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Дигитални репозиторијум Рударско-геолошког факултета Универзитета у Београду

[ДР РГФ]

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10.5937/bnhmb2316035N

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Bulletin of the Natural History Museum, 2023, 16: 35-54.
Received 23 Feb 2023; Accepted 13 Dec 2023.

doi:10.5937/bnhmb2316035N
UDC: 551.791(497.11)
Original scientific paper

MORPHOSTRATIGRAPHICAL CORRELATION OF THE SAVA RIVER SEDIMENTS NEAR BELGRADE AND THE JUŽNA MORAVA TERRACES

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In the riparian area of the Sava River near Belgrade in the southern part of the Pannonian basin, Pleistocene fluvial deposits have a significant distribution and thickness which varies from 10 to 40 meters. These sediments are almost universally overlain by younger Pleistocene loess sediments or Holocene alluvial deposits, while they are underlain by sediments of Pliocene-Pleistocene age. Pleistocene deposits of similar characteristics form high and middle erosional-accumulative terraces of the South Morava valley system. Beneath the Pleistocene fluvial deposits are pre-Quaternary deposits of different compositions and ages. Although there are significant height differences between the alluvial Pleistocene deposits in the area of the Sava River near Belgrade compared to the high terraces of the Morava River, created as a result of opposite tectonic movements in the northern and southern parts of Serbia. Moreover, the terraces of the Južna Morava were formed in the mountainous areas, while the Sava river sediments near Belgrade are in the lowland area. They cannot be successfully correlated on the basis of their lithofacies and paleontological characteristics. The morpho-stratigraphical correlation would be useful to be applied first on the relation terraces of the Zapadna and Južna Morava, the results would be correlated with the

terraces of Velika Morava, while the Velika Morava terraces can be correlated with the Sava sediments near Belgrade.

Key words: Pleistocene, stratigraphy, alluvial deposits, Sava River, Belgrade, Morava terraces

INTRODUCTION

An obvious but commonly overlooked observation is that not all river valleys contain terraces, so studies of terrace stratigraphy and genesis are necessarily biased towards that subset of fluvial and watershed-scale processes that conspire to make and preserve terraces. Similarly, the vast majority of terrace sequences are in the context of modern rivers and river valleys reflecting processes that dominate during the Quaternary, or even more temporally restrictive, of the Holocene. The Quaternary, with its characteristic high-amplitude and high-frequency glacial-interglacial climate unsteadiness, may be diagnostic, but not representative of prevailing late Cenozoic environmental conditions. We may live in a world where river terraces are so common because they represent a landform reflecting the unique conditions of Quaternary environmental change (Pazzaglia 2022).

Terraces are an expression of contrasting erosional and depositional processes, played out at the watershed scale, and orchestrated by base level, hydrology, hillslope sediment flux, and sediment caliber. The most basic conclusion that terraces demand is that these conditions and processes are not steady or necessarily uniform. It is possible that autogenic processes within the confines of a watershed can drive the unsteadiness, but it is more common that base level and climate, forces external to the watershed, dominate the unsteady erosion and depositional processes. Base level is a combination of eustasy and rock uplift with the former mostly lacking for more continental settings far from the coast. Climate refers not only to mean annual temperature and moisture, but also to precipitation intensity, seasonality, and inter-annual variability. For lofty mountainous settings and large watersheds climate is typically non-uniform, resulting in spatially variable terrace genesis and preservation. Because of their close genetic link to base level and climate, terraces embody core, if not necessarily high-resolution paleohydrologic and paleogeodetic data, specific examples of which follow below. There are, however, common errors that studies make in trying to use terraces for these purposes. In terms of paleohydro-

logy, it is erroneous to conclude that terrace genesis is uniformly in phase with a prevailing environmental setting. Rather, it is more common that

Fig. 1. - Geographical sketch of the investigated area.

terraces represent transient responses to an environmental change. Furthermore, the phase of that response can depend on aridity, substrate, and watershed relief (Pazzaglia 2022).

Pleistocene fluvial deposits have a significant distribution and thickness in the area of the Sava River near Belgrade, but similar deposits also build higher terraces of the valley systems of the Morava and Danube. These deposits are characterized by a significantly increased thickness and a cyclical shift of riverbed accumulations, floodplain, and oxbows in several sedimentation cycles. In the Sava area near Belgrade, they are mostly covered by loess deposits of younger Pleistocene age or alluvial sediments of Holocene age, while they are underlain by sediments of earlier Quaternary or Plio-Pleistocene age, in some places even of the Neogene and Mesozoic age. Terrace levels are of erosional-accumulative character, and pre-Quaternary deposits of different compositions and ages lie beneath the Pleistocene fluvial deposits.

This paper represents an attempt at the stratigraphic correlation of fluvial deposits of Pleistocene age from the area of southeastern Srem with deposits of the same age that form terraces in the area of Južna Morava. Similarly, a correlation was made with the Danube terraces in eastern Serbia (Nenadić & Bogićević 2014, Nenadić *et al*. 2015a).

In this work, the compilation data obtained from several boreholes in the area of the Sava River of Belgrade (Makiš field and Novi Beograd) are used (Knežević *et al*. 1998, 2018, Nenadić *et al*. 2009, 2015a, 2015b, Nenadić & Bogićević 2014) and the data on the Moravian terraces from the area of the southern part of Serbia were obtained based on the existing literature and Rakić's published papers (1977, 1990).

MATERIAL AND METHODS

In each of these cases the so-called morphostratigraphical unit is used to denote a body of sediment that is identified primarily from the surface form it displays (Frye & Willman 1962). Central to the recognition of such units is that they include both landform and lithology in their definition (Bowen 1978). Clearly these units are not directly comparable to standard lithostratigraphical units, where vertical and lateral changes, as well as relationships to other units, can generally be observed unambiguously. Morphostratigraphical units should, therefore, only be given informal status (Richmond 1959). However, in some Quaternary sequences, particularly in regions of recent glacial recession, moraine ridges mapped over considerable distances are often afforded virtually formal status, e.g. the Salpausselkä Moraines in southern Finland. Similarly, shorelines, either raised or submerged, have been used in a comparable sense in some regions (Rawson *et al*. 2002).

