are overlain by loess deposits of the Srem loess plateau.

There are several opinions on their age and origin: after HALAVATS (1915) they are “transitional” lacustrine beds between Late Pliocene and Pleistocene, while LASKAREV (1951), STEVANOVIĆ (1977) and MARKOVIĆ-MARJANOVIĆ (1978) considered them as fluviolacustrine sediments with *Viviparus boeckhi* in the lower part (Günz–Mindel after Alpine geochronological scale), and with *Corbicula fluminalis* in the upper part (Mindel–Riss).

The same deposits were identified in the territory of Romania (ONČESKU, 1960) as lacustrine deposits of Pliocene age, although they obviously contain fluvial fauna. According to other authors (GROMOV et al., 1960; MOSKVITIN, 1970), such layers in eastern England and glaciated areas of ex-USSR are known from the Riss glaciation and Riss/Würm interglaciation (Alpine geochronological scale).

Although the mentioned deposits in Serbia were mainly considered as lacustrine, alternation of riverbed, floodplain and oxbow deposits undoubtedly indicates fluvial character of the sediments, which are characterized also by an enhanced thickness. Only the younger part of these deposits was formed in a regime of relatively calm water (floodplain-palustrine conditions), with very slow water flow and long-term standstill (RAKIĆ, 1977a; RAKIĆ et al., 1998; NENADIĆ, 2003).

In these deposits, in contrast to limnic fauna of the Paludina beds, there are no sculpted unionids, *Viviparus* and *Fagotia*, *Corbicula* and other recent forms.

Earlier authors (e.g. LASKAREV, 1938; STEVANOVIĆ, 1977) used the presence of the fossil assemblage of molluscs *Corbicula fluminalis* (MÜLLER) and *Viviparus diluvianus* (KUNTH.), to determine the age as Middle Pleistocene, i.e. Mindel, Mindel/Riss (after the Pleistocene subdivision for the Alps). It has been later established that *Viviparus diluvianus* corresponds to species *Viviparus boeckhi* (KROLOPP, 1983), so the revision of age of the Makiš beds, as well as a more detailed regional correlation, became possible.

The guide fossils presently used for the age determination (Early Pleistocene) are *Viviparus boeckhi* (HALAVATS) and *Esperia esperi* (FÉRRUSAC) in the older coarse-clastic beds, and the Pleistocene *Corbicula* in the younger gravelly sands.

After recent studies and the revision of the guide species, such as *Corbicula fluminalis* (MÜLLER), *Viviparus boeckhi* (HALAVATS) and *Esperia esperi* (FÉRRUSAC), the Pleistocene fluvial deposits that contain the mentioned species have been dated as the Early–Middle Pleistocene (NENADIĆ et al., 2009).

The equivalents of fluvial polycyclic deposits in the area of southern Banat (RAKIĆ, 1985) are gravels and sands with occasional occurrences of silts and clays which cover deposits of Pontian age or Paludina beds (lower part of Upper Pliocene). At Belgrade hill chain, to the south of the Danube and Sava Rivers, lateral equivalents of these deposits are represented by poly-

genetic terrestrial and palustrine sediments (NENADIĆ, 2003). Fluvial polycyclic sediments could be correlated with the seventh terrace of the Danube River in the Dacian Basin (with a relative height 110–120 m), made of fluvial sediments of Early and Middle Pleistocene (PEH et al., 1998; ENCIU & BALTEANU, 2002).

These deposits can be correlated with “high terraces” (“visoke terase”) of the Danube and Morava valleys in the territory of Serbia (of 150–160 m and 90–110 m, respectively) in which the Pleistocene *Corbicula* was recorded (RAKIĆ, 1977b, 1990; NENADIĆ & BOGIĆEVIĆ, 2014).

Conclusions

This paper presents an overview of the Quaternary deposits on the left bank of the Sava River in the Belgrade area (boreholes RB 47/P-1 and RB 53/P-1), in the part of the terrain where the southern edge of the Pannonian Plain meets the Balkan Peninsula. The oldest horizon of the Quaternary deposits, which was only partially bored (borehole RB47/P-1), is represented by the Plio–Pleistocene sediments which have often been erroneously considered to be Neogene–Upper Miocene in age. According to lithological characteristics and very scarce fossil records, it is assumed that these sediments were formed in an environment of unstable shallow lakes and ponds which sporadically dried up, with significant influence of temporary riverine watercourses.

