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STRATIGRAPHICAL AND PALAEOGEOGRAPHICAL CHARACTERISTICS OF PLEISTOCENE SERIES IN THE SAVA RIPARIAN AREA AT BELGRADE (SERBIA)

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The older Pleistocene sediments of the Sava River at Belgrade are covered almost everywhere and insufficiently studied; the available information has been acquired from exploratory boreholes. Among them, four successive units with different lithological and palaeogeographical characteristics are distinguished: 1. bog-lake-terrestrial sediments (Pliocene-Pleistocene); 2. polycyclic fluvial deposits (Lower Pleistocene); 3. fluvial-palustrine deposits (Middle Pleistocene) and 4. aeolian sediments - loess (Upper Pleistocene). Their lithological and palaeontological contents are described and palaeogeographical reconstruction of the area during the formation of these deposits has been performed.

Key words: stratigraphy, palaeogeography, Quaternary, Pleistocene, the Sava River, Belgrade

INTRODUCTION

The Sava River, a right tributary of the Danube River, separates Belgrade township into the Old and the New Town, and geographically and geotectonically the flat land of the Pannonian depression (Pannonian basin) from the hilly country of the Balkans. Various genetic types of Quaternary

continental sediments - products of geodynamic processes under specific palaeogeographic conditions in the latest period - are found in the Sava valley and the adjacent area in Belgrade.

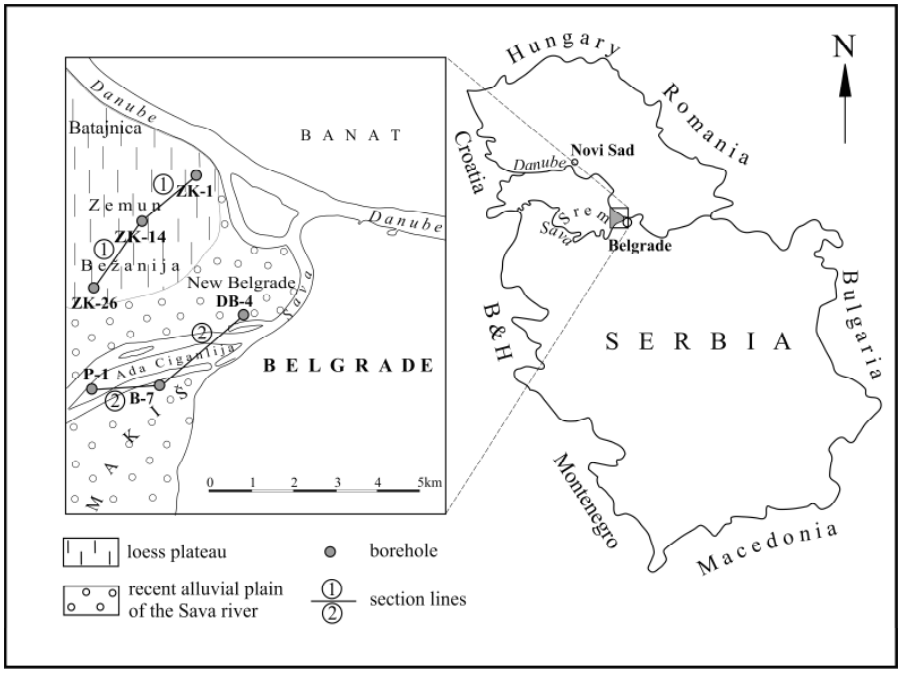

Fig. 1. Geographical location of the investigated area.

The boreholes in this area are mainly relatively shallow; however, we believe that the data collected in this way can provide us with a better understanding of stratigraphical and palaeogeographical characteristics of the area. This paper is an attempt to perform, by means of lithological and palaeontological analysis of the data obtained from several boreholes, the palaeogeographical reconstruction of the area during the Pleistocene.

MATERIAL AND METHODS

Material from several boreholes from the investigated area has been sampled and used. A few research methods have been applied: palaeontological analysis (mainly of mollusks and ostracods), sedimentological--petrological and classical stratigraphical principles of superposition.

The terms “Quaternary” and “Pleistocene” are used according to the latest (2009) recommendations of the International Union for Geological Sciences (IUGS) and the International Commission on Stratigraphy (ICS):

the Pleistocene includes the Gelasian Stage/Age, and begins about 2.6 million years ago.

STRATIGRAPHY AND LITHOLOGY OF THE PLEISTOCENE

Pleistocene sediments have an extensive distribution in the Sava riparian area at Belgrade, but are largely covered by the younger, Holocene (mainly recent) alluvial deposits. Pleistocene deposits are exposed on the margin of the Sava valley: on the left side, Srem loessland (Upper Pleistocene) covers Pleistocene fluvial sediments; on the right side of the valley, Cretaceous and Miocene deposits rise locally covered by outwash loess (younger Pleistocene) and residual older Pleistocene truncated terraces. On the basis of the origin, superposition and age, Pleistocene sediments in the Sava valley may be divided into:

- **bog-lake-terrestrial** sediments of the Pliocene - Pleistocene,

- **polycyclic-fluvial** deposits of the Lower Pleistocene,

- **fluvial-palustrine** formations of the Middle Pleistocene,

- **aeolian loess**, loess plateau above the left valley side of the Sava, outwash loess above the right bank, Upper Pleistocene.

