UDK: 556.5(497.113)

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HIDROGEOHEMIJSKA ISTRAŽIVANJA U JUGOISTOČNOM BANATU NA TERITORIJI REPUBLIKE SRBIJE

HYDROGEOCHEMICAL INVESTIGATION OF SOUTH-EASTERN BANAT, A PART OF REPUBLIC OF SERBIA

REZIME

U fazi istraživanja geološkog statusa područja jugoistočnog Banata, prikupljeni su uzorci sa površinskih akvatorija, bunara i jezera. U vodi je determinisan sadržaj U, Ra, Rn. Mreža uzorkovanja je prilagođena hidrografskim karakteristikama terena, i napravljena je hidrogeohemijska mapa 1:50 000. Pored hidrogeohemijske prospekcije, uzeti su uzorci rečnih sedimenata zemljišta kako bi se odredio profil obale sledećih jezera: Vračarevo, Šaransko, Bagersko i Veliko jezero.
Regionalna hidrogeohemijska prospekcija obuhvatila je područje Bele Crkve, koje dreniraju sedimente Neogena i Kvartara. U ovom području i šire, u skladu sa rezultatima regionalnih ispitivanja, obavljena su i poludetaljna geološka-geohemijska istraživanja u cilju identifikacije ležišta mineralnih sirovina, kao i izvorišta za vodosnabdevanje ruralnih naselja. U toku prospekcije, prikupljeni i ispitani su uzorci voda iz površinskih tokova, izvora, bunara, jezera, vodenih akumulacija, potočnih sedimenata i uzorci stena.

Ključne reči: voda, hidrogeohemija, prospekcija, životna sredina.

ABSTRACT

In the research phase of the geological status of the area of southeastern Banat, samples were collected from surface waters, wells, and lakes. The content of U, Ra, Rn is determined in water. The sampling network was adjusted to the hydrographic characteristics of the terrain, and a hydrogeochemical map has been made at a scale of 1:50 000. In addition to hydrogeochemical prospecting, samples of the soil river sediments were taken to determine the profile of the coast of the following lakes: Vračarevo, Šaransko, Bagersko and Veliko lake.
The regional hydrogeochemical prospecting included the area of the Bela Crkva, which drained the sediments of Negotin and Kvartara. In this area and wider, in accordance with the results of regional investigation, semi-geological and semi-geochemical research was carried out to identify resources of mineral deposits as well as the sources for water supply of rural settlements. During research, samples of water from surface streams, sources, wells, lakes, water reservoirs, creek sediments and wall samples were collected and examined.

Key words: water, hydrogeochemistry, prospection, environment.

UVOD

Područje istraživanja nalazi se u jugoistočnom Banatu i predstavlja krajnji jugoistočni deo Panonske nizije. U morfogenom smislu ovo područje podeljeno je na tri celine: peščaru, zapadno od Bele Crkve; lesnu zaravan i rečno jezersku terasu; najniže delove terena predstavlje aluvijalnim ravnima. Ovde je formirana izdan sa slobodnim nivoom ili takozvana prva izdan, koja se lokalno eksploatiše preko plitkih kopanih bunara za vodosnabdevanje ili navodnjanvanje.

Prisustvo uranskih ležišta u Rumuniji (Čudanovica Dobre), koja se nalaze u zoni Rešica–Moldava Nova, na relativno bliskom rastojanju od granice sa Srbijom,

INTRODUCTION

The research area is located in the southeastern Banat and it represents the extreme south-eastern part of the Pannonian Plain. In the morphogenic sense, area is divided into three parts: sandy terrain, west of Bela Crkva; a loess plateau and a fluvial terrace; the lowest parts of the terrain represented by alluvial ravines. Also, there is an aquifer formed with a free level or the so-called first issued aquifer, which is locally exploited through the shallow dug wells for water supply or irrigation.

The presence of uranium deposits in Romania (Čudanovica Dobre), located in the Rešica-Moldava Nova zone at a relatively close distance from the