Nevertheless, the apparently simple external morphology of some landforms, such as river terrace surfaces, dunes or ice-marginal formations, commonly masks internal complexities of sediment sequences preserved

beneath or within them. For this reason, whilst morphostratigraphy might prove to be very useful in some regions, it should never be regarded as a substitute for, or a short-hand way of referring to, other more precise types of stratigraphical unit, such as outlined under lithostratigraphical units (Rawson *et al.* 2002).

In this paper material from three boreholes (RB-47, B-7 and DB-4) from the area of southern Srem near Belgrade (Makiš field and Novi Beograd) has been sampled and used. A few research methods have been applied: paleontological analysis (mainly of mollusk and ostracod fauna), sedimentological-petrological and classical stratigraphical principles of superposition.

The specimens of fossils, visible to the naked eye, were collected by hand. For others, simple methods of disaggregating have been performed, including washing, heating, and dissolving the bulk of the material using 6% hydrogen peroxide. Identification of small-size shells (malacofauna and rarely ostracods) was done under a binocular microscope. The remains of mollusks and ostracods were picked out under a stereomicroscope Zeiss Stemi 1000 and identified to the species level wherever possible. All the discovered fossils were identified, and index fossils were used to delineate the stratigraphy. If no fossils were available, the age of the deposits was estimated by superposition.

The petrological composition of gravel was identified macroscopically. The magnetic fractions from the sandy facies were separated. For granulometric analysis of clayey fractions, the pipette method based on the Stokes law has been applied. In some gravel fractions roundness and sphericity of pebbles has been evaluated. The method of calcimetry was used to determine the calcium carbonate content.

Data on the terraces of Južna Morava, and their lithological and paleontological characteristics were obtained based on existing literature and research conducted by Rakić (1977, 1990).

STRATIGRAPHY AND LITHOLOGY

Riparian area of the Sava near Belgrade

The most widespread Pleistocene deposits in the riparian area of the Sava near Belgrade are fluvial deposits. They are known as "Beds with *Corbicula fluminalis*" and "Makiš Deposits" (Laskarev 1938, Stevanović 1977) and have a large distribution and considerable thickness. Lithologically they are made of a cyclical alternation of typical riverbed deposits (gravelly sands and sandy gravels) and sediments of the flood phase (sands and silty sands with intercalations of silts and clays) which alternate in the

vertical and horizontal directions. Cyclic alternation of typical riverbed deposits and sediments of flood phases could be observed in many places in this area. In some cycles flood deposits are missing (probably eroded before the sedimentation of the overlying cycle) and gradation of material has been formed with coarser material in the lower and finer in the upper parts.

Due to frequent alternation of coarse-grained and fine-grained fractions, in horizontal as in the vertical direction, these sediments are also known as „polycyclic fluvial deposits“. Based on lithofacies characteristics, two cycles of alluvial sedimentation could be singled out in these deposits: *older* fluvial phase (mostly sands and gravels) and *younger* fluvial-palustrine deposits, built mainly of sand and silts (Rakić 1990, Stejić 1997, Stejić & Rakić 1998, Nenadić 2003, Nenadić *et al*. 2001, 2009, 2015a, 2015b, Knežević *et al*. 2018).

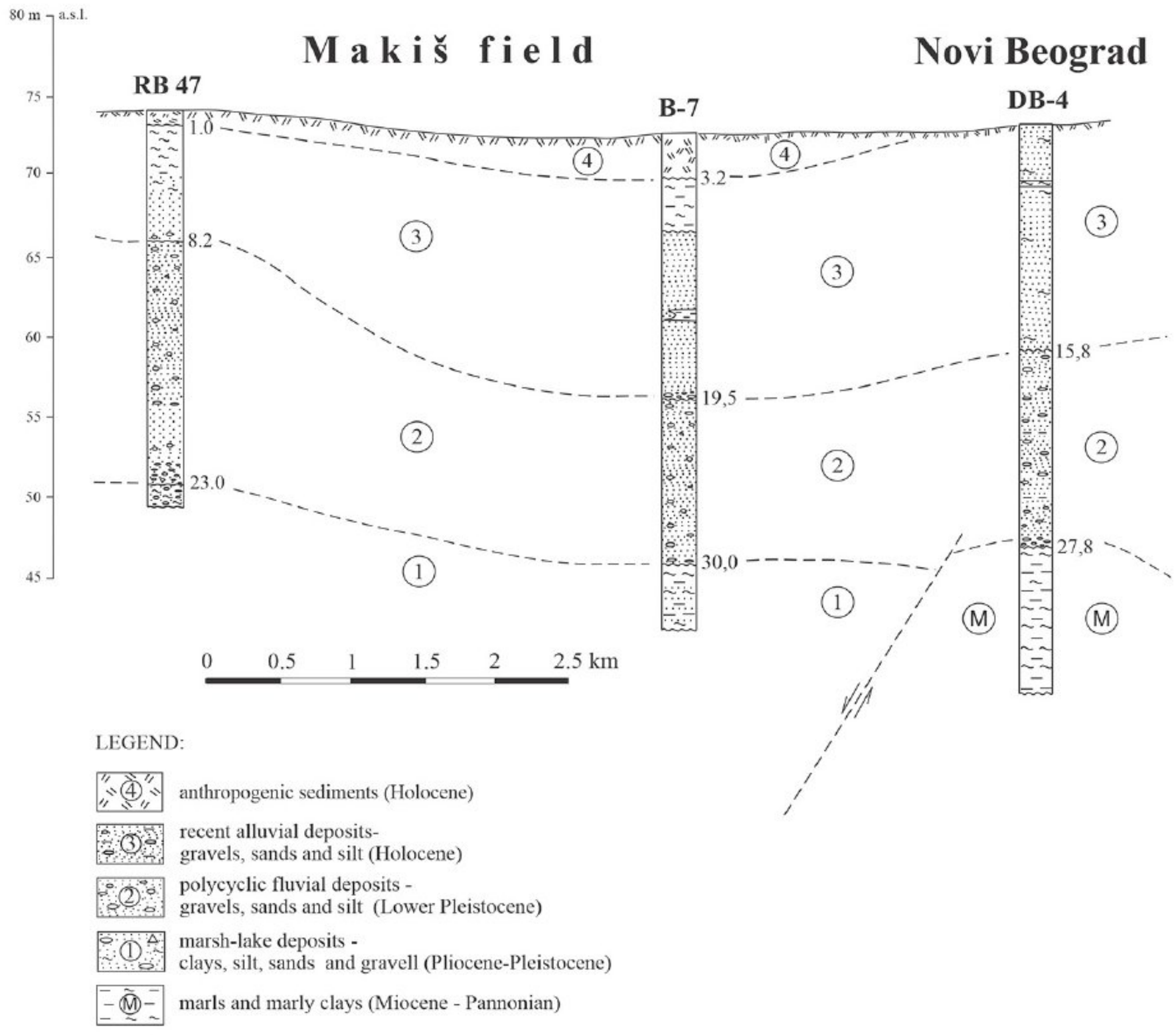

Fig. 2. - Stratigraphic correlation of Quaternary deposits based on drills on the stretch Makiš field- Novi Beograd (based on the data in Nenadić *et al*. 2015b, Knežević *et al*. 2018).

