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# Stratigraphy and lithology of the loess deposits in eastern Srem (Serbia)

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**Abstract**. Eolian loess sediments in the eastern Srem area, the youngest Pleistocene deposits, occur either as a loess plateau, or as a slope-type of loess, formed on the slopes of the Fruška Gora Mountain. Lithological, sedimentological, and mineralogical characteristics of these sediments, which were studied from several common clay deposits and boreholes, demonstrated differences between them and the underlying pre-loess sediments, and supported the stratigraphic division of the Quaternary sediments.

**Key words:** loess, Pleistocene, eastern Srem, Serbia.

**Апстракт**. Млађи нивои плеистоценских творевина на простору источног Срема изграђени су од еолских наслага које се јављају у виду лесног платоа на заравњеним деловима терена или као падински тип овог седимента на обронцима Фрушке Горе. Седиментолошко–минералошке карактеристике ових творевина испитиваних на основу података са изданака и бушотина на више локалитета указују на битну разлику у односу на седименте у подини, које неки истраживачи још увек сврставају у ниже хоризонте лесних наслага.

**Кључне речи**: лес, плеистоцен, источни Срем, Србија.

## Introduction

Young horizons of the Pleistocene deposits in the eastern Srem area are composed of an eolian loess formation, known as the Srem loess plateau (Fig. 1). These deposits were defined as loess earlier, which was confirmed by later research. Previously, when describing many loess horizons, researches included not only typical loess deposits but also the underlying polygenetic pre-loess sediments (Gorjanović-Kramberger, 1921; Laskarev, 1938; Marković-Marjanović, 1972; Rakić, 1977). Thus, the age of the loess formation appeared to be older than it is in fact.

Recent studies (Nenadić, 2000; Knežević *et al.*, 2001; Nenadić *et al*., 2002; Nenadić, 2003), revealed that the eolian deposits usually consist of 2–4 loess sequences, and a respective number of paleosol horizons. The loess formation is underlain by clayey silts, formerly called "loessal deposits", or "marsh loess". These deposits were ascribed as polygenetic fluvial-marshy facies, with typical aquatic marshy fauna of the Mindel age. Both these sediments and the loess formation are underlain by fluvial polycyclic and deluvial-proluvial sediments of the Eopleistocene to Mindel age (Nenadić *et al*., 2002).

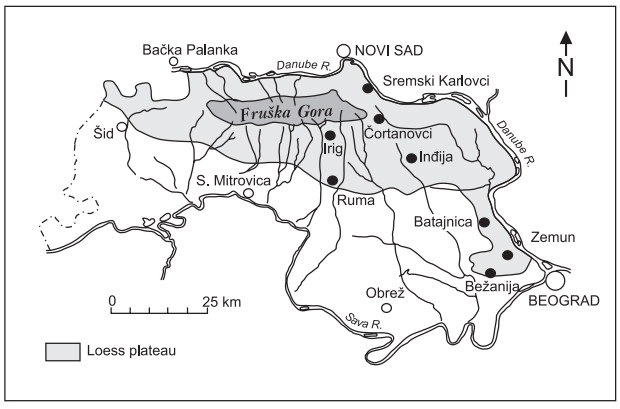


Fig. 1. Location of the Srem loess plateau with positions of clay pits and boreholes (solid circles)

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In this investigation, the loess deposits from the Čortanovci, Zemun, Ruma and Irig areas were studied. The paleontology and stratigraphy of representative samples was investigated. The mineral composition (bulk and clay fraction samples) was determined by X-ray diffraction (XRD) and optical microscopy (coarse fractions). Grain-size analysis was done using standard sieves; fractions <0.063 mm were separated by the decantation method. All analyses were performed in the laboratories of the Faculty of Mining and Geology, Belgrade.

## Results

### Zemun area

In the Zemun area, the Quaternary sediments have been thoroughly studied, but mostly from a stratigraphic and engineering aspect (LASKAREV, 1938; RAKIĆ *et al*., 1990; KUZMIĆ *et al*., 1999; NENADIĆ, 2000, 2003). The geochemical and mineralogical characteristics were studied by DANGIĆ (1995) and NENADIĆ *et al*. (2002).

