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HYDROGEOLOGICAL CHARACTERIZATION AND GENESIS OF MINERAL WATER "TESANJSKI KISELJAK"

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ABSTRACT

Ensuring the exploitation and use of mineral water "Tešanjski kiseljak" implies the analysis and performance of complex geological, hydrogeological, hydrological, quantitative, qualitative and genetic research, as well as the definition and establishment of high ecological standards in the researched area of the "Tešanjski kiseljak" source, along with exemplary field and laboratory and cabinet analyzes and data processing.
The basic criteria for defining the genesis and regime, hydrogeological relations and protection of mineral waters are geological and geomorphological characteristics of the terrain, climatic and hydrographic conditions, structural-tectonic and hydrogeological characteristics of the terrain, quantitative and qualitative characteristics of the source, existing and potential pollutants of the source, analysis of genetic and hydrodynamic aquifer parameters from which protection zones and source protection measures arise
Depending on the hydrogeological characteristics of the terrain, the relationship between permeable and impermeable rocks, the position of the aquifer in relation to atmospheric and surface waters, recharge conditions, permeability and hydrogeological parameters, the existence of the water body of mineral waters, the renewal of its reserves and the quality of mineral waters depends.

Key words: mineral waters, hydrogeological categorization, structural-tectonic relations, water genesis

INTRODUCTION

The source of "Tešanjski kiseljak" is in the valley of the Raduška river, whose valley stretches in a southwest-northeast direction all the way to lower Srednja Raduša, when it abruptly changes its direction to the east, in the direction of Tešnja. The width of the valley in the area that gravitates to the source is about 100-150 meters and was cut by erosion into relatively soft formations of the ophiolitic melange, while downstream from the source, the Raduša valley was cut into Oligomiocene sediments. The mineral water deposit "Tešanjski kiseljak" belongs to the hydrogeochemical area of mineral and thermomineral waters with CO2 of the "ophiolitic zone". The hydrogeological characteristics of the investigation area of the source should be observed through the prism of hydrogeological categorization, reionization and function of rock masses, filtration characteristics, crack systems and faults, hydrogeological collectors and isolators, and the directions of movement of underground water, along with the analysis of the complex conditions of the genesis of mineral water. The hydrogeological characteristics of the research area are conditioned by very complex stratigraphic-tectonic and genetic relationships. For this reason, underground water and currents move from greater depths through fault zones and larger cracks and appear on the surface in cracked rock masses. The primary and actual collectors are probably on the large depths, and all analyzes point to Triassic limestones. The system of cracks in the diabase-hornblende formation is connected to secondary faults perpendicular to the direction of the primary fault zones, a and the springs appear on the surface as overflow springs. The movement of groundwater in a porous environment is very complex due to the fact that in such massifs, groundwater is free level and moves along the line of least resistance, i.e. privileged directions or faults.

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1. GEOLOGICAL STRUCTURE AND TERRAIN TECTONICS

The geological structure and tectonic relations of the research area are given according to the data of OGK 1:100,000 sheet L 34-121 Zavidovići and Tumač, p. 1-47, Savezni geološki zavod, Belgrade, authors Olujić, J., and Coauthors , 1973, and OGK 1:100,000 L 33132 Teslić and Tumač, p. 1- 58., Savezni geološki zavod, Beograd, authors Olujić, J., and Coauthors, 1981. Within the broader and narrower area covered by the geological map, the terrain is predominantly built of Jurassic, Jurassic-Cretaceous, Tertiary and Quaternary formations.

Mesozoic or Jurassic deposits are made up of masses of ophiolites and mélanges, and are primarily represented by large masses of ultrabasic rocks such as peridotites, serpentinites, amphibolites, dolerites, diabases, metadiabases, shale and sandstone complexes, tuffs, carbonate rocks and conglomerates.
Jurassic-Cretaceous and Cretaceous deposits are represented by clastic and carbonate sediments, such as conglomerates, breccia limestones, marls, marly limestones and less often limestones with conglomerates, etc. Cenozoic deposits are represented by Paleogene flysch sediments and Neogene Tortonian limestones and clastites. The Quaternary is represented by various types of sediments: terrace, alluvial and slope.