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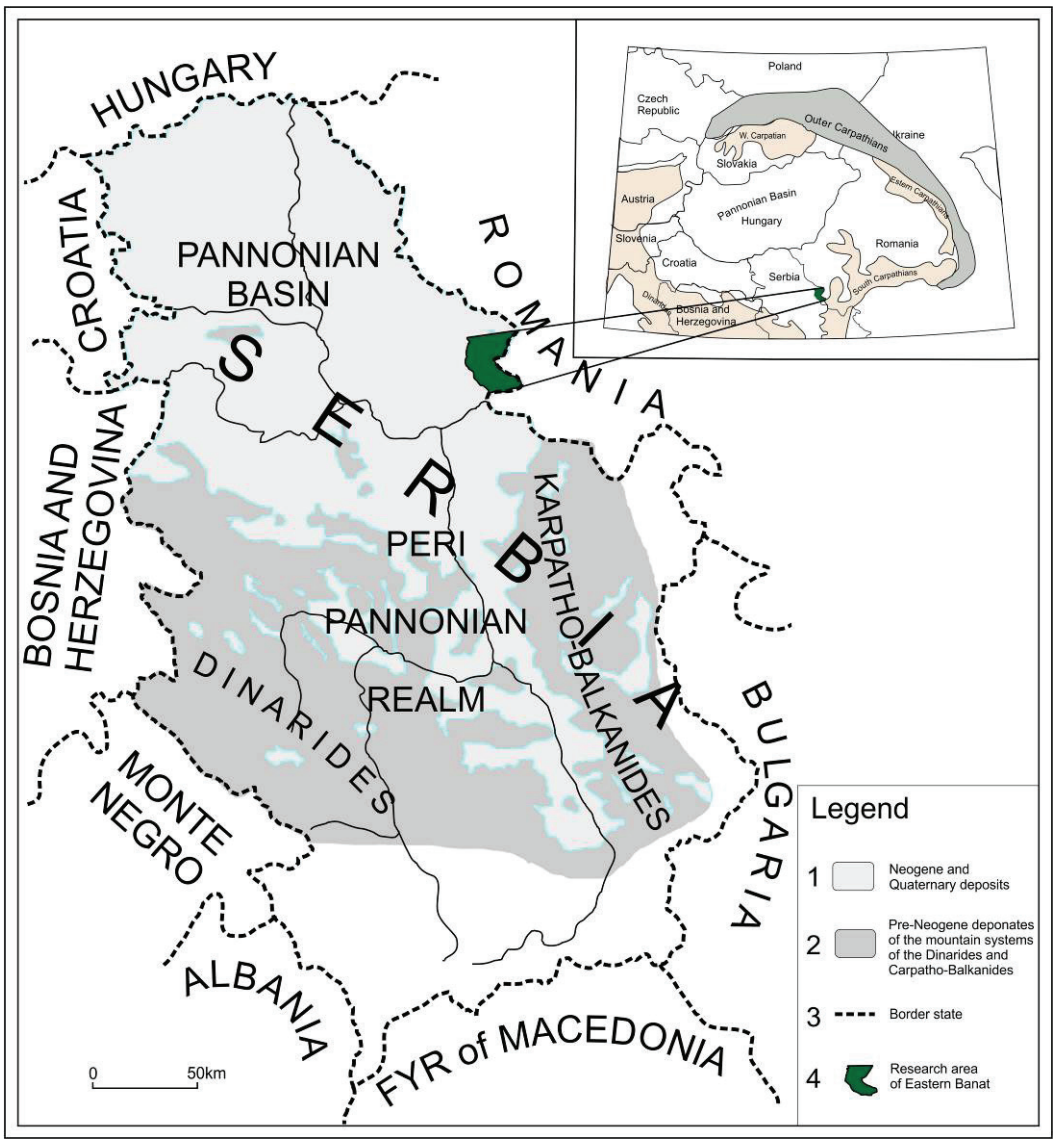
nametnula su potrebu za istraživanjem regiona Vršac-Bela Crkva, koji takođe pripada jugoistočnom Banatu, kao perspektivnom području za otkrivanja ležišta urana i drugih mineralnih sirovina (Slika 1).

Najranija istraživanja datiraju iz vremena XIX veka, od J.Halavats (1880-1886) [1] koji je uradio prvu geološku kartu okoline Vršca u razmeri 1:144000 sa tumačem. Najvažniji podaci o ispitivanom području dobijeni su prilikom istraživanja nafte i gasa. Istraživanja su nastavljena sa povremenim prekidima i obuhvatila su brojna ispitivanja iz oblasti geologije, hidrogeologije, geofizike, geohemije. Za potrebe vodosnabdevanja grada (Bela Crkva) i okolnih ruralnih naselja, u području Bele Crkve izvršeno je sistematsko praćenje distribucije hemijskih elemenata u različitim sredinama geosfere, što je od posebnog značaja za praćenje prirodnog i antropogenog uticaja na životnu sredinu i definisanje geo-ekološkog statusa.

U određivanju geo-ekološkog statusa područja

border with Serbia, imposed a need for exploration of the Vršac-Bela Crkva region of the southeastern Banat as a perspective area for the uranium detection and deposits of other mineral raw materials (Figure 1).