Loess deposits have been investigated by many geologists and geographers (Gorjanović-Kramberger 1921, Laskarev 1938, Marković--Marjanović 1972, Stevanović 1977, Rakić *et al.* 1990, Nenadić 2003, Marković *et al.* 2006 etc), so their stratigraphical and palaeogeographical characteristics are rather well known and clear enough. On the other hand, pre-loess deposits, which are not exposed on the surface, have been much less explored (Rakić 1973, 1990, Knežević *et al.* 1998, Nenadić 2003) and their relation to the older (Neogene) and the younger (loess) strata is yet unclear.

Pliocene - Pleistocene Bog-Lake-Terrestrial Sediments

The oldest Quaternary in Belgrade environs is represented by the bog--lake-terrestrial deposits recognized in boreholes drilled in the Sava valley and the Srem loess plateau in the new part of Belgrade and Zemun (Knežević *et al.* 1998, Nenadić 2003). In the Makiš area of the Sava valley, Ada Ciganlija, and on the left riverbank in Novi Beograd (borehole DB-4), these deposits unconformable overlie Miocene sediments (fig. 3) of the Paratethys (mainly Pannonian marlstone), and in Zemun (ZK-14) they lie over the lacustrine Pliocene. Their thickness increases from the Sava toward the Srem loess plateau (Fig. 2 and 3), from several meters in Ada

Ciganlija (P-1) and the Makiš area (B-7) up to 100 m in Bežanijska Kosa (ZK-26) and upper Zemun (ZK-14).

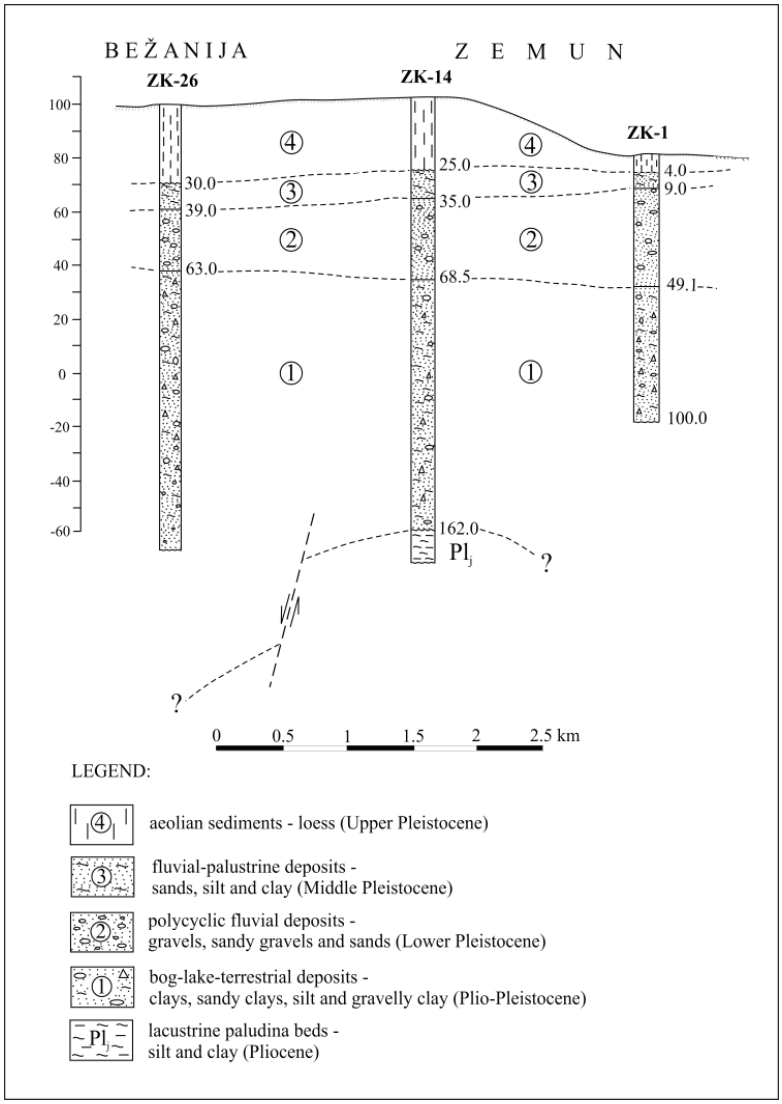

Fig. 2. Correlation of stratigraphical sections of Bežanija - Zemun.

Lithologically, the oldest Quaternary deposits in the Sava valley consist of heterogeneous light-brown, grey, brown-reddish clay, sandy clay and silt, clayey sand, gravelly clay, etc. There are many occurrences of ooliths and manganese- and iron-oxide lenses, which sometimes give to deposits a dark brown or grey colour. There are also local dense lenses and concretions of calcium carbonate. The deposits are almost without fossils.