Beside index fossils the Pleistocene *Corbicula* and *Viviparus boeckhi* (Halavats) the commonest mollusks in these deposits are *Microcolpia daudebartii acicularis* (Férussac), *Esperiana esperi* (Férrusac), *Holandriana holandrii* (Pfeiffer), *Lithoglyphus naticoides* (Pfeiffer), *L. fuscus* (Pfeiffer), *Theodoxus transversalis* (Pfeiffer), *T. danubialis* (Pfeiffer), *Bithynia tentaculata* (Linnaeus), *Pisidium amnicum* (Müller), *Unio crassus* (Philipsson), etc. (Nenadić & Gaudenyi 2013, Nenadić *et al*. 2001, 2009, 2015a, Knežević *et al*. 2018).

In the area of the Sava River near Belgrade, these sediments are mainly deposited over the palustrine-lacustrine deposits of early Pliocene and older Pleistocene, and only in a small part, in the area of the confluence of the Danube and Sava, they are underlain mostly by the Late Miocene (Pannonian) age marls and marly clays with microfauna of ostracods and rare remains of fossil mollusks: *Congeria banatica* Hoernes, *Gyraulus praeponticus* (Gorjanović Kramberger), *Limnocardium* sp., etc. Underlying these deposits are fluvial deposits of Holocene age connected to the Sava riparian belt or younger Pleistocene loess deposits distributed across the Srem loess plateau (Knežević *et al*. 1998, 2018, Nenadić 2003, Nenadić *et al*. 2009, 2015a).

The thickness of the Pleistocene fluvial deposits varies from 10–15 *m* in the area of Makiš and Novi Beograd to 40 and more meters in Zemun in the north, and they have great importance as aquifers for the water supply of Belgrade (Fig. 2).

Fluvial deposits of the Južna Morava

According to Rakić (1977), terrace deposits in the middle and lower parts of the Južna Morava and its tributaries (Nišava, Toplica, etc.) were built of gravel, sand, loam, *terra rossa*, and loessoid sediments. As indicated by the same author, six terraces of Quaternary age can be distinguished in the lower part of the Južna Morava basin: two high (200–210 *m* and 150–160 *m*) of fluvial-lacustrine character and four lower ones (90–110 *m*, 50–60 *m*, 25–35 *m*, and 10–15 *m*) which belong to typical river terraces. The lowest terrace, 3–5 *m* high, forms the floodplain of this river. For all terraces, their relative height in relation to the recent Morava riverbed is shown (Fig. 3).

Lithological and paleontological characteristics of the terraces of Južna Morava were obtained based on the existing literature data and research carried out by Rakić (1977, 1990).

Two high terraces (200–210 *m* and 150–160 *m*) represent the equivalents of the fluvial-lacustrine phase. They are widespread in several places in the Leskovac, Niš, and Aleksinac basins. These terraces formed

clearly recognizable plains and were built of medium-grained pebbles of a limestone, sandstone, or schist character. In the Leskovac basin, they are built of poorly sorted lenses of gravel and sands, slightly less sandy siltstones that lie over Mio-Pliocene lacustrine sands and clays. The sediments of these terraces, up to 60 *m* thick, are characterized by clear cross-bedding, and the pebbles are mostly made of quartz grains, less often of crystalline schist and andesite. The youngest part of the profile consists of fine-grained sands and sandy siltstones with slight horizontal lamination. The stratigraphic position of these terraces in relation to older and younger formations indicates the Upper Pliocene-Early Pleistocene age.

The terrace with a height of 90–100 *m* (the fourth river terrace) represents the oldest river terrace; it is 10–20 *m* thick and is built of several gravelly horizons that lie over reddish sands and soils. Its presence was established in the Leskovac basin (the right bank of the Toponica River).

The 50–60 *m* high terrace (the third river terrace) was established in the form of isolated lots along the entire length of the Južna Morava. It is hardly noticeable because it is partially eroded and covered with deluvial deposits. It is small in thickness and is built mainly of weakly rounded pebbles, without clearly defined riverbed and floodplain sediments, which is probably a consequence of the high speed of the flow and the large drop in the river profile. In the youngest part of this terrace, the ostracod species *Scottia browniana* (Jones), *Candona neglecta* Sars, *Ilyocypris gibba* (Ramdohr), and others were found.

