

Uranium mineral resources of Serbia and their potential economic importance

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By means of geological explorations of nuclear mineral raw materials carried out of Serbia during the period 1948-2000, nine deposits and 11 significant uranium mineral occurrences were registered. The total uranium mineral resources within the identified deposits in Serbia are estimated at 11.1 million tons containing 4,150 t of uranium while the potential and insufficiently explored uranium resources contain more than 3,000 t of uranium. Today, no active uranium mines are evident in Serbia, but the same existed during the '60 of the 20th century.

The primary genetic and economic types of uranium deposits of Serbia are hydrothermal vein type related to granitoid complexes and infiltration-sediment type in sandstones. The level of geological knowledge of the deposits is different and suggests the necessity of further geological exploration.

Economic evaluation of uranium mineral resources of Serbia in this paper encompasses the analysis of geological, metallogenic, mining, marketing, technological (metallurgical), legislative-lawful, regional and geo-ecologic factors. The real possibilities of utilization of uranium from the deposits of hydrothermally-vein type within the granitoid complex of Janja in eastern Serbia have underlined as well as the utilization of infiltration-sedimentary uranium deposits in the Permian-Triassic sediments of the Stara planina and Neogene sediments of Belanovica and Iverak basins in central and western Serbia.

Key words: Serbia, uranium, mineral resources, ore deposit.

Introduction

The uranium mineral resources of Serbia and the metallogenic units where the same are located represent constituents of regional metallogenic and geotectonic units being extended out of its territory. Accordingly, the position, time and conditions causing the formation of the same primarily depended on the geotectonic evaluation of the large area and accompanying volcanic, sedimentary and metamorphic processes. From the metallogenic point of view, the same are completely incorporated into the NE Mediterranean Sector of the Tethyan-Eurasian Metallogenic Belt [8, 9] (or, the Alpine-Balkan-Carpathian-Dinaride metallogenic and geodynamic province), being a part of the Tethyan (or Alpine-Himalayan) orogenic system and extending from the Western Europe to South East Asia [5, 22]. A more detailed territorial grouping of these units is based on the analysis of the relations of mineral deposits and the geological environment being genetically and spatially associated with [15].

Uranium mineral deposits of Serbia are concentrated into two regional metallogenic units that spatially extend out of the territory boundaries of the country: 1) the Carpatho-Balkan metallogenic province (CBMP) and 2) the Serbo-Macedonian metallogenic province (SMMP), all of which are subdivided into several metallogenic zones, ore districts and ore fields, and some of which have specific features associated with the origin of the ore deposits.

The most significant concentrations of uranium in the territory of Serbia are associated with the granitoid complexes of the Hercynian and Tertiary age, sedimentary series of the Permian age and Neogene basins in the marginal zones of granitoid. Uranium deposits associated with the granitoid complexes belongs to the group of hydrothermal vein and stockwork types of mineralization located in the fault zones while uranium deposits related to the sedimentary series belong to the group of roll-front type of mineralization [2, 12, 14, 15, 16].

History and Applied Methods of Uranium Exploration Works

The second half of the 20th century represents a period when, within the territory of Serbia, the enormous exploration works of uranium mineral resources were carried out. Apart from the exploration works of the regional features covering over 50% of the territory of Serbia, the detailed exploration works have also been carried out systematically and in several stages (Fig. 1). The result of the above-mentioned explorations is evidenced in discovering of more than several hundreds of zones of anomalously increased radioactivity, several tents of uranium occurrences and a small number of uranium deposits [8, 13, 17, 19].

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Geological features of the studied uranium deposits are recognized to a relatively high degree, and the mineral resources and reserves of the same are estimated to a relatively high degree of reliability. In the direct vicinity of the explored deposits, potential ore bearing areas are selected where finding the possible new mineral uranium resources. However, a series of unsolved questions remained covering both geological problems (precise establishing of the control factors of the spatial position of the uranium mineralization, the conditions of its formation and others), and technical-metallurgical, in fact particularly economic parameters of the deposits valorization. The fate of further geological exploration activities of the uranium mineral resources of Serbia depends on the long-term development strategy of the mineral sector and the strategic determination of the state concerning the usage of either nuclear or other types of energy (coal, oil, gas and other ways of energy). The history dealing with exploration works of uranium mineral resources in Serbia can be divided into three significant periods.