Only a few remains of aquatic bog gastropods (*Limneus*, *Planorbis*) have been found. Without the palaeontological material the deposits could not be dated by biostratigraphic-palaeontological methods. Only the evidence of superposition (younger Lower Pleistocene over and Pliocene under) indicated their deposition in the younger Pliocene (Romanian) and Early Pleistocene.

Recent investigations in adjacent Zemun Polje and the upper Zemun areas of the Srem loess plateau indicated transient intermittent streams in the Pliocene - Pleistocene which deposited grey-brown sand and clayey sand. It was in these sands that the remains of aquatic fossil molluscan fauna were found in upper Zemun near the Danube (in aquiferous sand) at a depth of 103 m (altitude about 3 m), including the species *Viviparus boeckhi* HALAVATS, on the basis of which the Pliocene - Pleistocene age was determined. Both above and under the Pliocene - Pleistocene stream sands, clays with ooliths and lenses of manganese and iron oxides, typical of the Pliocene - Pleistocene bog-lake-terrestrial development stage, were deposited.

In other parts of the Pannonian basin (Slavonia, southern Banat, Bačka), formations of similar age and origin are „beds with *Viviparus vukotinovici*" (the youngest horizon of „Paludina beds") and „beds with *Viviparus boeckhi*" (Nenadić 2003). Fluvial-pond-lake deposits are rather wide-spread in neighbouring areas and they are mostly considered to be of the Late Pliocene age, as are, for example, those on the Vukovar plateau in Croatia (Bačani *et al*. 1999) or in the southern parts of Moldavian plateau (Ghenea 1970). Fluvial deposits were also common during the Pliocene - Pleistocene: in Slovenia (Krško basin) non-carbonate sands and gravels on the oldest (fourth) terrace of the Sava River (Verbić *et al*. 2000); in Romania (Dacian basin) (Upper Romanian-Lower Pleistocene) deposits with mammal remains: *Zygolophodon borsoni* Hays, *Anancus arvernensis* (Croizet & Jobert), *Mammuthus meridionalis* (Nesti) (Enciu & Balteanu 2002).

Lower Pleistocene Polycyclic Fluvial Deposits

The most widespread Pleistocene deposits in the Sava riparian area of Belgrade are polycyclic fluvial deposits of the Early Pleistocene. They are very important aquifers from which water is supplied by collector wells to Belgrade waterworks. These deposits have been referred to as 'Makiš Beds' or 'beds with *Corbicula fluminalis*' (Laskarev 1938; Stevanović 1977). On the right Sava bank, the deposits overlie the Miocene with unconformity only rarely over pre-Neogene sediments, and sporadically over the bog--lake-terrestrial beds of the Pliocene - Pleistocene. The deposits overlie the thick Pliocene - Pleistocene bog-lake-terrestrial deposits on the left Sava

bank and the Upper Miocene Pannonian marls near the Sava and the Danube confluence.

The deposits vary in thickness from a few metres to tens of metres (in places in excess of 100 m). Younger beds of the complex in the Sava valley at Belgrade are eroded and unconformably overlain by recent alluvial deposits from the Sava (fig. 3). Under the Srem loess plateau at Bežanijska Kosa (ZK-26) and in Zemun upper town (ZK-14) these deposits have an average thickness of about forty metres (Knežević *et al.* 1998, Jevremović & Kuzmić 1999, Nenadić 2001, 2003).