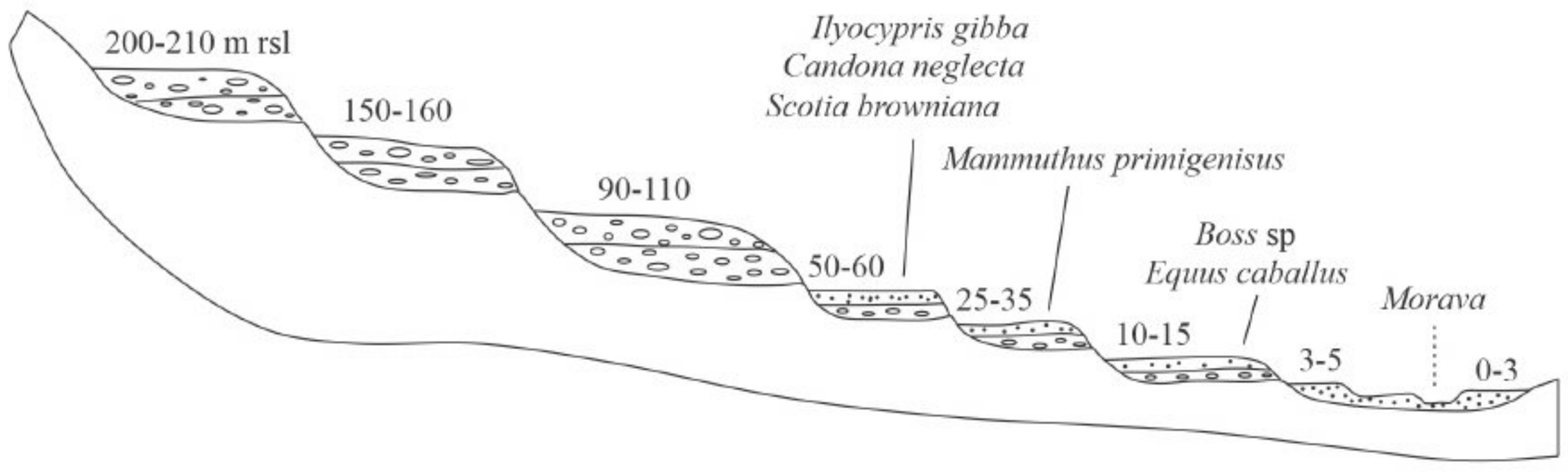

Fig. 3. - Morava river terraces with the position of characteristic fossils (after Rakić 1977,1990).

The stratigraphic affiliation of the third and fourth terraces was determined by the superposition method because they are located below the assumed fluvial-lacustrine high terraces, and above the river levels with the presence of the species *Mammuthus primigenius* Blumenbach. Based on such a position, and since the mentioned types of ostracods undoubtedly

indicate the Pleistocene age of the deposits, their age is suggested as the Middle Pleistocene.

A terrace with a height of 25–35 *m* (the second river terrace) was developed on a wide area of the lower and middle part of the Južna Morava basin, around the edge of the Leskovac field, in the Niš basin and the Aleksinac Pomoravlje. In the lower part, the terrace is built exclusively of riverbed deposits (pebbles and sands); above them are deluvial deposits represented by pebbly and siltstones-sands. In these deposits, remains of malacofauna, ostracods and mammals, such as *Esperiana* sp., *Planorbis* sp., *Pisidium amnicum* (Müller), *Candona neglecta* Sars, *Ilyocypris gibba* (Ramdohr), *Mammutus primigenius* Blumenbach and others were found. Using the superposition method, it is considered that this terrace seems to belong to the older part of the Upper Pleistocene.

The first river terrace (terrace level of 10–15 *m*) is mainly of erosional-accumulative character with relatively small thickness (from one to several meters); it includes riverbed and floodplain deposits (pebble-sand-silt deposits) and characteristic facies change over short distances. The silt predominated sediments originates from the floodplain deposits. Based on the superposition method, after Rakić (1977), this terrace is considered as the younger part of the Upper Pleistocene.

The lowest position in relation to the level of the recent riverbed of the Južna- and Zapadna Morava and their tributaries is occupied by floodplain terraces and alluvium of Holocene age (levels 3–5 and 0–3 *m*). They are built of the coarse-grained riverbed and floodplain deposits: sands and silts of variable thickness. Floodplain deposits may be poorly represented or completely absent in the middle and upper parts of the streams.

DISCUSSION

The Pleistocene fluvial deposits of the investigated area were considered by various authors as lacustrine, fluvial-lacustrine, or fluvial sediments deposited in the Late Pliocene, Older Eopleistocene, Plio-Pleistocene or Early and Middle Pleistocene (Laskarev 1938, Stevanović 1977, Rakić 1985, 1990, Nenadić 2003, Nenadić *et al*. 2001, 2009, 2013, 2014, 2015a, Gaudenyi *et al*. 2014, Knežević *et al*. 1998, 2018).

Based on the presence of mollusk species *Corbicula fluminalis* (Müller) and *Viviparus diluvianus* (Kunth.) Laskarev (1938) and Stevanović (1977) determined the age of these deposits as the Middle Pleistocene. Based on the revision of the species *Viviparus diluvianus* which corresponds to the species *Viviparus boeckhi* (Krolopp 1983), a more detailed revision of the age of Makiš Beds is possible.

Somewhat later, it was considered that the lacustrine phase lasted for a long time in this area and that these deposits represent transition layers between the Neogene and the Quaternary (Laskarev 1951).

According to Rakić (1990), the presence of the species *Viviparus boeckhi*, *Unio sturi* and *Bithynia crassitesta* indicates that fluvial deposits belong to the Lower Pleistocene, while younger, fluvial-palustrine deposits with *Corbicula fluminalis* and *Planorbis planorbis* probabaly belong to the Middle Pleistocene.

In contrast to the sediments underlying the Pleistocene fluvial deposits in the investigated area, but also in the wider area of Srem, they are enriched with heavy minerals (garnets, hematite, limonite), while the magnetite content is somewhat lower, which is characteristic for fluvial deposits in this area. The increased amount of hematite and limonite can be explained by the partial transformation of magnetite in the oxidizing environment. Also, unlike the underlying deposits, the content of amphibole and pyroxene is increased, while the amount of epidote is slightly lower (Danilović 2008, Nenadić *et al.* 2015b).

From the lithological point of view, the Pleistocene fluvial deposits are mainly dominated by sandy-pebbly deposits containing fragments and pebbles of various igneous, sedimentary, and metamorphic rocks. The presence of finer-grained fractions (clay and sandy clays) is much rarer, especially in the area of Makiš and Zemun (Nenadić *et al*. 2015b).

The guide fossils related to the coarse-clastic fluvial deposits, which indicate the Lower Pleistocene are *Viviparus boeckhi* (Halavats) and *Esperiana esperi* (Férrusac), while the Pleistocene *Corbicula* is mostly found in younger pebbly sands, and it is one of the best known Pleistocene warm stage (interglacial) guide fossils. Based on the species present, it is possible to distinguish older Pleistocene fluvial deposits from Upper Pleistocene and recent fluvial sediments of the Sava River (Fig. 4). In the sandy deposits outside the Sava valley, almost no fossils were found, while below the loess plateau, the fossil fauna was found in fluvial sequences consisting of layers and lenses of gray and gray-brown silt and sandy clay with the presence of *Planorbis planorbis* dentata (Krolopp) and the ostracod species *Scottia browniana* (Jones), etc. (Knežević *et al*. 1998, 2018, Nenadić, 2003, Nenadić *et al*. 2015b).

