GEOLOŠKI ANALI BALKANSKOGA POLUOSTRVA
Volume 83 (2), December 2022, 9–31
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https://doi.org/10.2298/GABP210306007G
Original scientific paper
Оригинални научни рад

The revision of Quaternary stratigraphy of the Zrenjanin artesian well borehole profile (Banat, Vojvodina, Serbia)

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Key words: *Quaternary stratigraphy, fluvial sediments, Serbia, Pannonian Plain, malacology*.

Abstract. The geological analysis of artesian borehole material from Sombor, Subotica, and Zrenjanin, was in the first campaign of detailed stratigraphic studies of Vojvodina in 1892-1895. The results of Quaternary stratigraphy from Zrenjanin were published by Halaváts more than a decade later (1914). The significance of the Zrenjanin, Sombor, and Subotica artesian well profiles for more than a century is considered the representative local profiles for the Quaternary stratigraphy of Vojvodina recognized by Serbian (Yugoslavian) and Hungarian geologists. Significant changes were after the taxonomical revision of molluscan material and its stratigraphic context, which was done through the excellent work of Krolopp in the 1970-ies. Unfortunately, the mentioned changes were not applied in the studies during the geological surveying of former Yugoslavia. The developments in Quaternary geology, changes in the Quaternary chronostratigraphic scale, and the results shown by this paper enable the Lower Pleistocene fluvial deposits to be defined as the Pleistocene *Corbicula* beds, the *Viviparus boeckhi* Horizon.
The Lower Pleistocene at Zrenjanin was documented from 234.54 to 58.36 m depth. The interval between 234.54 and 208.50 m comprises the Upper Paludina – *Viviparus vucotinovici* zone, while the *Viviparus boeckhi* Horizons were identified between 135.18 m and 58.36 m. The interval between 58.36 m and 37.75 m is defined as Pleistocene (Lower- and Middle Pleistocene) based on sedimentological and the molluscan record. The interval from 37.75 m to 21.67 m depth was identified as Middle Pleistocene, according to its lithology and the paleontological material. The fluvial sediments' 21.69 m and 7.31 m depths cannot be determined according to the faunistic data; we can only consider them as Pleistocene age. The Holocene sediment and soil horizons ascend to a 2.90 m depth.

Апстракт. Резултати стратиграфских анализа бушотине артешког бунара у центру Зрењанина (поред бушотина у Суботици и Сомбору) спадају у најстарије резултате стратиграфије квартара речних седимената са подручја Војводине. Материјали из ове три буштине артешких бунара су задовољавајуће детаљно литолошки анализирани, док палеонтолошки

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материјал који је сачуван у геолошком институту у Будимпешти је омогућио еваулацију некадашњих резултата. Поменуте бушотине артешких бунара, због добијених резултата квартарне стратиграфије спадају у најзначајаније бушотине на јужним деловима Алфледа. Профили Суботице, Сомбора и Зрењанина су препознати као „станардни" / руководећи профили од стране мађарских и српских геолога, и представљају основу за даљу регионалну корелацију. Таксономска ревизија малакошког материјала урађена од стране Кролопа 1977. године, довела је до значајних стратигафских измена, и допринела потпунијој корелацији и анализа квартарног геолошког записа из Мађарске и бивше Југославије. Међутим, при геолошком картирању и изради Основне геолошке карте Југославије ови резултати корекција нису узети у обзир. У последњој декади истраживања нови резултати кваратарне стратиграфије су допринели бољем разумевању развића флувијалних депозициних система квартара на подручју Србије, и у томе је материјал из Зрењанина имао значајан допринос.
Резултати стратиграфске ревизије артешке буштине у Зрењанину су следећи: Доњи плеистоцен је утврђен на дубинама 234,54 до 58,36 m. Итервал између 234,54 и 208,50 m представљен је горњопалудинским слојевима – зоном *Viviparus vucotinovici* (ова зона представља почетак флувијлне фазе и квартара/плеистоцена), док слојеви са *Viviparus boeckhi* су идентификовани између 135,18 m и 58,36 m дубине и везују се за доњи плеистоцен. Интервал између 58,36 m и 37,75 m дубине на основу седиментолошког и малаколошког записа је одређена плеистоценска старост (доњи- и/или средњи плеистоцен). На дубинама од 37,75 m до 21,67 m је утврђен средњи плеистоцен према седиментолошком и палеонтолошком запису. Речни седименти су од 21,69 m до 7,31 m и једино указује на плеистоценску старост. Холоценски наноси и земљиште су до 2,90 m дубине.

Кључне речи: *стратиграфија квартара, флувијални седименти, Србија, Панонска низија, малакологија*.

Introduction

In the southeastern (Serbian) part of the Carpathian Basin, there are only a few exposures with more-less complete Quaternary Lower- and Middle Pleistocene records. They occur in Syrmia (Serb.: *Srem*, Croat. *Srijem*) on the banks of rivers or river valleys. The analysis of bore cores (mainly those for artesian wells) represents the Quaternary fluvial succession of cyclic sedimentation. The campaign for quality water supplies for settlements at the end of the 19th century resulted in several analyzed and defined Quaternary stratigraphy based on the material in the artesian wells' cores. In most cases, the engineering works for drilling were performed by Zsigmondy, who had an experience from Hungary (Alföld), while Halaváts, the prominent geologist from the geological institute of Budapest, performed the geological analysis (Zsigmondy, 1872; Halaváts, 1896a, 1896b). The early results of geological investigations from Sombor and Subotica (Fig. 1). Halaváts led the geological mapping of Banat later continued in the area, which encompasses the south parts of the Danube- and Tisza interfluve. He also analyzed the material from artesian bore cores (Halaváts, 1895, 1914). Data from the geologic surveying from the area of Bačka and Banat examined by Halaváts became a vital source to understand the development of the Quaternary geology of Vojvodina. The detailed analysis and contents qualify the profiles from Sombor, Subotica, and Zrenjanin (Halaváts, 1895, 1914) to the representative local profiles for major Quaternary stratigraphic studies. Its importance was recognized by Serbian (Yugoslav) and Hungarian geologists. Moreover, these profiles were essential and served as the basis for the regional stratigraphic correlation. Unfortunately, few authors used their stratigraphical frame of these artesian well profiles in an obsolete context with the outdated stratigraphy (Halaváts, 1895, 1914), nevertheless, Krolopp (Krolopp, 1977) made their taxonomical revisions of the molluscan material and significant changes implied changes in the fluvial stratigraphy.

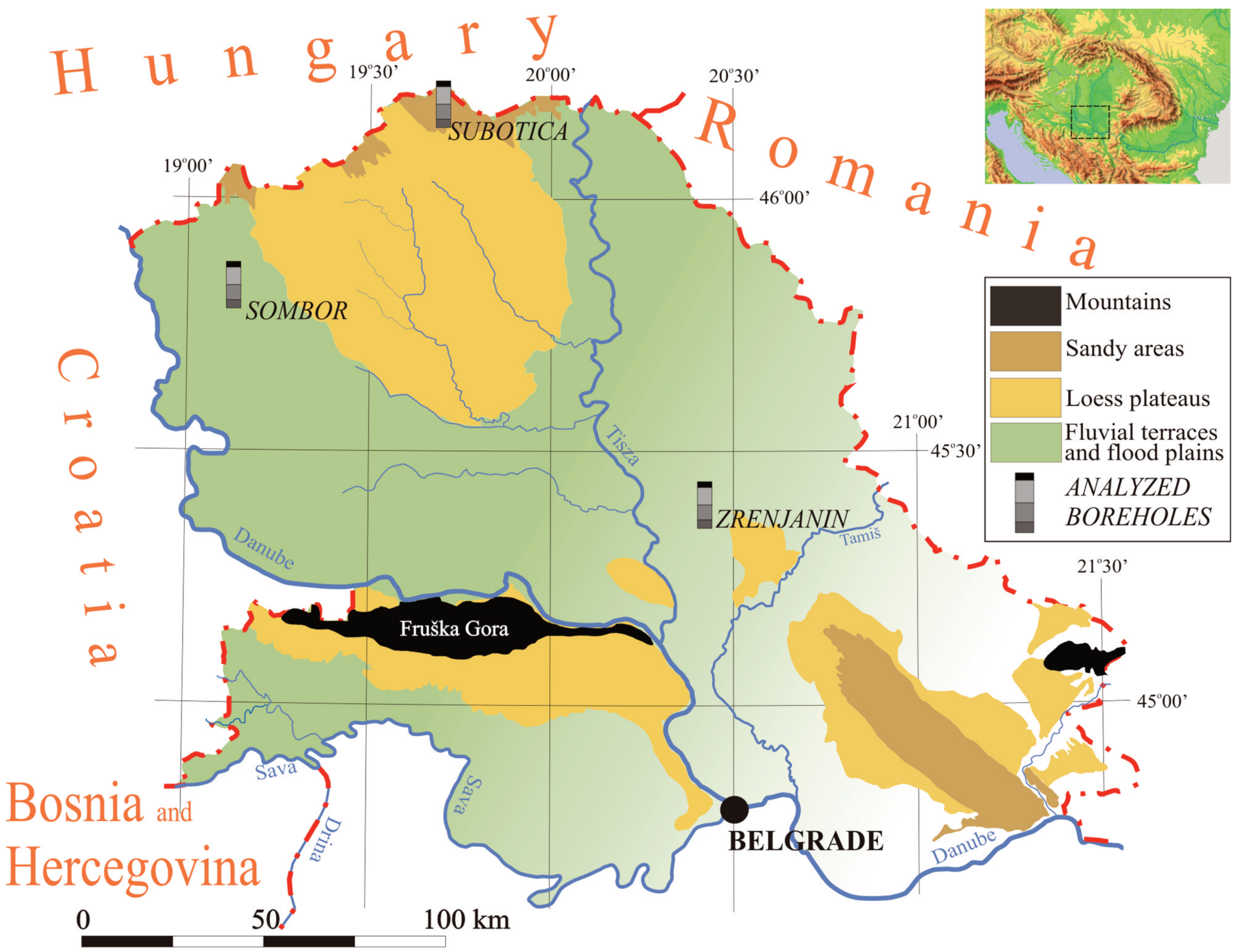

Fig. 1. *Locations of the artesian wells from Vojvodina analyzed by Halaváts (Subotica, Sombor, Zrenjanin) (from* Gaudenyi *et al., 2018).*

The last decade's studies summarize stratigraphy development and changes in the official chronostratigraphic scale (e.g., GAUDENYI et al., 2013, 2014, 2015a, b, 2018).

This study aimed to apply the results of investigations in Quaternary geology according to the changes on the international stratigraphic scale and based on the molluscan record. Same way as in the case of core samples from artesian wells in Bačka (Sombor and Subotica), according to GAUDENYI et al. (2018).

Geographical setting

The Serbian Banat is located in Vojvodina's eastern part (east of the Tisza River). The surface geology of the Serbian Banat (except the Vršac Mts.) is exclusively composed of Quaternary sediments (Fig. 1). The identified Quaternary sediments are aeolian, fluvial, or lacustrine origin. The main rivers that "framed" the area of Banat (the *Maros/Moriš/Mureș* northwards, the Danube partly west-wards and southwards, the Tisza westwards) with their tributaries have its lowland (meandering) fluvial architecture and mainly transported fine-grained sediments such as sand, silt, and clays. The southeastern (Košava) wind prevails in the Banat Plain. The relief of the Serbian part of Banatis composed of the Banat Mountains (Vršac Mts.) and the Banat Plain of Vojvodina, which is alluvial plains of the Danube, the Tisza as well as its tributaries, Holocene terraces, upper- and lower terraces, loess plateaus (the Tamiš- and South Banat Loess Plateau) and Deliblato Sands. The remnants of the Pleistocene landscape, such as terraces and loess plateaus, changed its surface due to climatic and anthropogenic impacts. The terraces comprised fine-grained fluvial material from alluvial plains and riverbeds (sand, silt, clay). The terrestrial Quaternary record prevailed with the loess series of the loess plateaus.