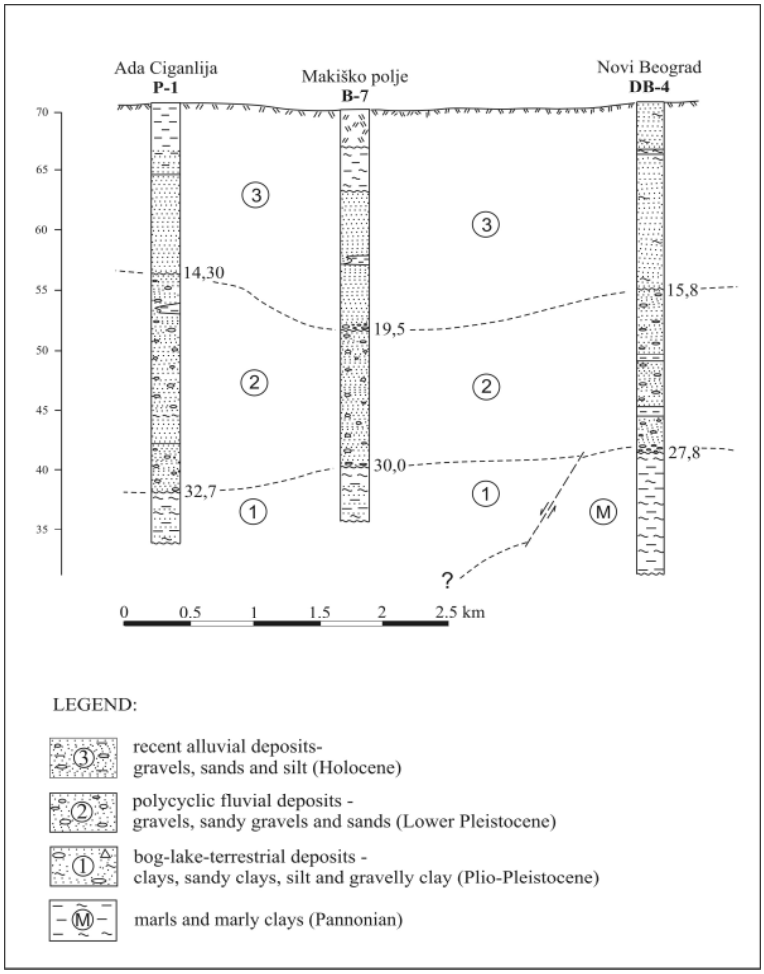

Fig. 3. Correlation of stratigraphical sections of Ada Ciganlija – – Makiš – Novi Beograd.

The floods from the old river tributaries largely controlled the facies of Lower Pleistocene fluvial deposits in the Sava riparian area. High above the

present Topčiderska Reka (old Belgrade area) are remnants of truncated terraces built-up of coarse clastics (of Sarmatian limestones and less of Cretaceous limestones and sandstones). Also lithofacies of an old tributary lateral alluvial cone are recognized in the Lower Pleistocene accumulation area around the Ada Ciganlija point in the Sava valley (Marković *et al.* 1984).

Investigation of many boreholes in the Sava riparian area, the river valley and away in the Srem loess plateau of Bežanijska Kosa, upper Zemun, Zemun Polje and Batajnica, revealed that facies of the old Pleistocene fluvial deposits are changed laterally. The deposits change in composition so the amount of coarse clastics (coarse gravels, gravels, sandy gravels) increases near the river, on the right bank in particular, and decreases northward below the Srem loess plateau toward Zemun Polje and Batajnica.

Polycyclic fluvial deposits from borehole B-7 in the Makiš field are composed of sandy gravels, gravelly sands and sands. Sands are mainly well sorted and, according to grain size, three categories (medium- to coarse-grained, medium-grained, and fine- to medium-grained sands) can be singled out. Coarse-grained sediments (sandy gravels and gravelly sands) are generally poorly sorted, and rarely moderately- or well-sorted. The degree of rounding of gravels is medium to high, and the most rounded are fragments of sandstones and vulcanites. Unlike them, fragments of Neogene rocks that were transported across relatively short distances are sub-angular to medium-rounded in form. Fine-grained sediments (silts, clays and varieties) are very rare and are represented by small lenses in coarser sediments. Among coarse-grained sediments, quartzite pebbles are the most prominent, then sandstone and fragments of Neogene rocks, whereas the frequency of shale and chert fragments is lower. The contents of stable components vary from 55 to 77%, and of unstable from 18 to 32%. The contents of $CaCO_3$ in these deposits rises from the lower horizon (basal gravels) where it reaches 5.44%, while in higher horizons (sandy gravels) are enhanced up to 24%.

The petrographic analysis of fluvial polycyclic deposits from borehole B-7 in Makiš shows that they contain fragments and pebbles of: granitoides, basites, vulcanites, quartzites, gneiss/KF rocks, shales, serpentinites, sandstones, conglomerate, chert, siltstones, carbonates, opal, fragments of fossils, fragments of Neogene rocks and clay balls. Vulcanic rocks are certainly the most significant since they are very abundant, although they belong to unstable components. The contents of metallic minerals vary from 0.7 to 1.77% and can be described as low to medium.

The older set of Pleistocene polycyclic fluvial layers in all boreholes along the Sava (at its confluence with the Danube, on Ada Ciganlija,

Makiš, etc.) contains coarse gravels, grey-brown sandy gravels, rusty--reddish to ochre in colour (high percentage of iron oxide), that pass upward into a younger set of grey-brown or grey gravelly sands. These layers contain fossil mollusks, the commonest of which are *Fagotia acicularis* (FÉRRUSAC), *Fagotia esperi* (FÉRRUSAC), *Lithoglyphus naticoides* (PFEIFFER), *L. fuscus* (PFEIFFER), *Amphimelania holandri* (FÉRRUSAC), *Theodoxus transversalis* (PFEIFFER), *T. danubialis* (PFEIFFER), *Bithynia tentaculata* (LINNAEUS), *Viviparus boeckhi* (HALAVATS), *Unio crassus* (PHILIPSSON), *Pisidium amnicum* (O. F. MÜLLER), etc., and a form of the genus *Corbicula* earlier determined as *Corbicula fluminalis* (O. F. MÜLLER) according to Laskarev (1938) and Stevanović (1977). More recently (in Rakić *et al.* 2002, based on revised GOŽIK fauna), the form was identified as the species *Corbicula apsheronica* ANDRUSSOV.