Pleistocene fluvial deposits have a great economic value in the area of Belgrade Posavina because they represent underground water collectors that are used for the water supply of the capital, but also for other settlements in the wider area of Srem.

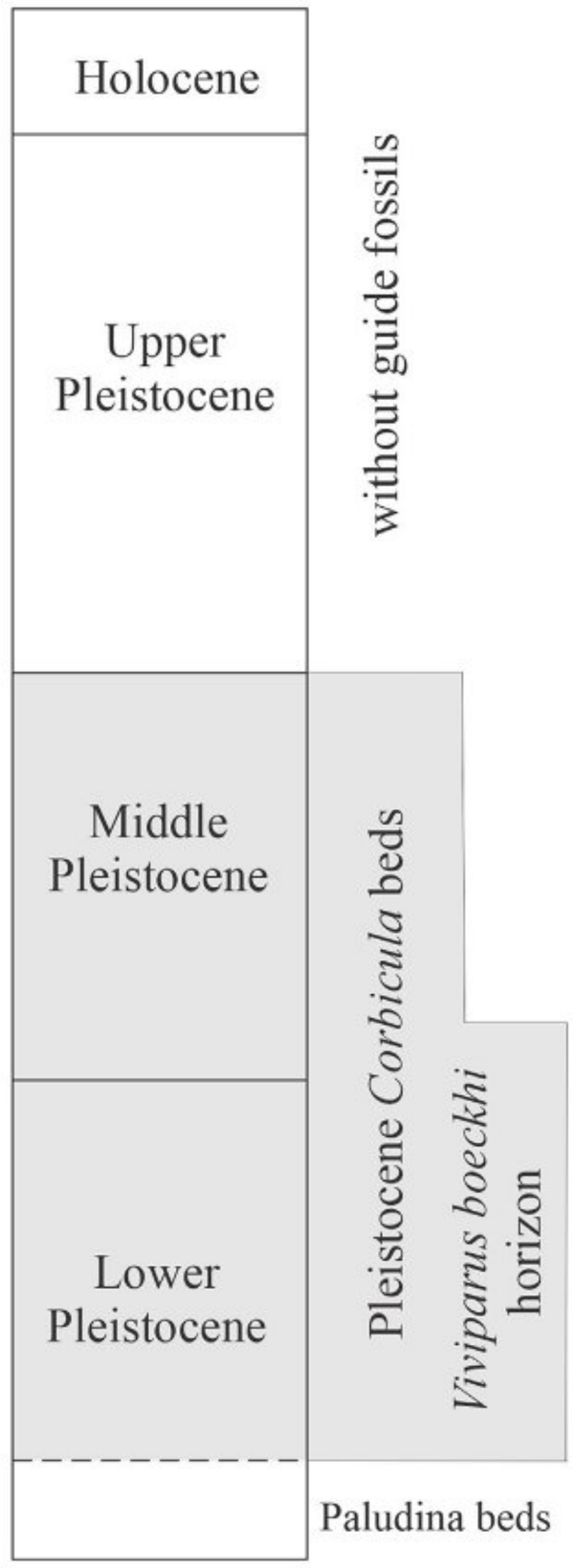

Fig. 4. - Stratigraphic position of Pleistocene fluvial deposits in the Sava coastal area near Belgrade (after Nenadić *et al*. 2015b).

Similar deposits make the highest terrace floors not only in the valleys of the Zapadna- and Južna Morava, Nišava and the Azanja fossil valley, but also in the area of the Danube valley (Rakić 1972, 1977, 1990, Rakić & Simonović 1997). Sediments that make high terrace floors (150–160 *m*, 90–110 *m*, and 50–60 *m*) are characterized by multiple alternations of gravels and sands with occasional occurrences of silts, so 2–4 accumulation cycles could be discerned, i.e. a vertical shift of riverbed deposits (gravels and sands) and flood deposits (silts). These deposits mostly have an increased thickness, with values over 15 *m*, while lower terraces are characterized by a normal thickness of alluvium from 3 to 15 *m* (Fig. 5).

According to Cvijić (1909), the high terraces of the Južna Morava (200–210 *m* and 150–160 *m*) belong to the Upper Pliocene. This is based on the fact that they were developed from the top of the youngest lacustrine phase, which is of the Pontian (Mio-Pliocene) age. Based on Rakić (1977), their position is defined in relation to the Upper Miocene and Lower Pliocene freshwater equivalents in the foothills, where they are undo-

ubtedly older than the Pleistocene river terraces that cut into them. Based on the analysis of spores and pollen, dominated by species of humid and temperate climates (beech, pine, willow), the same author claimed that the climatic conditions during the creation of these terraces were similar to those prevailing in Northern- and Central Europe during the Upper Pliocene and Lower Pleistocene. Since there is not enough evidence for a closer stratigraphic division, the fluvial-lacustrine deposits in the Južna Morava valley would belong to the Upper Pliocene or the Lower Pleistocene in narrow sense (Rakić 1977).

