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STRATIGRAPHICAL AND LITHOLOGICAL CHARACTERISTICS OF PRELOESS SEDIMENTS IN EASTERN SREM (SERBIA)

by

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In the area of Eastern Srem Pleistocene sediments cover large territories. Their facial diversity and very complex interrelations of lithological units are one of the important features of this part of the Pannonian basin. Study of stratigraphic, lithologic, sedimentologic and mineralogic characteristics of these deposits from boreholes in Zemun, Indija, Čortanovci and Ruma led to conclusion that the interaction of tectonic and climatic changes, as well as difference in sedimentological environments, caused formation of genetically different lithostratigraphic units.

Key words: Pleistocene, preloess sediments, boreholes, Eastern Srem.

На подручју источног Срема плеистоценске наслаге имају велико распрострањење, при чему њихова фацијална променљивост и врло сложени односи литолошких јединица чине једну од битних карактеристика овог дела Панонске низије. Проучавајући стратиграфске, литолошке, седиментолошке и минералошке карактеристике ових наслага на основу бушотина рашчлањених на потезу Земун, Инђија, Чортановци и Рума може се уочити да су међусобним деловањем тектонских и климатских промена стварање генетски веома издвојене јединице, чија је смена како у вертикалном, тако и у хоризонталном правцу, последица веома изражене динамичке активности које је ово подручје доживело током плеистоцена.

Кључне речи: плеистоцен, прелесне наслаге, бушотине, источни Срем.

INTRODUCTION

In the area of Pannonian basin, in lowland region between Sava river and Fruška Gora Mt. (Fig. 1), Quaternary sediments are widely exposed and occur as a single compact belt. These sediments are characterised by intense facial diversity, commonly with changes on short distances, both vertical and latteral. These characteristics were caused by paleogeographic conditions, tectonic and climatic changes during Pleistocene in the area of Eastern Srem.

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Generally looking, in this area occur deposits of mostly all stratigraphic units of Quaternary, except glacial deposits. Preloess deposits are divided in three genetic types:

- terrestrial–aquatic sediments of upper Pliocen–older Eopleistocene,
- fluvial policyclic sediments along the river valleys,
- deluvial–proluvial sediments on the slopes of Fruška Gora as latteral equivalent of former sediments.

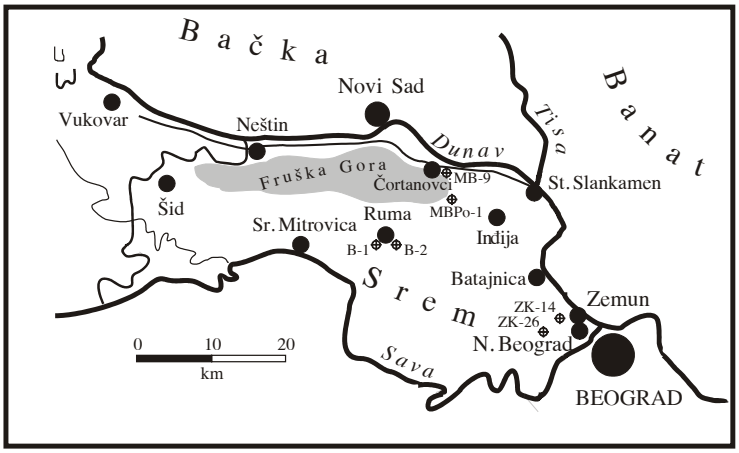

Fig. 1. Geographic position of the studied area with borehole locations.
Сл. 1. Географска карта истраживаног подручја и положај бушотина.

Schematic lithostratigraphic division is given in Fig. 2.