Material that composes these deposits in the investigated area originated in the hilly region of the Belgrade promontory, representing an area of intensive denudation. Most of this material was previously deposited in loosely cemented Early Neogene (Pannonian and Pontian) deposits. It was later redeposited in the areas of present-day New Belgrade, Zemun and Bežanija, where thickness of these deposits may be substantial (over 100 m) (KNEŽEVIĆ et al., 1988; NENADIĆ, 2001, 2003; NENADIĆ et al., 2009).

Among the Pleistocene deposits in boreholes RB 47/P-1 and RB 53/P-1, the sediments with the most extensive spatial distribution are polycyclic sediments of Early and Middle Pleistocene, as is generally the case along the banks of the Sava River. Their paleontological indicators include greater abundance of species *Viviparus boeckhi* in the older and *Corbicula fluminalis* in the younger horizons. In the floodplain sediments (clays, silts) these species were replaced by dominant forms of *Planorbis planorbis* (morph with denticula) and the ostracod species *Scottia browniana* (KNEŽEVIĆ et al., 1988; NENADIĆ, 2003; RAKIĆ et al., 2002).

The polycyclic fluvial deposits of Pleistocene age were formed in the ancient valley of the Sava River, under the influence of multiple tectonic movements, as a product of a large lowland river that changed the

shape of its bed in cycles, causally connected to tectonic movements and specific paleoclimate conditions. Large amounts of sand and gravel indicate humid climate and intense precipitation, the largest number of present mollusc genera and species are generally associated with beds of fast and moderately fast rivers with clear water, while there is a much smaller number of species characteristic for a less mobile aquatic environment (NENADIĆ, 2003; NENADIĆ et al., 2009).

The results of the core analyses in the 1990s and 2000s suggest that the Pleistocene *Corbicula* species of the Sava River riparian basin belongs to the temperate stages (equivalent to the interglacials) of late Early and early Middle Pleistocene age (NENADIĆ et al., 2009; NENADIĆ & BOGIĆEVIĆ, 2014; GAUDENYI et al., 2015).

In addition to their stratigraphic importance, these sediments also have a high economic significance due to their connection to aquifers utilized to provide the City of Belgrade with drinking water. Besides, it is worth mentioning that up to recently the fossils of bivalves and gastropods from investigated sediments were predominantly used for biostratigraphical subdivision, neglecting the importance of palaeoecological analysis and its comparison in the abundance and expansion with the recent representatives. This kind of study, as it is pointed by RADULOVIĆ et al., (2016) should be incorporated in future studies as it could shed light on the questions related to anthropogenic factors and their influence to expansion and invasive character of recent representatives of *Corbicula fluminalis* and *Dreissena polymorpha*. Additionally, the importance of palaeoecological data provided from Quaternary sediments has been acknowledged as crucial in terms of global conservation related to species invasion, biodiversity crisis, natural variability, climate changes, etc. (BIRKS, 1996; WILLIS & BIRKS, 2006).

A large part of the alluvial Pleistocene sediments at the banks of the Sava River were eroded after the formation of its present bed and the recent alluvial plain of the Sava River and its tributaries. From the lithological point of view, the Holocene alluvial sediments are similar to the fluvial deposits of Pleistocene age. The palaeontological criterion for their separation includes species *Corbicula fluminalis*, present only in older fluvial deposits and species *Dreissena polymorpha*, which is much more common in the formations of Holocene age.

It is supposed that in the geological past, probably in early Holocene, the beds of the Sava River and its tributaries were situated significantly more northward than the present-day riverbed, as evidenced by numerous abandoned and compressed meanders. In addition to the migration from the north, the riverbed of the Sava River was occasionally also situated more to the south, and meandering from the edge of the Makiš area to Bežanija escarpment, it left behind many marshes and oxbow lakes which are presently visible

as remnants of its old bed (NENADIĆ, 2002, 2003). Significance of this movement of the riverbed was in redeposition of the previously deposited Pleistocene or even Holocene sediments, as may be determined according to the data from the investigated boreholes.

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Резиме

Стратиграфске карактеристике квартарних наслага леве обале Саве код Београда

У раду је дат приказ квартарних наслага леве обале Саве код Београда (бушотине RB 47/P-1 и RB 53/P-1), у делу терена где се граничи јужни обод Панонске низије са Балканским полуострвом.

