

The Possibilities of Ground Water Recovery and Protection in the Period of Subsequent Exploitation of Bauxite Deposits in the Region of Vlasenica

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ABSTRACT

The paper outlines the basic geological and hydrogeological properties of a broader zone of two major bauxite deposits "Podbraćan-Braćan" as well as the possibilities of karst water utilization for water supply. The hydrogeological conditions in the immediate and broader zone of the deposit necessitate continuous dewatering for the purpose of exploitation of its deepest parts. In this way some 500 l/s of high-quality karst aquifer water will be captured. It could be utilized for water supply of population in this part of Eastern Bosnia by constructing regional waterworks from the mines to Zvornik.

INTRODUCTION

Bauxite deposits of Vlasenica represent one of the most important occurrences in Yugoslavia regarding the reserves and mining possibilities of such deposits. The construction of alumine factory at Zvornik created conditions for processing large quantities of bauxite which is recovered mostly from the mines of Vlasenica (Fig. 1). Along with the mining of individual deposits enormous efforts are being made to explore new deposits and make timely preparations necessary for development works with the purpose of providing optimal capacity for alumina processing. Separate activities are directed at determining conditions and possibilities of bauxite mining in "Podbraćan-Braćan" deposits below base level of erosion, represented by the river bed of Zeleni Jadar.

The latest initiative from bauxite mine of Vlasenica is aimed at examining possibilities of mining the bauxite deposit up to elevation of 310 m by means of open working i.e., deepening of the existing open pit mine of "Podbraćan". In this

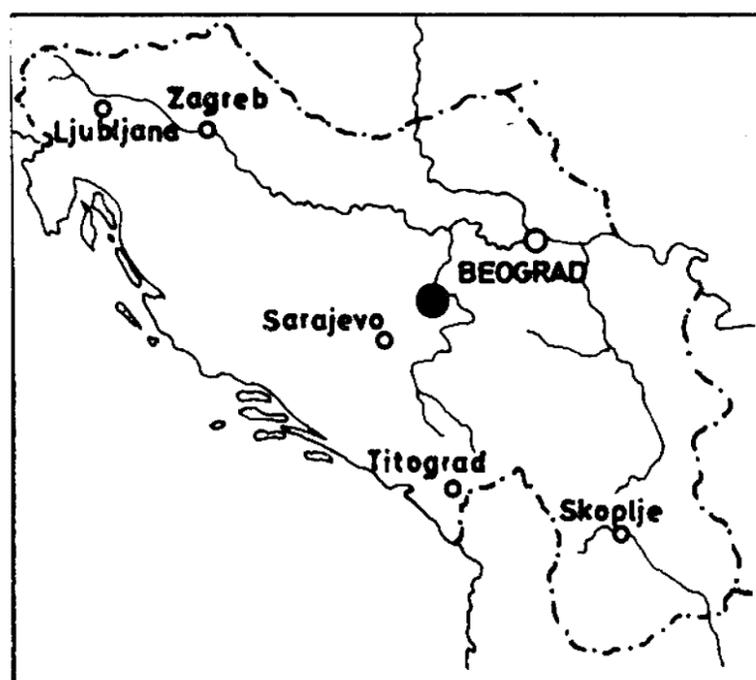


Figure 1 Geographical position bauxite of "Vlasenica"

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way hydrogeological investigation to this effect has been actualized again. In order for these two major bauxite deposits to be mined it is necessary to dewater them first. This would continue in the process of mining works as well.

For the cost of mining to be reduced, the water pumped may also be utilized for bringing water supply to the mine and surrounding settlements along with the corresponding measures of their protection.

GENERAL CHARACTERISTICS OF A BROADER ZONE OF "PODBRAĆAN-BRAĆAN BAUXITE DEPOSITS

"Podbraćan-Braćan bauxite deposits are the largest and at the same time the most important deposits within the bauxite-bearing region of Vlasenica. They are situated in its central part on altitude from 560 to 700 m. As a result of geomorphic processes, they represent the remains of a karst field (polje) deformed by action of secondary agents, i.e., tectonic and erosional movements. The immediate edge is represented by mountainous areas with altitudes sometimes exceeding 1200 m. This greatly influences the annual amount of precipitation ranging from 1060 to 1350 mm/y. The relief and geographical position of this part of the terrain have their direct and strong influence on the amount and unevenness of precipitation. As a result, frequent changes of dry periods followed by rain and snow are distinctly noticeable. They represent the main features of the mountain climate. Geomorphic and hydrometeorological characteristics, along with the geology of the region itself are directly related to hydrologic characteristics. Steep, hilly-mountainous relief, high values of precipitation during the year as well as geologic base have had their impact on the development of the river system characteristics of this region. Its main water drain is the Zeleni Jadar river, as the only permanent water-course. It flows along the immediate, northern boundary of the deposit with elevations from 400-410 m. Indented relief is conditioned by numerous surface intermittent flows in the form of torrents due to uneven atmospheric precipitation reflected directly on the regime of flow of Zeleni Jadar.