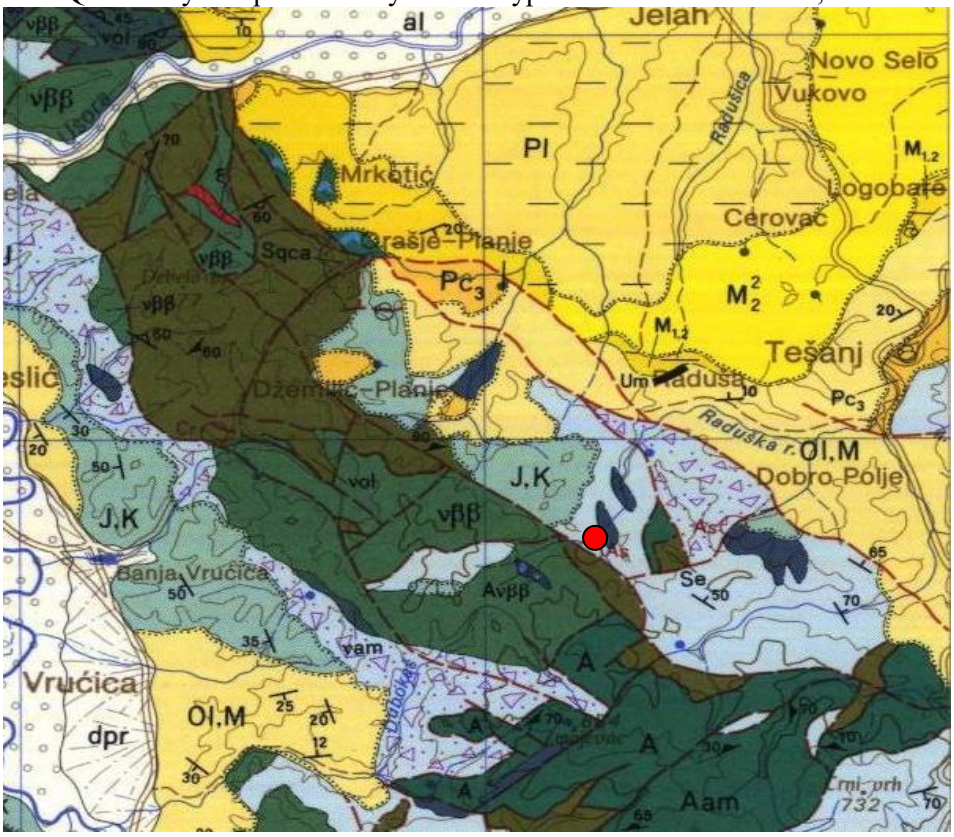

Figure 1. Geological map of the wider area of Raduša 1:100,000 (OGK list Teslić)

From a structural-tectonic point of view, the terrain around Raduša, according to the interpreter of the OGK sheets Teslić and Doboj, belongs to the structural-facies unit Central-ophiolitic melange, i.e. the Doboj block. The lowest member in this block is the ophiolitic mélange (J). Jurassic-Cretaceous, Paleogene and Neogene sediments lie discordantly over the sedimentary members of the melange. The wider area of Raduša is characterized by complex and insufficiently studied structural-tectonic relationships. Among the more important disjunctive structural forms in these areas, the fault that stretches from Oraš Planje through Raduša to Dobro Polje is assumed. In addition to the mentioned fault in this area, the presence of several smaller diagonal and transverse faults is assumed, among which the most important fault is in the valley of the Raduška river, along which mineral waters and CO2 circulate. The composition of the melange includes sediments of the oceanic crust, then ultrabasic rocks that appear as olistoliths, as well as different basic rocks: spilites, gabbros, diabases, gabbrodiabases, dolerites, peridotites, serpentinites and others. It is interesting to note that here we do not have olistoliths from Mesozoic limestone formations from the rim of the melange basin (trough). The relations between the sedimentary formations of the oceanic crust and the igneous rocks are tectonized without primary contacts, and the character of their boundaries is olistolithic. Sedimentary formations include greywacke sandstones, multicolored clays, conglomerates and

less commonly cherts. The relationships of these different lithological members are irregular - chaotic, so that the primary relationships or structures in them cannot be reconstructed.