Најстарији хоризонт квартарних творевина, који је само делимично набушен (бушотина RB47/P-1) представљен је наслагама плиоцена–плеистоцена које су раније често погрешно сврставане у творевине неогене старости (горњи миоцен). Према литолошким карактеристикама и врло ретким налазима фосила претпоставља се да су ове насlage стваране у амбијенту несталних плитких језера и бара које су повремено пресушивале, уз утицај повремених речних токова.

Материјал који је коришћен за акумулацију ових творевина на проучаваном подручју води порекло са брежуљкастих терена београдског рта, који су представљали област интензивне денудације. При томе је највећим делом одношен преталожени материјал из слабије везаних млађих неогених наслага (панона и понта) и таложен је на простору данашњег Новог Београда, Земуна и Бежаније, где ове насlage местимично имају јако велику дебљину (KNEŽEVIĆ i dr., 1988; NENADIĆ, 2001, 2003; NENADIĆ i dr., 2009).

Најраспрострањеније плеистоценске творевине у бушотинама RB 47/P-1 и RB 53/P1, али и шире у приобаљу реке Саве представљене су речним полицикличним седиментима старијег и средњег плеистоцена. Палеонтолошки су обележени чешћим присуством врсте *Viviparus boeckhi* у старијим и *Corbicula fluminalis* у млађим хоризонтима. У седиментима поводња (глине, алеврити) уместо поменутих врста јављају се као карактеристичне форме *Planorbis planorbis* са зубом и остракодска врста *Scottia browniana* (KNEŽEVIĆ i dr., 1988; NENADIĆ 2003; RAKIĆ i dr., 2002).

Полицикличне речне творевине плеистоценске старости настале су у прадолини Саве, под утицајем вишеструких тектонских покрета, као продукт велике разливане реке која је у циклусима мењала контуре свога корита, узрочно везаним за тектонске покрете и специфичне палеоклиматске услове. Велике количине песка и шљунка указују на влажну климу и обилне падавине, при чему је највећи број присутних родова и врста мекушаца везан за корито брзих и умерено покретљивих бистрих река, а знатно мањи број указује на слабо покретљиву водену средину (NENADIĆ, 2003; NENADIĆ i dr., 2009).

Резултати добијени из бушотина указују да плеистоценска *Corbicula* приобаља Саве припада умереним фазама (еквиваленти интергласијала) горњег дела старијег плеистоцена и доњег дела средњег плеистоцена (NENADIĆ i dr., 2009; NENADIĆ & BOGIĆEVIĆ, 2014; GAUDENYI i dr., 2015).

Ове наслаге, поред стратиграфског имају и велики економски значај пошто су за њих везани аквифери подземних вода из којих се преко рени бунара Београд снабдева пијаћом водом. Осим овога, указано је на значај палеоеколошке анализе проучавање фосилне фауне шкољака и пужева, као и на значај поређења бројности и динамике ширења фосилних и савремених представника у кон-

тексту проучавања антропогеног утицаја на инвазиван карактер врста *Corbicula fluminalis* и *Dreissena polymorpha*.

Велики део алувијалних плеистоценских наслага у приобаљу Саве еродован је након усецања корита и формирања савремене алувијалне равни Саве и њених притока. Литолошки, холоценски алувијални седименти слични су речним наслага плеистоценске старости. Палеонтолошки критеријум за њихово раздвајање послужила је врста *Corbicula fluminalis*, присутна само у старијим речним творевинама и врста *Dreissena polymorpha*, чије је присуство далеко чешће у творевинама холоценске старости.

Сматра се да је корито Саве и њених притока у геолошкој прошлости, вероватно у старијем холоцену, било знатно северније од данашњег о чему сведоче бројни напуштени и стиснути меандри. Поред миграције са севера, корито реке Саве некада се налазило и јужно, те је меандрирајући од Макишког обода па до Бежанијског одсека, остављао за собом баруштине и мртваје, које данас представљају остатке њеног старог корита (NENADIĆ 2002, 2003). Овакво померање корита реке Саве имало је велики утицај на преталожавање раније депонованих плеистоценских, али и холоценских седимената, што се и може констатовати на основу података из проучаваних бушотина.

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