The earliest research dates back to the 19th century, done by J. Halavats (1880-1886) [1] who made the first geological map of the Vršac area at the scale of 1: 144000 with an interpreter. The most important data of the investigated area were obtained during the exploration of petroleum and gas. The investigations continued with intermittent interruptions and included numerous studies in the field of geology, hydrogeology, geophysics, geochemistry. For the needs of city water supply (Bela Crkva) and the surrounding rural settlements, a systematic monitoring of the chemical elements distribution in different geosphere areas was performed. This is of particular importance for monitoring the natural and anthropogenic impact on the environment and defining the geo-ecological status.



Slika 1. Lokacija istraživanog područja Panonskog basena u Srbiji

Figure 1. Location of the investigated area of the Pannonian basin in Serbia

jugoistočnog Banata korišćeni su sledeći rezultati: regionalno istraživanje za nuklearnim sirovinama na području Bela Crkva-Vršac i rezultati geohemijsko-radiometrijske prospekcije iz perioda 2014. godine. Istraživano područje obuhvata oblast od 500 km², a izgrađena je na kristalastim škriljcima, granitu, zatim miocenskim, pliocenskim i kvarternarnim sedimetima sa pojavama ruda Pb i Zn.

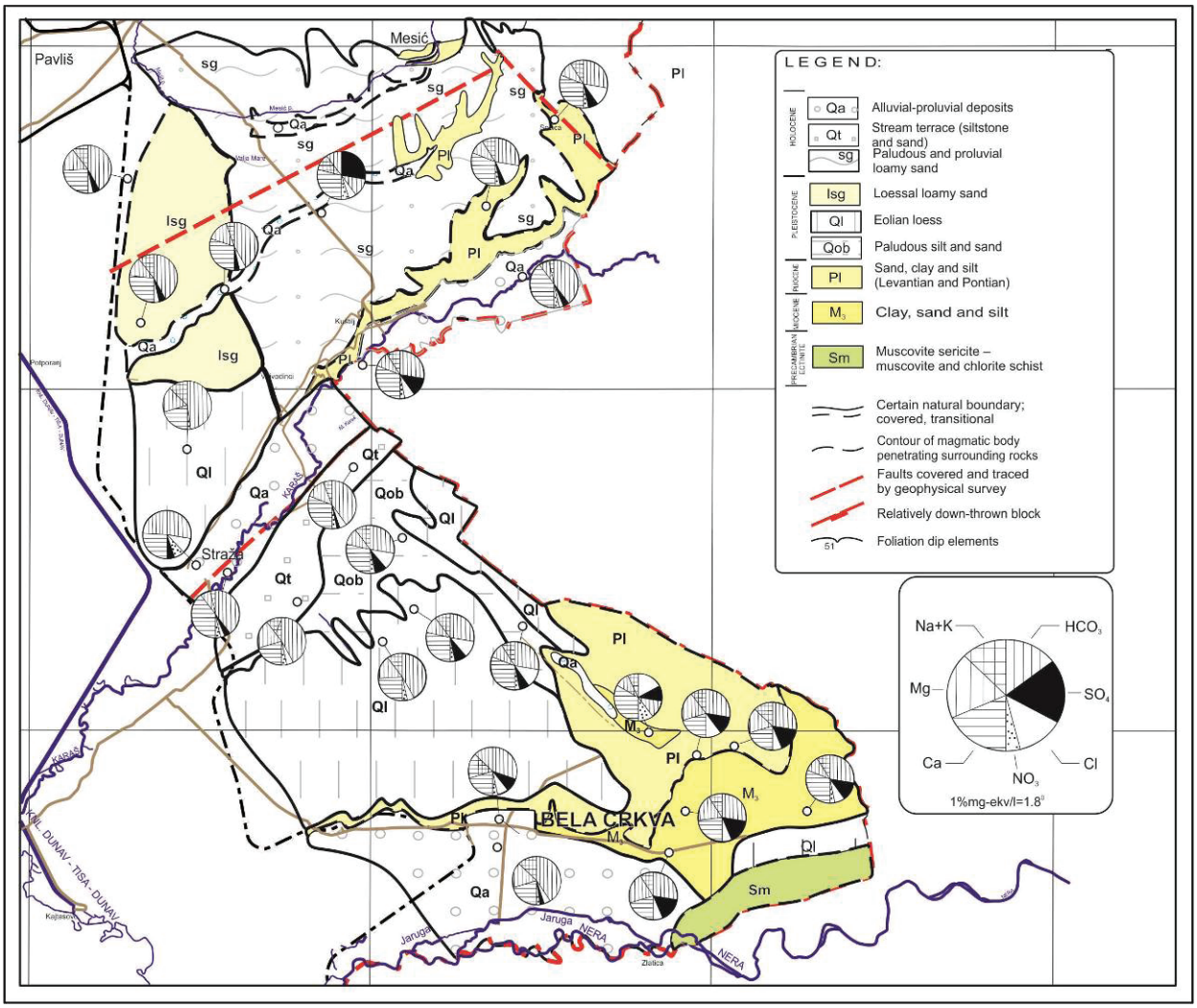
GEOLOŠKA STRUKTURA TERENA

Na području jugoistočnog Banata, kvaternarne formacije su fluvijalnog i eolskog porijekla, a deponirane su u vreme kada je Panonski basen bio zemljište sa rekama i jezerima. Debljina kvartarnih formacija je oko 120 m. Pleistocen je prisutan na širem području Bele Crkve [2]. Sedimenti stvoreni u kontinentalnim uslovima imaju fluvijalno i eolsko poreklo. Holocen se razvija u morfološki najnižim delovima terena (podnožje severno i južno od brda Vršca) i duž korita manjih i većih reka (Mesić, Guzijana, Nera, Karaš). Sedimenti su heterogenog sastava i sastoje se od: barskih, proluvijalnih suglina

In determining the geo-ecological status of the area of southeastern Banat, the following results were used: regional research of nuclear raw materials and results of geochemical-radiometric research from the period of year 2014. The investigated area covers 500 km², and it was built on crystalline shales, granite, then on Miocene, Pliocene, and Quaternary sediments with Pb and Zn ores.

METHODOLOGY AND GEOLOGICAL STRUCTURE OF TERRAIN