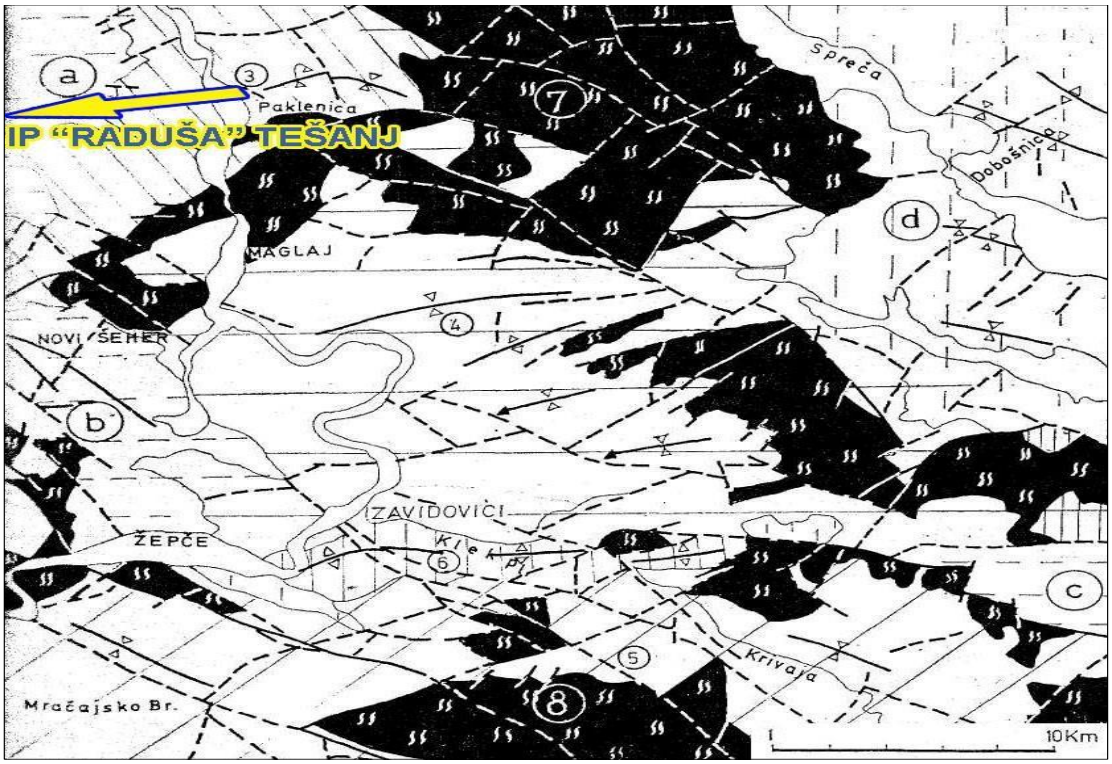

Figure 2. Tectonic map sheet Zavidovići OGK R 1: 100000 (Olujić, J., and Coauthors, 1973);

2. HYDROGEOLOGICAL CHARACTERISTICS OF THE BROAD RESEARCH AREA

The hydrogeological characteristics of the research area should be observed through the prism of hydrogeological categorization, reionization and function of rock masses, filtration characteristics, fissure systems and faults, hydrogeological collectors and isolators, and groundwater movement directions.

The hydrogeological characteristics of the research area are conditioned by very complex stratigraphic-tectonic relationships. For this reason, underground water and currents move from greater depths through fault zones and larger cracks, and appear on the surface in cracked rock masses. The primary and actual reservoirs are probably at great depths, and all analyzes indicate Triassic limestones. The system of cracks in the diabase-hornblende formation is connected to secondary faults perpendicular to the direction of the primary fault zones, and the springs appear on the surface as overflow springs. The movement of groundwater in a porous environment is very complex due to the fact that in such massifs, groundwater has a degree of freedom and moves along the line of least resistance, i.e. along privileged paths or faults (turbulent regime) and through the fractured collector system (laminar micro-regime). Looking at the hydrogeological characteristics of the narrower research area, it can be seen that potential water collectors are in more or less cracked rocks of the volcanogenic-sedimentary complex. According to the drilling works carried out so far, it has been established that it is a system of microcracks with complicated hydraulic relations and connections of a wider area.