The town of Zrenjanin is located in the central part of the Serbian Banat on the terrace of the Begej river (Fig. 1). The area of Zrenjanin's wells was contaminated by waste waters and the floods from 1871 to 1873. Artesian wells needed are for the water supply of drinkable water.

The last official name of Zrenjanin was Nagy-Becskerek (the 2nd part of 19th century, till 1918). The location of the artesian well was at the former *Ferenc Józseftér*, today's Trg Slobode. The drills for the artesian wells were organized by Ladányi from Szeged in 1893. and 1894. Junker had previous unsuccessful drilling attempts with consultations of Zsigmondy (from Marienfeld, now Teremia-Mare in the Romanian Banat) at the former *Búza-tér*, today's Žitni trg in 1885. The depth of the analyzed bore cores ascended to 452.48 m, and two aquifers were identified at around 80 m and 120 m depths. The material from the bore core was sent to the geological institute in Budapest, where it was analyzed by Halaváts (the malacological analysis carried out by Kormos) (the material at a depth between 21–35 m), and Halaváts (the rest of material from deeper parts of the bore core). In the year of publishing of the article (1914) in Zrenjanin were 14 public- and two private wells (Halaváts, 1914).

The examined borehole material was based on its lithology and biostratigraphy. Some conceptual changes were made in Quaternary stratigraphy in the last hundred years. One of the most significant were in the 1950-is, 1985, and 2010. These changes in the international Quaternary chronostratigraphic scale also suggest significant corrections.

Milestones in Quaternary stratigraphy of the Zrenjanin

Laskarev (1951, 1952) summarized his investigations' results and correlated bore core profiles from the Sava valley in Serbia with the representative profiles from other parts of Vojvodina. In that retrospective, we should point out that it was the time before the campaign of the Basic Geologic Map of Yugoslavia (Osnovna geološka Karta Jugoslavije – OGK 1:100,000), and due to the small number of analyzed bore cores, the available material was limited, and the results lack details. However, these results were the basic interpretations of the results for the OGK sheet – Zrenjanin (L 34 – 89) published in 1994 (see: Terzin et al., 1994).

The great project of the Quaternary of the Alföld ("Great Hungarian Plain") of the Hungarian Geological Institute, Krolopp, was indebted for the biostratigraphy based on the molluscan record. The whole material of Quaternary malacofauna stored in the public collection was examined and gone under taxonomic revision. The results of investigations on molluscan material of Subotica, Sombor, and Zrenjanin were published by Krolopp (1977).

Due to the proposal of Cholnoky (1910), in this paper, we use the term Alföld contrary to the term "Great Hungarian Plain." Great Hungarian Plain is inappropriate because it encompasses an area outside Hungary. Moreover, the Serbian part of the Alföld was defined by Ćalić et al. (2012). More about the terminology war gine in the paper of Gaudenyi & Mihajlović (2022).

The data from the artesian well bore core material was extremely important for the stratigraphy of the Serbian segment of the Carpathian Basin. During the geologic surveys and prepared the basic geologic map of (former) Yugoslavia, the results Krolopp's (Krolopp, 1977) were ignored in the review and the analysis of Quaternary stratigraphy (e.g., Rakić, 1977) or in the explanatory booklets of geologic maps at scale 1:100,000 (i.e., Terzin et al. 1994).

Stratigraphic concepts at the beginning of the 20th century and remarks on the "Levantine Stage"

The concepts and recommendations of the investigations at the geological institute in Budapest, which was followed for the Neogene and Quaternary sediments, were followed by Halaváts (1914). However, significant changes made in the last hundred years made that some conclusions made by Halaváts for the Neogene and Quaternary in a modern perspective are abandoned. It is evident that the so-called monoglacial concept of the Quaternary glaciations at that time was not fully accepted. Like the investigations of Agassiz and Lyell, they are not fully accepted by older generations of geologists in Central Europe (Gaudenyi et al., 2018).

Historical aspects during the Medieval age and the dogma promoted by the church have significant influences on the explanation of natural phenomena. In this period of history, most naturalists must accept the dogma provided by the church. In the scope of modern interpretation, these "scientists," later entitled "Diluvialists," due to their support of the theory of the Biblical deluge and its explanation in the field of science. According to the theory of the Biblical deluge, the terms "Diluvium" and "Alluvium" were frequently used during this time. In the studies of Halaváts, the terms "Diluvial" and "recent" were employed for the Pleistocene and Holocene, respectively. Halaváts also used the term "Levantian Stage" (*Levantische Stufe*), borrowed from Hochstetter (1870), to identify freshwater formations of the Upper Miocene age in eastern parts of European Turkey (now territory more-loess denominated Southeastern Europe). In this paper, we use the term "Levantian" or "Levantian Stage"; however, in some older papers, the incorrect forms "Levantine Stage" and "Levantinian" have also been employed. Based on the stratigraphic concepts at the time in the Austro-Hungarian Monarchy, the "Levantian Stage" concept was defined according to Pliocene freshwater (fluvial-lacustrine-palustrine) deposits. According to the studies of Neumayr & Paul (1875), the "Levantian" stage includes the *Paludina* beds. However, in studies by Halaváts, the "Levantian" stage included the Paludina beds and the *V. boeckhi* Horizon (Gaudenyi et al., 2015a, 2018).

Stratigraphic revision of the Zrenjanin borehole material by Laskarev (1951–1952)

Quaternary geology became the focus of the purpose of the engineering works of the Danube-Tisza-Danube (DTD) channel project. Within the proposed IV INQUA Congress in Budapest and one field trip organized to Yugoslavia (unfortunately not realized). In 1947 Laskarev was charged with preparing a guidebook for the excursion for the Quaternary sites in Yugoslavia. The results of this project and event were published a few years later, in 1951 and 1952 (Laskarev, 1951, 1952). The systematic evaluation of recent developments in Quaternary stratigraphy was published.

The investigations of Laskarev and the stratigraphical concept were based on the papers of geoscientists (Cvijić, Gorjanović-Kramberger, Petrović, Marković-Marjanović, Milojević, Bukurov, Stevanović, Cholnoky, Bulla, Sümeghy, Szadecky-Kardos, Scherf, Mottl and Halaváts). Based to the development in paleogeography of Central Europe at the beginning of the 20th century in his studies Laskarev (1951) distinguished four phases in the Quaternary history of Vojvodina:

1. The lake phase which existed from the Pliocene till the end of the Middle Pleistocene ("Riss glaciation"). In Slavonia and Vojvodina existed the Paludina Lake in the Middle Pleistocene. The fossil molluscan record from Zrenjanin the shows that the "*Corbicula fluminalis* beds" disappeared with the stagnation of the lake, infilling with sandy-muddy sediments and aeolian dust.

2. The environment is transferring into the marsh, and which is later over it, aeolian sediments accumulated.

3. The forming of the loess plateaus and the terrestrial landscape prevailing.

4. The phase of ingression of waters from the north and dissection of the previous plateaus. The erosion was manifested as forming of river terraces and active deflation.

Taxonomical revision of malacological material from the artesian well at Zrenjanin by Krolopp (1977)

It became evident that, the stratigraphic model of Halaváts (1895, 1914) and the published results of Halaváts (1895, 1914) had become outdated. After more than two decades of systematic geological studies of the Neogene and Quaternary formations of the Carpathian Basin by the staff of the Geological Institute in Budapest, in that place where the collections survived the destruction of wars and revolutions. The paleontological material was taken under taxonomic revision. The Quaternary molluscan material finished its revision by Krolopp during the 1970s.

Stratigraphic revision of the Zrenjanin borehole material by Rakić (1977)

By lowering the Quaternary boundary in the official stratigraphic 1.68 Ma, it became evident that its changes must be implemented on the national scale also. Rakić (1977) adopted the stratigraphic changes according to experience in the (former) USSR. The changes became the results and conclusions of the Neogene and Quaternary stratigraphy conference from Kishiniev in 1972 (Stevanović & Rakić, 1973). He borrowed the term "Eopleistocene" from the Russian/Soviet nomenclature and implemented it in the Quaternary terminology of (former) Yugoslavia.

The results stratigraphic overviews and revisions

An overview of the results and stratigraphic analysis of Halaváts

The study conducted by Halaváts (1914) was the first to effect stratigraphic research for artesian well materials from Banat (Zrenjanin). Previous studies mainly weak on lithologic description and correlations (e.g., Halaváts, 1891)

The results of the 452.48 m deep borehole at Zrenjanin in the petrographic point did not deliver new data to previous results. The contents are clay, silt, clayey sand, sand, and similar sediments, which were known from the other well boreholes from the Alföld. The "Levantian" sediments show similarities to the material from Debrecen and Subotica.

The material from Zrenjanin artesian wells related to the "Recent" (Holocene) unit was identified at a depth between 0.00 m and 2.9 m. The "Diluvial" (Pleistocene) sequences were recognized at a depth ranging from 2.9 m to 58.36 m, and they should connect the south rim of the tectonic basin location of the town (Halaváts, 1914).

The "Diluvial" (Pleistocene) age sediments were classified mostly during the geologic surveying based on those sediments, which contain predominately clays. These formations (particularly their upper parts in most cases pertaining to the southern parts of the Alföld) were not structured as continuous formations. In some places, they were manifested on surfaces that were similar to the facies and lenses of river floodplains. The materials from boreholes support that during the Pleistocene, there existed a river network in the Alföld, and that these facies had been formed in meanders and alluvial plains (Halaváts, 1895).

The interval between a depth of 58.36 m and 135.18 m was identified as the "Upper Levantian Stage" of the Neogene, according to the presence of *Viviparus boeckhi* fauna, which similar as in profiles of the local artesian wells have three quartz sand layers as a good aquifer and they can be distinguished from the clay layers of different thickness. The mentioned sand layers which are intercalated of clay layers, are recognized in Subotica, Hódmezővásárhely, Szentes, Szarvas, Mezőtúr and Debrecen and concluded the *Viviparus boeckhi* Horizon formed in lake environment of the great area in the Alföld between Debrecen and Zrenjanin which cannot be occasionally formed lenses in the sedimentary record. The good aquifer characteristics of sand layers are degraded by uncontrolled drilling of wells and using the hydrostatic pressure, water decreases, and it happened nearly the synchronously same time. The borehole profiles in Debrecen, Subotica, and Zrenjanin suggest that the thick clay beds area the product of the limnic sedimentary basins and not the fluvial deposition (Halaváts, 1914).

The "Levantian" fauna has been identified from eight layers, it was mainly from the upper part of the Levantian sedimentary record represented with the *V. boeckhi* Horizon, however, it was for the first time that from the artesian well material at the area of Vojvodina the fossils from the middle part of the "Levantian" stage has been identified. This layer at depths of 234.54 and 208.50 has been identified as the *Viviparus vucotinovici* zone of the Upper Paludina beds (after NEUMAYR & PAUL, 1875). A similar assemblage suggests that the Upper Paludina beds ascend and are identified the up to 323.74 m depth (HALAVÁTS, 1914).