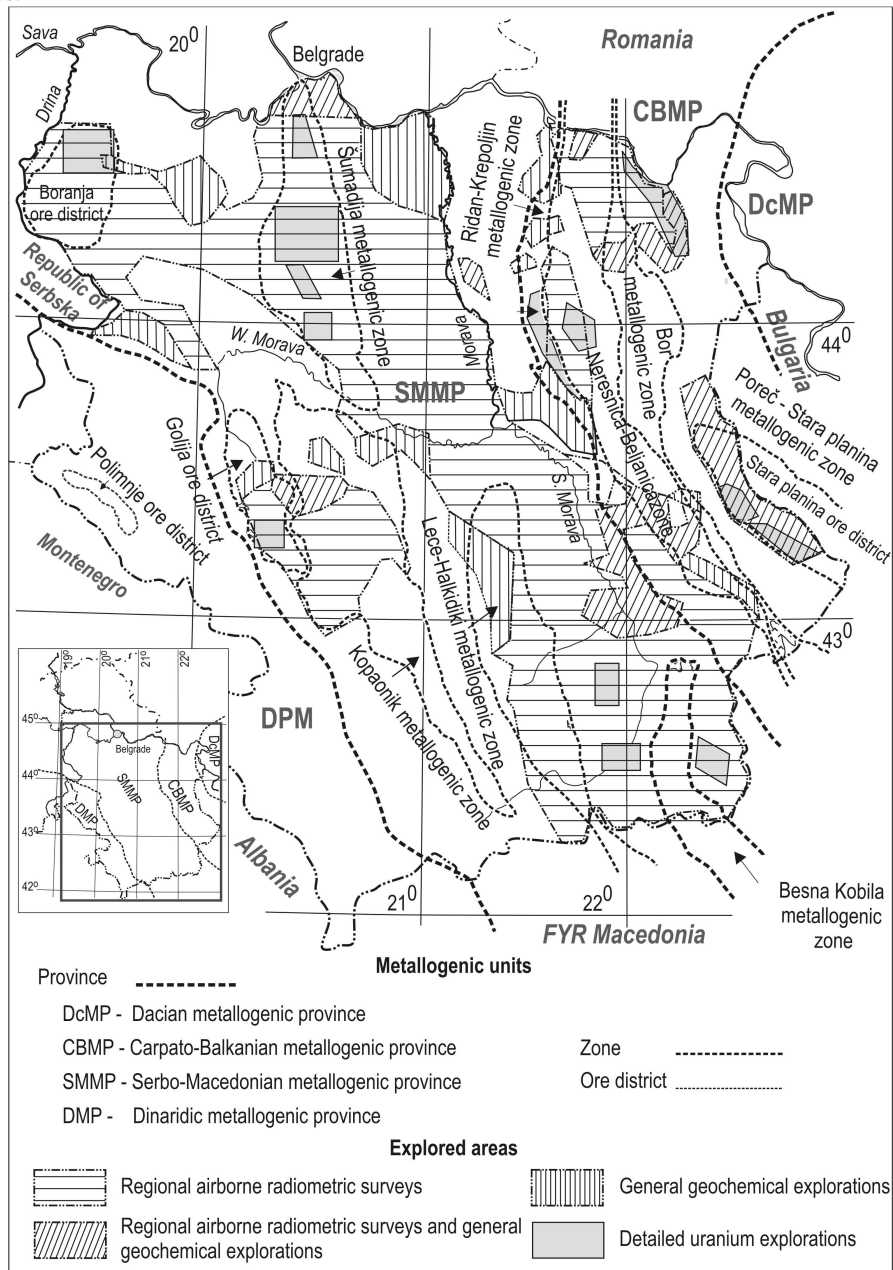


Fig. 1. The position of the explored areas of uranium mineralization in Serbia.

The first period of the uranium exploration works in Serbia (1948-1955) covered the metallogenetic analysis, prognosticated evaluations of ore-bearing areas potentials, geological recognition of the uranium mineralization different in types and various ratios, mostly applying methods of radiometric and hydrogeochemical field geology.

Geological and geophysical field geology of the uranium mineralization within the second exploration period (1956-1971) included the application of the following methods: regional geophysical exploration (airborne, helicopter, vehicle and pedestrian field gamma spectrometry and aircraft magnetic surveys), and geochemical explorations (hydrogeochemistry of the uranium, 2-3 samples per km²), stream sediments (0.5 samples per km²) and ore testing (1 test per km²). The exploration works were performed in the areas covering up to 10,000 km², in the scale of 1: 50,000 to 1: 25,000. The above-mentioned type of exploration activities includes around 70 % of the territory of Serbia, namely around 60,000 km² of the terrain. Radioactive anomalies were checked through exploration digging, drilling and mining works.