The hydrogeological categorization and functions of rocks in the Raduša area was made on the basis of water-bearing capacity, that is, the ability of the rock to leak, accumulate or release groundwater. Based on the above criteria, two categories of rocks were distinguished in the studied terrain: permeable rocks and impermeable rocks.

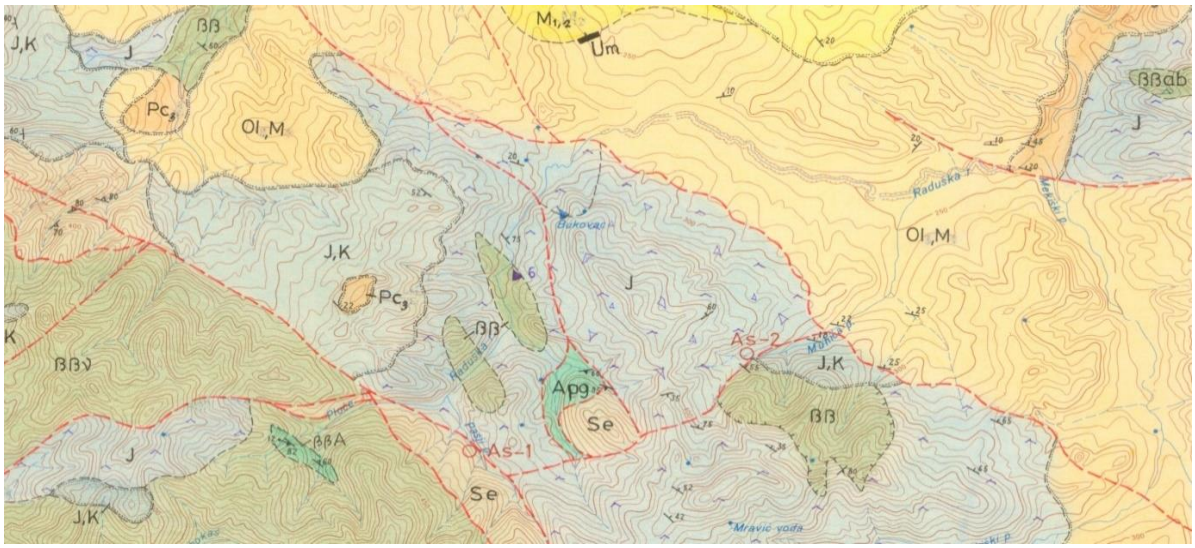

Figure 3. Hydrogeological map of the surroundings of Raduša (Federal Geological Institute of SFRY)

3. GENESIS OF MINERAL WATERS

Hydrogeological mapping of the terrain of the wider and narrower area "Tešanjski kiseljak" was carried out during the development phase of the Project for detailed geological and hydrogeological investigations of mineral waters in the Tešnja area. Hydrogeological mapping was carried out on a scale of 1:25,000 and 1:5,000. During the mapping, hydrogeological categorization and rezoning of rock masses was carried out, geomorphological forms were recorded, all water phenomena and objects, assumed directions of groundwater flow, and hydrogeological conditions of recharge and discharge of groundwater reservoirs were registered. Previous hydrogeological research, and especially based on the results obtained by exploratory drilling during the last four decades, concluded that the hydrogeological characteristics within the investigation area of the spring "Tešanjski kiseljak" in Gornja Raduša are conditioned by very complex stratigraphic-tectonic relationships. For this reason, groundwater also moves in transit currents from greater depths through fault zones and larger cracks and appears on the surface in cracked rock masses. The primary and actual hydrogeological collectors are probably at great depths, and all analyzes point to Triassic limestones that have their surface distribution concentrically in the environment around the "Tešanje Neogene Basin" at a distance of ten kilometers. Crack systems within the diabase-rose formation, or ophiolite melange, are connected to secondary faults perpendicular to the directions of primary fault lines and fault zones, as well as to the directions of thrust structures, and groundwater sources using such pre-induced directions appear on the surface of the terrain as overflow sources.