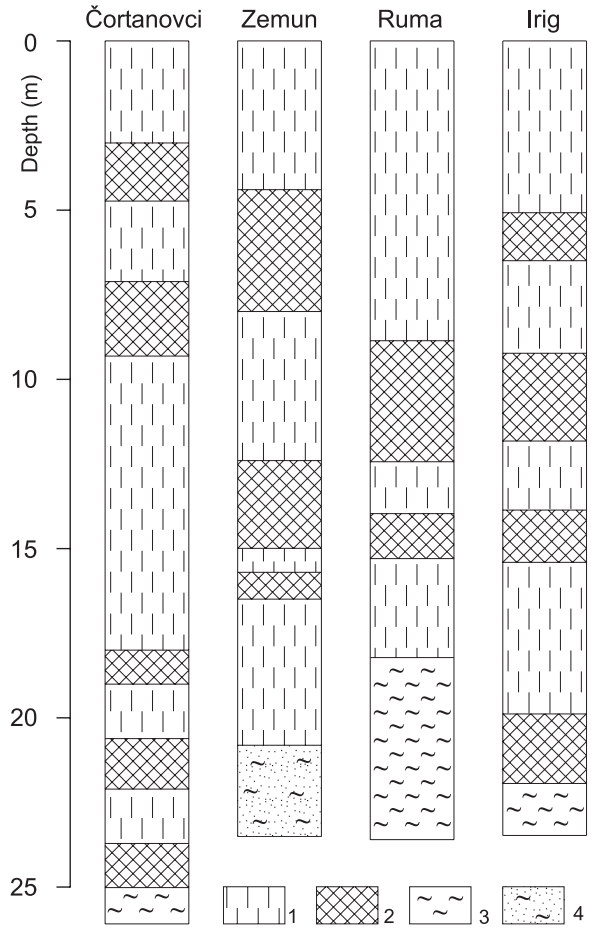


Fig. 2. Idealized stratigraphic logs of the loess formation in eastern Srem. 1 = loess sequence; 2 = palaeosol; 3 = fluvial-marshy and deluvial-proluvial clay and silt; 4 = fluvial polycyclic sand deposits.

According to the lithologic and stratigraphic data from numerous boreholes, the thickness of the eolian loess averages about 20 m (Figs. 2, 3). The loess formation in Zemun consists of four loess sequences (I to IV in decending depth), and three paleosol sequences (Fig. 2).

The I and II loess sequences are typical subaeral deposits, formed by the accumulation of wind-transported silt and sand (with a minor clay content) on dry land, and their thickness is usually 10–15 m. They contain only terrestrial mollusks. The III and IV loess sequences were deposited on wet grassland, under variable climatic conditions. These loess sequences contain more clay particles, and a number of Fe- and Mn-oxyhydroxide nodules. Their thickness is usually less than 10 m. These horizons contain both terrestrial and aquatic mollusks.

The previously described V loess sequence, together with the paleosol formed on it (Fig. 3), is composed of silt genetically related to a fluvial-marshy environment. The total thickness is around 5 m.

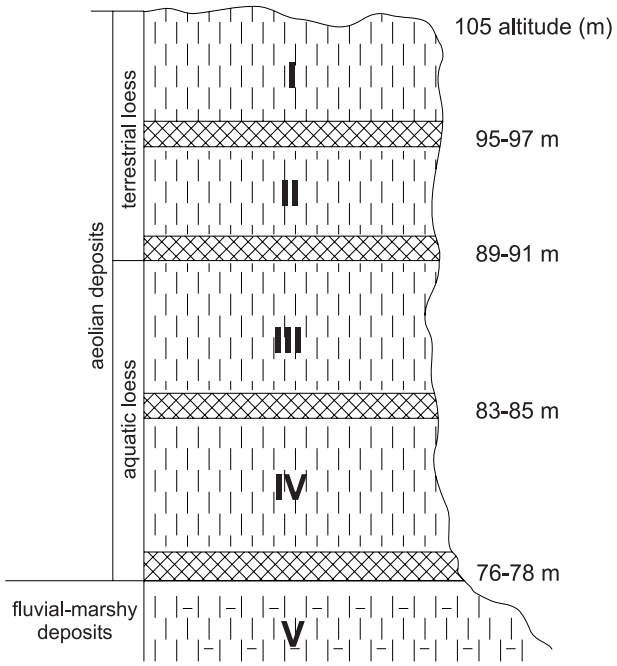


Fig. 3. General section of the loess formation based on the boreholes in the Bežanija–Zemun–Batajnica area. I–IV: loess sequences.