In the area of Bela Crkva, Quaternary formations are of fluvial and eolian origin and they were deposited in the time when Pannoinan basin became land with rivers and lakes. Thickness of Quaternary formations is about 120 m. Pleistocene is present in the wider area of Bela Crkva [2]. These sediments were created in continental conditions and they are of fluvial and eolian origin. Holocene is developed in morphologically lowest parts of the terrain (foothill northern and southern from Vršac hill) and along the smaller and bigger river-bads (Mesić, Guzijana, Nera, Karaš). Sediments have heterogeneous composition



Slika 2. Anjonsko-katjonski sastav područja jugoistočnog Banata

Figure 2. Anionic-cationic composition of the south-eastern Banat

(Sg), drobina, rečnih terasa (alevrita i peska-Qz) i aluvijalnih proluvijalnih tvorevina (plavina sa šljunkom, peskom i alevroliti-Qa). U jugoistočnom delu područja Banata nalaze se sedimenti Miocena (M) i Pliocena (Pl1) koji sadrže pesak, glinu, peščanu glinu, laporit, alevrolit (panon) i epidot-amfibolit, epidot-hlorit-aktinolit, epidot-hlorit škriljce (Sep) i hlorit-serikitni-kvarcne škriljce (Sco) Devonskog doba (prikazano na osnovnoj geografskoj karti razmere 1: 100000, slika 2.).

U skladu sa karakteristikama geološke strukture terena u istraživanom području izolovane su dve različite hidrogeološke jedinice. Na severu, izdvaja se područje Vršačkih brda izgrađeno od kristalastog škriljca u masama granita, dok se na jugu, u predelu Bele Grkve izdvaja područje ravnih terena sa naslagama tercijarnih i kvarternarnih sedimenata. Zbog položaja stenskih masa i njihove poroznosti formirani su različiti tipovi izdani u palaelozojskom periodu (Vršačka brda). Ovaj kompleks je tektonski prilično uzdrman, a strukture su formirane i protežu se duž pravca severoistok-jugozapad. Izdani se snabdevaju isključivo padavinama, i isušuju se preko manjih izvora, čija su vrela protočnosti od 0,1 L/sec do 1,1 L/sec i nalaze se na 50-100 m ispod vrhova Vršačkih brda. Površina sa koje se odliva voda ovim područjem proteže se pravcem severoistok i jugozapad u skladu s strukturnim i morfološkim karakteristikama terena. Kompaktni akviferi su formirani u međugranularnim akviferima tercijarnih i kvartarnih naslaga. U njima postoje više vodenih horizonta, koji su međusobno povezani. Ova vrsta položaja arteških vodenih horizonta omogućava preliv mineralizovane vode iz dubljih u plitke slojeve.

U svim uzorcima voda određeni su sadržaji U, Eh, pH i Ep. U vodama sa povišenim sadržajem urana, promenama pH, Eh i Ep urađene su kompletne hemijske analize voda, i to: anjonsko-katjonski sastav, sadržaj mikroelemenata i radioaktivnih elemenata U, Ra i Rn, sadržaj gasova O_2, CO_2, H_2S [3] (Slika 2).