The movement of groundwater in such a broken porous environment is very complex due to the fact that groundwater has a free level and moves along the line of least resistance, i.e. along privileged paths or faults (turbulent regime) and through the fracture collector system (laminar regime). Looking at the hydrogeological characteristics of the narrower research area, it can be seen that potential hydrogeological water collectors are positioned in more or less fractured rocks of the ophiolitic melange, i.e., the latest research has confirmed a slightly more significant water abundance within the degraded and cataclased breccia complex of mostly diabase-amphibolite petrographic composition.

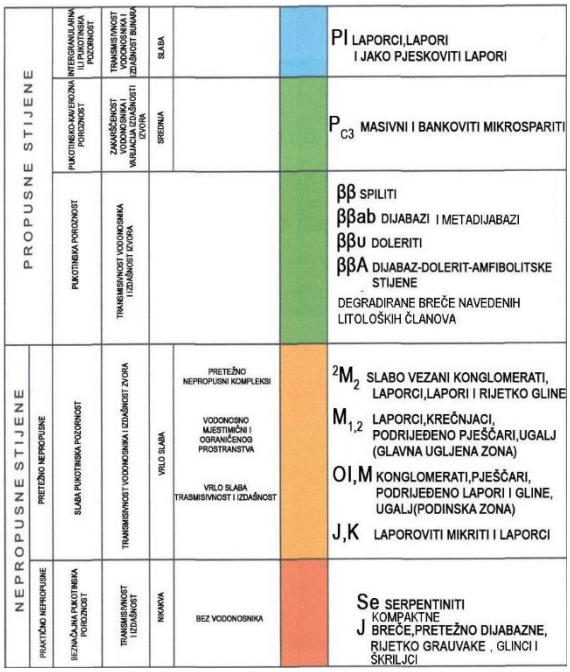

Figure 4. Hidrogeologicasl categorization of the research area Gornja Raduša -Tešanj (Vidačić,M.M.,2022)

By analyzing the swollen core material from previous and recent drilling works, it can be concluded that these are systems of microcracks with complex hydraulic relationships and connections, and as such they can be viewed as hydrogeological collectors of the transit type, and to a lesser extent as more significant accumulation spaces. This conclusion is based on the previous exploratory drilling in the immediate vicinity of the production facilities of Zema d.o.o. Tešanj in the flow zone of the Raduška River especially refers to the hydrogeological profile of the exploration and exploitation wells IBR-1/2002, IBR-5/2017-18, while for the aquifer in which the exploration and exploitation wells IBR-2/2003, IBR-3/ 2011, IBR-4/2017, IBR-6/2020, IBR-7/2020, IBR-8/2020 and IBR-9/2020, it can be said that from the hydrogeological point of view, it represents a somewhat more significant storage space for underground water with millimeter-centimeter cracks dimension within the breccia complex of rocks, which is connected to the main dislocation zone of the "Raduška fault" which is intersected by transverse faults and thus forms a blocky structural-tectonic complex along the course of the Raduška river. About the intensity, verticality and sub-verticality of faulting within the research area of the "Tešanjski kiseljak" source in Gornja Raduša, there is ample evidence in the geomorphology of the terrain, on the measured lines of geophysical reflective seismic profiles, within the swollen local geological columns of structural-research wells, and especially in the core material that is interspersed with cracks of divergent spatial arrangement of mapped slope in core of 30-90° filled or unfilled type.

The slopes of these cracks and crack systems have their surface distribution in the margins of the left and right banks of the Raduška River within the open profiles of the local relief around the production facilities, as well as within the riverbed itself in diabase and metadiabase rock complexes. A special proof of the circulation of natural CO2 gas in this terrain is the high degree of mylonitization and secondary calcification, i.e. silicification (open cracks and fissures, microcavernous channels) on the largest part of the determined extracted core from exploratory wells, as well as for the first time its clear identification by logging tests in the exploratory column -structural wells IBR-9/2020. Somewhat earlier, gas exhalations with natural CO2 were registered on the margins of fault blocks, where along tectonically predisposed directions they made their way to the

