

THE LOWER QUATERNARY BOUNDARY IN THE SOUTHEASTERN SREM (NORTH SERBIA)

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Quaternary deposits in the area of the southeastern Srem have continuous distribution, and in some places a considerable thickness (more than 100 *m*). On the basis of their origin, the deposits formed in the northern parts of the investigated area (on the Fruška Gora slopes) can be differentiated from those formed in the wider area of the Danube-Sava valley system. Although the lower boundary of the Quaternary with the pre-Quaternary sediments is usually clear, some further investigations are required to give a more detailed view of its precise stratigraphic position. The "Srem series" need to be more precisely dated so that the proluvial-deluvial processes and their relation to tectonics and climatic changes can be better understood. In the case of fluvial polycyclic sediments it is possible (on the basis of sedimentological characteristics and palaeontological records) to differentiate clearly pre-Quaternary from Quaternary sediments. The problem with the marsh-lake sediments is much more complex. In the *Paludina* beds neither the position of

the Pliocene-Pleistocene (Neogene-Quaternary) boundary has been precisely established, nor has the time span in which particular stages of development of the Slavonian (Paludina) lake took place.

Key words: Quaternary, lower boundary, southeastern Srem.

INTRODUCTION

The majority of the area of the southeastern Srem (north Serbia) is covered with Quaternary sediments (Fig. 1), with the exception of the higher parts of the Fruška Gora mountain, where the surface sediments are of pre-Quaternary age. The lowermost Quaternary deposits in the southeastern Srem are represented by two different lithogenetic formations: (1) marsh-lake, and either (2a) fluvial polycyclic sediments developed in the Danube and Sava River valleys, or (2b) proluvial-deluvial formations formed on the slopes of the Fruška Gora mountain.

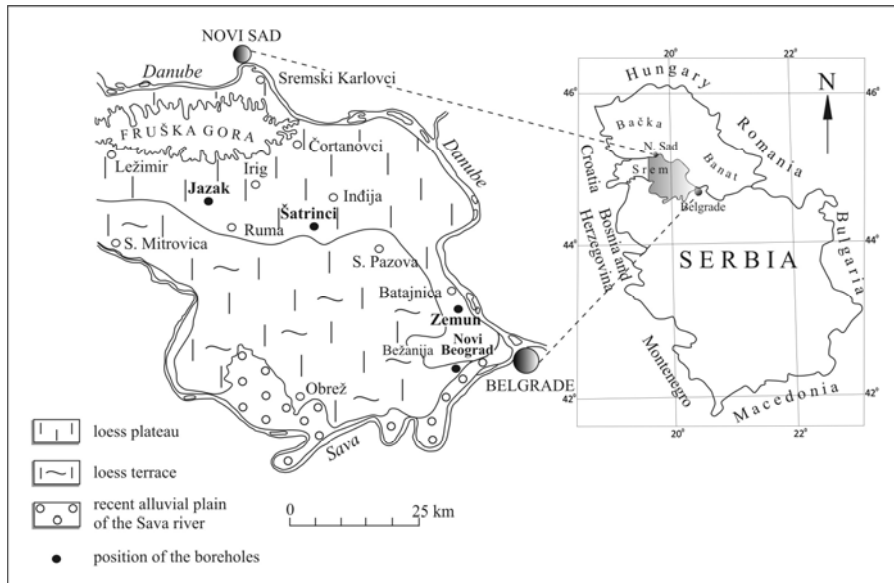


Fig. 1. Geographical and geological sketch of the investigated area with the position of the reference boreholes.

Older Quaternary formations, which are not exposed on the surface, have been much less explored (Rakić 1973, 1990, Knežević *et al.* 1998, Nenadić 2003, Nenadić *et al.* 2009, 2010) than the loess and loess-like sediments which lie on them. The genetic and stratigraphic relations of the older (Neogene) and the younger strata (loess series) are still unclear. The

contacts of the mentioned units with the pre-Quaternary deposits are still partly defined and more precise defining of their position would require new investigations. According to the changes of the Quaternary time-scale, the Pliocene-Pleistocene (Neogene/Quaternary) boundary is lowered to 2.588 Ma (Gibbard *et al.* 2009), so all the previous views and results need a review.