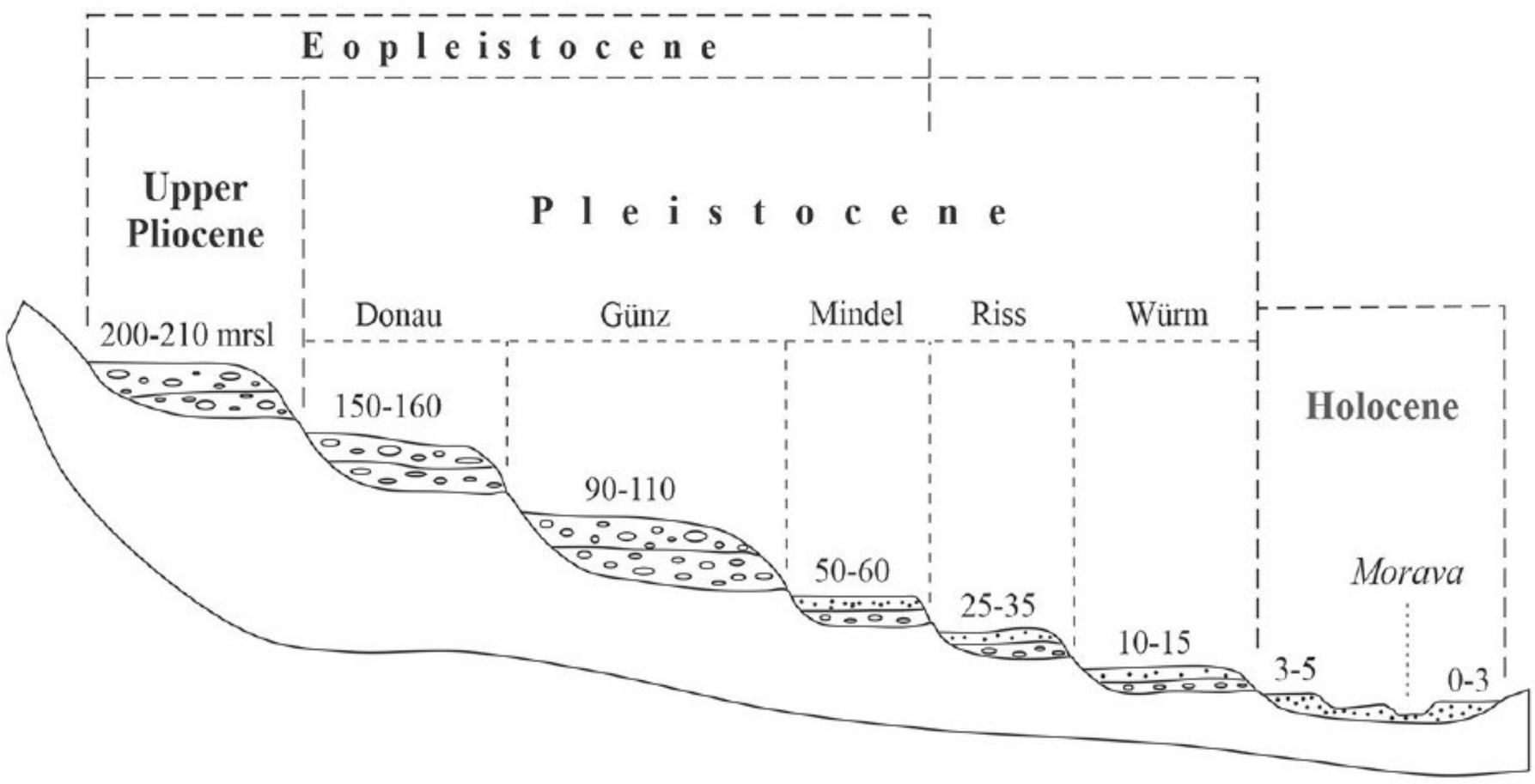

Fig. 5. - Stratigraphical position of the river terraces of the Morava River after Rakić (1977, 1990).

The middle terraces of the Južna Morava (90–110 *m* and 50–60 *m*) are distinguished, in contrast to the lower terraces, by a uniform facies composition in the entire longitudinal profile and by a matrix of the *terra rossa* type. In the terrace 50–60 *m* high, ostracod species of undoubtedly Pleistocene age were found: *Candona neglecta* Sars, *Ilyocypris gibba* (Ramdohr), *Scottia browniana* (Jones), and others (Rakić 1977). The most important for its stratigraphic determination is the ostracod species *Scottia browniana*, which was found in the sediments of the Holstein interglacial (according to the North European division of the Pleistocene) in the vicinity of Berlin, then in the Middle Pleistocene formations and the Cromer complex of Thuringia and in Hungary, near Szolnok, in the Middle Pleistocene interglacial deposits. This species can be considered as a characteristic fossil that indicates Pleistocene deposits (older part of the Upper Pleistocene), which indicates that the age of the third river terrace (50–60 *m*) is most likely Middle Pleistocene (Rakić 1977). In the last nearly half century we have more accurate and rich stratigraphical data related to *Scottia browniana.* Namely the records from Germany show the continuous

record from the Holsteinian (Middle Pleistocene) to the recent, during the temperate stages (interglacials) (Fuhrmann 2012).

The low terraces of the Južna Morava (25–35 *m* and 10–15 *m*) represent the best-preserved fossil accumulative forms. Although they occur in the form of isolated parties, they can be continuously followed on longitudinal profile at a greater distance. A paleontological association of mollusks such as *Pisidium amnicum* (Müller), *Euglesa casertana* (Poli), *E. obsutalis* (Lamarck), *E. milium* Held, *Planorbarius corneus* (Linnaeus), *Vallonia costata* (Müller), and others. Regarding the age of the low terraces, the presence of *Mammutus primigenius* Blumenbach, *Equus caballus* Linnaeus and *Bos* sp. clearly indicates that they were created during the Late Pleistocene. Since the finds of mammoths indicate a colder climate, so the Južna Morava valley was connected to the open, mammut-steppe-like environments in that period. Based on the ostracods *Candona neglecta*, *Ilyocypris gibba,* and *Cypricercus* sp. which are equally present in both terraces, one could only approximately determine the age as Upper Pleistocene for the second terrace (25–35 *m*) and the youngest Pleistocene for the first terrace (10–15 *m*) (Rakić 1977). The lithofacies characteristics of the low terraces indicate accumulation according to the type of the early stage of the perstrative dynamic phase of the river flow.

The floodplain terraces of the Južna Morava consist of two morphological entities: the inundation plain, where constant processes of river erosion and accumulation take place and the periodically flooded terrace 3–5 *m* above the modern river level. At the bottom of both morphological units, there are always coarse-grained, well-rounded gravels and sands, while the younger (higher) parts are mostly made of siltstones, sands, and clays. For the lower parts of the streams, in the basin expansions, oxbow lakes and organic-palustrine deposits are often present. According to Rakić (1977), both morphological entities were created during the perstrative dynamic phase of the evolution of the river course.

Morphostratigraphy seems to be difficult in case of Južna Morava terraces and Sava (vicity of Belgrade) sediments. First of all, the Južna Morava terraces are in the mountainous area, while the Sava sediments are in lowland area. The altitude differences of the Sava river near Belgrade is 78 *m* a.s.l. while the confluence of the Južna Morava with Zapadna Morava is at 135 *m* a.s.l. According to the available data it is quite problematic to have an accurate correlation.

Based on the paleontological and lithofacies characteristics, Pleistocene fluvial deposits of the riparian area of the Sava River near Belgrade could be correlated to the synchronous ones that form high and medium Morava terraces (Fig. 6).