The guide fossil mollusks for age identification (Early Pleistocene) presently used are *Viviparus boeckhi* (HALAVATS) that is more abundant in the older coarse-clastic beds and *Corbicula apsheronica* ANDRUSSOV in the younger gravelly sands. The presence of the mentioned characteristic fossils distinguishes the older Pleistocene fluvial deposits from the younger, recent fluvial sediments of the Sava. Fossils have not been found in clastic (mainly sandy) layers further from the Sava. Under the loess plateau, fossil fauna was found in fluvial sequences composed of beds and lenses of grey and grey-brown silt and sandy clay with the guide fossils *Planorbis planorbis* with a tooth (KROLOPP) and ostracod species *Scottia browniana* (JONES), etc.

A common characteristic of the Pleistocene polycyclic fluvial sediments in the Sava riparian and adjacent areas is the occasional occurrence of planar lenses of hard sandstone with carbonate matrix. Their equivalents under the Sava valley, where there are coarse clastic layers, are interbeds and lenses of conglomerate strongly cemented with calcium carbonate. There are various interpretations of the origin of the lenses. Some authors consider them as a synsedimentary product laid under specific climatic conditions (warm and arid) on the depositional surface. Others argue that these solid carbonate-clastic bodies were post-sedimentary products leached from ground water rich in calcium carbonate solution.

Earlier authors (Laskarev 1938, Stevanović 1977) used the presence of the fossil assemblage of mollusks *Corbicula fluminalis* (MÜLLER), *Viviparus diluvianus* (KUNTH.) to determine the age as Middle Pleistocene - Mindel, Mindel/Riss (after the Pleistocene subdivision for the Alps). On the basis of the recent studies and the revision of the guide species such as *Corbicula apsheronica* ANDRUSSOV and *Viviparus boeckhi* (HALAVATS), the polycyclic fluvial deposits that contain the mentioned species are dated as Early Pleistocene (Danubian phase and Günz). Hydrogeologically, the

entire complex of the Lower Pleistocene polycyclic fluvial sediments forms a large aquifer that has been long used by local population for domestic water supply.

Fluvial deposits of similar lithology (gravels and sands, with occasional occurrences of silt and clay) occur in southern Banat (northern Vojvodina, Serbia) and overlie deposits of the Pontian age or „the Paludina beds" (lower part of the Upper Pliocene). On the Belgrade Cape (to the south of the investigated area) lateral equivalents of this series are polygenetic terrestrial and pond sediments (Nenadić 2003). In eastern Slavonia (Croatia) fluvial sediments of the Early Pleistocene age are somewhat finer--grained than those in eastern Srem (Bačani *et al.* 1999). The oldest (fourth) terrace of the Drava River in Croatia, and the seventh terrace of the Danube in the Dacian basin (relative height 110-120 m) are also composed of fluvial sediments of the Early and Middle Pleistocene age (Peh *et al.* 1998, Enciu & Balteanu 2002).

Middle Pleistocene Fluvial-Palustrine Sediments

These deposits in the Srem loess plateau of the northern Sava riparian area at Belgrade lie directly over the preexisting polycyclic-fluvial deposits and are below sands of the 'loess terrace'. They vary in thickness from 5 m to 10 m in boreholes on Bežanijska Kosa (ZK-26) and in upper Zemun (ZK-14), and spread northward from 20 m to 30 m above sea level (Knežević *et al.* 1998, Jevremović & Kuzmić 1999, Nenadić 2001, 2003). In the boreholes in the area of Makiš, Ada Ciganlija and Novi Beograd these deposits are absent (fig. 3), and instead of them, recent alluvial sediments lie discordantly over fluvial polycyclic ones. The regional position of the deposits in relation to the underlying formation has not been defined, whereas their direct contacts in boreholes indicate the so-called lithological unconformity manifested as abrupt changes in the lithological composition and the character of fossil fauna.

The constituents are dominantly silt and clay of flood-type sediments, and sporadically channel sands. The complex has notably high concentrations of carbonates, iron and phosphorus. Being adjacent to the alluvial plain, most of this content certainly has been redeposited into the recent alluvial deposits. The commonest forms of fossil mollusks are: *Armirger cristata* (LINNAEUS), *Bithynia leachi* (SHEPPARD), *B. tentaculata* (LINNAEUS), *Planorbis carinatus* (MÜLLER), *P. planorbis* (LINNAEUS), *Succinea oblonga* DRAPARNAUD, *Pisidium casertanum globulare* (CLESSIN), etc. This fauna is typical of the Tiraspol faunal complex of the Middle Pleistocene age (Rakić *et al.* 2002).

In eastern Slavonia (Croatia) clayey-sandy deposits of the Middle Pleistocene age were formed in the remaining marshes and lakes (Bačani *et al.* 1999) and are very similar to the mentioned ones. Such deposits are found in the valley of the Sava River near the village of Jakuševac (Velić & Malvić 1999), and to the west of Krapina (Velić & Saftić 1991), where they are somewhat coarser-grained than those in eastern Srem. The Middle Pleistocene deposits in Croatia are also found in the higher levels of the fourth terrace of the Drava River (Peh *et al.* 1998), and in Slovenia (Krško basin) on the third terrace of the Sava (Verbić *et al.* 2000) where they are composed of mixed silicate-carbonate sand and gravel. In the western Carpathians, deposits of the Middle Pleistocene age are represented by alluvial fans with horizons of palaeosols (Sliva *et al.* 2002), which are covered by the younger loess formations.