The aim of this paper is to create a general picture of where the Pliocene-Pleistocene (Neogene/Quaternary) boundary is or should be, based on the mineralogical, lithostratigraphic and palaeontological analysis of the reference drill-cores of the southeastern Srem. The paper further aims to show directions which future investigations of Lower Quaternary sediments would take.

MATERIAL AND METHODS

Four cores (boreholes) have been sampled in the investigated area (Fig. 2). Preliminary analysis of the mineralogical and petrological composition of these samples has been done. Remains of mollusks and ostracods have been picked out under a binocular microscope and, when possible, determined to the level of species using qualitative methods. When no fossils were available, the age of deposits has been estimated by the superposition principle.

Brief stratigraphic description of the lowermost Quaternary deposits of the southeastern Srem

On the basis of their genesis, superposition and age the following units can be distinguished:

1. Lower - Middle Pleistocene proluvial-deluvial sediments ("Srem series") formed mainly on the northern slopes of the Fruška Gora;
2. Pliocene – Pleistocene marsh-lake sediments;
3. Lower Pleistocene polycyclic-fluvial deposits developed in the southern parts of the investigated area.

PROLUVIAL-DELUVIAL SEDIMENTS ("SREM SERIES") (LOWER - MIDDLE PLEISTOCENE)

In the northern part of the area, on the southern slopes of Fruška Gora, deposits of proluvial - deluvial origin were formed (Rakić 1973, Nenadić 2003, Nenadić *at al.* 2010). In the Serbian literature these deposits were identified as "Srem series" (Rakić 1973). Based on the drill-core material from Jazak, Šatrinci, Irig and Sremski Karlovci the thickness of these heterogeneous deposits varied between 40 and 70 m (Fig. 2).