The detailed geological explorations of the uranium mineralization were done in the areas of up to 10 km² in size and scale of 1: 10,000, encompassing structural geological mapping, lithofacial and morpho-structural surveys, gamma radiometric measurement, application of emanometric method and uranium – secondary mineral zoning (usually along the net 50x10m), gamma probing, digging up, exploration drilling and radiometric surveying of the core. The general and detailed geophysical surveys included ER (Electric Resistivity) and IP (Induced Polarization), geoelectric mapping of exploration drill holes and mining works. The uranium content is determined in two ways: a) fluorometric total and diluted uranium (U and U_{total}) and b) radiometric: uranium and radium equivalent to uranium (U and U_{eq}) Th, K. Petrological, mineralogical, and spectral analyses were simultaneously carried out as well as the radiometric, thermometric and other surveys.

The third exploration period (1976-1990) encompasses the checking of previously detected radioactive anomalies according to the similar methods being applied during the second exploration period, as well as the application of modern gamma spectrometry for the direct determination of the contents of U, Th and K in situ, the application of alphametry and similar. Ore-bearing and potential ore bearing areas were geologically mapped in the scale 1: 5,000 and lithological maps in scale 1:10,000 were made.

Mineral Deposits and Uranium Occurrences of Serbia

Uranium mineral resources in Serbia were formed in different geological environments and physicochemical conditions, in complex endogenous, exogenous, partly in metamorphogenous processes. Considering the metallogenic characteristics of mineralization, morpho-structural and genetic types of mineral deposits, mineralization of uranium demonstrates a wide spectrum of varieties. It is mostly associated with products of intermediary and acid magmatism and their intrusive equivalents (granitoid complexes and others), when belonging to the group of hydrothermal deposits of mineral raw materials, and subordinated to the transitional magmatic/hydrothermal type (mineralization of the uranium into pegmatites). A significant part of uranium mineralization is of infiltration-sedimentary type, spatially and genetically associated with the various terrigenous sedimentary rocks (sandstones and others) with the presence of organic matter and other sedimentary formations. Economically less important uranium mineral resources in Serbia are related to crystalline schist [12].

By systematic studies of the reported geological environments including the determination of the natural background of the radioactivity of the same, the units being the constituent part of the geological framework of the territory of Serbia are as per the degree of uranium prospective divided into the following groups:

- a) Crystalline massifs, as remainings of Pre Alpic basement and intruded by granitoid massifs within the same,
- b) Terrigene sedimentary basins of different age (Tertiary, Permian-Triassic, Permian and Permian-Carbonian), and
- c) Acid and intermediary volcanic rocks and their pyroclasts, volcanoes and surrounding sedimentary basins, the sediments of which are mixed with the pyroclastites (volcano-sedimentary series).

From metallogenic point of view, the deposits and numerous occurrences of uranium in Serbia are grouped into Carpatho-Balkanian and Serbo-Macedonian metallogenic unit (Fig. 2).

According to economic and morpho-structural types of mineralization as well as the formation conditions, among the selected uranium occurrences and uranium deposits in the territory of Serbia, the most significant are the hydrothermal vein and infiltration-sedimentary uranium deposits.

The mineralizations of the first type are the largest and the most significant ones. The same may be found in fault and fault zones with the thickness of 0.2 m to several meters, most frequently one with 0.5 to 2 m in various lithological environments (granitoid, volcanic and crystalline schists). The host rocks of ore bodies are intensively hydrothermally altered; kaolinization, chloritization and silicification are predominant facies of hydrothermal alterations [10, 14, 18]. The scale of ore veins ranges from several to 300 m (average). The content of uranium varies and ranges from 100-500 ppm to over 1000 ppm (most frequently about 300 ppm). Compared to the world uranium deposits of this type, the uranium contents, and the overall quantity of ore in the uranium deposits in Serbia are relatively low, i.e. the same belong to a group of low graded and smaller ones.

The second type of uranium mineralization could be found in sedimentary basins of the Tertiary and Permian age. Although, in certain cases, the same contain local high uranium concentrations (over 2,500 ppm),

sporadically even significant ore quantities (Dojkinci and Ribarice deposits), the established mineral resources in the majority of cases proved not to be economically attractive due to insignificant quantities.

The uranium contained in deposits of this type is unevenly distributed. The same can be found in the function of geochemical and other features of productive lithological members. Both the shape and dimensions of the ore bodies being contained in the same are determined according to the boundary content of the uranium in the mineralized mass and can usually be found within the interval of 100-300 ppm. From the point of view of the world uranium deposits, the mentioned ones represent relatively small values.