METODE

Za određivanje sadržaja metala u vodama, primenjena je atomsko apsorpciona spektrofotometrija (AAS Perkin Elmer M306). Za ostale komponente, u vodenim rastvorima korišćene su kolorimetrijske, volumetrijske, potenciometrijske i turbidmetrijske metode. Uran je određivan pomoću laserskog fluorimetra UA firme Scintrex kanadske proizvodnje, sa fluranom kao karakterističnim reagensom. Koncentracije radijuma su merene pomoću radon detektora RD-200 EDA, a koncentracije radona merene su emanometrom ETR-1 Scintrex, Kanada.

and they consist of: prolluvial clay (Sg), debris, river terraces (alevrites and sand-Qz) and alluvial prolluvial formations (flood gravel, sand and alevrolites-Qa). In southeastern Banat there are sediments of Miocene (M) and Pliocene (Pl1) composed of sand, clay, sandy clay, marls, alevrolites (panon) and epidote-amphibolite, epidote-chlorite-actinolite, epidote-chlorite schists (Sep) and chlorite-sericite-quartz schists (Sco) of Devonian age (presented at the geographical map at the scale 1:100000, figure 2).

In accordance to geological-structural characteristics of the terrain in the investigated area two different hydrogeological units were isolated. In the north, the area of Vršac hills is built of crystalline schists in granite masses, and in the south flat terrains are intruded (the area of Bela Crkva) with deposits of Tertiary and Quaternary sediments. Due to the position of rock masses and their porosity different types of aquifers were formed during the Palaeozoic period (Vršac hills). This complex is tectonically quite disturbed, and the formed structures extend along northeast-southwest direction. The aquifers are exclusively supplied by infiltration of precipitation. They drained over smaller springs, with a flow of 0,1 L/sec to 1,1 L/sec and they appear at 50-100 m below the Vršac hills. The water outflow surface expands in the direction northeast-southwest which is in compliance to structural and morphological characteristics of the terrain. Compact aquifers were formed in intergranular aquifers (mainly sand) of Tertiary and Quaternary deposits. There are different water horizons in aquifers which are interconnected. This position of artesian water horizons enables the overflow of mineralized water from deeper into the shallower layers.

In all water samples, contents of U, Eh, pH and Ec were determined. In water with the increased content of uranium, pH, Eh and Ec changes, the complete chemical analyses were conducted: anionic-cationic composition, content of microelements and radioactive elements U, Ra and Rn, content of gases O_2, CO_2, H_2S [3] (Figure 2).

METHODS

To determinate the metal content in water, atomic absorption spectrophotometry has been used (AAS Perkin Elmer M-306). For other components in water solutions, colorimetric, volumetric, potentiometric and turbidimetric methods were used. Uranium was determined using the laser fluorimeter UA of Canadian production of Scintrex company, with fluran as the characteristic reagent. Radium concentrations were measured by radon detector RD-200 EDA, and radon concentrations were measured by radon emanometer ETR-1 Scintrex, Canada.

REZULTATI I DISKUSIJA

Teren je izgrađen od kvartarnih tvorevina, koje su fluvijalnog i eolskog porekla i taložene su u vreme kada je Panonski basen postao kopno, sa rekama, jezerima i barama. Tvorevine se sastoje barskim alevrolitima (Qab), eolskim lesom (Ql), lesoidnim glinama (Slika 2). Kvartarne tvorevine Pleistocena i Holocena, zahvataju oko 70% ukupne površine područja jugoistočnog Banata.

Debljina Pleistocena u području Vršca je oko 30-60 m, a u severnom i zapadnom delu dostiže 100 m. Holocen je razvijen u morfološki najnižim delovima terena (severno i južno od Vršačkih brda) kao i duž korita manjih ili većih reka, Nere i Karaša.

U hidrogeološkom smislu teren je složene geološke građe. U severnom delu od Bele Crkve teren je izgrađen je od starih stenskih masa – graniti, gnajsevi, albitsko–muskovitski škriljci a sa južne strane nailazimo na naslage tercijarnih i kvartarnih sedimenata [4]. Položaj stenskih masa i karakter poroznosti u njima uslovili su da se u tom delu terena formiraju izdani različitog tipa. Strukturni elementi stenskih masa se prostiru u pravcu severoistok jugozapad, te su u tom smeru razvijeni površinski tokovi koji dreniraju ovo područje. Podzemne vode su pretežno, slabo mineralizovane (oko 0,4-0,5 g/L), pH neutralne reakcije i umereno tvrde. Nalaze se u otvorenoj hidrogeološkoj strukturi, gde se vrši intenzivna vodozamena, pa su i sadržaji pojedinih hemijskih komponenti podložni promenama u funkciji vremena. Slobodna izdan zbijenog tipa formirana je na celom prostranstvu aluvijalno-jezerskih sedimenata. Ova izdan je razvijena u aluvijalnoj ravni reke Karaš i Nera, zatim u peskovima koji se lokalno nalaze na različitoj dubini [5]. Dubina do podzemne vode je pretežno 5-10 m, a na manjem prostranstvu dubina varira iznad i ispod ove vrednosti. Hidroizohipse prve izdani uglavnom prate izohipse terena i ukazuju na pravce dreniranja podzemnih voda.