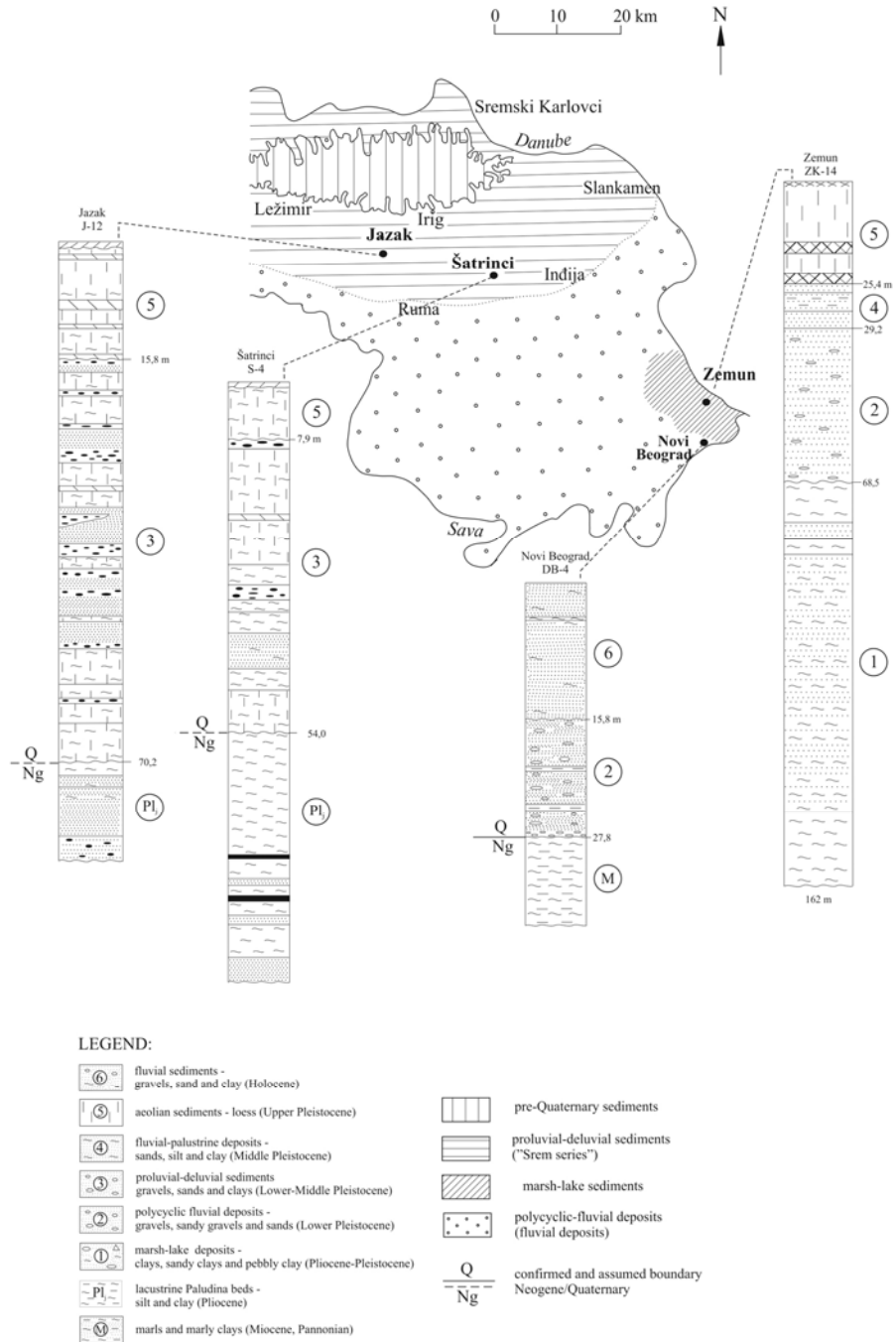


Fig. 2. Core logs of the studied boreholes and pre-loess Quaternary sediments in the investigated area.

The lower parts of this heterogeneous series are composed of coarse-grained sediments (gravel sands, sands and silts), whereas the upper parts are formed of fine-grained material and have much similarity with the so-called "marsh loess". These deposits are intensely red and they can be easily distinguished from the underlying and overlying deposits. They are characterized by the presence of unsorted material with many lenses of irregular shape. The mineralogical analysis of the heavy fractions shows high content of metallic (27-78%) and Fe-oxyhydroxide minerals (~25%) (Rakić 1973), unlike the significantly smaller concentrations found in the underlying layers.

The following terrestrial and freshwater molluscan assemblage was found: *Succinea oblonga* Draparnaud, *Parafossarulus crasitesta* (Brömme), *Anisus leucostoma* (Millet), *Aegopis klemmi* Schlickum & Ložek, *Pupilla muscorum* (Linnaeus), *Gyraulus albus* (Müller) etc. (Rakić 1973).

This lithostratigraphic unit probably formed as a result of uplifting of the Fruška Gora horst and subsidence of the neighboring area (especially the Slavonija-Srem trough). These tectonic movements might have had regional character and were likely linked to the Pliocene-Pleistocene climate changes (Clothing *et al.* 2002).

The proluvial-deluvial sediments lie directly below the loess series and above the Paludina beds (green clays or whitish Pliocene sands). According to their fossil content and the superposition, an Early to Middle Pleistocene age has been proposed (Nenadić 2003).

Sediments of similar composition and fossil content, but with much greater thickness, were found during the drilling works in the wider area of Banat and Bačka (Vojvodina) over the polycyclic-fluvial sediments with *Viviparus boeckhi*, and beneath the deposits of "Varoš terrace" and "loess terrace" (Nenadić 2003). These sediments are similar to the deposits of the Early Pleistocene age ("red beds") that were formed by ephemeral streams in the western Carpathians (Sliva *et al.* 2002). They are commonly identified as "Srem series" in the Serbian literature (Rakić 1973); its lateral equivalents are named "Kličevac series" in the vicinity of Požarevac and "Zagajica series" in southern Banat (Rakić 1977, 1985).