The stratigraphic subdivision of the Pleistocene and Pliocene sequences of the Alföld was preferred to use for lithological principles. Based on the boreholes data, it seems easy do distinguish the coarser and fluvial sediments contained in the Pleistocene series from the predominantly fine-grained, clayey sediments declared as hailing from the Pliocene. Within the Pleistocene sequences, three-partial subdivisions were manifested. The uppermost part had a high percentage of coarser sediments and was identified as belonging to the Upper Pleistocene; the middle part with finer factions was identified as belonging to the Middle Pleistocene, while the coarser sequences were identified as belonging to the Lower Pleistocene age. This subdivision was implemented in the studies of URBANCSEK (1963a, b, 1965) and ERDÉLYI (1967), based on lithology and hydrogeological analysis. These data show many regional connections and correlations. The systematic coring in the Hungarian part of the Pannonian Plain started in 1964, headed by Rónai's research campaign involving the Hungarian segment of the Alföld. The results at primarily a 100 m depth and sometimes 3 m – 500 m deep boreholes were published in part alongside palaeontological data by RÓNAI (1966, 1967, 1968), while the most important data concerning molluscs and vertebrate fauna was published by KRETZOI & KROLOPP (1972) (KROLOPP, 1970). An overview of the investigations from the Hungarian part of the Alföld was published at a later date (RÓNAI, 1985).

The lithostratigraphy of the fluvial sediments, which characterizes cyclic sedimentation, is extremely important because it is applied as a potential for water supply. The water-yielding capacity of coarser-grained sediments is very good, unlike clayey sediments. However, the very intensive exploitation changed the situation in the last 50 years. Based on the lithostratigraphy, the Upper- and Lower Pleistocene sequences are considered as good aquifers, while the Middle Pleistocene characterized poorer aquifer capacity.

Remarks on the "Levantian Stage"

The "Levantian Stage" was also identified as having the characteristics of a poor aquifer. This subdivision is only suitable for identifying the water supply potential of sequences. From a stratigraphic viewpoint, it is not acceptable because it is not connected or correlated with other stratigraphic proxies, particularly based on the biostratigraphic subdivision. In this case, this subdivision cannot relate to any European stratigraphic model or to any international stratigraphic standards (KROLOPP, 1970).

The "Levantian Stage" sequences have the great economical potential for indicating water supply, and most of the artesian wells in the Carpathian Basin get their water from these deposits. ROTH TELEGDI (1879) was the first scientist to predict the existence of the "Levantian Stage" in artesian well material from Püspökladány and from the evidence of Paludina fauna in the Alföld. This statement was based on the results following Halaváts' analysis of malacological material from the Szentes artesian well (HALAVÁTS, 1895).

The "Levantian Stage" was identified in the facies of sand with interbedded laminations of clay, which represents the potential horizons with water that were formed during longer stages, as denoted by the sedimentation record of sequences. The boreholes' lithology confirmed the existence of the Paludina Lake (or "Slavonia Lake") system in the southern part of the Alföld. The boundary between the Pleistocene and "Levantian Stage" is not clearly delineated. The existence of the "Levantian Stage" is confirmed by the *Viviparus (Paludina)* fauna. Regarding the delineation and connections pertaining to the "Levantian Stage" sequences, their thickness and position suggest that the inner (central) part of the Alföld affects by neotectonic subsiding. The Pleistocene sediments in the southern part of the Alföld are thicker, which confirms the Quaternary subsiding theory (HALAVÁTS, 1895).

The freshwater palaeontological record manifests because of the dominance of the genus *Vivipara (Paludina)* with *Unio* shells of an "American shape". Several new species were identified from the Slavonian (Paludina) Lake system facies, while for the area of the Alföld, a new guide fossil was found and determined as *Viviparus boeckhi* within the assemblage of some recently living species. The richest malacofauna was found in the south of Hungary (Szentes, Hódmezővásárhely, Szeged), while material from the Subotica and Sombor boreholes was quite poor but with sufficient fossil, material to confirm the "Levantian Stage" (Halaváts, 1895).

Corrections to and revision of the Halaváts stratigraphic studies by Laskarev

One of the main analyses of Laskarev was focused on the 21 m depth when according to his conclusions the "*Corbicula fluminalis* beds" transferred to fluvial terraces of the (Paleo)Tisza. These changes are lithogically visible when the grey clayey sand with fossil detritus which confirms the disturbed sedimentation in their basement have a "*Corbicula fluminalis* beds" (similar as Makiš in the vicinity of Belgrade). The youngest beds are represented with terrace sediments of the (Paleo)Tisza, which is 8–16 m above the water level of Tisza. This terrace, after Cholnoky named "Varoš" terrace (*varoška terasa*) or the 2nd terrace, which age is between the Pleistocene and the Holocene. The terrace is composed of the following units: 1. cultural layer (till 2.9 m depth); 2. loess of 4.41 m depth; 3. upper swamp loess of 7.26 m thickness; 4. grey sandy clay of 3.93 m thickness; 5. grey clayey sand with some fossil detritus of 3.19 m thickness. The terrace determined in the frame of the younger part of the Middle Pleistocene to Holocene ("Riss" glaciation to Holocene), which beginnig at 21.69 m depth (Laskarev, 1951) (Fig. 1, Table 1, App. 1).

Based on the geology of the Tisza valley, Laskarev concluded (Paleo) the Tisza eroded some parts of the "*Corbicula fluminalis* beds," and the parts of the mentioned layer were preserved in the opposite banks of the Tisza (Titel Loess Plateu) (Fig 2). The final stage of transition after "*Corbicula fluminalis* beds" are the clayey sands (lower swamp loess) with iron dots and *Planorbis* and *Lymnaeus* in their fossil record, the environment described as limnic to transition to swap environs. The age of the "*Corbicula fluminalis* beds" corresponds to the "Mindel-Riss," which Laskarev identified as a limnic environment. The "*Corbicula fluminalis* beds" after Laskarev (1951) corresponds to the older part of the Middle Pleistocene ("Mindel-Riss" interglacial); this stratigraphical unit identified from 56.64 m depth (Laskarev, 1951) (Figs. 1, 4; Table 1, App. 1).

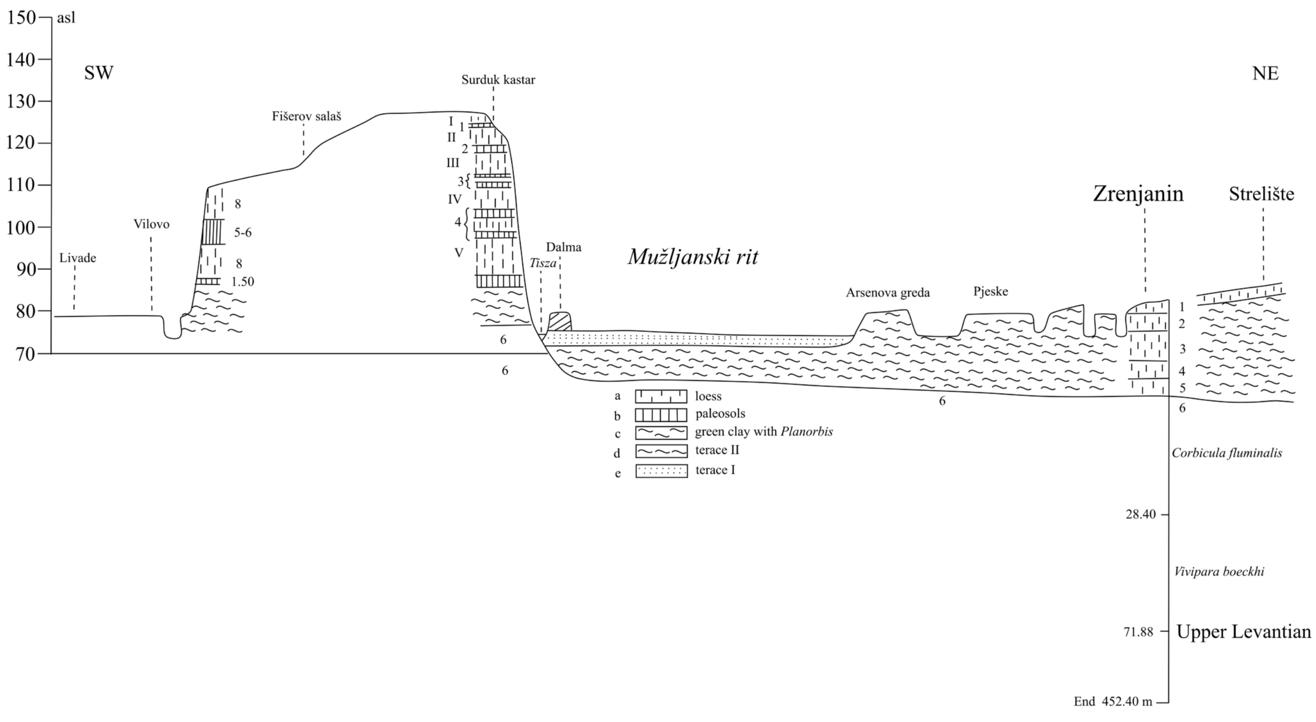

Fig. 2. *A geological transect of the Tisza Valley; Titel Loess Loess Plateau – Zrenjanin. Redrawn from Laskarev (1951).*

Table 1. *Local stratigraphical correlation table of the Tisza Valley. Redrawn from* Laskarev *(1951).*

	Laskarev 1926	Laskarev 1938	Laskarev, 1938, 1951								Laskarev 1952
	vicinity of Belgrade		After Penck & Brückner (1909-1911)		Makiš (Sajmište, Pančevački rit)	Zemun	Belgrade Plateau	Ovča	Complete Subdivision	After Milanković absolute chronology	Zrenjanin
Holocene	Holocene	Holocene			Sands, clayey sand, loessoid loam Sands with: *Unio pictorum, Amphimelania holandri* etc. Gravels with the same fauna	I Loess (first paleosol of Belgrade) II Loess	I Loess Cultural stratum of Neolithic-Bronze age I Paleosol II Loess *Elephas, Equus, Bos.* sp.				Holocene
Ice Age-Pleistocene			Upper	Würm	(eroded)	II Paleosol III Loess III Paleosol IV Loess IV Paleosol	II Paleosol III Loess III Paleosol Belgrade Plateau gola brda		W_3 W_2-W_3 W_2 W_1-W_2 W_1	22.100 (years BP) 71.900 115.000	
Ice Age-Pleistocene			Upper	Riss - Würm	(eroded)	V Loess Lake-palustrine and aeolian sands, clays, freshwater loess			PW-W_1 PW R_2-PW	145.000	Szentes deposits
Ice Age-Pleistocene			Middle	Riss		Dark sandy clays, yellow sands and gravels, grey sandstones and sands			R_2 R_1-R_2 R_1	187.000 230.000	Szentes deposits
Ice Age-Pleistocene		older Pleistocene	Middle	Mindel-Riss	Yellow and grey sands, gravels, conglomerate with *Corbicula fluminalis*, *Vivipara diluviana* etc (Makiš)	Gray sands with sandstones, gravels and grey sands		Gray sands, gravels with *Corbicula fluminalis*	PR-R_1 PR M_2-PR		*Corbicula fluminalis* beds
Ice Age-Pleistocene	older Pleistocene	older Pleistocene	Lower	Mindel	Ferruginous sands and gravels with *Vivipara diluviana* (Makiš)				M_2 M_1-M_2 M_1	435.000 475.000	*Viviparus boeckhi* beds
Ice Age-Pleistocene			Lower	Günz-Mindel					G_2-M_1		*Viviparus boeckhi* beds
Ice Age-Pleistocene			Lower	Günz					G_2 G_1-G_2 G_1	550.000 590.000	*Viviparus boeckhi* beds
Tertiary					Tertiary grey clays	Fine clayey and marly sandstones with mica (Tertiary)		Levantine deposits with thick *Viviparas.* Tertiary clays.		800.000 1.6 mya	Levantine deposits

The *Viviparus boeckhi* Horizon corresponds to the Lower Pleistocene (from "Günz" to "Mindel" glaciation) and is identified between 121.9 and 56.6 m in depth. In their basement are the "Tertiary" units which ended with *Viviparus vucotinovici* – Paludina Beds (of the "Danube" stage) (Laskarev, 1951) (Figs. 1, 3, Table 1, App. 1).