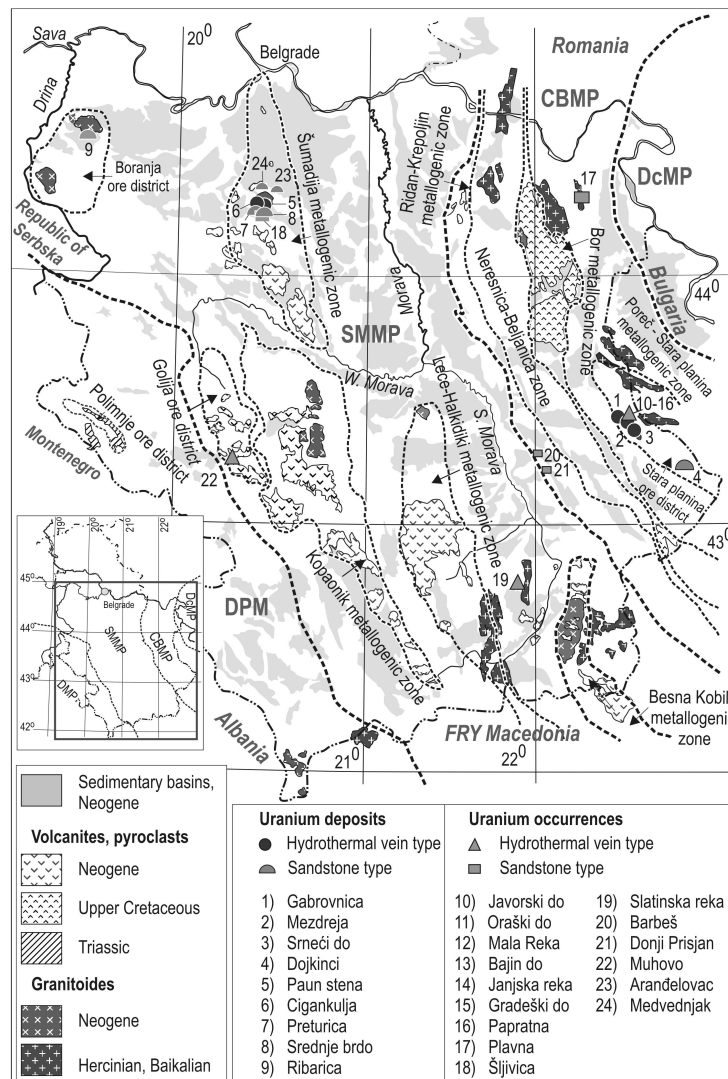


Fig. 2. Uranium mineral deposits and occurrences of Serbia.

Bearing in mind the spatial distribution of the uranium deposits in Serbia and their relevant economic importance, the most attractive area for further geological exploration proves to be the Stara planina ore region. This region's abundance in considerably more uranium occurrences and deposits, being for the last 50 years thoroughly explored and at the same time abounding in a large number of collected geological data. Among the most economically attractive regions are the Janja ore field and Dojkinci-Senokos zone as well.

The uranium deposits of Stara planina demonstrate differences, both from the genesis and control factors of the spatial position and economical significance. Apart from the detailed explored uranium deposits such as Mezdreja and Grabovnica, a large number of nuclear mineral raw materials occurrences, characterized by insufficiency determined mineral resources, have been discovered in those regions. The most significant are:

- The group of uranium ore occurrences located at the farthest northwest part of the Janja granite: Bajin Do I and II, Mala Reka, and Papratna;
- The group of uranium occurrences (Gradeški do, Oraški do) in the south part in the granite complex of Janja, and

- c) The group of uranium ore occurrences of the Inovska reka. Those uranium ore occurrences are located along the contact zone of Inovska series with Janja granites (the left side of Inovska series): the Inovska reka and Tumba.

The underground pilot exploitation of uranium at the Stara planina commenced in 1960 during the opening of the mine in the Gabrovnica deposit near the Kalna village. It lasted until 1966 when suspended. Around 95,000 t of ore was excavated during that period. Mining works were abandoned for several reasons: economic unprofitability of exploitation (low, medium uranium contents, limited mineral reserves and high costs of processing), and determination of the SFR Yugoslavia for usage of some other sources of energy and other reasons, as well.

Gabrovnica and Mezdreja deposits are explored in detail while the mineral raw materials are studied, both in the laboratory and semi-industrial and industrial level. All the studies encompassed the process from preconcentration to acquiring technical concentrate of Na-diuranates or UO₂ concentrates. Simultaneously, the studies of leaching of uranium in a pit of the poor ore bodies in Mezdreja, as well as the other types of studies relevant to the process of uranium obtaining.