MARSH-LAKE SEDIMENTS (PLIOCENE – PLEISTOCENE)

The oldest Quaternary deposits in the studied area were found in the boreholes drilled in the southeastern part of the area, in the Sava Valley and in the area of the Srem loess plateau between Novi Beograd and Zemun (Knežević *et al.* 1998, Nenadić 2003, Nenadić *et al.* 2009). Their thickness increases from 18 m in the Sava Valley to 100 m and more in the basement of the Srem loess plateau.

These deposits are varied and include clays, sandy clays and silts, clayey sands, and gravel clays. The occurrence of oolites and lenses of Mn- and Fe-oxyhydroxides is common. Only occasionally were some remains of freshwater (marsh) gastropods found (*Limnaeus*, *Planorbis*). These characteristics are best seen in the Zemun area in the material of borehole ZK-14 that reaches a depth of 162 m (Fig. 2).

These deposits formed over long periods by the deposition of material of slope processes in the marsh-lake or terrestrial environments. The time frame was Late Pliocene to Middle Pleistocene, when active tectonic movements were building the fault fabric and blocky structures (e.g., Slavonija-Srem trough, Mačva trough, Kolubara-Tamna basin etc.) of the Serbian part of the Pannonian Basin System with the uplift of horst structures (e.g. Avala-Kosmaj and the Fruška Gora horst). The material of the deposits in the south part of eastern Srem was redeposited from the loose and easily weathered sediments of the Upper Neogene (Pannonian and Pontian age) (Marović *et al.* 2002, Nenadić 2003).

In the Sava Valley these deposits lie discordantly over Miocene sediments of the Paratethys (mostly marls of Pannonian age) or over lacustrine Pliocene deposits (Knežević *et al.* 1998).

Since their age could not be determined by biostratigraphic-palaeontological methods, on the basis of the superposition of sediments (they are covered by the Lower Pleistocene deposits and underlain by sediments of the Pliocene age) it can be assumed that they were deposited during the Late Pliocene and/or the early part of the Early Pleistocene.

In other parts of the Pannonian Plain (Slavonia, southern Banat, Bačka) formations of similar age and origin are the “beds with *Viviparus vukotinovi*” (the youngest horizon of “Paludina beds”) and “beds with *Viviparus boeckhi*” (Nenadić *et al.* 2001, Nenadić 2003). Fluvial-marsh-lake deposits are rather widespread in neighboring regions and they are considered to be mostly of Late Pliocene age, for example, those 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 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-Early Pleistocene) deposits with mammal remains *Zygodon borsoni* (Hays), *Anancus arvernensis* (Croizet & Jobert), *Mammuthus meridionalis* (Nesti) (Enciu & Balteanu 2002).

POLYCYCLIC-FLUVIAL DEPOSITS (LOWER PLEISTOCENE)

These deposits are associated with the valleys of the former rivers that meandered through the southeastern Srem. In some earlier papers (Laska-

rev 1938, Stevanović 1977) they were identified as “Makiš deposits” or beds with “*Corbicula fluminalis*”.

These deposits are widely distributed in the southeast part of the Pannonian Plain, and in the studied area they are connected to the river bank parts of the Danube and the Sava (Makiško polje, Ada Ciganlija, Novi Beograd, Zemun, Batajnica, etc.)

This unit is composed mostly of sands, gravel and silty sands, with intercalations of silt and clay. Typical coarse riverbed deposits often cyclically alternate with floodplain sediments. Index fossils for determining the age of these deposits are *Viviparus boeckhi* (Halavats) in the lower layers, and *Corbicula fluminalis* (Müller) without *V. boeckhi* (Halavats) in the upper ones. In the basement of the Srem Loess Plateau *Planorbis planorbis* with a tooth (Linnaeus) and *Scottia browniana* (Jones) have also been found (Knežević *et al.* 1998).

The thickness of these deposits is very variable, from several meters up to several tens of meters (sometimes even more than 100 m).