U području Bele Crkve i šire (Vršačka Brda) u fazi hidrogeohemijskog istraživanja, prikupljeni su uzorci voda iz površinskih tokova, izvora, bunara i jezera. Prema anjonsko-katjonskom sastavu, vode pripadaju hidrokarbonatnom tipu (Slika 2). Po zastupljenosti katjona, u vodama preovlađuju kalcijum i magnezijum, što ih svrstava u kalcijsko-magnezijske (Ca-Mg), magnezijsko-kalcijske (Mg-Ca) tipove voda. Od ostalih katjona u znatno manjoj količini su pronađeni Na^+ i K^+. Mineralizacija se kreće u intervalu od 138 mg/L do 4557 mg/L. U Vršačkim brdima koncentracija vodonikovih jona varira od 5,5-7,9, pa se ove vode mogu svrstati u grupu slabokiselih do slaboalkalnih voda. Povećani sadržaji litijuma uslovljeni su blizinom granitske intruzije u Vršačkim brdima, zone sitnozrnih gnajseva sa leptinolitima, aplitima i žicama pegmatita. Glinoviti materijali u sedimentima Bele Crkve, za razliku od drugih alkalnih elemenata (litijum, rubidijum,

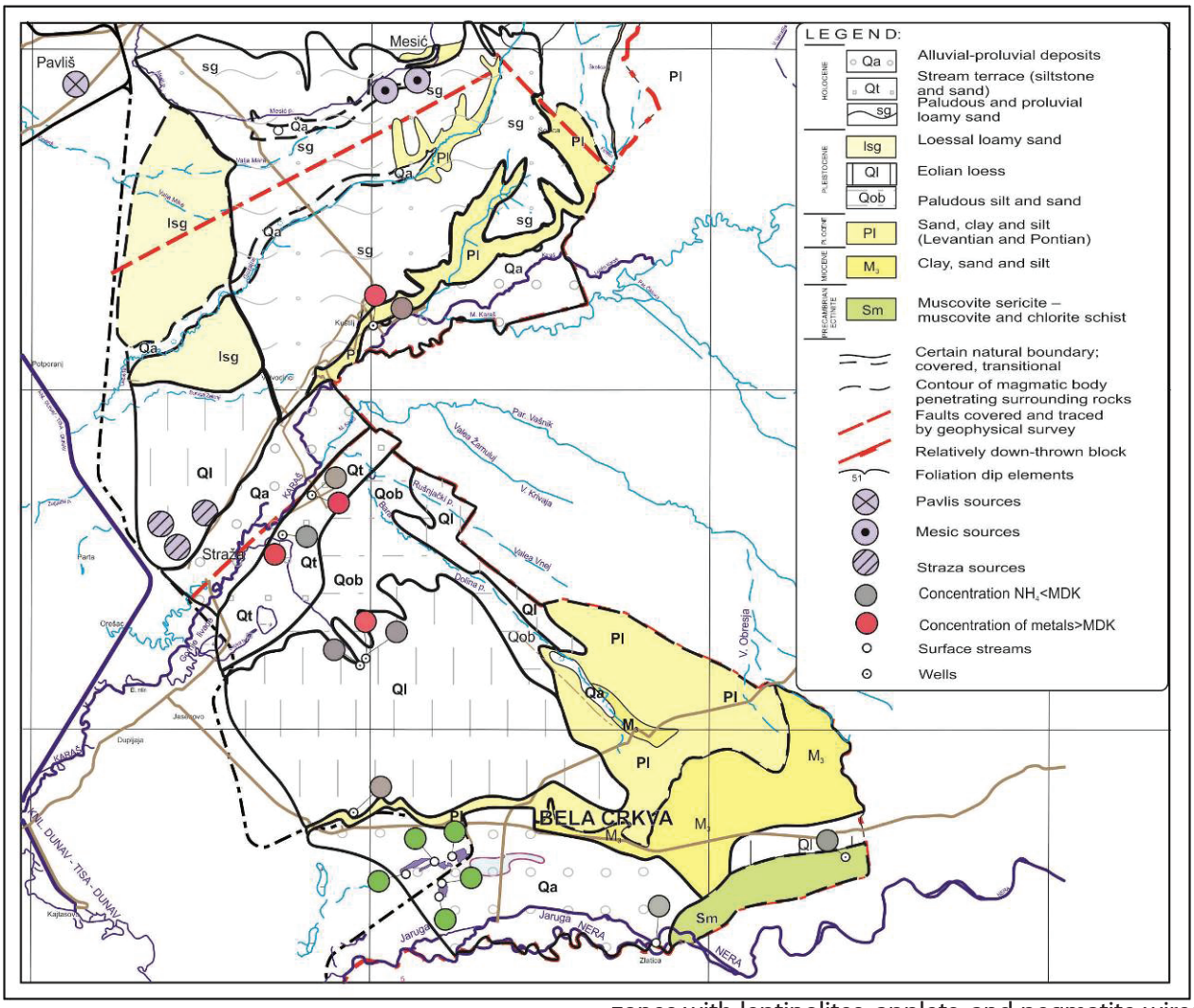
RESULTS AND DISCUSSION

The terrain is built of quaternary structures, which are of fluvial and eolian origin and deposited at a time when the Pannonian Basin became land, with rivers, lakes, and puddles. Structures are composed of puddle alevrolytes (Qab), eolian timber (Ql), loess clay (Figure 2). Quaternary structures of Pleistocene and Holocene occupy about 70% of the total area of the south-eastern Banat.

The thickness of the Pleistocene in the Vršac area is about 30-60 m, and in the north and west it reaches 100 m. Holocene was developed in the morphologically lowest parts of the terrain (north and south of the Vršac hills) and along the banks of smaller or larger rivers, Nera and Karas.

From the hydrogeological point, the terrain is of complex geological structure. In the northern part of Bela Crkva, the terrain was built of old rock masses - granite, gneiss, albite-Muscovite shale and on the south side we find deposits of tertiary and quaternary sediments [4]. The position of the rock masses and their porosity caused formation of different types of aquifers in this part of the terrain. Structural elements of the rock masses extend in the direction of the northeast southwest, and therefore in this direction surface streams are developed, which further drain the area. Groundwater is predominantly, poorly mineralized (approx. 