Laskarev (1952), in the analysis of the fluvial-limnic sediments of the Alföld in the transect Szarvas - Zrenjanin described as an older terrace of the (Paleo)Danube and named these sediments as "Szentes beds", these deposits have the maximum thickness of 202 m identified in the borehole material from Szentes (South Hungary). The "Szentes beds" are described as the younger layers than the "*Corbicula fluminalis* beds" ("Mindel-Riss" interglacial) and older than the "oldest Danube terrace" between Mohács and Adony (the oldest defined as "Würm – W3" stage) when the Danube changed its riverbed position in the fault along the Mecsek Mts. These "Szentes beds" should be developed in the latest fluvial phase and its transition to swamp and marsh environments (Figs. 1, 3, 4; Appendix 1).

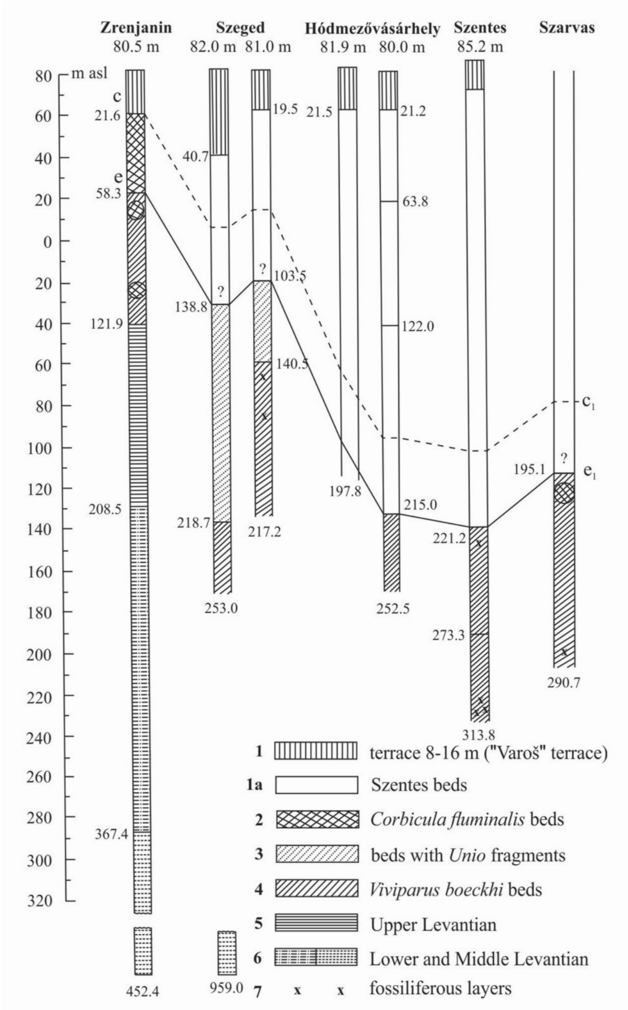

Fig. 3. Stratigraphical correlation chart of the Zrenjanin – Szarvas transect (Laskarev, 1952).

Stratigraphical overview by Rakić

The lowering of the Quaternary boundary to nearly 1.8 (or 1.6) Ma at the beginning of the 1970s by adding the Calabrian Stage to the Quaternary, it became evident that in the new stratigraphical scheme, a gap was created of nearly 1 Myr. This gap between the Quaternary and the Pleistocene chronostratigraphic frame (1.8–0.8 Ma) should also have been named among stratigraphers in the (former) Yugoslavia. The term "Eopleistocene" seemed to solve that problem for the case of the fluvial and limnic sediments in the Serbian Quaternary stratigraphical terminology was suitable to implement for the missing oldest Quaternary formations (Gaudenyi et al., 2014).

The investigations of Rakić were adopted in his paper regarding the beginning of the Quaternary Period in Vojvodina, where he stated that the Quaternary period should begin on that time when the fluvial phase became the prevailing over the "limnic phase" in the SE part of the Pannonian realm. These phenomena identified in the Middle- or Upper Paludina Beds.

Corrections to and revision of the Halaváts geological analysis and Laskarev's stratigraphic studies by Krolopp

In 1973, Krolopp finished the taxonomic revising of fossils recovered from artesian wells material in the area of the Alföld. The entire report regarding the Quaternary molluscan studies in the Alföld concerning the parts of Serbia / former Yugoslavia was published in the third paper of the Annual Report Series of the Hungarian Geological Institute (Krolopp, 1977). The revisions pertaining to molluscan species were remarks on the results of Halaváts' (1914) which were based on the borehole material records from Vojvodina. The studies of Krolopp after the taxonomical review of the molluscan record (Krolopp, 1977) are noted below shown in Appendix 1:

In the material at depth from 21.69 to 35.75 m, the species *Corbicula fluminalis* (Müll.) Halaváts quotes the species only in the faunal list of the above interval. In the paleontological part of his paper, he does not mention this interval, through discussing in detail its Hungarian occurrences (Halaváts, 1914). The occurrences of the *Corbicula* are restricted as shown by wells drilled later to the Lower Pleistocene, and sediments of such an age are expected to occur in this area from about 60 m depth (Kretzoi & Krolopp, 1972; see also the following intervals of the well at App. 1) Not a single Lower Pleistocene species does not occur in the assemblage of the associated fauna. There it should be supposed that the given depth interval may have erroneously attributed to the specimen, which is, for that matter, undoubtedly *Corbicula* (Krolopp, 1977).

Remarks on *Potomida sturi* (Hoernes) and *Potomida cf. wilhelmi* (Penecke) at depth between 58.36 and 88.52 m, on account of these two Pliocene species, are discarded from the wells until new species of higher diagnostic value are found (see Krolopp, 1976a, b). For a systematic revision of *Vivipara acerosus zsigmondyi* (Halaváts) which has a "chrono-specific" value, see the discussion of the Hódmezővásárhely well (Krolopp, 1976b).

At depth between 107.4 and 121.9 m, the *Lymanaea stagnalis* (Linneaus) specimen found in the material is a very slim form of *L. stagnalis*, similar to the case of the specimen from Szentes (Krolopp, 1976a, 1977).

The interval from 208.50 to 234.54 m depth of eight specimens of Halaváts' new species may regard as syntypes, as he did not distinguish the holotype. In the paper of Krolopp (1977), a detailed description of the new species *Viviparus berthae* (Halaváts) and *Viviparus etelkae* (Halaváts) and photographs of the holotypes was given in the paper of Krolopp (1977). *Melanopsis sp*. cannot be precisely identified. It is certain, that the mentioned species should a slimmer form of *M. pyrum* (Krolopp, 1977)

The single specimen (right valve) of *Unio levanticus* from a depth between 265 and 268 m which was represented as a new species Halaváts (1914) has been lost. On the basis of the description and photo (Halaváts, 1914), it has been identified as the species of *Potomida wilhelmi*.

Summarizing the changes due to taxonomic revision in the case of Zrenjanin artesian well material like the other local wells, the 58 to 135 m depth fauna belongs to the *Viviparus boeckhi* Horizon, which Halaváts consisered as "Upper Levantian" which we have to interpret as of Lower Pleistocene age (similar as the conclusions of Krolopp, 1976a). At depth in between 208 and 323 m depth, the fauna turned out to be, in fact, "Upper Pliocene." Revision investigations of in the paper have been restricted to corrections of taxonomic errors in identifying the molluscan record; to record the new form in compliance with existing rules, furthermore to compare them with the Paludina Beds species (Neumayer & Paul, 1875; Penecke, 1883). Krolopp summarizes that the revision of Paludina Beds will be an urgent task to solve, as the possible changes in taxonomy and nomenclature of species occurring there may, of course, concern this fauna (Krolopp, 1977).

Molluscan assemblages identified as the "*Corbicula fluminalis* Beds" and the *Viviparus boeckhi* Horizon, without any doubt can be found exclusively in the fluvial environment.

"Szentes beds" of Laskarev (1952) Krolopp as referred in his paper (Krolopp, 1970) pointed that the "Szentes Beds" cannot exist as a discrete stratigraphic unit due its age of the lower part of "Szentes Beds" belongs to the "Günz-Mindel" - *Viviparus boeckhi* Horizon and the uppermost part is identified as Upper Pleistocene. Moreover, Laskarev's earlier paper (1951) has a similar result in his synthesis regarding the conclusions of Krolopp in the case of the *Viviparus boeckhi* Horizons whose existence is considered as Lower Pleistocene ("Günz", "Günz-Mindel" and "Mindel") (Krolopp, 1970).

Overviews and Discussion

Studies of Halaváts (1914)

The first published results based on the analysis of borehole material from Zrenjanin were done by

Halaváts (1914). Besides numerous Quaternary stratigraphic studies, the borehole from Zrenjanin became one of the most referred Quaternary sections in the case of Quaternary fluvial sediments of Vojvodina. The detailed lithologic description was state-of-the-art. The taxonomic identification of the recorded molluscan fauna was revised by Krolopp (1977), the taxonomic of the molluscan record generates changes several times due to conceptual changes in the global and local time scale, and the final version is presented in this paper.

Corrections of the stratigraphic studies of Krolopp (1977)

"*Developments in Quaternary river network/systems research suggest that, according to current developments, species-rich fauna from the warmest parts of the warm/temperate stages (interglacials) are the only fauna suitable for developing molluscan biostratigraphy. Fauna from the early or late parts of warm stages, which are usually made up of a restricted number of species, are not directly comparable with fluvial climatic optimum fauna, and may therefore be difficult to fit into any general biostratigraphic scheme*" (Keen, 2001 p. 1658).

"*The fauna that has been used for stratigraphic investigations were from fluvial deposits; the advantage of using these is that they are usually from similar facies and are therefore directly comparable with one another. In fluvial assemblages, during flooding, the flow of the river collects the inhabitants of many of the ecological niches of the river and floodplain, as was recognized by Sparks (1964). This homogenization of the molluscs from different environments, while sometimes causing problems regarding the interpretation, also allows for the comparison of fauna from the same or different ages*" (Keen, 2001 p. 1658).

"*Furthermore, in the creation of a biostratigraphic scheme, it should be considered that the presence/absence of species across the southern parts of the Carpathian Basin may be controlled by climatic- and biogeographic boundaries between catchments, rather than by genuine absence. To some extent, this modern distribution is artificial and not a guide for evaluating the warm stages. The development of canals since the 19th century linking all major catchments (especially the Danube-Tisza-Danube canal system) together in the "canal basin" in the south-eastern part of the Carpathian Basin has tended to homogenize fluvial faunas; there is no evidence from either earlier Holocene times or the Pleistocene warm stages that there had been any biogeographical boundaries that may have caused species to be restricted to individual catchments and in this way provide false indications of the biogeographical /habitat presence or absence*" (Gaudenyi et al., 2018, p.106).