This, the mineral groundwater aquifer is connected to geologically older rocks (diabases, serpentinites, amphibolites), which are deeply localized within the Gornja Raduša terrain at very different depths within the hitherto swollen geological column. As part of the younger deposits of the Oligomiocene, Plioquaternary and Quaternary (sandstones, gravels, sands, various types of rubble, etc. - rocks of intergranular porosity), and which make up the roof of the older five-described rocks, shallow subsurface releases of groundwater were formed, which do not have significant amounts of water, but they can be enriched with emanations of natural carbon dioxide and thus "acidified" themselves. Younger Povlat sediments with a particularly clayey composition are interesting from the aspect of isolation of the

previously described hydraulic and hydrochemical processes in the source area itself. However, their structural position in the local geomorphology and tectonics itself is not uniform, there are frequent misalignments and reliance on exposed parts of magmatic-metamorphic complexes (diabase, amphibolite, serpentinite, etc.), which should not be ignored either by lateral water communication from Tertiary, Cretaceous and Jurassic sediments.

Replenishment of aquifers (aquifers) of natural mineral waters, which is formed in tectonized diabases and amphibolites, that is, much less often in ultrabasites, is carried out from the water cycle of the precipitation of this climatic area, and the emptying of hydrogeological reservoirs is at local sources and through drainage at well water catchment facilities in the Raduška river basin. enriched with CO2 gas that ascends the underground water to the surface of the local terrain.

Such specific local hydrodynamics, hydraulics and hydrochemistry of surface and underground waters in the researched area of the source of "Tešanjski kiseljak" was made possible primarily by the existing geomorphology and geology of the terrain in the Raduš fault zone.

The basin type of the narrow alluvial plain of the Raduška River and the heterogeneous lithological composition of rock complexes in a small area with distinct kinematic movement in the vertical column of the younger and older chronostratigraphic range contribute to the specific hydrogeological conditions prevailing in this terrain.

On the other hand, the high artesian pressure of underground mineral waters "Tešanjski kiseljak", in the optimal mode of extraction and exploitation, prevents the mixing of mineral waters with ordinary waters of the alluvium of the Raduška River and surface waters in the catchment area of the surrounding terrain of Gornja Raduša (the latest evidence in the local hydrogeological column of drilled and extracted IEB IBR-8/2018 and IBR-9/2020).

The mentioned hydrogeological conditions, despite the complex factors, contribute to a good extent to the fact that the quality of the mineral waters of the research area "Tešanjski kiseljak" in Gornja Raduša shows constancy and stability over a long period of hydrogeological monitoring and observation (the waters have not changed since the first analyzes from the nineteenth century), and which is the result of their genesis, geological, geotectonic and hydrogeological characteristics of the terrain.

CONCLUSION

The mineral water deposit "Tešanjski kiseljak" belongs to the hydrogeochemical area of mineral and thermomineral waters with CO2 of the "ophiolitic zone". Cracked rocks of the ophiolite zone have the function of an aquifer of lower water abundance with springs yielding less than 0.1 l/s. The water conductivity of aquifer deposits is higher in fault zones, and mineral springs appear in the zone of the transverse fault along the Raduška river, i.e. its intersection with the longitudinal fault of the northwest-southeast. Mineral water is most likely of atmospheric origin, where by infiltration it penetrates into deeper parts of the terrain and is enriched with CO2, and by decomposition of rocks it increases mineralization. According to the temperature of the spring water, it can be concluded that the infiltration of atmospheric water and mineral enrichment does not take place at great depths.

Due to the hydraulic pressure and CO2 content, the mineral water flows out at the Kiseljak spring along the fault of the Raduška River. CO2 is most likely thermometamorphic, created by the action of SiO_2 on carbonates in deeper parts of the earth's crust, possibly in Middle-Upper Triassic carbonates, which lie deep below the ophiolitic zone in the "ophiolitic mantle" zone. It is not excluded that the formation of CO_2 causes intrusions of young Tertiary magmatism in the deep fault zone extending northwest-southeast Maglaj-Crni vrh and vrh Raduša-Oraš Planje, which should be proven by isotopic tests.

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