Upper Pleistocene Aeolian Sediments (Loess)

A younger stratigraphic unit of the Pleistocene in the Sava riparian area in Belgrade consists of aeolian genetic series - loess. It is described by many authors (Laskarev 1922; Mihajlović-Matić 1952; Stevanović 1977; Marković-Marjanović 1969, 1972, 1977; Marković *et al.* 1984; Kuzmić *et al.* 1999; Marković et. al. 2000, 2006; Nenadić 2000, 2003). Also a variable thickness of slopewash loess is widespread over Miocene and Cretaceous deposits on the southern margin of the right Sava bank.

The eastern margin of the Srem loess plateau rises on the left Sava bank on Bežanijska Kosa and in upper Zemun, composed of four loess horizons and the same number of paleosols. The most recent researchers (Kuzmić *et al.* 1999; Nenadić 2003) reported terrestrial loess deposits from 15 m to 20 m thick, deposited at altitudes between 105 m and 89 m; at older levels, 'loessoide' is less porous, formed in a spacious fluviatile or periodically flooded fluvial lake (89-76 m above sea level). Two loess horizons, deposited during periods of very dry climate, are terrestrial loess deposits, and the older (lower two) horizons are of the loessoide type. The Srem loess plateau extends from the Sava bank far eastward to the northern Srem and there passes into the slopewash loess of Fruška Gora Mountain. Fossil molluscan assemblage characteristic of the described loess is represented by snails: *Succinea oblonga* DRAPARNAUD, *Pupilla muscorum* LINNAEUS, *Arianta orbustorum* LINNAEUS, *Choclicopa lubrica* MÜLLER, *Clausilia pumila* PFEIFFER, *Orcula dolium* DRAPARNAUD, *Carichium minimum* MÜLLER, etc. - an association characteristic of steppe regions.

Malacofauna in all loess levels is almost uniform and cannot be used in stratigraphic zonation. Bearing in mind that the remains of mammals, *Mammuthus primigenius* (BLUMENBACH), *Rhinoceros tichorinus* PISCH., *Equus caballus* (LINNAEUS) and *Bos primigenius* BOJANUS as typical

representatives of upper Palaeolithic or Hazaran complex (Gromov *et al.* 1960), were found in the loess of Srem and near Belgrade, it may be stated that loess was deposited during the Late Pleistocene.

Recent alluvial deposits (Holocene) in the Sava valley at Belgrade are developed after the geodynamic model of a river meandering in the plain. They wedge into the preexisting Quaternary sediments, and largely lie over the polycyclic fluvial sediments of the Lower Pleistocene (fig 3). Deposition of the recent alluvium was preceded by erosion of the younger sets of Pleistocene polycyclic fluvial deposits. The recent Sava valley differs from the old Pleistocene fluvial-lacustrine and fluvial systems by a narrower accumulation plain, much smaller total and average sediment thickness, subhorizontal surface of erosion, lithofacial composition, and vertical distribution of the main facies and lithofacial sets.

A brief Review of Palaeogeographic History through the Quaternary

Sedimentation in the Sava riparian border area between the northern Pannonian margin and the peri-Pannonian region evolved in the Quaternary under variable geodynamic conditions controlled by tectonic events and climatic changes, alternating warm and cold episodes, wet and dry intervals. This area, a part of the Pannonian depression marginal belt in the late Pliocene and the Pliocene - Pleistocene, was a flat to gently rolling plain. In the preceding Pliocene epoch, it repeatedly sank along a complex system of faults in relation to the relatively uplifted parts of Balkan hills. An environment of shallow lakes and bogs was formed in the late Pliocene and the Pliocene - Pleistocene in which heterogeneous, mostly clayey or silty material was deposited (Knežević *et al.* 1998, Nenadić 2003).

Shallow lakes or ponds periodically dried up and watered again. In some places, streams periodically flowed and were filled with sand. The areas of denudation and sources of materials filling the depositional environment were higher lands of the southern Pannonian margin built up of slightly consolidated Neogene sediments. The great thickness of the deposits in the north of the present Sava riparian area is evidence that the sedimentation was for a long time balanced with the slow subsidence of the present Bežanijska Kosa and upper Zemun. The northern part of the Sava riparian area began its evolution in the late Pliocene and Pliocene - Pleistocene as a part of the elevated land that was subsequently eroded. Only subsequently did it gradually subside and the bog-lake-terrestrial sedimentation expanded to the south.