Although their geologic structure seems simple at first sight, these are in fact very complex lithologic and tectonic relations especially in the immediate zone of the deposits (Fig. 2a).

The bauxite underlying formation also widely represented in a wider zone of the deposit is made up of the Middle Triassic massive limestones, with the depth exceeding 500 m at same places. Limestones are extremely karstified with all the features of the occurrence of surface and underground karst forms. On the northwestern slope of the zone of deposit the underground chambers up to 25 m high have been discovered.

The paleorelief of the Triassic limestones is extremely marked and filled with bauxite whose thickness ranges from 13-14 m.

Between the Middle Triassic limestones and Upper Cretaceous series are the layers of bauxite. Their reserves justify any economic investments to be made under present conditions of economic appraisal of deposits. Thick series composed of the Upper Cretaceous

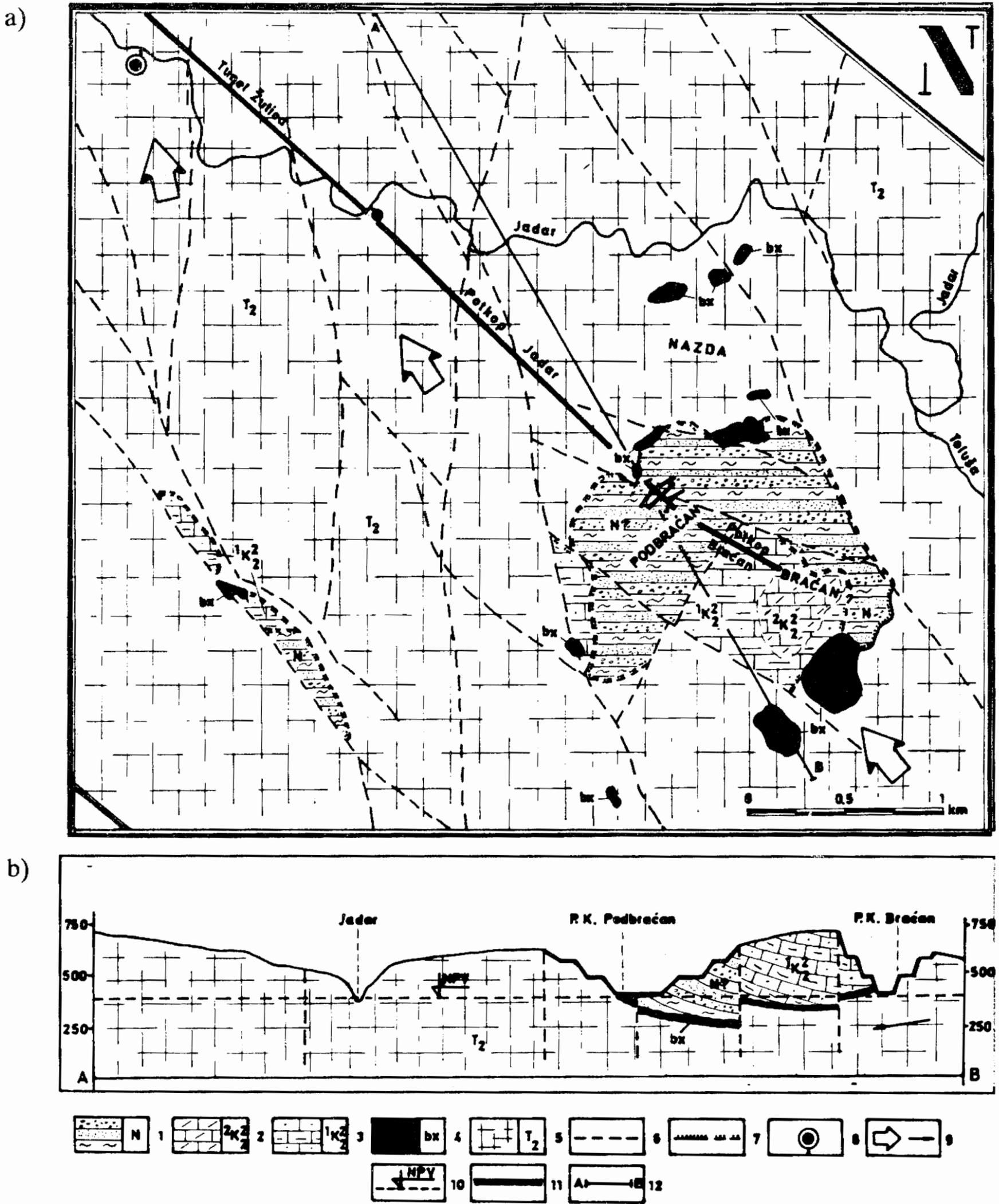


Figure 2 Hydrogeological map and schematic hydrogeological cross-section of the zone "Podbraćan-Braćan"

1. Neogene gravels, sands, clays (aquifer with intergranular porosity); 2. Senonian limestones (karst aquifer); 3. Turonian limestones with marls and sands (karst aquifer); 4. Bauxite; 5. Triassic karstified limestones (karst aquifer); 6. Fault supposed; 7. Geological boundary; 8. Group of the springs; 9. Direction of circulation of ground waters; 10. Ground water level, supposed; 11. Trace of tunnel and adit; 12. Trace of cross-section A-B.

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clastic rocks is deposited in bauxite roof. Its most marked units are: quartz sandstone, sand, marl, clay, limestone and marly limestone, with total thickness exceeding 300 m (western part of "Braćan" deposit). Overlying these lithologic units are the Upper Cretaceous series of limestone and marly limestone ($^2K_2^2$), in the form of an isolated oasis in the region of Braćan hill.

The wider and narrower zones of the deposit represent an extremely tectonized region with the main tectonic zone of NW-SE direction which divides the two parts (Fig. 2b). The fault tectonics has had an extremely great impact on preservation of bauxite layers on one hand and on the complexity of geologic and hydrogeological conditions, on the other.

The narrower zone of the deposit has been intensely faulted and displaced to its present position due to strong tectonic movements. This reflects significantly on the overall hydrogeological conditions.