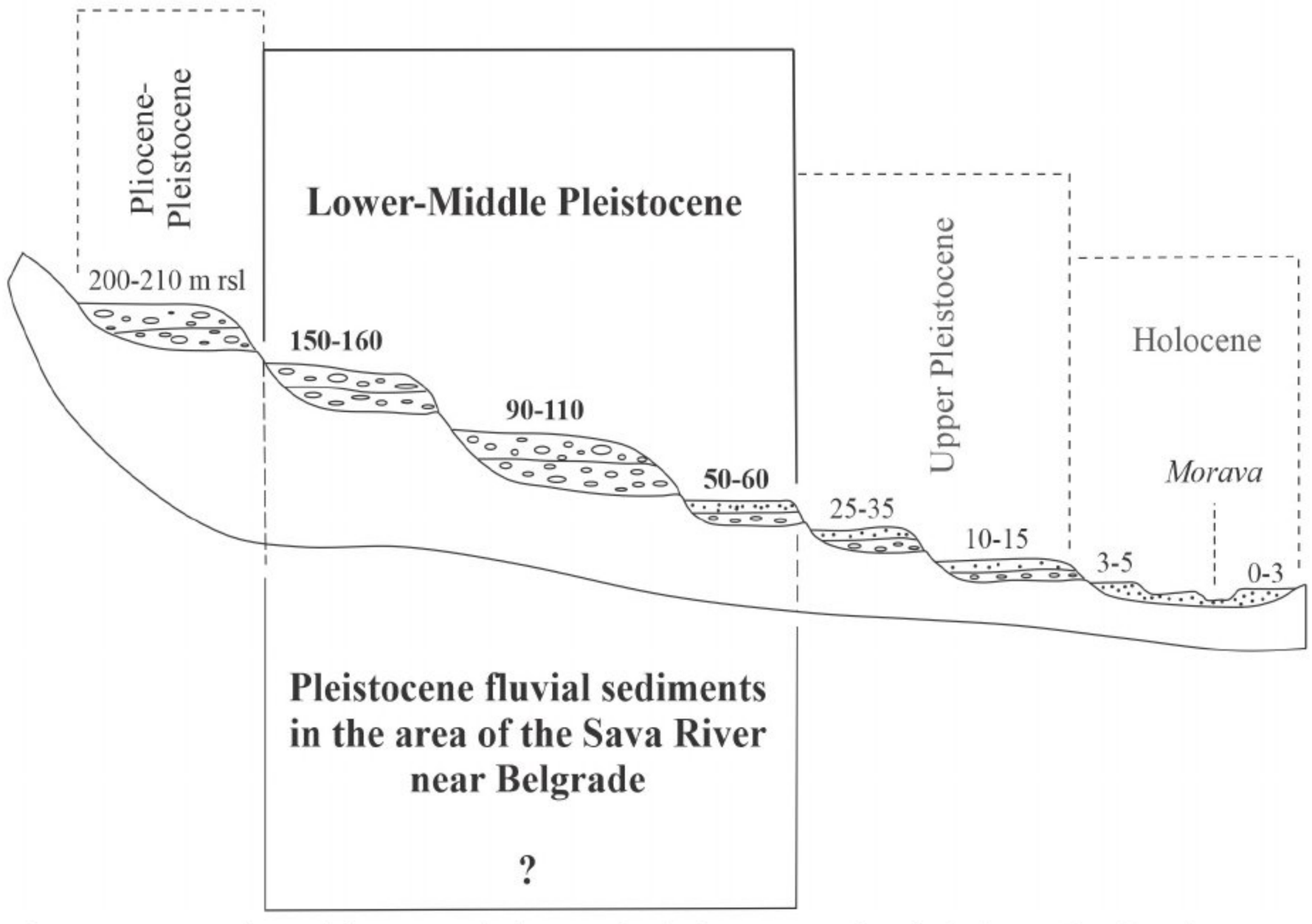

Fig. 6. - Stratigraphic correlation of Pleistocene fluvial deposits in the Sava riparian area near Belgrade and the terrace levels of the Južna Morava.

CONCLUSION

Based on the data on lithological characteristics, the thickness of deposits and dynamics of their deposition, it can be concluded that there is a significant difference between the Pleistocene deposits formed in the area of the Belgrade plain and those of the Morava terraces.

In contrast to the deposits that build the Morava terraces, Pleistocene fluvial deposits in the riparian area of the Sava River near Belgrade are not visible on the surface, and they are covered by younger Pleistocene aeolian sediments or contemporary Holocene deposits of an alluvial character.

The lithofacial characteristics of the Pleistocene fluvial deposits, alternation of coarse-grained clastic sediments of the riverbed (sands and gravels), and silty and clayey sediments of oxbows and their significantly increased thickness indicate that they were formed in wide alluvial plains which cyclically changed its riverbed, because of tectonic movements and paleoclimate changes. Paleontological content and characteristic stratification imply that the formation of the deposits took place in a mobile environment with a warm climate and abundant precipitation (Nenadić 2003, Nenadić *et al*. 2009, 2015a).

Based on recent research, it can be concluded that the Pleistocene *Corbicula* of the Sava riparian area belongs to the temperate stages (equivalent to interglacials) of the late part of Early- and a part of Middle Pleistocene (Nenadić *et al.* 2009, 2014, 2015b), which fits with studies in the Hungarian localities (Krolopp 2002). Based on the presence of the guide species, such as *Corbicula fluminalis* (Müller), *Viviparus boeckhi* (Halavats), and *Esperiana esperi* (Férrusac), Pleistocene fluvial deposits have been determined as the Lower-Middle Pleistocene (Nenadić *et al*. 2009, 2015a, Gaudenyi *et al*. 2013, 2015a, 2015b, Knežević *et al*. 2018).

Formations with similar characteristics also build the high terraces of the valley systems of the Velika-, Južna- and Zapadna Morava. From the morphological point of view, the terrace levels have an erosive-accumulative character, and below the alluvial deposits of Quaternary age are pre-Quaternary formations of different compositions and ages. According to Rakić (1977, 1990), the lower river terraces are characterized by sediments of classic alluvium thickness (3–15 *m*), while the higher terraces (above 50–60 *m*) include sediments with increased thickness, which is one of the significant characteristics of fluvial deposits of Pleistocene age.