Major palaeogeographic changes took place in the Early Pleistocene. A wide, tectonically controlled depression was formed between the system of

south-Fruška Gora faults in the north and the Sava fault in the south. This depression became a depositional environment (Rakić *et al.* 2002). Sedimentation in the Sava pre-valley is cause-and-effect associated with tectonic events of the early Pleistocene (phase of Alpine tectogenesis) and intensive erosion in the areas of the valley-side rise and simultaneous accumulation of abundant clastic materials in the river channel. Major breaks in the old Sava depression resulted in a valley system with the linear trunk stream in the form of a powerful overflowing river, wide as a lake and fed by many flooding tributaries. The river changed the contour of its channel in cycles, through alternating tectonic subsidence and palaeo-climatic change, which is manifested in the cyclic alternation of typical channel sediments (gravel-sandy gravel-gravelly sand-sand) and alluvial sediments (silt, sandy clays).

Fluvial and bog-fluvial deposition in the Sava pre-valley during the middle Pleistocene took place in a semiarid climate (steppe river). The prevailing sediments - clay and silt, frequent lithological changes both vertical and horizontal, and mixed bog-terrestrial fauna - indicate a steppe river in the semiarid zone. Very strong spring floods that formed large lakes and ponds in the alluvial plain characterized the hydrologic regime in the given climate. During warm and short summers, most of the basins dried up, transforming into saltpans, hydromorphic pedogenetic complexes, podzolized carbonate soils and red laterite of the terra fusca type. Tectonic movements of lower intensity than in the preceding period did not deform the ground surface.

Younger Pleistocene of the Sava riparian area was a period of mainly dry and cold climate. The area was part of a large periglacial region in which extensive and relatively thick loess was deposited. The deposition of loess began in a predominantly flooded environment, and ended in dry steppe. The large Srem loess plateau was formed in the flat part of Srem within the Pannonian depression, whereas slopewash loess was deposited on hills rising on the right valley side. Strong winds, which then blew from the SE Pannonian hinterland, and from other directions, deposited large amounts of dust and sand. Because deposits contain dust transported from the abandoned, dry streambeds, in addition to the syngenetic aeolian dust from the deposited morainic material in the north, most upper Wurmian formations in the given area may be termed 'loessoide' or descrfibed as having loess-like sediments.

The Sava River formed as a part of the large Danube and Black Sea drainage system in the late Pleistocene and during the Holocene under the influence of a changed climate (disappearance of large glaciers in Europe and global warming). Cutting the recent Sava valley caused erosion of Pleistocene sediments: fluvial deposits of the upper Pleistocene, fluvial-bog

deposits of the middle Pleistocene and southern margin of the Srem loess plateau (upper Pleistocene aeolian sediments). The river shifted its channel, formed a wide flood plain, and undercutting the primary loess deposits in the north made a specific stream channel with alluvial, oxbow and oxbow lake deposits. During high flow, most of the area was water-covered, suitable for deposition of fine sediments in cyclic succession with deposits of lower flows.

CONCLUSION

This paper describes Pleistocene deposits of the Sava riparian area at Belgrade, where the southern margin of the Pannonian depression borders on the Balkan Peninsula. It is particularly focused on the inadequately studied covered deposits of the Lower Pleistocene, based on the data from exploratory boreholes. Continental deposits in the given area were formed in the Lower, Middle and Upper Pleistocene.

The Neogene (Late Miocene) age was previously erroneously ascribed to the Pliocene-Pleistocene deposits. The lithological character and a relatively poor fauna suggest their formation in shallow lakes and ponds that periodically dried up. They are similar to the deposits exposed in the southern part of the Moldavian plateau, assigned to the Pliocene (Ghenea 1970). These are characterized by complex horizontal and vertical changes in different genetic types of continental sediments: lacustrine, fluvial--lacustrine, palustrine, subareal formations with substrate. Fossil mammals from these very thick deposits are known as "Bereshti-Malushteni fauna": *Hipparion* sp., *Stephanomys donnezani* in assemblage with *Zygolophodon borsoni* and *Anancus arvenensis.* On the basis of their presence the age of the series is considered to be the Pliocene. Lacustrine and fluvial deposits of the Belgrade environs may correspond in stratigraphy to the biostratigraphic zone with *Viviparus vukotinovici* (the youngest horizon of the lake Paludina beds) and beds with *Viviparus boeckhi* (lacustrine-fluvial and fluvial deposits) of the Pannonian basin.

Polycyclic fluvial sediments of the Early Pleistocene (with fossil mollusks *Corbicula apsheronica* and *Viviparus boeckhi* in lower horizons) represent most widespread Pleistocene formations in the Sava riparian area. The high-flow sediments (clays, silts) have, instead of the mentioned species, *Planorbis planorbis* with a tooth, ostracod species *Scottia browniana*, etc. Polycyclic fluvial deposits of the Early Pleistocene formed in the Sava pre-valley were controlled by cyclic tectonic events that resulted in repeated subsidence of the riverbed. These deposits have great economic importance as aquifers from which Belgrade is supplied with water.

Middle Pleistocene deposits are much thinner than the Pliocene - Pleistocene and Lower Pleistocene ones. They are situated beneath the loess plateau and studied only on the basis of drilling data. Their depositional environment was the ancient steppe river and its floodland during the period of semiarid climate. These deposits have been compared with similar formations in Croatia and northern Vojvodina of the Middle Pleistocene age.