On the left bank of the Sava River they are underlain by thick Pliocene - Pleistocene deposits, and near the junction of the Sava and the Danube Rivers, by the Late Miocene (Pannonian) marls (Knežević *et al.* 1998, Jevremović & Kuzmić 1999, Nenadić *et al.* 2001, Nenadić 2003).

Fluvial deposits of similar lithology (gravels and sands) with occasional occurrences of silt and clay (Rakić 1985, Rakić *et al.* 2002) are found in southern Banat (northern Vojvodina, Serbia) and overlie deposits of the Pontian age or “the Paludina beds” (lower part of the Upper Pliocene and the youngest parts of Lower Pleistocene). In eastern Slavonia (Croatia) fluvial sediments of the Early Pleistocene age are somewhat finer-grained than those in the 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).

DISCUSSION

In the southeastern part of Srem the oldest Quaternary deposits can generally be placed in two different genetic categories:

1. deluvial-proluvial deposits in the north of the investigated area, connected to the southern slopes of Fruška Gora;
2. marsh-lake and fluvial polycyclic deposits in the southern part of the terrain, connected to the Danube and Sava valley systems.

1. **Deluvial-proluvial deposits**, due to their intensive red colour and lithological characteristics, could be distinguished relatively easily from the overlying and underlying deposits. They are undoubtedly covered with loess series (Nenadić 2003), which, in the peripheral parts of this complex conus, acquire similar characteristics as the underlying deposits. Below these deposits Pliocene “Paludina” green clays (at Šatrinci, Mali Radinci, Irig) (Rakić 1973, Rakić *et al.* 1998) or whitish sands (Borkovac, Jazak) are situated, always discordantly. These underlying deposits contain fossil fauna with smooth *Viviparus*, *Melanopsis*, unionids and *Theodoxus*, as well as with the species *Viviparus ex. gr. rudis*: an association characteristic of the Paludina beds. The fossil fauna of the “Srem series” is a typical Quaternary malacofauna with representatives of terrestrial and transitional environment. The mentioned fauna points to a certain cooling of climate, which is a quantitatively new feature in relation to conditions which prevailed during Pliocene. Deluvial-proluvial deposits are also sedimentologically different from the underlying deposits: they have a greater content of metallic minerals and Fe-oxyhydroxides. They also contain different minerals of light fraction: quartz, feldspars and a small quantity of muscovite. On the basis of the palaeontological data and position of the sediments we suppose that the deluvial-proluvial deposits were formed during Early and Middle Pleistocene, although neither of two boundaries has been precisely defined. For now, we can draw the lower boundary with some assurance only hypothetically, although some pollen spectra in the lower horizons point to the end of Pliocene and an early phase of Quaternary (Pantić 1967).

2. **Marsh-lake deposits** have been found in several boreholes in the area of Zemun and Bežanija (southeastern part), always over some Pre-Quaternary deposits: Pannonian marls or the Paludina lake deposits. Blue-greenish sand and middle-grained sands without fossils lie below them in Zemun. It can be assumed, according to lithological similarity with the deposits in the northern part of the area, that they belong to the Lake Paludina beds of Pliocene age. Lake-terrestrial deposits have no continuous distribution. They are usually represented as isolated zones which laterally alternate with much more widespread fluvial polycyclic deposits. On the basis of their stratigraphic position and the succession of Neogene and Quaternary deposits, and according to the method of superposition, it can be assumed that they were formed in the Late Pliocene and Early Pleistocene. There is a possibility that in the areas where they achieve an extremely great thickness (e.g., in the area of Zemun), the older horizons of polygenetic lake-terrestrial deposits may represent, in fact, lateral facies of the Lake Paludina beds.