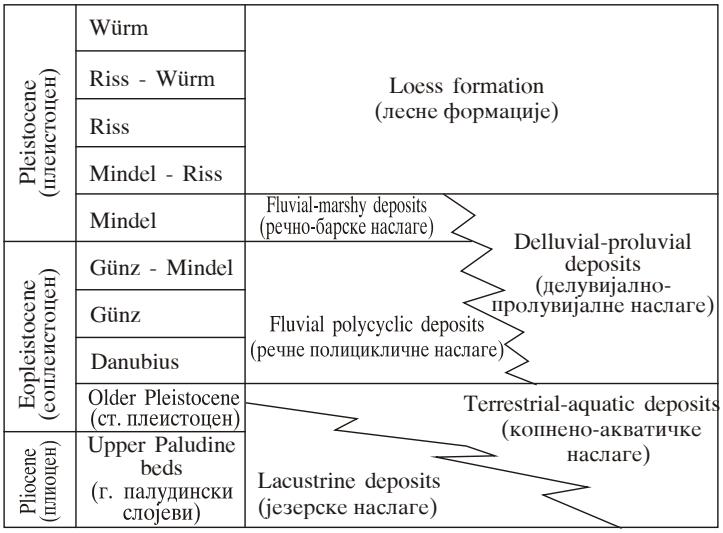

Fig. 2. Schematic division of Quaternary sediments in Eastern Srem.
Сл. 2. Шематизована подела квартарних седимената на подручју источног Срема.

Study of material from numerous boreholes and open profiles gave new data on stratigraphic relations between Quaternary and Neogene in this area. For the first time a complex study of these sediments included sedimentologic and mineralogic analysis. Thus was discovered an important lithostratigraphic unit of the upper Pliocene–lower Pleistocene age, which in the earlier literature had no precise interpretation.

TERRESTRIAL–AQUATIC SEDIMENTS OF THE UPPER PLIOCENE–LOWER PLEISTOCENE

These polygenetic sediments were formed in the upper Pliocene and at the boundary of Pliocene–Pleistocene. They are underlain by lacustrine Paludine deposits of Pliocen age, and overlain by younger sedimetns, so they do not occur as exposures.

In ZK–14 borehole in Zemun (near old Beograd–Zagreb railway line), these sediments are underlain (at depth of 162.0 m) by aquatic bluish–green clays and middle–grained sands, unfortunately without fossils, which are supposed to be part of the lacustrine Paludine beds. Paludine sediments are overlain by more than 90 m thick heterogenous series of sediments with variable lithologic composition. They are made of variegated sandy clays with gravel, greyish–green and brown sandy silts, with common occurrences of Fe and Mn lenses, occasionally with $CaCO_3$ concretions, and, rarely, with lenses of sand and gravel. Sometimes occur dark grey clays with carbonaceous matter. Gravels consist of quartz, black and red jasper, Cretaceous limestone, sandstone, serpentinite, rarely dacite. Common occurrences of joints, fractures, fractured material, $CaCO_3$ concretions, and Fe and Mn lenses suggest intensive influence of postdiagenetic processes. These deposits originated as a result of different processes: eluvial, deluvial, proluvial, and lacustrine and marsh accumulation. Lithologic features indicate polygenetic terrestrial–marshy–lacustrine character of sediments.

Unfortunately, these deposits are almost sterile in paleontologic material. Only badly preserved marshy–aquatic forms of shells of *Lymneus* were found, and palinologic analysis were negative.

In the northern part of the studied area, near Čortanovci, similar sediments were found in several boreholes. In borehole MBPo–1 these deposits occur at the depth 37.0–71.6 m, and consist of blue lacustrine clays and clayey sands with drying joints and numerous $CaCO_3$ concretions.

Mineralogical analysis (XRD and optical methods), and grain size analysis gave the following results (Table 1).

Mineral composition of these sediments, specially the abundance of smectite in clay fraction and only traces of feldspars, indicate erosion and deposition of weathered material, thus supporting the deluvial–proluvial origin of deposits.

The age of these sediments cannot be precisely determined, due to the lack of paleontological material. However, according to their lithostratigraphic position and method of superposition, it is believed that they were formed in the younger Pliocene (Romanian) and older Pleistocene. There is a possibility that in some parts of the studied area, where these sediments are extremely thick (like Zemun), older beds may represent latteral facies of lacustrine Paludine beds, thus being equivalent of Dacian.

Table 1. Mineralogic and sedimentologic characteristics of terrestrial–aquatic sediments from Čortanovci.
Табела 1. Минералошке и седиментолошке карактеристике терестрично–акватичних наслага на подручју Чортановаца.