0.4-0.5 g / L), of pH neutral reaction, and moderately hard. It is located in an open hydrogeological structure, where intensive water intake is carried out, so the contents of certain chemical components are subject to changes in the function of time. The free aquifer groundwater of compact type is formed on the entire area of alluvial-lakes sediments. This aquifer was developed in the alluvial plane of the Karas and Nera River, then in sands locally at different depths [5]. The depth to the groundwater is predominantly 5-10 m, and at a smaller expanse the depth varies above and below this value. Hidroizohipse of the first aquifer generally follow the contour lines of the terrain and point to directions of underground water draining.

Water samples from surface streams, springs, wells, and lakes were collected in the area of Bela Crkva and the wider (Vršačka Brda) in the phase of hydrogeochemical research. Due to the anion-cation composition, the water belongs to the hydrocarbonate type (Figure 2). Calcium and magnesium are prevalent cations in water, and due to their presence, these waters belong to calcium-magnesium (Ca-Mg), magnesium-calcium (Mg-Ca) water types. Na+ and K+ are found in very small concentrations. Mineralization ranges in the interval from 138 mg/L to 4557 mg/L. In the Vršac hills, the concentration of hydrogen ions varies from 5.5-7.9, so these waters can be classified into a group of low-acid water to low-alkaline waters. The increased lithium content is due to the proximity of the granite intrusions in the Vršac hills, the fine-grained gneisses



Slika 3. Geoekološka karta hemijskih sadržaja preko maksimalno dozvoljene koncentracije (MDK)
Figure 3. Geoecological map of chemical content over maximum permissible concentration (MDK)

cezijum) slabo apsorbuju stroncijum. Kako su joni ovih elemenata veliki, oni ne mogu biti apsorbovani u zgusnutu strukturu glinovitih minerala s izuzetkom višeslojne strukture monmorionita. Povišeni sadržaji stroncijuma vezani su za hidrokarbonatne vode i verovatno vode poreklo od granitskog intruziva. Anomalne koncentracije U, Ra i Rn u vodama nalaze se u području Vršačkih Brda.