It can be assumed that the lake-marsh deposits were mainly destroyed by the subsequent fluvial phase, by the action of a system of meandering

rivers with wide alluvial plains. These deposits continuously cover the central and southern part of the eastern Srem, from the contact with “Srem series” in the north to the recent Sava riverbed in the south. In places where fluvial polycyclic deposits do not overlie older lake-terrestrial deposits, they are in discordant relation to the Pre-Quaternary deposits of the Pannonian and Pontian Ages. Pannonian deposits are represented by grey to grey-greenish marls and marly clays with ostracode microfauna and rare remains of fossil molluscs (*Gyraulus praeponticus*, *Congerina banatica*, *Limnocardium* sp.) (Knežević *et al.* 1998). On the basis of the palaeontological contents and superposition, it has been assumed that these deposits were formed during Early Pleistocene. Index fossil for Early Pleistocene is *Viviparus boeckhi*. Fluvial polycyclic deposits are lithologically and palaeontologically clearly different from underlying Miocene layers, so their contact could be safely taken as the lower boundary of Pleistocene.

CONCLUSIONS

The recent changes to the Quaternary time scale enable us to recognize the Pliocene-Pleistocene boundary only in the case of fluvial-polycyclic sediments that lie under the beds with *Viviparus boeckhi* (Halavats).

The age of the “Paludina beds” has not, up to now, been clearly defined and their position in the Cenozoic time scale has to be established more precisely. In this paper the old data are still used because we cannot estimate the exact age of “Paludina beds” using the available data.

The age of the “Srem series” is based on superposition of strata, but more exact data are needed to estimate the intensity and the importance of mass movements.

In the borehole on the territory of Novi Beograd (DB-4), the contact between Pliocene and Pleistocene (Neogene and Quaternary) could easily be established at the depth of 27.8 *m*. This contact represents the lithological boundary of Pannonian marls with Pleistocene fluvial polycyclic sediments.

In the boreholes Jazak (J-12) and Šatrinci (S-4) the lower boundary of Quaternary could not be established with certainty because the Pliocene/Pleistocene boundary has been only vaguely drawn both in the Paludina beds and in the “Srem series”.

In the borehole near Zemun (ZK-14), the drilling process reached a depth of 162 *m*, and at that depth colored clays of Early Pleistocene age were still found (Nenadić 2003). Since this area was subjected to subsidence (Marović *et al.* 2002), the Pliocene/Pleistocene boundary is

situated at greater depths, most probably in the Paludina beds, according to their regional distribution.

It can be concluded that the area of southeastern Srem was subjected to neotectonic movements and that the boundary Pliocene/Pleistocene is situated at a depth of 27 *m* or even deeper, which is conditioned by tectonic subsidence and geomorphological processes.

Acknowledgments. This work was supported by the Ministry of Science and Environment Protection of Serbia, project numbers 176015 and 177023. Special thanks go to Mrs. Danica Pilić for her help with the English translation. The authors are very thankful to the reviewers, whose suggestions improved the paper.

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ДОЊА ГРАНИЦА КВАРТАРА НА ПОДРУЧЈУ ЈУГОИСТОЧНОГ ДЕЛА СРЕМА (СЕВЕРНА СРБИЈА)

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РЕЗИМЕ

На простору југоисточног дела Срема најстарије квартарне творевине могу се генерално издвојити у две различите генетске категорије:

- насlage делувијално-пролувијалног карактера на северу испитиване области везане за јужне падине Фрушке горе и

- језерско-барске и речне полицикличне творевине у јужном делу терена, везане за долинске системе Дунава и Саве.

1. Пролувијално-делувијалне насlage због своје изразито црвене боје и литолошких карактеристика релативно се лако могу издвојити од подинских и повлатних творевина. Несумњиво је да су прекривене лесним серијама (Nenadić 2003) које у периферним деловима овога сложеног конуса попримају сличне карактеристике са подлогом.