"*The uniformity of fauna across a relatively small area like the Pannonian Plain is controlled by the rapid dispersal potential of many aquatic species, which has allowed for the colonization of entire continents by a number of taxa in the present century. Many examples of rapid rates of colonization by freshwater molluscs involve a species introduced to new eras by human activity (i.e., Potamopyrgus antipodarum (Gray)), likely introduced to Europe from New Zealand since 1859 (Haynes et al., 1985; Kerney, 1977, 1999), as well as the rapid spread of Corbicula fluminea into the Rhine and Danube systems since 1985 (bij de Vaate & Grejidanuus-Klass, 1990; Kinzelbach, 1991; Turner* et al., *1998). Nonetheless, despite this element of artificiality in their spread, these examples denote the potential of nonmarine mollusks to colonize new habitats (Keen, 2001)*" (Gaudenyi et al., 2018, p.106).

Thus, even the linking effects of canals between river basins and the spread of freshwater species from catchments can be rapid and seems unlikely to allow for the development of biogeographic provinces in an area as small as the Carpathian Basin.

"*With the revisions by Krolopp (1977) of the borehole materials from Sombor, Subotica, and Zrenjanin, as studied by Halaváts, the number of molluscan fauna species in individual horizons have been highlighted as the following: 37 species from the Upper Pleistocene, 44 species from the Middle Pleistocene, 45 species from the Lower Pleistocene and 20 species from the Upper Pliocene. These results do not deviate from Halaváts' (1895, 1914) data in numerical terms. However, the fauna of individual wells and/or intervals show considerable changes. The borehole* *material from Sombor indicates significantly poor paleontological material; nonetheless, it still enables us to make revisions based on the fossil molluscan fauna.*" (Gaudenyi et al., 2018, p. 106)

For a more detailed stratigraphy, we want to clearly determine only the molluscan horizons according to recent advances in Quaternary geology and in international stratigraphic models. The primary criteria were the guide fossils for the Pleistocene warm stage fauna, from which only the Pleistocene *Corbicula* beds (Gaudenyi et al., 2014) and *Viviparus boeckhi* Horizon (Gaudenyi et al., 2014) were identified (Appendix 1) their appearance cannot interpret as continuous and biostratigraphical only linked as Quaternary climato-lithostratigraphic units (disappearance during the stages).

Some problems appear to have been solved in the past decade regarding Serbian Quaternary stratigraphy. The term "Eopleistocene" as a stratigraphic unit has been rejected and should now be interpreted as a younger part of Lower Pleistocene (Gaudenyi et al., 2014, 2015b). Furthermore, "*Corbicula fluminalis* beds" should be renamed to Pleistocene *Corbicula* beds because the systematics of *Corbicula* require revision. Thus, while this problem remains unresolved, we suggest using the term Pleistocene *Corbicula* beds (Gaudenyi et al., 2013, 2015a). According to the data derived from borehole material, it is evident that Pleistocene *Corbicula* beds are linked with the environment of the Pleistocene warm/temperate stages, which are considered to be the younger part of Early Pleistocene and the Middle Pleistocene (Gaudenyi et al., 2013, 2015a,b). In terms of *Viviparus boeckhi* Horizon, following revisions of existing data, their age is now considered as having been part of the Early Pleistocene warm/temperate stages and as an older subunit of the Pleistocene *Corbicula* beds (Gaudenyi et al., 2013, 2015a,b).

According to the observation of Krolopp (1977), the Pleistocene *fluminalis* beds should not be identified at such depth as 21.69 to 27.75 m, and it could be a mistake in Halaváts (1914) paper regarding the description. We cannot accept this statement because similar situations when the Pleistocene *Corbicula* beds are quite close to the surface have been in the vicinity of Belgrade (see lithological columns of Makiš, Ada Cignalija, Obrenovac, Sajmište, Pančevo) detailed have been discussed in the paper of Gaudenyi et al. (2015b).

The taxonomical changes of molluscan fauna were implemented and shown in Fig. 4 due to the recent advance-based form database (molluscabase.org).

Conclusions

The Quaternary paleogeographic succession at Zrenjanin Main Square is recorded in the artesian well borehole material which is published in by Halaváts (1914). Laskarev (1951, 1952) due to developments in the Quaternary stratigraphy and terminology changed the time frame. The first advances regarding the revision of the stratigraphy of Zrenjanin artesian well profiles were made by Krolopp (1977), via taxonomic revision of the malacological record and clearly recognized the temperate stage fluvial environments in which the Pleistocene *Corbicula* beds and the *Viviparus boeckhi* Horizon was formed. The same author (Krolopp, 1977) confirmed the presence of the Paludina beds from the 208.50 m depth. The corrections of the stratigraphic nomenclature regarding the beginning of the Pleistocene on the regional scale adopted in the investigations of (e.g., Rakić, 1977) when the Pleistocene record is confirmed in the Upper Paludina beds and in the Middle Paludina beds is not confirmed. This study adopted the advances that resulted in the studies of the Pleistocene fluvial sequences in the SE part of the Carpathian Basin regarding the stratigraphy of Quaternary fluvial sediments found in Serbia (Gaudenyi et al., 2013, 2014, 2015a, b, 2018). The changes are presented in Appendix 1 and summarize the following:

The oldest Quaternary sediments recorded at a depth between 208.50 and 234.54 m, as the assemblage of the *Viviparus vucotinovici* zone of the Upper Paludina beds, which is defined by Neumayr & Paul (1875), and in case of Zrenjanin published by Halaváts (1914), it has recognized as a fluvial assemblage (Laskarev, 1951, 1952), it was confirmed by Krolopp (1977) and belongs to the Quaternary (pointed out by Rakić, 1977) its Lower Quaternary position confirmed in this study based on the data from 1970-is.

Three *Vivparus boeckhi* Horizons were identified at 135.18–129.40, 121.90–107.40, and 58.36 – 88.52 m depth, the stratigraphic unit was defined by Halaváts (1888) for Serbia reviewed by Gaudenyi et al. (2013b) in case of Zrenjanin borehole recognized by Halaváts (1914), who proposed its Levantian stratigraphic position. The taxonomic identification of the malacological record was reviewed by Krolopp (1977), who identified its Lower Pleistocene position, while according to the local distribution and characteristics of the assemblage (Gaudenyi et al., 2013, 2014, 2015a, b, 2018), it is defined as an older subunit of the Lower Pleistocene warm stages Pleistocene *Corbicula* beds which belongs to the younger part of the Lower Pleistocene published in this study.

The Pleistocene *Corbicula* beds were identified at 21.69 to 27.75 and, in this study, defined as Middle Pleistocene age warm stage.

The Pleistocene sequences, which should contain the Upper Pleistocene and the Middle Pleistocene, are not confirmed and are identified at depths from 2.90 to 21.69 m.