The Dojkinci uranium deposit of roll-front type, located in the southeast part of the Stara planina, disposes of potential resources of around 3.8 Mt of the uranium ore based on the obtained results of the performed geological explorations.

The second place, according to the degree of performed investigations, namely the volume of investigations and the amount of the invested financial funds, takes mineralization of the uranium in the Bukulja region. This region is characterized by more small uranium deposits both in a granitoid complex of Bukulja (Paun Stena, Milanov potok, and Cigankulja) and in the nearby sediment basin of Belanovica (Kamenac, Preturica, Srednje Brdo, etc.). Uranium mineralization was thoroughly studied and analyzed to a great extent resulting in finding out the existence of mineral resources. Within the same sites, somewhat less number of technological (metallurgical) studies of the ore under laboratory conditions are performed. Out of the known uranium deposits in the territory of Serbia, the deposit of Ribarice in the Cer region is technologically (metallurgical) less tested.

Economic Significance of Uranium Mineral Reserves and Resources

In Serbia, there is no active uranium mines nor installed processing capacities nowadays, although such facilities existed previously. However, it was found out that there exist several deposits of resources, the ore quality, and possibilities of eventual exploitation of which are partly defined. For certain ore fields, the prognosticated geological-economical estimation was made, namely prognosticated mineral resources (Prognosticated Mineral Resources after IAEA-TECDOC-1629), was done, namely the reserves of D₁ and D₂ category.

Although the uranium deposits located at the territory of Serbia have been, with short or long interruptions, investigated for more than half a century, their reserves were not studied and accepted as economically marketable by the competent state commissions, implying the degree of exploration and the necessity of further investments aimed at economical defining of the mineral raw material potential of the same. The data on the relevant quantities, classification and categorization of the ore reserves grouped in A, B and C₁ category could be found in the numerous reports stored in the funds of the professional documents of organizations dealing with uranium investigation, then in the Ministry of Mining and Energy of Serbia as well as in various publications.

The uranium ore reserves presented in this paper originate from the monograph edited by Janković and Vujić (1999) [26], while the review of their basic geological features is thoroughly given in scientific papers [2, 3, 4, 11, 12, 14, 16, 18].

Under the so far obtained results of geological explorations, both the identified and potential reserves of the uranium in Serbia are classified and presented in Table 1.

Tab. 1. Uranium mineral resources of Serbia.

MINERAL RESOURCES												
Deposit	Measured ¹			Indicated ¹			Inferred ¹			Speculative ²		
	Initial (Global) ²						Prognosticated ²					
	B category ³			C ₁ category ³			C ₂ category ³			D ₁ category ³		
	Ore [t]	Grade [%, U]	U [t]	Ore [t]	Grade [%, U]	U [t]	Ore [t]	Grade [%, U]	U [t]	Ore [t]	Grade [%, U]	U [t]
Gabrovica	68,571	0.0297	20.36	54,000	0.025	13.5	39,000	0.034	13.26	-	-	-
Mezdreja	235,116	0.0365	85.82	520,214	0.026	135.26	277,414	0.025	69.35	-	-	-
Srneći do	-	-	-	115,000	0.034	39.1	140,000	0.034	47.6	3,067,567	0.031	950.95
Dojkinci	-	-	-	-	-	-	1,800,000	0.054	972	2,000,000	0.046	920
Paun stena	-	-	-	-	-	-	3,360,181	0.028	940.8	-	-	-
Cigankulja	-	-	-	-	-	-	1,338,510	0.053	709.41	121,000	0.037	44.8
Preturica	-	-	-	-	-	-	450,000	0.028	126	-	-	-
Srednje brdo	-	-	-	-	-	-	1,231,680	0.052	640.47	-	-	-
Ribarica	-	-	-	711,593	0.025	177.9	791,175	0.020	158.24	-	-	-
Total PERC:			106.18			365.76						
Total IAEA:						471.94			3,677.13			1,915.75
Occurrence												
Javorski do	-	-	-	-	-	-	728,000	0.034	247.52	-	-	-
Oraški do	-	-	-	-	-	-	27,000	0.025	67.5	-	-	-
Mala reka	-	-	-	-	-	-	88,000	0.015	13.2	-	-	-
Bajin do	-	-	-	-	-	-	280,000	0.030	84	-	-	-
Janjska reka	-	-	-	-	-	-	628,000	0.030	188.4	-	-	-
Gradeški do	-	-	-	-	-	-	388,000	0.019	73.72	-	-	-
Plavna	-	-	-	-	-	-	105,000	0.059	61.95	160,000	0.040	64
Šljivica	-	-	-	-	-	-	3,500	0.029	1.02	-	-	-
Slatinska reka	-	-	-	-	-	-	148,500	0.02	29.7	-	-	-
Donji Prisjan	-	-	-	-	-	-	111,000	0.014	15.54	-	-	-
Barbeš	-	-	-	-	-	-	1,379,000	0.029	399.9	-	-	-
Total:									1,182.45	64		

¹ - PERC Code (2008) - Pan-European Code for Reporting of Exploration Results, Mineral Resources, and Reserves ("The Perc Reporting Code") - The Pan European Reserves and Resources Reporting Committee.