Typical fossil species found in the subaeral sequences (I and II) of the loess formation are: *Clausilia dubia* DRAPARNAUD, *Abida frumentum* DRAPARNAUD, *Pupilla muscorum* LINNE, *Helicopsis* sp., while in the lower sequences (III and IV) they are: *Armiger cristata* (LINNE), *Succinea oblonga* DRAPARNAUD, *Bithynia leachi* (SHEPARD), *Planorbis planorbis* (MÜLLER), etc.

Quartz is the most abundant mineral in the loess formation at Zemun (DANGIĆ, 1995). Carbonates, feldspars,

mica, clays, rock fragments, and amphibole (in decreasing order of their appearance) are minor. Calcite is the major carbonate mineral, and occurs either as a finely dispersed matrix, or as nodules of different size. The clay minerals are illite and chlorite with occasionally traces of smectite.

## Čortanovci area

Several loess samples from the boreholes drilled in the Čortanovci area have been studied mineralogically and sedimentologically.

The loess formation here is around 25 m thick (Fig. 2), and consists usually of 3–4 loess sequences with the same number of paleosols. Eolian deposits cover the polygenetic deluvial-proluvial sediments of the "Srem series", represented by clayey silt or silty clay. The grain size distributions of the loess and "Srem series" are completely different, especially when comparing the sand and clay fractions (Table 1).

Table 1. Grain size distribution of the loess formation and "Srem series", Čortanovci area.

| | Sand (>0.063 mm) | Silt (0.063–0.005 mm) | Clay (<0.005 mm) |
|---|---|---|---|
| Loess formation | 7.43 | 78.42 | 14.15 |
| "Srem series" | 1.15 | 68.85 | 30.00 |

According to our XRD studies (Fig. 4), quartz, feldspar, calcite, dolomite, and mica (in decreasing order of their appearance) are the main minerals of the loess formation. The clay minerals are illite and chlorite, with minor amounts of smectite, which seems to be more abundant in the lower parts of the loess sequences. In the sand fraction, quartz, carbonates, and mica are dominant, with minor amounts of feldspar, sphen, ore minerals, rutile, altered grains, and rock fragments.

## Sremski Karlovci – Inđija area

In the area between Sremski Karlovci and Inđija, the loess formation consists of 2–4 loess sequences and the same number of palaeosol horizons. The total thickness varies between 10 and 22 m, depending on the degree of erosion during the Holocene. Loess sequences are sandy silt or silty sand, with abundant carbonate nodules. Palaeosol horizons are made up of dark grey clayey silt, or brown silty clay, with different amounts of organic matter. The fossil remains are typical for the terrestrial forms of cold biotypes, such as: *Vallonia costata* (MÜLLER), *Punctum pygmaeum* DRAPARNAUD, *Succinea oblonga* DRAPARNAUD, *Chondrula tridens* DRAPARNAUD, *Vitrea cristalina* (MÜLLER), *Arianta arbustorum* LINNE, *Pupilla* sp., and indicate the Late Pleistocene (Riss and Würm).