HYDROGEOLOGICAL CHARACTERISTICS OF THE NARROWER ZONE OF "PODBRAĆAN-BRAĆAN" DEPOSITS

Hydrogeological characteristics of the wider as well as narrower zone of "Podbraćan-Braćan" deposits have been the focus of attention on numerous scientific gatherings so far. They have mostly related to the degree of deep exploration of deposits up to the base level of erosion that is, up to elevations from 410-420 m, where the river bed of the Zeleni Jadar is cut in the zone of deposit. There are a number of works published on this subject so far as well as numerous documents (cf. References). Hydrogeological data relating to the deeper parts were rather scarce until 1988-89 when a number of explorations to this effect was undertaken. On basis of these as well as data obtained from earlier hydrogeological investigation, hydrogeological conditions in the narrower zone of deposits may be defined in more detail.

As it is well known, bauxite underlying formation below elevations of 320-330 m is made up of karstified Triassic limestones, tectonically intensely dislocated and faulted. Up to elevations from 400-410 m (up to the level of Jadar) the caverns and fissures are flushed. There are also underground chambers which may reach 25 m in diameter (data based on drilling results). Below these elevations, especially in the zone of deposits, caverns in limestones are filled with argillaceous and bauxite materials. This influences the hydrodynamic conditions i.e., the formation of confined aquifer is possible in these parts of the terrain. Within the limestone underlying seem, wide karst aquifer is formed. This is a water-table aquifer on the edge but in the zone of deposit it is confined. This is the main problem which may be crucial for mining from deeper parts of the deposits. A part of karst aquifer above the riverbed of Zeleni Jadar is discharged naturally by flowing into the river or, through adit with gravity drainage. The main occurrences of water discharge are at a distance of about 1500 m with minimum outflow of about 150 l/s. Apart from these two possibilities, the waters from Jadar would most probably flow into the deepened parts of opencast mine with minimum inflow from 150-200 l/s, and maximum of several m^3/s . Based on the data obtained so far, total quantities of water pumped from the deposits under conditions of hydrologic minimum would be about 500 l/s. The described quantities of water along with the existing

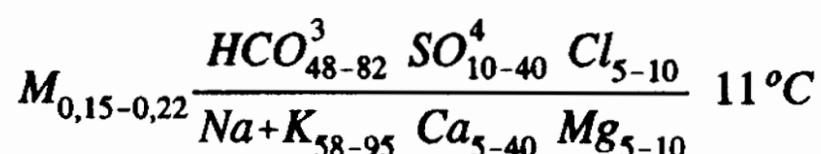
waterworks facilities of Zvornik will completely meet the needs for water supply of this part of Eastern Bosnia in the next 20-year period.