² - IAEA-TECDOC-1629, 2009 - World Distribution of Uranium Deposits (UDEPO) with Uranium Deposit Classification, 2009 Edition.

³ - The Book of Regulations on Classification and Categorization of Reserves of Solid Mineral Raw Materials and Keeping a File on Them (issued in former SFR Yugoslavia, 1979).

On the grounds of the given data on uranium mineral resources in Serbia, it can be found out that the uranium mineralizations situated in the stated deposits could be economically attractive.

The main indicators of exploration and exploitation of the uranium mineral deposits in the Janja granitoid complex as the most prospective ones are the following:

1. Within the period 1950-1986 aimed at the detailed explorations and exploitation of deposits in Mezdreja, Gabrovnica, and others, more than 21 km of exploration drilling were done, as well as around 36 km of underground mining works (adits, corridors, etc.), 2,300 m of inclined drift and 537 m of shafts.
2. As per the data set in the Final Report – Study on mineral reserve estimation [3] for Kalna, the following requests concerning excavation and processing of ore were determined:
 - a) Input quality of the ore processing plant: min. 0.047 % U_3O_8 (cut-off content of excavation for blocks with medium content 0.047 % U_3O_8 would be 0.032 % U_3O_8).
 - b) The minimum thickness of ore bodies 0.1 m for excavation.
3. Within semi-industrial explorations and experimental production of the uranium from the Mezdreja and Gabrovnica deposits, the following quantities of ore and metals were mined [3]: 50,027 t of ore with average 0.027 % U_3O_8 , namely 13,507 t U_3O_8 in Mezdreja and 44,222 t of ore with average 0.05 % U_3O_8 , namely 22,111 t U_3O_8 in Gabrovnica.
4. Dilution of the ore mass as a result of the applied excavation method amounted up to 35 %.

According to current experiences with similar deposits, mining dilution run as high as 25 % [1]. The increased rates of dilution in the Mezdreja and Gabrovnica deposits are the consequence of an inadequate method of exploitation, something that can most definitely be improved.

Hydrothermal mineralization of the uranium being spatially and genetically associated with granitoid complexes according to the conditions of the spatial setting and morphology of the ore bodies request underground exploitation, as well as low production capacities with relatively high initial monetary investment, being under present economic conditions hardly feasible.

Contrary to the uranium deposits in granitoid complexes, mineral concentrations within the sedimentary basins primarily deposits in the Dojkinci-Senokos region, as well as in the Belanovica basin within the Bukulja region, could be exploited through open pits as the depth of occurrence of the same is not great.

The future of further exploration works of the uranium mineral resources of Serbia can be seen in function of mineral policy and the development strategy of a mineral sector of the country, as well as its determination to the mineral resources of the uranium as the possible energy resources. The existing degree of the performed research works in Serbia from the viewpoint of the uranium reserves is relatively low. Additional financial investments are required, especially for thorough geological exploration of mineral resources, so as to improve their geologic reliability, and, given the appropriate economic parameters, render them into mineral reserves. The priorities requiring additional exploration works are previously defined deposits in granitoid complexes in the uranium-bearing regions of Stara planina, Bukulja, Plavna, namely, the accompanying sediment basins of Belanovica, Zaplanje, and Pčinja, as well as the red sandstones of Stara planina. As an illustration, there is the need to continue with the geological exploration of uranium mineral resources in the area encompassing Paun Stena and Cigankulja in the Bukulja granitoid. The degree of their exploration is relatively low, at the C_2 category of reserves (which signifies inferred resources), which are of great significance and ought to be explored further. Additionally, there are geological and genetic preconditions for the discovery of new uranium mineral resources along the Paun Stena ore-bearing zone, as well as the area between Cigankulja and Paun Stena uranium deposits (Milanov Potok area), thereby increasing Serbia's mineral and raw material base of uranium.