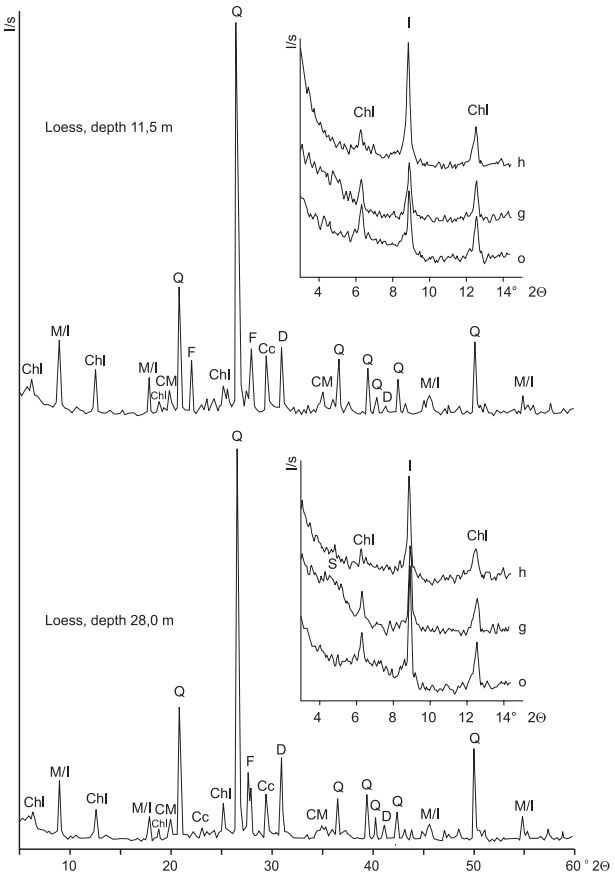


Fig. 4. XRD patterns of loess samples, Čortanovci area. Q = quartz; Chl = chlorite; M/I = mica/illite; CM = clay minerals; F = feldspar; Cc = calcite; D = dolomite; S = smectite; I = illite; o = oriented pattern; g = saturated with glycerine; h = heated to 450° C.

## Ruma area

The loess formation in the area of Ruma consists of three loess sequences and two palaeosol horizons (Figs. 2, 5), which are underlain by red to brown clayey silt or silty clay (KNEŽEVIĆ *et al*., 2001; NIĆIFOROVIĆ *et al*., 2001). The loess sequences are yellow to grey-brown or yellow-brown, usually with small carbonate nodules (up to 2 cm in diameter), while the palaeosols are brown to red clayey silt. The total thickness of the loess formation is up to 20 m, and the whole formation dips towards SSE at an angle of ~ 10°.

Both the loess sequences and paleosols consist of quartz, mica, calcite, feldspar, with minor amounts of dolomite, and clay minerals (illite and chlorite, with traces of smectite) (Fig. 6). The clay mineralogy of the

pre-loess sediments is quite different: with smectite as the absolutely dominant clay mineral, with traces of illite and chlorite.

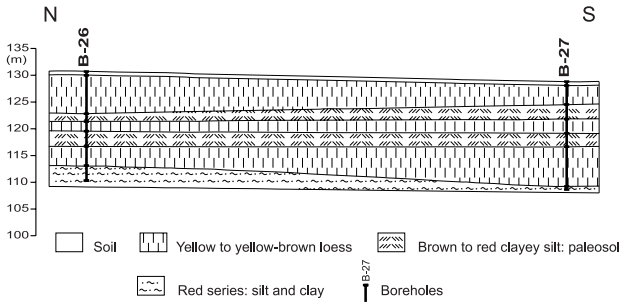


Fig. 5. Typical cross-section of the loess deposit in Ruma.

Grain size analyses of the loess sequences, palaeosol, and pre-loess sediments (Table 2), suggest a difference in the provenance of the material and the depositional environment.

Table 2. Grain size distribution of loess and underlying sediments, Ruma

| | Sand (>0.063 mm) | Silt (0.063–0.005 mm) | Clay (<0.005 mm) |
|---|---|---|---|
| Loess sequences | 3.11 | 70.19 | 26.70 |
| Paleosol | 0.82 | 63.07 | 36.11 |
| Underlying sediments | 4.28 | 52.77 | 42.95 |

## Irig area

In the Irig area, the loess formation is composed of four loess sequences, and four palaeosols (Figs. 2, 7), which are underlain by brown plastic clay of the "Srem series" (SIMIĆ, 2004). The loess sequences are yellow to yellow brown, occasionally with levels rich in carbonate nodules (usually up to 10 mm in diameter). The carbonate content of the Irig loess formation is 11–18%, on average ~ 14%. The average content of sand, silt, and clay fraction is 2.90%, 78.99%, and 18.21%, respectively.

The mineral composition is typical for the loess (Fig. 8): quartz is the dominant mineral, accompanied by calcite (as small nodules, shell fragments, and finely dispersed matrix); feldspar, dolomite, and mica occur in minor amounts; illite and chlorite are the dominant clays, smectite occurs in traces.