Подину овим творевинама (Rakić 1973, Rakić *et al.* 1998) чине плиоценске палудинске зелене глине (Шатринци, М. Радинци, Ириг) или беличасти пескови (Борковац, Јазак), при чему је однос дискордантан. Ове подинске творевине садрже фауну глатких вивипара, меланопсиса, унионида и теодоксуса, где је констатована и врста *Viviparus ex. gr. rudis*, дакле асоцијацију која је везана за палудинске слојеве. Фаунистички садржај „сремске серије“ има карактеристике типичне квартарне малакофауне са представницима копнене и водено-копнене средине. Наведена фауна у палеоеколошком погледу указује на извесно захлађење, што је такође квалитативно нова особина у односу на услове који су владали током плиоцена. Пролувијално-делувијалне творевине се и седиментолошки разликују од наслага у подини, имају већи садржај металичних минерала и хематит-лимонита. Разлика се уочава и у минералима лаке фракције: кварцу, алтерисаним зрнима, фелдспатима и малој количини мусковита. На основу палеонтолошких података и положаја седимената може се претпоставити да су делувијално-пролувијалне творевине таложене у деловима доњег и средњег плеистоцена, мада обе границе нису тачно стратиграфски детерминисане. О доњој граници се за сада може са сигурношћу тврдити само оквирно, мада наласци поленовог спектра из подине предгорног конуса који указују на флору која је егзистовала на крају плиоцена и раној фази квартара (Pantić 1967), донекле потврђују њен положај.

2. Језерско - барске творевине констатоване су на основу неколико бушотина на подручју Земуна и Бежаније (ЈИ део терена), при чему се увек налазе преко преквартарне подлоге, панонских лапораца миоцена или палудинских језерских наслага. У Земуну њихову подину чине модрозеленкасте глине и средњезрни пескови, без присуства фосила. Претпоставља се, на основу литолошке сличности са творевинама у северном делу терена, да припадају плиоценским језерским палудинским слојевима. Језерско-континенталне насlage немају континуирано распрострањење, већ се више јављају као изоловане зоне које се бочно смењују са много распрострањенијим речним полицикличним творевинама. На основу њиховог стратиграфског положаја, те сукцесије неогених и квартарних наслага, а на основу методе суперпозиције, може се претпоставити да су стваране у млађем плиоцену и старијем плеистоцену. Постоји могућност да у теренима где имају екстремно велику дебљину (нпр. подручју Земуна) старији хоризонти полигенетских језерско-терестричних творевина представљају бочне фације језерских палудинских слојева.

Може се претпоставити да су језерско-барске творевине добрим делом разорене накнадном речном фазом, системом меандрирајућих

река широких алувијона. Ове наслаге континуирано прекривају средишњи и јужни део источног Срема, од контакта са „сремском серијом“ на северу до савременог корита Саве на југу. На местима где речне полицикличне творевине не леже преко старијих језерско-континенталних наслага, запажа се њихов дискордантан контакт са преквартарном подлогом – наслагама панона и понта. Панонски слојеви су представљени сивим до сивозеленастим лапорима и лапоровитим глинама са микрофауном остракода и ретком фауном фосилних мекушаца (*Gyraulus praeponticus*, *Congeria banatica*, *Limnocardium* sp.) (Кнежевић *et al.* 1998). На основу палеонтолошког садржаја и суперпозиционог положаја, за ове творевине се претпоставља да су таложене током доњег плеистоцена. Реперни фосил за дефинисање доњег плеистоцена представља врста *Viviparus boeckhi*. Дакле, речне полицикличне творевине се литолошки и палеонтолошки јасно разликују од миоценских слојева у подини, тако да се овај контакт може са сигурношћу дефинисати доњом границом плеистоцена.

Иако је доња граница квартарних наслага са преквартарном подлогом у већини случаја оквирно јасна, само нека наредна истраживања могла би пружити детаљнији увид у њен прецизнији стратиграфски положај. За „сремску серију“ потребно је прецизније одредити временски оквир настанка, да би се боље разумели пролувијално-делувијални процеси и њихова повезаност са тектоником и климатским променама. У случају речних полицикличних седимената, на основу седиментолошких карактеристика и палеонтолошког записа, могуће је јасно раздвојити преквартарне од квартарних седимената. У барско-језерским седиментима то је много комплекснији проблем, јер у палудинским слојевима није прецизно одређена граница плиоцен-плеистоцен (неоген/квартар), нити који временски оквир захвата развиће поједних стадијума Славонског (палудинског) језера.