The accumulative parts of the Morava terraces are built of heterogeneous, well-rounded gravels of the riverbed deposits, overlaid by the siltstone formations of the floodplain, of significantly less thickness. All the lithological members are in the form of lenses of irregular shapes and different dimensions, which, along with the increased thickness, indicates the lowering of the bottom of the accumulation plane.

Based on the presence of species such as *Scottia browniana* and *Mammuthus primigenius*, the age of the middle and lower Morava terraces is determined as the Middle- and Upper Pleistocene. Due to the lack of paleontological evidence for a closer stratigraphic division of the high terraces, according to Rakić (1977), their position should be better evaluated due to the official changes in the stratigraphical time-frame. From 1950 to 2010 it was significant changes in the Quaternary time-scale frame, the boundary of Quaternary has been lowered from 1 Ma to approx. 2.6 Ma.

Pleistocene fluvial deposits of the riparian area of the Sava River near Belgrade, could be correlated, according to their paleontological and lithofacies characteristics, to the synchronous ones that form high (150–160 *m*) and medium (90–110 and 50–60 *m*) Morava terraces. Significant height differences between the Pleistocene alluvial deposits of the Belgrade area in relation to the higher and medium terraces of Južna Morava are the consequence of differential tectonic movements, which in the Pannonian basin are reflected in a descending of 0.5–2 *mm*/year, while in the river valleys were manifested by stagnation or uplifting of 0.5 *mm*/year (Toljić *et*

al. 2014, Nenadić *et al*. 2015a), however we do not have more detailed analysis of these movements during the Quaternary.

The Južna Morava terraces and the Sava sediments (near Belgrade) cannot be successfully correlated on the basis of their lithofacies and paleontological characteristics. One of the possible solution in morpho-stratigrphical correlation should be to be applied the stratigraphic correlation first on the relation of Zapadna- and Južna Morava terraces, the results would be correlated with the terraces of Velika Morava, while the Velika Morava terraces can be correlated with the Sava sediments near Belgrade.

Acknowledgments

This work was supported through the Project NEEMO of the Fund for Science of the Republic of Serbia number 7746827 and by Ministry of Science, Technological Development and Innovation of the Republic of Serbia through the Agreement on the implementation and financing of scientific research work of the SRO (NIO) in 2023, no. 451-03-66/2024-03/ 200126. The authors are very thankful to the unknown reviewers for their useful advices and suggestions which improved quality of the paper.

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МОРФОСТРАТИГРАФСКА КОРЕЛАЦИЈА САВСКИХ НАСЛАГА ОКОЛИНЕ БЕОГРАДА И ТЕРАСА ЈУЖНЕ МОРАВЕ

ДРАЖЕНКО НЕНАДИЋ, КАТАРИНА БОГИЋЕВИЋ

Р Е З И М Е

Плеистоценске флувијалне наслаге или речне полицикличне творевине имају велико распрострањење на подручју приобалног дела реке Саве код Београда, са дебљинама које на основу података из доступних бушотина износе од 10–20 метара на подручју Макиша и Новог Београда, до преко 40 метара на подручју Земуна. За разлику од класичних алувијалних наслага, оне су формиране у констративној фази динамичке еволуције речног тока и због тога се одликују повећаном дебљином и цикличном сменом седимената корита, поводња и старача изражених у више седиментационих циклуса.

У приобалном делу Саве ове наслаге прекривене су рецентним алувијалним седиментима или плеистоценским лесним наслагама еолског порекла (подручје Земуна). Њихову подину углавном представљају хетерогене наслаге плио-плеистоцена, а местимично и седименти неогене старости.

Индексним фосилима за стратиграфску детерминацију плеистоценских речних наслага припадају представници врсте *Viviparus boeckhi,* који су углавном откривени у нижим деловима ових творевина и представници плеистоценских *Corbicula*, далеко присутнији у вишим деловима. На основу присутних фосила, овим наслагама одређена је доњо- и средњоплеистоценска старост.

Творевине сличних карактеристика изграђују високе терасе долинских система Велике, Јужне и Западне Мораве. Морфолошки посматрано, нивои тераса су ерозионо-акумулационог карактера, а испод речних наслага квартарне старости налазе се прекварtарне творевине различитог састава и старости. Према Ракићу (1977, 1990), ниже речне терасе се одликују седиментима класичне дебљине алувијона (3–15 метара), док се више терасе (изнад 50–60 метара) одликују седиментима повећане дебљине, што представља једну од значајних карактеристика флувијалних наслага плеистоценске старости.

Акумулациони делови моравских тераса изграђени су од хетерогених, добро заобљених шљункова корита, преко којих леже алевритске творевине поводња, знатно мање дебљине. Сви литолошки чланови налазе се у облику сочива неправилних облика и различитих димензи-

ја, који уз повећану дебљину указују на спуштања дна акумулационе равни.

На основу присуства представника врста *Scottia browniana* и *Mammuthus primigenius,* старост средњих и ниских моравских тераса одређена је као средњи и горњи плеистоцен. Услед недостатка палеонтолошких доказа за ближу стратиграфску одредбу високих тераса, њихов положај је дефинисан позицијом у односу на слатководне еквиваленате горњег миоцена и доњег плиоцена у подини, тако да им је одређена горњоплиоценска или еоплеистоценска старост у ужем смислу (Ракић 1977).

На основу палеонтолошких и литофацијалних карактеристика флувијалне наслаге плеистоценске старости приобалног дела реке Саве код Београда могуће је корелисати са синхроничним наслагама високих (150–160 метара) и средњих (90–110 и 50–60 метара) моравских тераса. Знатне висинске разлике између плеистоценских алувијалних наслага Београдске Посавине у односу на високе и средње терасе Јужне Мораве последица су диференцијалних тектонских покрета које се у Панонском басену огледају у спуштању од 0,5–2 мм/год., док се у речним котлинама манифестују стагнацијом или издизањем од 0,5 мм/год. (Тољић *et al*. 2014, Ненадић *et al*. 2015а). Међутим, потребно је детаљније истражити динамику спуштања да би могло да се приступи прецизнијој стратиграфској кореалцији квартара.

Прецизна морфостратиграфска корелација Јужне Мораве и Саве (околина Београда) није могућа. Можда би решење овог проблема било у корелацији тераса Јужне и Западне Мораве, чији би се резултати потом корелисали са терасама Велике Мораве. Резултати ове морфостратиграфске корелације могли би да укажу на могућност корелације са савским наслагама у околини Београда.