Economic estimation of the uranium mineral resources in Serbia is based on the quantities and quality of mineral resources and reserves in the uranium deposits and occurrences, underlying the high economic significance of the quality of mineral in relation to the quantity of the same [23]. From the economic point of view, this estimation covers economic estimation of the deposits where mineral reserves of the uranium can be found on one side, and on the other side the economic estimation of the occurrences where mineral resources of uranium are located [24]. The complete economic analysis requires the analysis of necessary factors and indicators of estimation, which follow all the stated individual deposits and occurrences as geological-economic objects of estimation, show no complete necessary data [25]. Uranium mineral resources of Serbia are characterized by varying degrees of geological exploration, geological and economic study and a lack of economic evaluations for each particular deposit and occurrence of uranium, based on which a cumulative or the aggregate economic evaluation could currently be done at the level of the mineral sector in the country. Thus, such an economic estimation of the uranium mineral resources bears general characteristics of analysis at the level of the most significant factors and together with the additional geological investigations and geological-economic studies, it may be additionally and precisely made and completed.

The analysis of metallogenic factors indicates the existence of prognosticated reserves, mineral resources, and the finding, defining and evaluation of which require continuation and intensifying of geological

exploration. The present state and the degree of prospecting illustrate the existence of around 7 Mt of potential resources of the uranium ores and 1,000 t of potential mineral resources of the uranium.

The analysis of geological factors indicates the medium suitable geological conditions of formation and localizing the uranium mineral resources. The predominant economic type of the uranium mineral is pitchblende while the subordinate economic significance represents uraninite, autunite, torbernite and coffinite. Among the economic types of deposits and occurrences predominate hydrothermal veins and infiltration sediment type. According to the morphology, the plate-like, namely vein and lens-like ore bodies predominate, then nest-like to stockwork or bodies, and to the less extent irregular ore bodies. The ore bodies are mainly of small dimensions so that the following can be distinguished: a) small ore bodies up to million tons of ore and b) medium size ore bodies exceeding million tons of ore. According to the reserves, small ore bodies contain up to several hundred thousand tons of ore, while the ore bodies of a medium size rarely exceed 3 million tons. The uranium reserves in ore bodies are relatively small and range from a couple of hundreds up to more hundreds of tons of the uranium. The medium contents of the uranium in the ore vary and range up to average 0.035% U in deposits and 0.028% U in the occurrences.

A preliminary analysis of mining factors shows that, considering the location of the ore bodies, the application of underground mining methods would predominate. With the aim of increasing the degree of exploitation of the mineral resource and cutting, mining losses and dilution, the use of modern technologies during the exploitation of each particular deposit is necessary, having an effect of exploitation and reducing specific costs per unit of reserves. As concerns, the individual deposits, the method of exploitation and the relevant procedure of processing uranium should be specified.

Analyzing the market factors, considering the specificity of uranium, it requires taking into account both economic and non-economic aspects. According to the current state, economic factors are favorable, whereas non-economic factors, among which strategic factors predominate, have certain limitations and are not favorable in the short-term. The advantage is reflected in the existing requirements of uranium, namely yellow cake both for the requirements of energetics in the regional market and the uranium for the requirements of medicine and various investigations at the local market of the country.

The price of 1lb of uranium from the mineral reserves from deposits in Serbia can, at this very moment, be stated only in approximative values. Bearing in mind the economic classification of the International Atomic Agency, Vienna [6, 7] for uranium on the grounds of the relevant production costs for categories can be set out: \$ 40/kg U (\$15/lb U_3O_8) or less, \$40-\$80/kg U (\$15/lb U_3O_8 -\$30/lb U_3O_8), \$80-130\$/kg U (\$30/lb U_3O_8 -\$50/lb U_3O_8), \$130-\$260/kg U (\$50/lb U_3O_8 -\$100/lb U_3O_8). According to the same source the ore from a deposit containing U_3O_8 from 0.01 % to 0.05 % could, in future, be mined at the price of US \$50/lb U_3O_8 or less. As the deposits in Serbia contain the uranium concentrations generally within the stated values, the stated price could approximately be considered as the mining cost not covering the costs of the geological investigations. With the view of the current price, actual when preparing this paper in the amount of \$30/lb to \$37/lb U_3O_8 , the question of classification of the existing deposits as mineral resources or mineral reserves should be imposed and should become the subject of the detailed economic analysis.