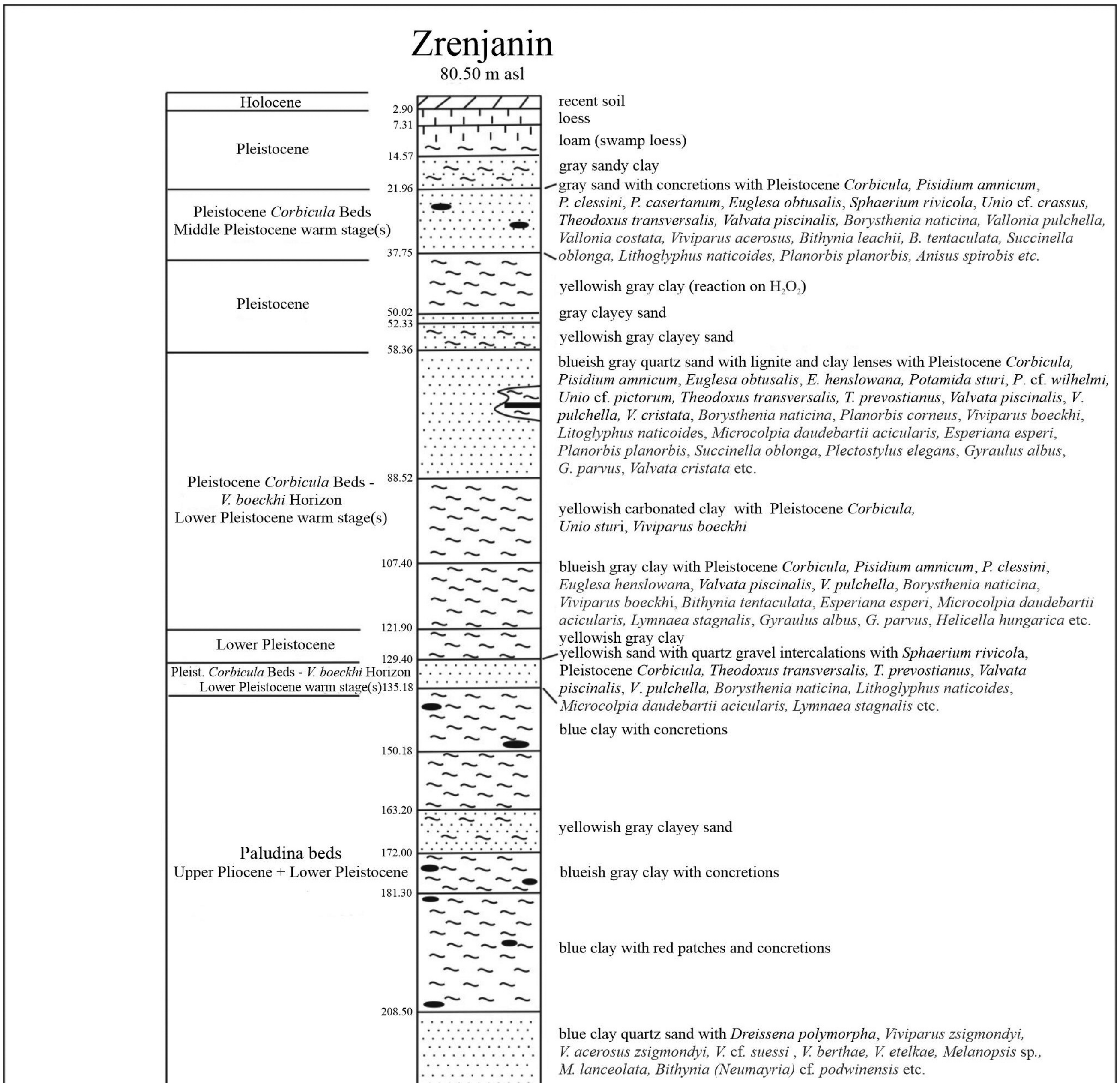

Fig. 4a. *The revision of the stratigraphical column of Zrenjanin.*

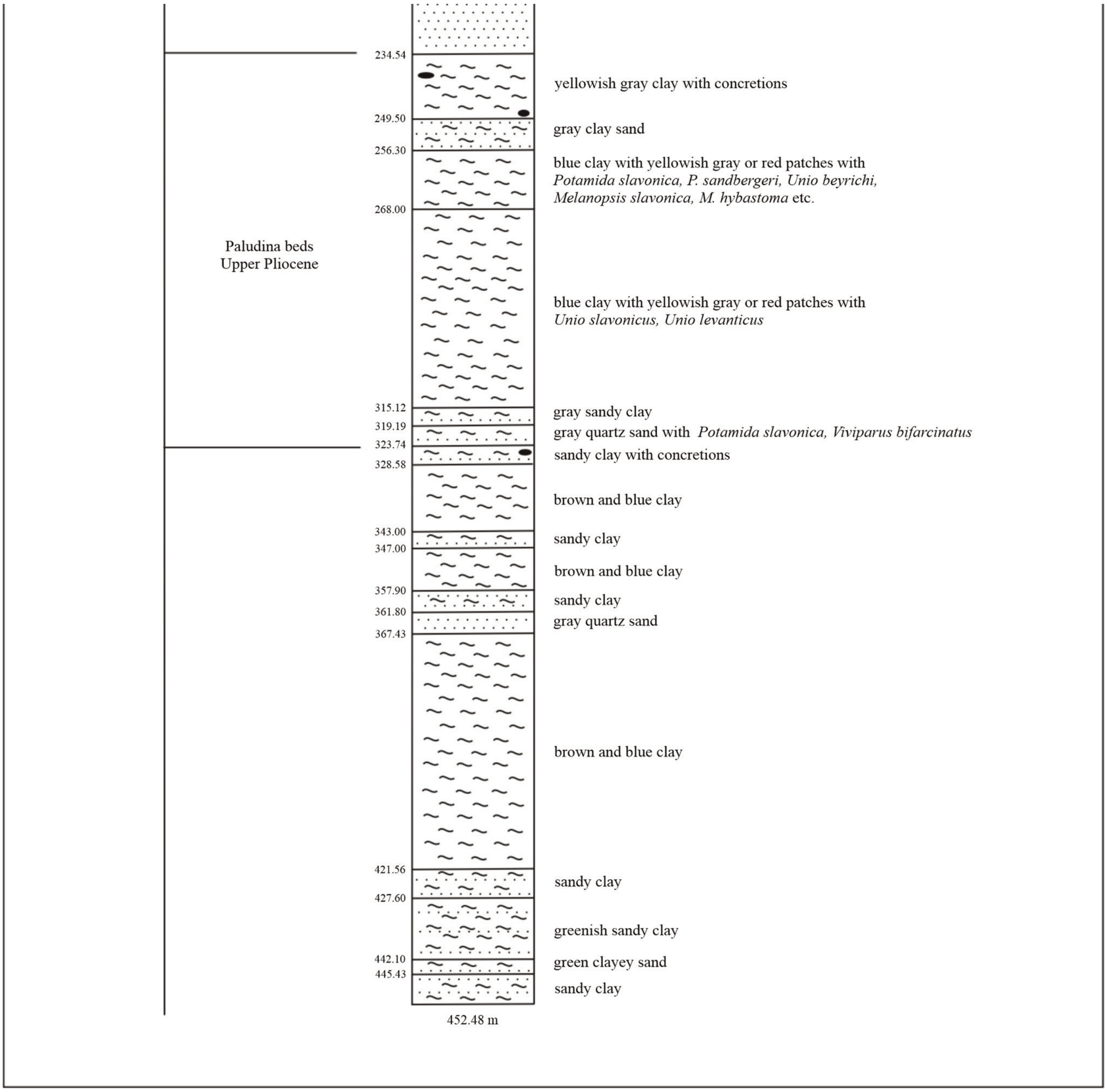

Fig. 4b. *The revision of the stratigraphical column of Zrenjanin.*

The recent soil horizon represents the youngest sequences which ascend till the 2.90 m depth (Fig. 4).

Acknowledgements

We would like to thank the two anonymous reviewers for their suggestions and comments. The work of D. Nenadić was financed through the Project NEEMO of the Fund for Science of the Republic of Serbia number 7746827 and the Agreement on the implementation and financing of scientific research work of the SRO (NIO) in 2022, no. 451-03-68/2022-14/ 200126.

References

Bij de Vaate, A. & Greijdanus-Klaas, M. 1990. Asiatic clam, Corbicula fluminea (Müller, 1974) (Peleypoda, Corbiculidae), a new immigrant to the Netherlands. *Bulletin*

Zoologisch Musem, Universitet van Amsterdam 12, 12: 173–177.

Ćalić, J., Gaudenyi, T., Milošević, M.V., Štrbac, D. & Milivojević, M. 2012. Geomorphomertical method for the delineation of plains – case study of the south-eastern (Serbian) segment of the Pannonian Plain. C*arpathian Journal of Earth and Environmental Sciences,* 7 (2): 239–248.

Cholnoky, J. 1910. Az Alföld felszíne [The surface of the Alföld - in Hungarian]. *Földrajzi Közlemények*, 38: 413–436.

Erdélyi, M. 1967. A Duna-Tisza közének vízföldtana [Hydrogeology of the Danube-Tisza interfluve - in Hungarian]. *Hidrológiai Közlöny*, 47 (6): 331–340; 357–365.

Gaudenyi, T., Nenadić, D., Jovanović, M. & Bogićević, K. 2013. The stratigraphical importance of the Viviparus boeckhi Horizon of Serbia. *Quaternary International*, 292: 101–112.

Gaudenyi, T., Nenadić, D., Jovanović, M. & Bogićević, K. 2014. The stratigraphical position and the use of the term Eopleistocene in the Serbian geological literature. *Quaternary International*, 319: 150–159.

Gaudenyi, T., Nenadić, D., Stejić, P., Jovanović, M. & Bogićević, K. 2015a. The stratigraphy of the Serbian Pleistocene *Corbicula* beds. *Quaternary International*, 357: 4–21.

Gaudenyi, T., Nenadić, D., Stejić, P., Jovanović, M. & Bogićević, K. 2015b. Stratigraphic revision of the Quaternary material from the vicinity of Belgrade and the Serbian segment of the Tisza valley analysed by V.D. Laskarev. *Quaternary International*, 357: 93–109.

Gaudenyi, T., Nenadić, D., Jovanović, M., & Stejić, P. 2018. The revision of Quateranry stratigrphy of the Sombor and Subotica artesian well borehole profiles (Bačka, Vojvodina, Serbia). *Quaternary International*, 478: 97–107.

Gaudenyi, T., Mihajlović, M. 2022. The Alföld: Denomination and Its Southern Boundary. *European Journal of Environment and Earth Sciences,* 3 (1): 61–66.

Halaváts, Gy. 1891. Adatok Torontálmegye földtani viszonyainak ismeretéhez [Data to the geology of Torontál County – in Hungarian]. *Földtani Közlöny*, 24: 165–178.

Halaváts, Gy. 1895. Az Alföld Duna-Tisza közötti részének földtani viszonyai [Die geologischen Verhältnisse des Alföld (Tieflandes) zwischen Donau und Theiss]. *Földatni Intézet Évkönyvei*, 11: 103–175. (117–198 German Edition).

Halaváts, Gy. 1896a. Magyarország artézi kútjai [Artesian wells of Hungary - in Hungarian]. *Természettudományi Közlemények*, 28: 366–374.

Halaváts, Gy. 1896b. A magyarországi artézi kutak története, terület szerinti felosztása, mélységök, vizök bőségének és hőfokának ismertetése. [*Artesian wells of Hungary - the history, distribution, introduction of water depth, quality and temperature* – in Hungarian]. Memoirs of the Royal Hungarian Geological Institute for the Millennial Exhibition in the year 1896, Budapest. 103 pp.

Halaváts, Gy. 1914. A nagybecskereki fúrólyuk [Die Bohrung in Nagybecskerek]. *Földtani Intézet Évkönyvei*, 22: 171–202 (187–222 German Edition).

Haynes, A., Taylor, B.J.R. & Varley, M.E. 1985. The influence of the mobility of *Potamopyrgus jenkisi* (Smith, E.A.) (Prosorbachia; Hydrobiidae) on its pread. *Archiv für Hydrobiologie*, 103 (4): 497–508.

Hochstetter, F. 1870. Geologie des östlichen Teils der europaischen Türkei. *Jahrbuch der k. k. Geologischen Reichanstalt*, 20 (3): 365–461.

Keen, D.H. 2001. Towards a late Middle Pleistocene non-marine molluscan biostratigraphy for the British Isles. *Quaternary Science Reviews*, 20: 1657–1665.

Kerney, M.P. 1977. British Quaternary non-marine Mollusca: a brief review. In: Shotton, F.W. (Ed.). *British Quaternary Studies: Recent Advances*. Clarendon Press, Oxford, 43–53.

Kinzelbach, R. 1991. Die Kröbchenmuscheln *Corbicula fluminalis, Corbicula fluminea* and *Corbicula fluviatilis* (Bivalvia: Corbucliidae). *Mainzer Naturwissenschaftliches Archiv,* 29: 215–228.

Kretzoi M. & Krolopp, E. 1972. A harmadkor végi és a negyedkor rétegtana az őslénytani adatok alapján [Oberpliozäne und quartäre Stratigraphie des Alföld (Grosse Ungarischen Tiefbene) aufgrund paläontologischen Angaben – in Hungarian]. *Földrajzi Értesítő,* 21 (2–3): 133–158.

Krolopp, E. 1970. Őslénytani adatok a nagyalföldi pleisztocén és felsőpliocén rétegek sztratigráfiájához [Contribution to the stratigraphy of the Pleistocene and Upper Pliocene deposits of the Great Hungarian Plain– in Hungarian]. *Őslénytani Viták / Discussiones Palaeontologicae*, 14: 5–39.

Krolopp, E., 1976a. Revision of fossil molluscs gained from the Great Hungarian Plain I. Artesian well drilling at Szentes. *A Magyar Állami Földtani Intézet Évi Jelenései 1973-ról*, 195–218.

Krolopp, E., 1976b. Revision of fossil molluscs coming from the material of deep boreholes driven by Zsigmondy in the Great Hungarian Plain and studied by Halaváts II. Artesian wells drilled at Szeged, Szarvasi and Kecskemét. *A Magyar Állami Földtani Intézet Évi Jelenései 1974-ről*, 133–156.

Krolopp, E. 1977. Revision of fossil molluscs coming from the material of deep boreholes driven by Zsigmondy in the Great Hungarian Plain and studied by Halaváts. - III. Artesian well drilling at Zombor (Sombor), Szabadka (Subotica) and Nagybecskerek (Zrenjanin). *Magyar Állami Földtani Intézet Évi Jelenései 1975-ről*, 145–161.

Krolopp, E. 1980. Pleistocene mollusc type material at the Hungarian Geological Institute. *A Magyar Állami Földtani Intézet Évi Jelentése 1978-ról*, 359–383.

Laskarev, V.D. 1951. Sur la stratigraphie des depots Quaternaries de la Vojvodina (Yugoslavie). *Geološki anali Balkanskoga poluostrva*, 19: 1–16. (in Serbian, summary in French)

Laskarev, V.D. 1952. Beitrag zur kenntnis des geologischen baues des Theiss-Tales. *Geološki anali Balkanskoga poluostrva*, 20: 1–19 (in Serbian, summary in German).

Marović M., Đoković I., Rundić, Lj., Toljić M. & Milivojević J. 2007. *Neoalpine tectonics of Serbia*. Ser. Monographies 1. Serbian Geological Society, 154 pp.

Neumayr, M. & Paul, C.M. 1875. Die Congerien- und Paludinenschichten Slavoniens und deren Faunen. *Abhandlungen der K-k geologischen Reichanstalt - Wien,* 7 (3): 1–113.

Penecke, K.A. 1883. Beiträge zur Kenntniss der fauna der Slavonischen Paludinenschichten. *Beiträge zur Paläontologie Öesterreich-Ungarns und des Orients*, 3. 87–100.