Borehole and depth Бушотина и дубина	MBPo–2 (41.5 m)	MBT–3' (41.8 m)
Mineral composition (bulk sample, XRD) минерални састав (укупан узорак, XRD)	Quartz, calcite (кварц, калцит)	Quartz, calcite, traces of feldspar (кварц, калцит, трагови фелдспата)
Mineral composition (clay minerals, XRD) минерални састав (глиновити минерали, XRD)	Smectite, traces of illite and kaolinite (смектит, трагови илита и кварцлатит)	Smectite, traces of illite, kaolinite and chlorite (смектит, трагови илита, каолинит и хлорит)
Mineral composition of sand fraction (песковита фракција) (+0,063 mm)	Quartz, calcite, feldspars, metalic minerals, limonite, altered grains, rock fragments (кварц, калцит, фелдспат, металични минерали, лимонит, алтерисана зрна, фрагменти стена)	Quartz, feldspars, calcite, metalic minerals (кварц, фелдспат, калцит, металични минерали)
Grain size (гранулометријски однос):		
Sand – песак (+0.063 mm)	4.60 %	5.45 %
Silt – прах (–0.063+0.005 mm)	59.40 %	57.10 %
Clay – глина (–0.005 mm)	36.,00 %	37.45 %

FLUVIAL POLICYCLIC AND FLUVIAL–MARSHY SEDIMENTS

Over terrestrial–aquatic sediments in the peripheral parts of the basin lie clastic sediments of policyclic fluvial origin, known as "Makiš beds" or "beds with *Corbicula fluminalis*" (Laskarev, 1938; Stevanović, 1977). According to data from boreholes, these deposits have a large extention, specially in coastal parts of the Danube and Sava rivers. Their thickness varies from 20–30 m in peripheral parts, to more than 100 m in depressions of Vojvodina. Lithologically, these deposits are made of brownish–yellow and grey sands, sands and gravels, silty sands, with lenses of silt and clay. Often occur cyclic alternation of typical channel sediments (sand, gravel) with flood sediments (silt, clay). In some cycles flood sediments are missing, probably as a resut of later erosion.

According to numerous mineralogical analysis, in light fraction of sand dominate altered grains, quartz and carbonate. In heavy fraction garnet is the most abundant, than epidote, amphiboles, hematite–limonite and metalic minerals.

In the borehole ZK–26 (near Bežanija graveyard) fluvial sediments occur at the depth between 38.4 and 63.0 m. From the lenses of grey silty clays (flood and oxbow facies), the following fauna was identified: *Planorbis planorbis* with hunch Linne, *Illiocypris bradyic* Sars, *I. gibba* (Ramdohr), *Candona neglecta* Sars, *C. compresa* (Koch), *C. fabaeformis* (Fisher), *Cytherissa lacustris* Sars, *Limnocythere inopinata* (Baind), and others.

In Zemun polje fluvial sediments underlie loess. Analysis of one typical sample gave the following results (Table 2).

Table 2. Mineralogic and sedimentologic characteristics of fluvial sediments from Zemun.
Табела 2. Минералошке карактеристике речних творевина на подручју Земуна.

Mineral composition (sand fraction, optical method) Минерални састав (песковита фракција, оптичка метода)	Quartz, feldspars, muscovite, altered grains, rock fragments (кварц, фелдспат, мусковита, алтерисана зрна, фрагменти стена)
Mineral composition (clay fraction, XRD) Минерални састав (глиновита фракција, XRD)	Quartz, mica/illite, little feldspar, chlorite (кварц, микашист/илит, фелдспат, хлорит)
Grain size: Гранулометријски однос:	
Sand – песак (+ 0,063 mm)	65.44 %
Silt – прах (–0,063 + 0,005 mm)	25.13 %
Clay – глина (–0,005 mm)	9.42 %

There are different opinions on the age of these deposits. After Halavatz (1915), this is a transitional lacustrine facies between upper Pliocene and Pleistocene, but Laskarev (1951), and Stevanović (1977), treat them as fluvial–lacustrine sediments, in lower parts with *Viviparus boeckhi* (Günc–Mindel), and in upper parts with *Corbicula fluminalis* (Mindel–Riss). After the latest studies and revision of typical species such as *Corbicula apsheronica* Andrussov, and *Viviparus boeckhi* (Halavatz), the age of polycyclic fluvial sediments was determined as younger Eopleistocen (Danubius and Günc phases).

Fluvial clastic sediments in Zemun are overlain by fluvial–marshy sediments formed by occassional flooding of the Danube and Sava rivers. Thus shallow basins were formed, which were transformed to ponds during summer drought, or even completely drained off. Main lithologic components of these deposits are silts, clays, and fine grained silty sand with lenticular and micro lamination. Material is well sorted.