Područje Bele Crkve uključuje i vodene akumulacije jezera: Vračarev Gaj, Jezero, Šaransko jezero, Bagersko jezero. Analize voda iz ovih jezera, pokazale su, na osnovu dobijenih rezultata da su slabo alkalnog karaktera. Koncentracija amonijum jona, prema maksimalno dozvoljenoj količini opasnih materija MDK, [6] svrstava ove vode u kategoriju III/IV. Izražen je azotni ciklus ali sadržaj nitrata ne prelazi maksimalno dozvoljenu vrednost. Ni u jednom uzorku nije detektovan vodonik-sulfid, kao proizvod anaerobnog raspadanja, što znači da nema procesa truljenja i raspadanja. Ove vode su po svom sastavu uglavnom kalcijum-sulfatne, a po mineralizaciji uglavnom pripadaju vodama I odnosno II kategorije

zones with leptinolites, applets, and pegmatite wires. The clay materials in the sediments of Bela Crkva, unlike other alkaline elements (lithium, rubidium, cesium), poorly absorb strontium. As the ions of these elements are big, they cannot be absorbed into the thickened structure of clay minerals, with the exception of the multilayer structure of the monomionite. Increased strontium content is associated with hydrocarbonate water and is likely to originate from granite intrusive. Anomalous concentrations of U, Ra and Rn in waters are found in the area of Vršac hills.

In the area of Bele Crkve we also found water reservoirs of the following lakes: Vračarev Gaj Jezero, Veliko, Šaransko, and Bagersko lake. Water analysis from these lakes has shown, on the basis of the obtained results, that they are poorly alkaline. The concentration of ammonium ion, according to the maximum permitted quantity of hazardous substances, MDK, [6] places these waters in category III / IV. A nitrogen cycle is expressed, but the nitrate content does not exceed the maximum allowed value. Hydrogen sulphide was not detected in any sample, as a product of anaerobic decomposition, meaning that the process of decay and decomposition is absent. These waters have calcium-sulphate, and according to mineralization, they mostly belong to the waters of I and II categories [7]. It is important to point out that, by the content of

[7]. Bitno je istaći da se, i po sadržaju teških metala mogu svrstati u I/II kategoriju voda prema navedenoj uredbi.

Povećani sadržaji amonijaka i nitrita daju lošu bakteriološku sliku. U većini bunara je povećan sadržaj Fe i Mn što je karakteristika podzemnih voda ovog područja, pa se iz pojedinih bunara prikazanih na hidrogeohemijskoj karti (Slika 3) ne mogu koristiti kao voda za piće [8].

ZAKLJUČAK

U fazi regionalnih, poludetaljnih i detaljnih istraživanja, u region Bele Crkve i Vršačkih brda, definisan je nivo izdani za vodosnabdevanje ruralnih naselja.

U toku hidrogeohemijskog ispitivanja, u svakom uzorku vode: površinskih tokova, izvora, bunara i bušotina, urađene su hemijske analize od značaja za istraživanje ležišta mineralnih sirovina, a koje čine osnovu u proceni uticaja geološkog sastava na životnu sredinu.

U području Bele Crkve, evidentne su anomalne koncentracije elemenata u vodama reke Karaš i Nere i drugih vodopunktova, koje su posledica antropogenog uticaja prekograničnog zagađenja, a prikazane su na geoekološkoj karti.

Prikazani rezultati hemijskih analiza voda, izabranih vodopunktova u ruralnim naseljima kao što su tip izdani i kvalitet voda, čine osnovu u prostornom planiranju i zaštiti životne sredine.

ZAHVALNICA

Ovaj rad je realizovan uz finansijsku podršku Ministarstva prosvete, nauke i tehološkog razvoja, Republike Srbije (Projekat OI 176018).

heavy metals, they can be classified in the I / II category of waters in line with actuel regulations.

The increased levels of ammonia and nitrite give a pure bacteriological picture. In most wells the content of Fe and Mn is increased, which is a characteristic of the underground waters of this area, and from some wells shown on the hydrogeochemical map (Figure 3) water cannot be used for drinking [8].

CONCLUSION

At the stage of regional, semi-detailed and detailed research, in the region of Bela Crkva and Vršačka hills, the level of aquifers for the water supply of rural settlements has been defined.

During hydrogeochemical testing, in each water sample: surface streams, springs, wells and wells, chemical analyzes of importance for the research of deposits of mineral resources have been performed, forming the basis for assessing the influence of geological composition on the environment.

In the area of Bela Crkva, there are evident anomalous concentrations of elements in the waters of the Karash and Nera River and other watercourses, which are the result of anthropogenic impact of transboundary pollution, and are shown on the geoecological map.

The presented results of chemical analyzes of water, selected watercourses in rural settlements, such as aquifers tzpe and water quality, form the basis for spatial planning and environmental protection.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Education, Science and Technological Development, Republic of Serbia (project No. OI 176018).

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