Rakić, M.O. 1977. Pleistocen Srema i Banata [Pleistocene of the Srem and the Banat – in Serbian]. In: Petković, K. (Ed.) *Geologie de la Serbie II-3 Stratigraphie.* Institute de Geologie Regionale et de la Paleontologie, Faculte des Mines et de geologie, Universite de la Belgrade, 399–405.

Rónai, A. 1966. Földtani és geofizikai térképezés Szolnok környéken [Geological and geophysical mapping in the vicinity of Szolnok – in Hungarian]). A *Magyar Állami Földtani Intézet Évi jelentései 1964-ről*, 503–511.

Rónai, A. 1967. *Magyarázó Magyarország 200 ezres Földtani Térképsorozatához L-34-IX Szolnok* [Explanation notes for the 1:200 000 geological map of Hungary, sheets L-34-IX Szolnok -in Hungarian], 1–132.

Rónai, A. 1968. A Síkvidéki kutató osztály 1966. évi munkálatai [The results of the Department of Plain Research for the year 1966 – in Hungarian]. *A Magyar Állami Földtani Intézet Évi jelentései 1966-ról*, 241–256.

Rónai, A. 1985. The Quaternary geology of the Great Hungarian Plain. *Geologica Hungarica – Series Geologica*, 21: 446 pp. (in Hungarian with English summary)

Roth Telegdi, L. 1879. Adatok az Alföld altalajának ismeretéhez [Geological data for the basement of the Alföld – in Hungarian]. *Földtani Közlöny*, 9: 312–317.

Sparks, B.W. 1964. Non-marine Mollusca and Quaternary ecology. *Journal of Animal Ecology,* 33: 87–98.

Stevanović, P. & Rakić, M.O. 1973. Izveštaj o medjunarodnom kolokvijumu „Granica između neogena i kvartara“ održanom u Kišinjevu (SSSR, maj-juni, 1972. godine) [The report from the international conference „The Boundary Between Neogene and Quaternary“ held in Kishiniev (USSR, May-June, 1972) – in Serbian]. *Zapisnici SGD za 1972. godinu*, 135–140.

Terzin, V. Rakić, M. & Hadži-Vuković, M. 1994. Osnovna geološka karta SRJ 1:100 000. Tumač za list Zrenjanin L34-89 [*Basic Geologic Map of Federal Republic of Yugoslavia 1:100 000. Explanatory booklet for the Sheet Zrenjanin* - in Serbian]. Geological Institute “Gemini” & Nafta-Gas, 70 pp.

Turner, H., Kuiper, J.G.J., Thew, N., Bernasconi, R., Rüetschli, J., Wütrich, M. & Gosteli, M. 1998. *Atlas der Molluskens der Schweiz und Liechtensteins*. Fauna Helvetica, 2. Centre Suisse de cartographie de la faune, Neuchâtel.

Urbancsek, J., 1963a. A földtani felépítés és a rétegvíznyomás közötti összefüggés az Alföldön. [Links between the hydrologic pressure and the geology of Alföld – in Hungarian] *Hidrológiai Közlöny*, 43 (3): 205–218.

Urbancsek, J. 1963b. Pliocén és pleisztocén üledékek földtani szinézisének újabb lehetőségei a vízföldtani kutatásban [The possibilities of scientific synthesis for the Pliocene and Pleistocene sediments in hydrogeology – in Hungarian]. *Hidrológiai Közlön*y, 34 (5): 392–400.

Urbancsek, J. 1965. Az Alföldi negyedkori földtani képződmények mélyszerkezete [The deep structures of the Quaternary formations in the Alföld - in Hungarian]. *Hidrológiai Közlöny,* 45: 111–124.

Zsigmondy, V. 1872. Észleléseim az artézi kutak körül [Observations on artesian wells - in Hungarian]. *Földtani Közlöny*, 2: 154–156.

Резиме

Ревизија стратиграфије квартара на основу материјала из бушотине артешког бунара у Зрењанину

Резултати стратиграфије бушотине у Зрењанину (поред бушотина у Суботици и Сомбору) спадају у групу најстаријих резултата добијених за стратиграфију квартара са подручја Војводине. Материјали из ове три буштине артешких бунара су детаљно литолошки анализирани и палеонтолошки материјал је сачуван у Геолошком институту у Будимпешти. Током прве кампање бушења артешких бунара (1892–1895), ово су биле најзначајаније бушотине артешких бунара на јужним деловима Алфледа. Резултати геолошких истраживања за буштину у Зрењанину су објављени године 1914 (Halaváts, 1914). Профили бушотина Суботице, Сомбора и Зрењанина су препознати као „станардни“ / руководећи профили од стране мађарских и српских геолога, и представљају основу за даљу регионалну корелацију. Таксономска ревизија малакошког материјала, урађена од стране Кролопа (Krolopp, 1977), имала је значајне стратигафске измене, који су били резултат корелација и анализа квартарног геолошког записа са других делова Мађарске и бивше Југославије. Последњих година нови резултати кваратарне стратиграфије су допринели бољем разумевању развића флувијалних депозициних система квартара на подручју Србије. Уврђено је да слојеви са *Viviparus boeckhi* престављају флувијалну фауну умереног појаса доњег плеистоцена и налазе се у заједници са фауном слојева са плеистоценском корбикулом (Gaudenyi et al., 2013). Термин “еоплеистоцен” не би требало користити и временски оквир одговара старијим слојевима раног плеистоцена (Gaudenyi et al., 2014). Слојеви са плеистоценском корбикулом су идентификовани у еквивалентима интерглацијала доњег- и средњег плеистоцена. Ова фауна је карактеристична за флувијано окружење (Gaudenyi et al., 2015a). Ревизија стратиграфије профила анализираних од стране Ласкарева је урађена 2015 (Gaudenyi et al., 2015b). Стратиграфска ревизија профила у Суботици и Сомбору је урађена 2018 (Gaudenyi et al., 2018). Резултати стратиграфске ревизије артешке буштине у Зрењанину су следећи: Доњи плеистоцен је утврђен на дубинама од 234,54 до 58,36 m. Интервал између 234,54 и 208,50 m представљена је горњопалудинским слојевима – зоном *Viviparus vucotinovici* (ова зона представља почетак флувијлне фазе и квартара/плеистоцена), док су слојеви са *Viviparus boeckhi* идентификовани од 135,18 m до 58,36 m дубине и везују се за доњи плеистоцен. Интервал између 58,36 m и 37,75 m дубине је уврђен као плеистоценске старости (доњи- и/или средњи плеистоцен), на основу седиментолошког и малаколошког записа. На дубинама од 37,75 m до 21,67 m је утврђен средњи плеистоцен на основу седиментолошког и палеонтолошког записа. Речни седименти су од 21,69 m до 7,31 m и указују на плеистенску старост. Холоценски наноси и земљишта су до 2,90 m дубине.

Manuscript received March 06, 2021
Revised manuscript accepted November 11, 2022

Appendix 1. *Stratigraphic and malacological revisions of the Zrenjanin artesian well (bold text refers to stratigraphic changes; empty boxes indicate undefined age or recor without fossil findings).*

Stratigraphy (this study)	Stratigraphy (Rakić. 1977)	Stratigraphy (Krolopp, 1977=)	Stratigraphy (Laskarev, 1951–1952)	Stratigraphy (Halaváts, 1914)	Depth (m) (Halaváts, 1914)	Lithology (Halaváts, 1914)	Molluscan record (Halaváts, 1914)	Revision of molluscan record (Krolopp, 1977)
Holocene	Holocene	Holocene	Holocene	Holocene	0–2.90	recent soil		
Pleistocene	Pleistocene (Würm 3)	Upper Pleistocene	Terraces - younger part of Middle Pleistocene to Holocene	Pleistocene	2.90–7.31	loess		
Pleistocene	Terraces - younger part of Middle to Upper Pleistocene	Upper Pleistocene	Terraces - younger part of Middle- to Upper Pleistocene	Pleistocene	7.31–14.57	loam (swamp loess)		
Pleistocene	Terraces - younger part of Middle to Upper Pleistocene	Pleistocene	Terraces - younger part of Middle Pleistocene to Holocene	Pleistocene	14.57–18.50			
Pleistocene	Terraces - younger part of Middle to Upper Pleistocene	Pleistocene	Terraces - younger part of Middle Pleistocene to Holocene	Pleistocene	18.50–21,69	gray clayey sand		
Middle Pleistocene warm stage (s) - Pleistocene *Corbicula* beds	Terraces - younger part of Middle to Upper Pleistocene	Pleistocene	Corbicula fluminalis beds - older part of Middle Pleistocene	Pleistocene	21,69–37.75	gray sand with concentrations	*Corbicula fluminalis* Müller	*Corbicula fluminalis* Müller
							Spaerium rivicolum (Leach)	*Sphaerium rivicola* (Lam.)
							Pisidium fontinale C. Pfr.	*Pisidium casertanum* (Poli)
							Pisidium obtusale C. Pfr.	*Pisidium obtusale* (C. Pfr.)
							Pisidium (Fluminina) amnicum Müller	*Pisidium amnicum* (Müll.) *Pisidium clessini* Neum.
							Unio sp.	*Unio cf. crassus* Retz
							Neritina transversalis C. Pfr.	*Theodoxus transversalis* (C. Pfr.)
							Valvata piscinalis Müller	*Valvata piscinalis* (Müll.)
							Valvata macrostoma Steenb	*Vallonia pulchella* (Stud.)
							Valvata naticina, Mke.	*Valvata naticina* Menke
							Vivipara hungarica Hazay	*Viviparus acerosus* (Bourg.)
							Bithynia ventricosa Gray	*Bithynia leachi* (Shpp.) + operculum *Bithynia tentaculata* (L.) + operculum
							Lithoglyphus naticoides Fér.	*Lithoglyphus naticoides* (Fér.)
							Lithoglyphus pyramidatus v. Mlldf.	*Lithoglyphus naticoides* (Fér.)