The upper Pleistocene is represented by loess deposited in the dry periglacial conditions of the late stage of the Last Glacial. Slopewash loess lies over the hilly country built-up of Neogene and Cretaceous sediments, above the right bank of the Sava. The vast Srem loess plateau borders the flatland of the Pannonian depression on the left side of the Sava valley at Belgrade. Mammal remains found in loess of the Srem plateau and near Belgrade, represented by *Mammuthus primigenius*, *Rhinoceros tichorinus*, *Equus caballus* and *Bos primigenius*, typical of upper Palaeolithic or Hazara complex, are used in determining the time of loess deposition as the Late Pleistocene.

Most Pleistocene deposits in the Sava riparian area were eroded after the river cut its recent channel and formed the alluvial plain with its tributaries. All the given data about the Pleistocene sediments of the Sava riparian area are important for correlation and interpretation of the late Quaternary stratigraphy and palaeogeography in central and southeastern Europe.

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СТРАТИГРАФСКЕ И ПАЛЕОГЕОГРАФСКЕ ОСОБИНЕ ПЛЕИСТОЦЕНСКИХ СЕДИМЕНАТА У ДОЛИНИ САВЕ КОД БЕОГРАДА (СРБИЈА)

ДРАЖЕНКО НЕНАДИЋ, СЛОБОДАН КНЕЖЕВИЋ, КАТАРИНА БОГИЋЕВИЋ

Р Е З И М Е

Континентални седименти квартарне старости у долини реке Саве код Београда, настали су током плио-плеистоцена, доњег, средњег и горњег плеистоцена. При проучавања плеистоценских седимената, посебна пажња посвећена је седиментима доњег плеистоцена, који до сада нису били довољно истражени. С обзиром да седименти доњег плеистоцена на терену нису директно откривени, подаци су добијени на основу анализа материјала из бушотина.

Плио-плеистоценским седиментима раније је погрешно приписивана неогена старост (горњи миоцен). Њихов литолошки састав и присуство релативно сиромашне фауне указују на настанак у плитким језерима и барама са периодичним пресушивањем. Ови седименти, по старости а делимично и по пореклу, могу се упоредити са вилафраншким наслагама у Италији, као и са седиментима плиоценске старости, откривеним у јужном делу Молдавског платоа (Ghenea 1970). Одликује их сложена хоризонтална и вертикална смена језерских,

речно-језерских и барских седимената. На основу присуства представника сисарске фауне, познатих као „Bereshti-Malushteni“ (*Hipparion* sp., *Stephanomys donnezani* заједно са *Zygolophodon borsoni* и *Anancus arvenensis*), старост ове серије одређена је као плиоценска. У стратиграфском погледу, језерско-делувијално-пролувијални седименти околине Београда могу бити синхрони зони са *Viviparus vukotinovici* (најмлађи хоризонт палудинских слојева) и слојевима са *Viviparus boeckhi* (језерско-речне и речне наслаге) Панонског басена.

Полициклични речни седименти доњег плеистоцена (у доњим хоризонтима са *Corbicula apsheronica* и *Viviparus boeckhi*) најраспрострањеније су творевине плеистоценске старости у долини Саве. Уместо представника поменутих врста, у седиментима поводња (глине и алеврити) откривени су *Planorbis planorbis* са зубићем и *Scottia browniana*. Полициклични речни седименти доњег плеистоцена настали су у прадолини Саве, као резултат цикличних тектонских покрета који су утицали на вишеструко спуштање речног корита. Економски значај ових седимента изузетно је велики с обзиром да представљају резервоаре подземне воде из којих се снабдева Београд.

У поређењу са седиментима плио-плеистоцена и доњог плеистоцена, средњеплеистоценски седименти знатно су мање дебљине. Представљају подину лесног платоа и проучени су на основу података добијених из бушотина. Настали су током периода семиаридне климе, у кориту старе степске реке и њене алувијалне равни. Седименти средњег плеистоцена могу се упоредити са сличним синхроним творевинама у Хрватској и северној Војводини.

Настанак лесних наслага горњег плеистоцена везан је за сушне периглацијалне периоде (крај последњег глацијала). Изнад десне обале Саве, у подини падинског леса откривени су неогени и кредни седименти. Обод велике сремске лесне заравни откривен је изнад леве стране реке Саве код Београда. Из леса Сремског платоа код Београда, одређени су представници врста сисара *Mammuthus primigenius, Rhinoceros tichorinus, Equus caballus* и *Bos primigenius*, типични за горњи палеолит („Хазарски комплекс“), на основу којих је одређена горњеплеистоценска старост леса.

Плеистоценски седименти у долини Саве великим делом су еродовани, након што је река усекла своје данашње корито и створила савремену алувијалну раван. Подаци о плеистоценским седиментима у долини Саве подједнако су важни за стратиграфске и палеогеографске интерпретације као и за корелације квартарних седимената у централној и југоисточној Европи.