Except rare Pleistocene *Corbicula* and *Viviparus*, fauna is mostly represented by modern Danube forms: *Fagotia esperi* Ferussac, *F. acicularis* Ferussac, *Theodoxus danubialis* (Pfeiffer), *Th. transversalis* (Pfeiffer), *Bithynia tentaculata* (Linne), *Valvata cristata* Müller and others. In younger parts of the series, together with freshwater fauna, occassionally were found terrestrial gastropoda: *Pupilla muscorum* Linne, *P. triplicata* (Studer), *Succinea oblonga* (Draparnaud), *Vallonia costata* Müller, *Chondrula tridens* (Müller), *Milax rusticus* (Müller), *Punctum pigmaeum* (Draparnaud), which led former authors to conclusion that these deposits have eolian origin.

Although these sediments sometimes look similar to loessal deposits, they have no typical loess structure and texture, so their eolian origin cannot be accepted. The age of this series is Mindel.

In Zemun (borehole ZK–14), fluvial–marshy type of sediments were found at depth of 32.0–38.0 m. The following fossils were found: *Valvata cristata* Müller, *Planorbis planorbis submarginatus* (Crist.–Jan.), *Eucypris pigra* Fischer operculum *Bithynia* sp., fragments *Lymnaea sp.*, and *Candonopsis sp.*

DELUVIAL–PROLUVIAL SEDIMENTS

Contemporary with initial fluvial facies, in the peripheral parts of the river basin, on slopes exposed to erosion, were formed polygenetic "covers" of deluvial–proluvial sediments. These deposits are known as "Sremska series" on slopes of Fruška Gora (Rakić, 1973). Genetically, these deposits originated in subareal fan deltas and complex alluvial fans.

Deluvial–proluvial sediments in older literature were treated as "terrestrial and/or aquatic loess", and only exceptionally as a distinct, separate lithogenetic unit older than loess formation. Sometimes these sediments are quite similar to aquatic loess, specially when rich in silt fraction.

Deluvial–proluvial sediments of "Sremska series" in Ruma were discovered at depths around 25 m, and only upper parts were studied. These deposits consist of greyish–brown silty clays, silts, sandy silts, with $CaCO_3$ lenses and concretions, Mn and Fe oxides and hydroxides, Mn oolites. Occasionally, lenses of finegrained gravel made of dark jasper and quartz were found.

Mineralogical analysis of nine samples from these deposits have shown that the dominant mineral is quartz, then calcite, while feldspars, mica, metalic minerals and rock fragments occur in small amounts. Clay mineral association in deluvial–proluvial sediments is completely different comparing to loess. In loess illite and chlorite are the dominant clay minerals, while smectite occurs in traces. On the contrary, in deluvial–proluvial sediments montmorillonite is the most abundant clay mineral, and illite and chlorite occur in small amounts. Deluvial–proluvial sediments are richer in clay fraction than loess (Table 3).

Table 3. Mineralogic and sedimentologic characteristics of preloess sediments from Ruma.
Табела 3. Минералошке и седиментолошке карактеристике прелесних седимената на простору Руме.

	Sand– песак (+0.063 mm)	Silt– прах (0.063–0.005 mm)	Clay – глина (–0.005 mm)
Loess – лес	3.11	70.19	26.70
Fossil soils – погребене земље	0.82	63.07	36.11
Deluvial–proluvial sediments – делувијално–пролувијални седименти	4.28	52.77	42.95

Based on superposition and lithologic characteristics, it is assumed that deluvial–proluvial sediments belong to older units of Pleistocene (middle and probably lower Pleistocene). Genetically, these are mostly deluvial and deluvial–proluvial sediments, deposited in shallow basins along the slopes of Fruška Gora.

Proluvial–deluvial sediments of "Sremska series" have been also discovered in the area between Sremski Karlovci and Indija. They originated either on slopes and margin of Fruška Gora in the form of complex alluvial fans, or on leveled bottom of the basin, in shallow water (marsh type). Sediments of alluvial fans consist mostly of sand, silt and gravel, while shallow water sediments are made of clay and silt. These sediments are paleontologically sterile, which is their typical feature.