							Limnaea (Fossaria) truncatula Müll. *var. ventricosa*	*Galba truncatula* (Müll.) *Stagnicola palustris* (Müll.)
							Planorbis (Tropidiscus) marginatus Müll.	*Planorbis planorbis* (L.)
							Planorbis (Gyrorbis) spirorbis Linné *Planorbis (Gyrorbis) leucostoma* Müll. *Planorbis (Bathomphatus) contortus* Linné *Planorbis (Corteus) corneus* Linné *Helix (Trichia) hispida* L. *Helix (Trichia) rubiginosa* Müller *Helix (Vallonia) pulchella* Müller *Helix (Striatella) striata* Müll. juv. *Succinea (Neritostoma) putris* Linné, juv *Succinea (Amphibina) Pfeiffeiri*, Rossm. *Succinea (Lucena) oblonga* Drap. *Clausilia (Kuzmićia) dubia* Drap. *Buliminus (Chondrula) tridens* Müll.	*Anisus spirorbis* (L.) *Anisus spirorbis* (L.) *Bathyomphalus contortus* (L.) *material lost *Trichia hispida* (L.) *Monachoides rubigiosa* (A. Schm.) *Vallonia costata* *Helicella hungarica* Soós et Wagn. [= *striata* (Müll.)] *material lost *Succinea elegans* Risso *Succinea oblonga* Drap. *Clausilia dubia* Drap. *Chondrula tridens* (Müll.)
Pleistocene	Viviparus boeckhi beds - older part of Middle- and Lower Pleistocene	Middle Pleistocene	Viviparus boeckhi beds - older part of Middle Pleistocene	Pleistocene	37.75–50.02	yellowish gray clay (reaction on H_2O_2)		
Pleistocene	Viviparus boeckhi beds - older part of Middle Pleistocene	Middle Pleistocene	Viviparus boeckhi beds - older part of Middle Pleistocene	Pleistocene	50.02–52.33	gray clayey sand		
Pleistocene	Viviparus boeckhi beds - older part of Middle Pleistocene	Pleistocene	Viviparus boeckhi beds - older part of Middle Pleistocene	Pleistocene	52.33–58.36	yellowish gray clayey sand		
Lower Pleistocene warm stage(s) *Viviparus boeckhi* Horizon of the Pleistocene *Corbicula* beds	Viviparus boeckhi beds - older part of Middle- and Lower Pleistocene	Lower Pleistocene - *Viviparus boechki* Horizon	Viviparus boeckhi beds - older part of Middle Pleistocene	Pliocene Upper Levantian Stage	58.36–88.52	blueish gray quartz sand with lignite and clay lenses	*Corbicula fluminalis* Müller	*Corbicula fluminalis* (Müller)
							Pisidium rugosum Neum.	*Pisidium amnicum* (Müll.) *Pisidium henslowanum* (Müll.) *Pisidium obtusale* (C. Pfr.) *Pisidium* sp. *Corbicula fluminalis* (Müller)
							Unio Sturi M. Hörn.	*Potomida sturi* (Hoern.)
							Unio Semsei Halav.	*Potomida cf. wilhelmi* (Pen.)
							Unio sp.	*Unio cf. pictorum* (L.)
							Neritina (Theodoxus) transvesalis Ziegl.	*Theodoxus transversalis* (C. Pfr.) *Theodoxus prevostianus* (C. Pfr.)
							Valvata piscinalis Müll.	*Valvata piscinalis* (Müller) *Valvata naticina* Menke
								Valvata pulchella (Stud.) *Valvata cristata* Müll. *Vallonia pulchella* (Müller) *Planorbarius corneus* (L.)
							Vivipara Zsigmondy Halav.	*Viviparus acerosus zsigmondy* (Halav.)
							Vivipara Böckhi, Halav.	*Viviparus boeckhi* (Halav.)
							Bythinia podwinensis, Neum	*Bithynia (Neumayria) crassitesta* Brömme *Bithynia nov.* sp.

							Bythinia tentaculata, Linné	*Bithynia tentaculata* (L.)
							Pyrgula (Prososthenia) Sturi, Brus.	*material lost
							Lyhoglyphus naticoides, Fér..	*Lithoglyphus naticoides* (Fér.) *Viviparus boeckhi* (Halav.)
							Melania (Melanella) Holandri, Fér..	*Amphimelania holandri*
							Limnaea Esperi, Fér..	*Fagotia acicularis* (Fér.) *Fagotia esperi* (Fér.)
							Limnaea peregra, Linné	*Succinea oblonga* Drap. *Succinea elegans* Risso
							Planorbis (Coretus) corneus, Müll.	*Planorbarius corneus* (L.) *Gyraulus albus* (Müll.)
							Planorbis (Tropidiscus) marginatus, Müll.	*Planorbis planorbis*
							Planorbis (Gyraulus) albus, Müll.	*Gyraulus albus* (Müll.) *Gyraulus laevis* (Ald.) *Valvata cristata* Müll.
							Clausilis (Kuzmićia) dubia, Drap.	*Clausilia pumila* C. Pfr.
Lower Pleistocene	Viviparus boeckhi beds - older part of Middle- and Lower Pleistocene	Lower Pleistocene	Viviparus boeckhi beds - older part of Middle Pleistocene	Pleistocene	88.52–107.40	yellowish carbonated clay		
Lower Pleistocene warm stage(s) *Viviparus boeckhi* Horizon of the Pleistocene *Corbicula* beds	Viviparus boeckhi beds - older part of Middle- and Lower Pleistocene	Lower Pleistocene Lower Pleistocene - *Viviparus boechki* Horizon	Viviparus boeckhi beds - older part of Middle Pleistocene	Pliocene “Levantian” Stage	107.40–121.90	blueish gray clay	*Corbicula fluminalis* Müller	*Corbicula fluminalis* (Müller)
							Pisidium rugosum Neum	*Pisidium amnicum* (Müll.) *Pisidium clessini* Neum *Pisidium henslowanum* (Müll.).
							Unio Sturi M. Hörn.	*Potomida sturi* (Hoern.)
							Valvata piscinalis Müll.	*Valvata piscinalis* (Müller) *Valvata naticina* Menke *Valvata pulchella* (Stud.)
							Vivipara Böckhi Halav.	*Viviparus boeckhi* (Halav.)
							Bythinia podwinensis Neum	*Bithynia (Neumayria) crassitesta* Brömme + operculum
							Bythinia tentaculata Linné	*Bithynia tentaculata* (L.)
							Lihoglyphus naticoides Fér.	*Lythoglyphus naticoides* (Fér.) *Bithynia tentaculata* (L.) Viviparus boeckhi (Halav.)
							Melanopsis Esper Fér.	*Fagotia acicularis* (Fér.) *Fagotia esperi* (Fér.)
							Limnaea (Acella) longa Halav.	*Lymnaea stagnalis* (L.)
							Planorbis (Gyraulus) albus Müll.	*Gyraulus albus* (Müll.) *Gyraulus laevis* (Ald.)
							Helicella (Xerophila) striata	*Helicella hungarica* Soós et Wagn. *[= striata* (Müll.)]
Lower Pleistocene	Viviparus boeckhi beds - older part of Middle- and Lower Pleistocene	Lower Pleistocene	Upper Levantian	Pliocene “Levantian” Stage	121.90–129.40	yellowish gray clay		

Lower Pleistocene warm stage(s) *Viviparus boeckhi* subzone of the Pleistocene *Corbicula* beds	Viviparus boeckhi beds - older part of Middle- and Lower Pleistocene	Lower Pleistocene	Upper Levantian	Pliocene "Levantian" Stage	129.40–135.18	yellowish sand with quartz gravels intercalations	*Unio* sp. *Pisidium rugosum* Neum. *Neritina transvesalis* Ziegl. *Valvata piscinalis* Müll. *Bythinia podwinensis* Neum. *Lihoglyphus naticoides* Fér. *Melanopsis Esperi* Fér.	*material lost *Spaerium rivicola* (Lam.) *Corbicula fluminalis* (Müller) *Theodoxus transversalis* (C. Pfr.) *Theodoxus prevostianus* (C. Pfr.) *Valvata piscinalis* (Müller) *Valvata naticina* Menke *Valvata pulchella* (Stud.) *Bithynia (Neumayria) crassitesta* Brömme + operculum *Lythoglyphus naticoides* (Fér.) *Fagotia acicularis* (Fér.) *Lymnaea stagnalis* (L.)
Lower Pleistocene		Lower Pleistocene	Upper Levantian	Pliocene " Upper Levantian" Stage	135.18–150.18	blue clay with concretions		
Lower Pleistocene		Lower Pleistocene	Upper Levantian	Pliocene "Upper Levantian" Stage	150.18–150.68	blueish yellow clayey sand		
Lower Pleistocene		Lower Pleistocene	Upper Levantian	Pliocene "Upper Levantian" Stage	150.68–163.20	blue clay		
Lower Pleistocene		Lower Pleistocene	Upper Levantian	Pliocene "Upper Levantian" Stage	163.20–172.00	yellowish gray clayey sand		
Lower Pleistocene		Lower Pleistocene	Upper Levantian	Pliocene "Upper Levantian" Stage	172.00–181.30	blueish gray clay with concretions		
Lower Pleistocene		Lower Pleistocene	Upper Levantian	Pliocene "Levantian" Stage	181.30–182.60	yellowish gray quartz sand		
Lower Pleistocene		Lower Pleistocene	Upper Levantian	Pliocene "Levantian" Stage	182.60–208.50	blue clay with red patches and concretions		
Lower Pleistocene Upper Paludina beds	"Eopleistocene" - Upper Paludina beds Vivipara vucotinovici zone	Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	208.50–234.54	blueish gray quartz sand	*Dreissena polymorpha*, Pallas *Valvata piscinalis*, Müller *Vivipara Zsigmondy* Halav. *Vivipara Berthae*, n. Sp. *Vivipara Etelkae* n. sp. *Bythinia podwinensis*, Neum.	*Dreissena polymorpha* (Pall.) *Valvata* cf. *obtusaeformis* L[illegible]r *Viviparus acerosus zsigmondyi* (Halav.) *Viviparus cf. suessi* (Neum) *Viviparus berthae* (Halav.) *Viviparus etelkae* *Bithynia (Neumayria)* cf. *Podwinensis* Neum.

							Pyrgula (Prososthenia) Sturi Brus. *Lithoglyphus decipiens* Brus. *Melanopsis pyrum* Neum. *Melanopsis* cfr. *Lanceolata* Neum.	*Hydrobia (cf. Prososthenia)* nov. sp. *Lithoglyphus* cf. *decipeins* Brus. *Melanopsis* sp. *Melanopsis lanceolata* Neum.
		Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	234.54–249.50	yellowish gray clay with concretions		
		Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	249.50–256.30	gray clayey sand		
Paludina Beds	"Eopleistocene"-Middle Paludina beds	Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	256.30–268.00	blue clay with yellowish gray or red patches	*Unio slavonicus* M. Hörn. *Unio Sandbergeri* Neum. *Unio levanticus* n. sp. *Unio Beyrichi* Neum.	*Potomida slavonica* (Hoern.) *Potomida sandbergeri* (Neum.) *material lost *Unio beyrichi* Neum.
Paludina Beds	"Eopleistocene"-Middle Paludina beds	Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	268.00–275.00	blue clay with yellowish gray or red patches	*Melanopsis recurrens* Neum. *Melanopsis hybastoma* Neum.	*Melanopsis slavonica* Neum. *Melanopsis hybastoma* Neum.
Paludina Beds	"Eopleistocene"-Middle Paludina beds	Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	275.00–315.12	blue clay with yellowish gray or red patches		
Paludina Beds	"Eopleistocene"-Middle Paludina beds	Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	315.12–319.19	gray sandy clay		
Paludina Beds	"Eopleistocene"-Middle Paludina beds	Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	319.19–321.00	dark brown clay		
Paludina Beds	"Eopleistocene"-Middle Paludina beds	Upper Pliocene	Middle Levantian	Pliocene "Middle Levantian" Stage	321.00–323.74	gray quartz sand	*Unio sibinensis* Pen. *Vivipara bifarcinata* *Melanopsis aff. Hybastoma* Neum.	*Potomida slavonica* (Hoern.) *Viviparus bifarcinatus* (Bielz.) *material lost
			Middle Levantian		323.74–328.58	sandy clay with concretions		
			Middle Levantian		328.58–343.00	brown and blue clay		
			Middle Levantian		343.00–347.00	sandy clay		
			Middle Levantian		347.00–357.90	brown and blue clay		
			Middle Levantian		357.90–361.80	sandy clay		
			Middle Levantian		361.80–367.43	gray quartz sand		
			Middle Levantian		367.43–421.56	brown and blue clay		
			Middle Levantian		421.56–421.93	sandstone		
			Middle Levantian		421.56–427.60	greenish sandy clay		
			Middle Levantian		427.60–442.10	brown and blue clay		
			Middle Levantian		442.10–445.43	green clayey sand		
			Middle Levantian		445.43–452.48	sandy clay		