THE POSSIBILITIES OF GROUND WATER UTILIZATION AND PROTECTION

The problems of water supply of the mine itself as well as of the surrounding settlements have not been solved in the adequate way so far. In the summer period large quantities of industrial water for the needs of the mine itself are provided by cisterns. This requires enormous material costs. On the other hand, the water supply for about 10.000 inhabitants in the immediate vicinity of the mine is not very satisfactory. To this should be added the fact that practically all larger settlements including Zvornik with its 30.000 inhabitants, are also faced with the unsolved problem of the supply of high-quality drinking water.

Bearing in mind the long-term development of this part of Eastern Bosnia and conditions for intensive economic development and urbanization of settlements, one of the most important tasks would certainly be to solve the problem of water supply for a longer period. This would require water collection from the new sources of ground water in order to obtain high-quality waters of greater capacity. One of the most promising possibilities would be utilization of water pumped from the zone of bauxite deposits. However, for its successful recovery below the local base level of erosion, intensive dewatering would be necessary.

Proceeding from the fact that by drainage from deeper parts of "Podbraćan-Braćan" deposits some 500 l/s of karst water will be pumped, provided, that a number of expensive structures is built, it would be cost-effective to use these structures for solving the problem of water supply too. This would include not only the mine itself but also settlements from Derventa and Milići up to Zvornik. As far as their chemical composition is concerned, these are high-quality karst waters. All major occurrences of waters explored so far in the broader zone of the mine are characterized by low-mineralization (below 0,5 g/l), with temperatures ranging from 7-12 °C. By their chemical composition they are hydrocarbonate-calcium waters. Their chemical composition can be represented by the formula as follows:



From the viewpoint of solving water supply problem, karst aquifer waters in a wider zone of deposits are certainly very interesting regarding their chemical composition and conditions of protection.

A broader region of deposits is thinly populated. This is a very favorable condition for preserving the required water quality. In this context, a potential danger could be provisional structures built on the karst ground for keeping livestock in the summer season. In order to reduce this kind of danger to a minimum, it is necessary to take preventive measures and

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remove from the immediate zone of influence all similar structures that could be potential source of contamination.

Apart from these facts, special threat to the quality of ground water could present some activities related to bauxite mining. They could significantly disturb the chemical composition and physical properties of ground water. Special threat might present the mine waste waters, naphtha and oil derivatives that are being abundantly used in the production process. This direct danger is the result of a series of circumstances. The most important of these is the fact that the administrative building, service workshop and similar structures have been erected exactly in the zone of sinkholes where underground chambers of 20-25 m in diameter were discovered in the process of drilling.

The sinkholes make rapid percolation of waste waters possible. In this way they have direct access to aquifer. This problem should inevitable be solved by constructing the sewage system and by the controlled deposition of waste waters.

We are of the opinion that there will be no difficulties for successful mining of high-quality waters from karst massif in a wider zone of "Podbraćan-Braćan" deposits if the problem of ground water protection is solved and dewatering system completed. By construction of "Žutice" tunnel and "Jadar" adit with total length of 4300 m, easier transport of water by means of pipe-lines will be made possible. This will also be the shortest way for water to reach consumers.

In this case, the investments necessary for the construction of 10 km longer pipe-line would be significantly reduced. It should also be noted that this pipe-line would have been built under very difficult conditions. The water would be conveyed by force of gravity and only a smaller part for local needs of workers, would be directed into the network by the pumpage system.

The above facts clearly show that along with minimum investments for future construction of the dewatering system, the problem of water supply can also be successfully solved by construction of regional water-works from "Podbraćan-Braćan" mines to Zvornik.