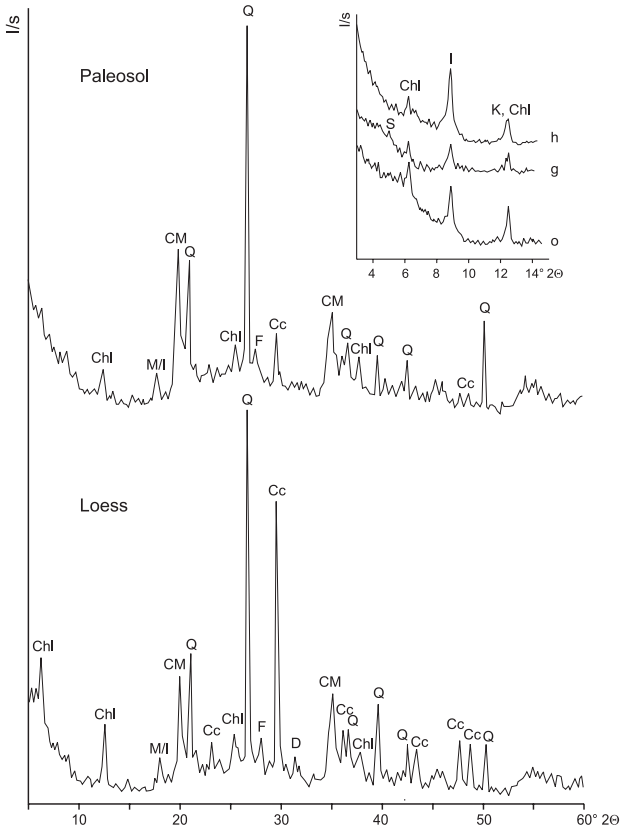


Fig. 6. XRD patterns of loess and palaeosol samples, Ruma. For abbreviations see Fig. 4.

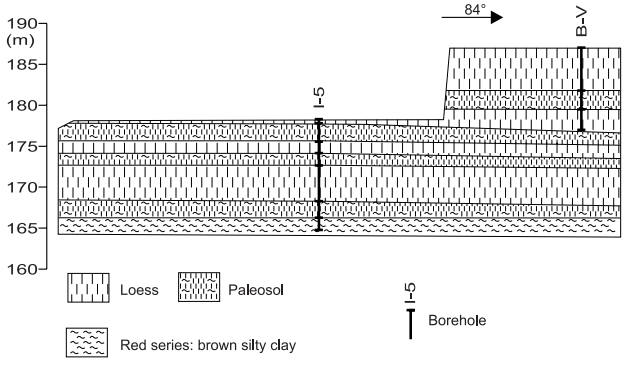


Fig. 7. Cross-section of the Gornji Batinci loess deposit near Irig (after SIMIĆ *et al.*, 2004)

## Conclusion

Loess is one of the major Quaternary formations in the Srem area. It formed as a result of eolian transport and deposition predominantly of silt, either in a wet grassland environment or on dry land. In the Srem, the loess occurs as the large "Srem loess plateau", or as a slope-type, formed along the Fruška Gora Mountain, up to 400 m above sea level.

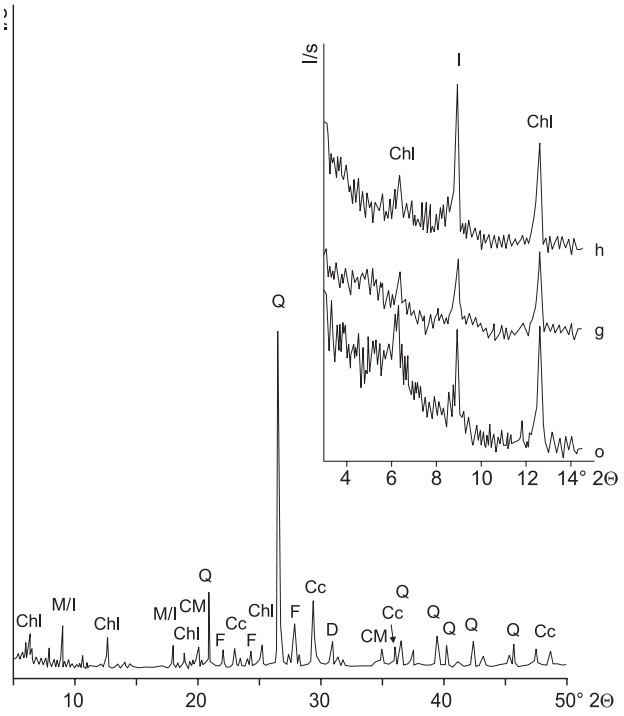


Fig. 8: XRD patterns of a loess and palaeosol sample, Irig (after SIMIĆ, 2004). For abbreviations see Fig. 4.