In the area of Stari Slankamen proluvial–deluvial sediments of older Pleistocene consist of silt, clayey silt (similar to loess), sand and gravel. For this type of sediments lithologic variations on short distances are characteristic, as well as occurence of red fossil soils, rede-

posited Miocene fauna, and disconformity between underlying and overlying beds. These deposits usually occur as lenses, either without stratification, or with thin horizontal, lenticular, and cross–bedding. In these sediments the following fauna was found: *Bithynia crasitesta* (Linne), *Anisus leucostomus* (Millet), *Aegopis clemi*, *Pupilla muscorum* (Linne), *Gyralus albus* (Müller) and others, which is characteristic for older Pleistocene.

In the area of Čortanovci "Sremska series" deposits overlie terrestrial–aquatic sediments of older Eopleistocene, or directly upper Pliocene beds. These deposits are made of reddish–brown clayey silts and sandy silts. Analysis of one typical sample gave the following results (Table 4).

Table 4. Mineralogic and sedimentologic characteristics of "Sremska series" from Čortanovci.
Табела 4. Минералошке и седиментолошке карактеристике "сремске серије" на подручју Чортановаца.

Mineral composition (bulk sample, XRD) минерални састав (укупни узорак, XRD)	Quartz, calcite, feldspars, muscovite (кварц, калцит, фелдспат, мусковит)
Mineral composition (clay fraction, XRD) минерални састав (глиновита фракција, XRD)	Illite, chlorite, traces of montmorillonite (илит, хлорит, трагови монморионита)
Mineral composition (sand fraction, optical method) минерални састав (песковита фракција, оптичка метода)	Quartz, calcite, metalic minerals, muscovite, feldspars, altered grains, rock fragments (кварц, калцит, метални минерали, мусковит, фелдспат, алтерисана зрна, фрагменти стена)
Grain size: Гранулометријски састав:	
Sand – песак (+ 0.063 mm)	1.15 %
Silt – прах (–0.063 + 0.005 mm)	68.85 %
Clay – глина (–0.005 mm)	30.00 %

Upper parts of these deposits are represented by loessal silts alternating with lenses of fossil soils and, rarely, silty sands. Fauna is of terrestrial origin: *Pupilla muscorum* (Linne), *Chondrula tridens* (Müller), *Clausilia dubia* (Draparnaud), *Valonia costata* Müller and others.

Lower parts of deluvial–proluvial sediments are equivalents of fluvial polycyclic deposits from river valleys, while upper parts od deluvial–proluvial sediments are equivalents of fluvial–marshy deposits.

Deluvial–proluvial sediments of the complex alluvial fans underlie loess formation, which means that they are older than upper Pleistocene. Lower parts overlie terrestrial–aquatic sediments (determined in the Čortanovci area), so their formation started during younger Eopleistocene. According to fauna and superposition method, this series was deposited in lower and middle Pleistocene.

CONCLUSION

In the studied area preloess deposits are divided in three genetic types:

- terrestrial–aquatic sediments of upper Pliocen–older Eopleistocene,
- fluvial policyclic sediments along the river valleys,
- deluvial–proluvial sediments on the slopes of Fruška Gora as latteral equivalent of former sediments.

Terrestrial–aquatic polygenetic sediments were formed in the upper Pliocene and at the boundary of Pliocene–Pleistocene. They are underlain by lacustrine Paludine deposits of Pliocen age, and overlain by younger sediments. The most abundant sediments are variegated sandy clays, with gravel, greyish–green and brown sandy silts, silty clays, with occurrences of Fe and Mn lenses, and $CaCO_3$ concretions. Mineral composition of these sediments, specially the abundance of smectite in clay fraction and only traces of feldspars, indicate erosion and deposition of weathered material, thus supporting the deluvial–proluvial origin of deposits.

Over terrestrial–aquatic sediments in the peripheral parts of the basin lie clastic sediments of policyclic fluvial origin, known as "Makiš beds" or "beds with *Corbicula fluminalis*". According to data from boreholes, these deposits have a large extention, specially in coastal parts of the Danube and Sava rivers. Their thickness varies from 20–30 m in peripheral parts, to more than 100 m in depressions of Vojvodina. Lithologically, these deposits are made of brownish–yellow and grey sands, sands and gravels, silty sands, with lenses of silt and clay. Often occur cyclic alternation of typical channel sediments (sand, gravel) with flood sediments (silt, clay). In some cycles flood sediments are missing, probably as a resut of later erosion.