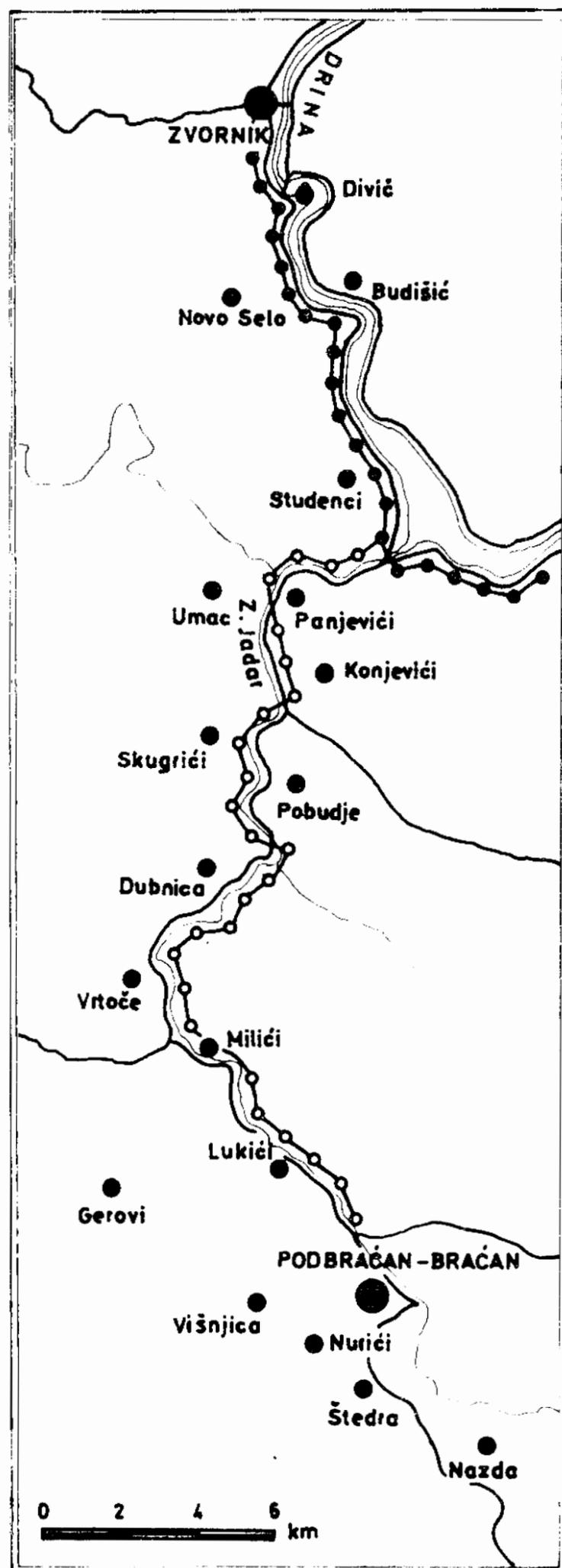


Figure 3 Regional pipeworks

This would make transport of pumped water to the consumer possible.

In the end, it should be pointed out that for this idea to be realized, it is necessary to complete the construction of the drainage system for "Podbraćan-Braćan" deposits and also to instal regional pipeworks with the total length of 25 km (Fig. 3).

This project requires substantial financial funds but bearing in mind all the relevant facts, the overall solution will be cost-effective since it is based on utilization of waters obtained from the dewatering of bauxite deposits.

CONCLUSION

The paper treats of the possibilities of ground water recovery and protection during exploitation of bauxite deposits in the example of Vlasenički bauxite deposits, "Podbraćan-Braćan".

This is a topical issue worldwide and in this country as well and it is for these reasons that hydrogeological explorations for the above needs are of great significance. This is manifested in the course of expanding, development and exploitation of bauxite deposits with ore body lying below the base level of erosion, which is the case with major deposits of the bauxite-bearing region of Vlasenica, i.e., the "Braćan" and "Podbraćan". In order for successful exploitation under such conditions to be possible, it is necessary to perform intensive drainage works which will, in turn, bring about the change in local and even regional hydrogeological conditions. The waters obtained through drainage may successfully be utilized for water supply purposes or, they may be used as technical waters since they meet the quality standards with specific protective measures against contamination due to bauxite exploitation being taken.

The hydrological conditions in the immediate and broader zone of deposit require compulsory drainage of its deepest parts for the needs of bauxite exploitation. The large quantities of water about 500 l/s taken in this way would be supplied to the surrounding settlements, from the mine to Zvornik. This, in turn, would reduce the costs and expenses of drainage works themselves.

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