Recent studies demonstrated that the loess formation is made up of 2–4 loess sequences, and 1–4 paleosol horizons, with a total thickness of approximately 20 m (less if eroded). The first two horizons are of subaeral and the two lower ones of aquatic origin. This can be inferred from their lithological and palaeontological contents.

Generally, for the loess fauna of eastern Srem, the following terrestrial snails are characteristic: *Succinea oblonga* DRAPARNAUD, *Pupilla muscorum* LINNE, *Arianta orbustorum* LINNE, *Choclicopa lubrica* MÜLLER, *Clausilia pumila* PFEIFER, *Orcula dolium* DRAPARNAUD, *Charichium minimum* MÜLLER, etc. Paleoecologically, this association is typical for steppe regions. According to the alternation of "cold fauna", such as *Chondrula tridens* and "warm fauna", such as *Arianta orbustorum*, it can be assumed that cold and warm sequences followed each other during glacial periods.

The malacofauna from all the studied areas is nearly identical, and cannot be used for more detailed stratigraphic divisions. Comparing these fauna with the occurrences of remnant of mammals in the loess deposits in the Srem and Belgrade, such as *Mammuthus primigenius* (BLUMENBACH), *Rhinnoceras tichorinus* PISCH., *Equus cabalus* LINNE, and *Bos primigenius* BOJANUS as typical representatives of the Upper Paleolite or Hazar complex (GROMOV *et al*., 1960), it can be concluded that the loess formation deposited during Riss and Würm.

The mineral composition of the loess formation is very similar in all the studied areas: quartz, carbonates, feldspar, mica, and clay minerals (illite and chlorite). Smectite usually occurs in traces. The mineralogy of the loess is quite different from that of the underlying sediments, confirming a totally different source of the primary material, as well as of the mode of transport and deposition. On the basis of the collected data, it could be concluded that the underlying units are genetically different from the overlying aeolian package. They were not formed by aeolian activity, as was generally thought, but by fluvial accumulation of material in the floodplains of steppe rivers or by processes of erosion on the slopes of the Fruška Gora.

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## Резиме

## Стратиграфија и литоглогија лесних седимената у источном Срему (Србија)

Лесне творевине на подручју Срема представљају релативно младе наслаге квартарне периоде одлагане под дејством ветра током глацијалних епоха плеистоцена.

Морфолошки, изграђују две карактеристичне целине. У нижим деловима терена формирале су велику сремску зараван, док се на падинама Фрушке Горе овај седимент јавља у форми "падинског типа леса" и то у виду покривача који пада према Дунаву и Сави са апсолутне висине од око 400 m.

У односу на старије податке, новија истраживања указују да се у лесном пакету уобичајено налазе 2–4 нивоа леса и одговарајући број погребених земаља, а бројни остаци кичмењака и остаци малакофауне највише указују о његовој депозицији за време последње две глацијације – рису и вирму (према алпској геохронолошкој подели).

У нижим деловима еолског пакета леже "лесоидне творевине", које садрже фауну карактеристичну за акватичну, замочварену средину ("барски лес"), а за које је утврђено да припадају полигенетским речно–барским седиментима и пролувијално–делувијалним наслагама старијим од еолске формације. У подини наведених творевина у домену речних долина налазе се песковито–шљунковити речни полициклични седименти млађег еоплеистоцена или старијии делови "сремске серије" везане за падине фрушкогорског масива, синхроничних са поменутом јединицом.

Поред палеонтолошких, минералошко–седиментолошке анализе лесних наслага такође указују на знатну разлику у односу на седименте у подини. Наиме, на основу добијених података може се рећи да се подлесне јединице разликују у генетском погледу од еолског пакета у њиховој повлати, тј. да нису постале еолском активношћу, како је сматрала већина аутора, већ флувијалном акумулацијом материјала у оквиру алувијалних равни степских река или процесима спирања и течења на подгорinама фрушкогорског масива.