The strategic economic frames for practical utilization of mineral reserves and resources of the uranium regarding the existing energy strategy of Serbia [20] and the existing moratorium on the construction of nuclear electric power plants up to 2015 [21] is limited to a certain extent. The ban refers to the construction of nuclear electric power plants, the plants for production of nuclear fuels and the plants for processing of the used nuclear fuel aimed at nuclear electric power plants in Serbia. The same encompasses: the passing of the investment decisions, preparing for investment programs and technical documentation for construction of nuclear electric power plants, the plants for production of nuclear fuel and the plants for processing of the used fuel aimed at nuclear electric power plants. However, this ban does not refer to the scientific investigation and investigation-development works, mining-geological investigation works and geological-geophysical investigations. Therefore, the professional, scientific and practical necessity exist for recognition of quantities and qualities of the mineral resources of the uranium in Serbia, both from the possible aspect of energy and ecology aspect and accordingly the connected spatial localizing of deposits and occurrences of the uranium in Serbia.

The strategy of the development of energy in the Republic of Serbia does not exclude the possibility of utilization of the nuclear energy in the future, but currently, no regulatory and administrative frame exists to regulate the construction and operation of the nuclear electric power plants. Whereas, the alternative of obtaining the nuclear electric energy based on the imported nuclear fuel is taken into consideration. The strategic estimation that the period of 10-15 years from the moment of canceling the Law on the construction of nuclear electric power plant ban would present the minimum required a period for overcoming all the accompanying problems and failures, up to the commencing of eventual work of such a plant in the Republic of Serbia.

The analysis of technological (metallurgical) factors indicates the necessity of processing somewhat poor uranium ores in foreign technological capacities for obtaining yellow cake as a final product. The above would be followed by higher costs of preparation and processing, but is inevitable due to the non-availability of the

required technologies, the impossibilities of introducing the same within a short period and the acceptable costs with the view to the available uranium mineral resources in Serbia.

The analysis of the regional factors requires, to a great extent, the analysis of each and every single case of deposit or occurrence of uranium and includes: conditions of transportation, the relief of the area, conditions of water supply, energy, and semi-finished products, climate conditions, population, mastering the area and availability of the required labour force. The problem of providing the required specialized labor force is evident, particularly experts indispensable for various phases of investigation and mastering the uranium deposits in Serbia.

The analysis of geo-ecological factors indicates the necessity of following the up-to-date measures of protection of the work and the living environment. The above stated encompasses all the phases of the uranium deposits investigation and in the part of living environment protection, particularly protection of ground waters and soil from contamination processes, as well. This part of the geological-economic analysis at the highest level should follow the process of prevention, pollution and due taking the preventive protection measures. Accordingly, special attention should be paid to the influence of the subject of geo-ecological costs to the overall cost charges of the reserve units, namely the final market production of the uranium ore.

Conclusion

Neither active uranium mines nor installed processing capacities are present in Serbia nowadays that existed during the second half of the 20th century. While making geological explorations, several small deposits were found, the reserves of which, quality of ore and possibilities of eventual exploitation are partially defined. Approximative economic analysis of the mineral resources of uranium given in this paper bears a general characteristic of studies at the level of the most important factors of economic feasibility valorization and along with the additional geological explorations, and the detailed geological-economic analysis should be made more precisely and completely. Within the existing deposits and occurrences, the predominant economic type of the uranium mineral represents pitchblende while the following are of the subordinate economic significance: uraninite, autunite, torbernite, and coffinite. Hydrothermal-vein and infiltration-sedimentary types genetic and economic types of deposits and occurrences predominantly occur in Serbia. From the morphological aspect, predominantly is plate-like, namely vein and lens-like ore bodies than nest-like to stockwork ore bodies and irregular ore bodies to a less extent. As regards the size of ore bodies, small ore bodies to million t of ore could be selected as well as the medium ore bodies exceeding million t of ore. Medium concentrations of uranium in the ore vary and range to the average of 0.035 % U in deposits and 0.028 % U in occurrences.

The strategical-economic frames for practical utilization of mineral reserves and resources of uranium according to the valid energy strategy in Serbia and the existing moratorium on the construction of nuclear electric power plants up to 2015 bear certain limitations. The ban, however, does not refer to the scientific-investigation and investigation-development works, mining, geological exploration and seismic exploration. Thus, from the point of view of legislation and legal aspect, there is an open space for a new estimation of the potential of certain metallogenic units, additional geological explorations of the uranium mineral resources as well as the defining of new mineral reserves of uranium. In the final review of the functional and economic role of the mineral reserves of the uranium in Serbia in providing the general stability of the country apart from the detailed review of the geological, mining, technological (metallurgical) and other relevant factors, special attention should be paid to the safety and the ecological aspects of the exploitation, preparation, processing and utilization of the mineral resources of uranium in Serbia.

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