Contemporary with initial fluvial facies, in the peripheral parts of the river basin, on slopes exposed to erosion, were formed polygenetic "covers" of deluvial–proluvial sediments. These deposits originated in subareal fan deltas and complex alluvial fans. Deluvial–proluvial sediments in older literature were treated as "terrestrial and/or aquatic loess", and only exceptionally as a distinct, separate lithogenetic unit older than loess formation. Typical feature of deluvial–proluvial sediments is very variable composition and morphology, due to the different sedimentary environments and the composition of primary rock subjected to weathering.

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РЕЗИМЕ

СТРАТИГРАФСКО–ЛИТОЛОШКЕ КАРАКТЕРИСТИКЕ ПРЕЛЕСНИХ ПЛЕИСТОЦЕНСКИХ НАСЛАГА НА ПРОСТОРУ ИСТОЧНОГ СРЕМА

На профилима дуж Земуна, Инђије, Чортановаца и Руме могу се издвојити подлесне наслаге од формације леса, која лежи у њиховој повлати. Палеонтолошка, минералошка и седиментолошка испитивања доказала су да се издвојене јединице разликују у погледу генезе, тј. да подлесне серије нису настале еолском активношћу, већ флувијалном акумулацијом у оквиру алувијалних равни степских река или процесима спирања и течења на подгоринама Фрушке Горе, у склопу сложеног конуса делувијално–пролувијалне генезе.

Утврђено је да су у теренима северно од Саве преко језерских палудинских слојева, али и као њихове бочне фације, наталожене полигенетске језерско–терестично–барске наслаге веома хетерогеног литолошког састава. То су творевине одлагане различитим падинским процесима у језерско–мочварну, барску или копнену средину током дугог периода од млађег плиоцена до старијег плеистоцена, у времену када је услед тектонских покрета обављено диференцијално кретање раседима раздвојених блокова и издизање београдског рта и хорста Фрушке Горе наспрам тонућих терена Панонске низије.

Пошто су те наслаге веома стерилне у погледу садржаја палеонтолошког материјала применом биостратиграфско–палеонтолошких метода није им се могла прецизно одредити старост. На основу методе суперпозиције може се претпоставити да су таложене у периоду млађи плиоцен (романијен) и старији еоплеистоцен.

Непосредну повлату поменутим наслагама у домену речних долина чине хетерогене речне полицикличне творевине. Због своје велике површине распростирања ови седименти имају изглед језерских наслага. Међутим, литостратиграфске карактеристике и садржај фосилне фауне, упућују на закључак да је акваторијум у коме су наталожени имао динамику речне средине. Наиме, повлачењем вода у Панонском домену ствара се нови флувиоденудациони систем који је, усецајући се у вишекратно потањајућу лимничку централну раван, створио услове за формирање седимената полицикличног карактера. Њихова повећана дебљина, коса слојевитост и специфична ритмичка седиментација указују на везу са тектонским процесима у смислу вишеструког потањања. Ови седименти заузимају широко пространство у домену речних долина, док њихово присуство није утврђено испод подлесних серија стваних на падинама. Старост ових творевина уврштена је у млађи еоплеистоцен (дунав и гинц фаза).

Непосредну повлату речним полицикличним седиментима чине речно–барске творевине до чијег таложења је долазило само после пролећног отапања снега у планинским регионима, када су се формирали широки и плитки водени басени, који су се за време летњих суша брзо трансформисали у низ бара или су потпуно пресушивали. Творевине таложене у оваквим срединама показују лесоидан хабитус, али без других битних карактеристика које би их сврстале у типичне лесне творевине. Важно је нагласити да испод оваквог типа седимената у домену речних долина леже еоплеистоценски речно–полициклични седименти, док њихово присуство испод подлесних серија стваних на падинама није утврђено. Према старости су уврштене у миндел.

Истовремено са иницијалном речном фазом у ободним деловима речног басена, на падинама подложним спирању, створени су полигенетски застори од пролувијално–делувијалних седимената. То су седименти настали процесима спирања и течења на подгоринама Фрушке Горе у склопу сложеног конуса делувијално–пролувијалне генезе.

С обзиром на овакав распоред материјала, може се рећи да је овде реч о делувијално–пролувијалним творевинама које су на јужном предгорју Фрушке Горе изградиле пространи сложени плавински конус, тзв. предгорну делту. Ове наслаге представљају еквивалент речних полицикличних и речно–барских седимената и одлагане су од млађег еоплеистоцена, завршно са минделом.