The Influence of Karst Aquifer on Ore Deposits in East Serbia, Yugoslavia

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ABSTRACT

The karst region in the eastern part of Serbia covers around 30 % of the territory. In the region there is a number of ore deposits (black and brown coal and copper deposits). The principal factor causing the water inflows for most of the deposits is the presence of carbonate rocks, that is the karst aquifer in the immediate vicinity of the deposits, often in the direct contact with it.

INTRODUCTION

The region of Eastern Serbia is characterized by the relatively numerous ore deposits that are being mined (fig.1.). Frequent occurrence of ground water inflows, sudden inflows, into mining works is not accompanied by the coriesponding degree of systematic hydrogeological investigation. This paper presents some of the examples of recorded underground inflows from karst aquifer which are the most usual form of inflows.

THE GEOLOGICAL AND HYDROGEOLOGICAL CHARACTERISTICS OF EASTERN SERBIA

In the region of Carpatho-Balkanides of East Serbia there occur geological formations starting from the oldest ones, the Precambrian to the youngest ones, the Quaternary. The Precambrian is represented mostly by metamorphites of a higher degree of cristallinity. The paleozoic appears as completely developed but in a broken line. During the Triassic and Lower Jurassic, the terrigenous and carbonate facies were formed, and it was only in the Dogger that the transgression bore its impact on the major part of these terrains. The sedimentary cycle during which the major part of carbonate rocks was formed, lasted until the end of the Lower Cretaceous (Albian), whilst during the Upper Cretaceous, the formation of a thick volcanic-sedimentary rock complex occurred in the Timok andesite massif ("Senonian tectonic graben", on eastern part of the region). During the Tertiary, the sedimentary cycle developed in isolated lake basins.

Intensive tectonic movements with faulting and magmatic activity were repeated in a number of phases. Major part of carbonate massifs is represented by separate anticlines with a core composed of old rocks (Kucaj-Beljanica, Svrljiske planine, Suva planina etc.).

The region of the Carpatho-Balkanides is characterized by predominantly hilly-mountainous relief, with carbonate rocks accounting for 30 % (3000 km^2). Karst aquifer are characterized by intensive karstification and rich water resources. Karst aquifer are drained through numerous springs on the contact of karst and nonkarst, and trough processes of subsurface outflow and evapotranspiration. The total safe yield in karst aquifer of the Carpatho-Balkanides is estimated at over 26 m^3/s.

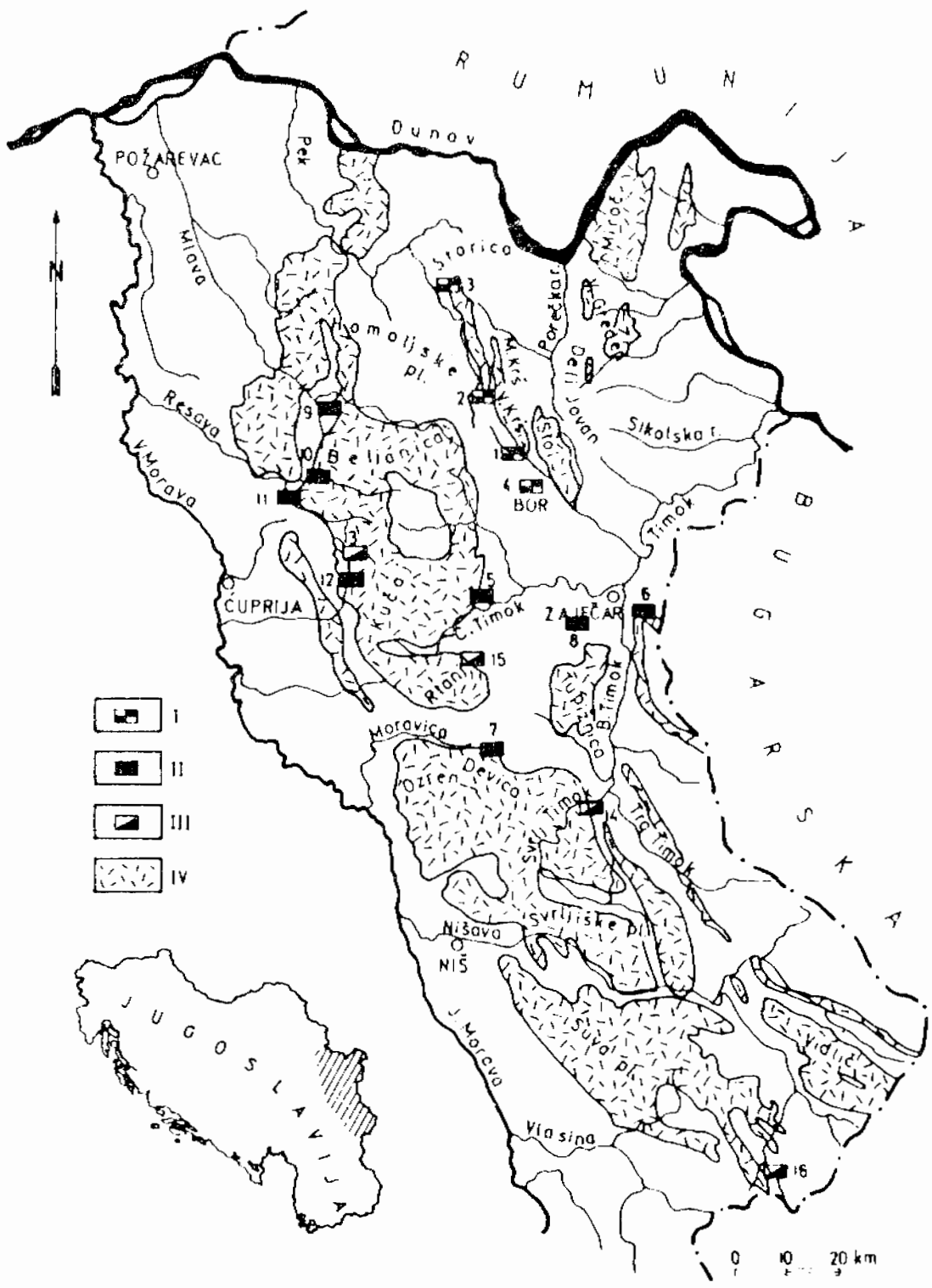

Fig.1. Schematic map of karst aquifer and ore deposits of Eastern Serbia

I. Copper mine; II. Coal mine; III. Abandoned mines; IV. Karst aquifer 1. Veliki Krivelj(cop.); 2. Cerova(cop.); 3. Majdanpek(cop.); 4. Bor(cop.) 5. Bogovina(coal); 6. Vrska Cuka(coal); 7. Soko(coal); 8. Lubnica(coal); 9. Jasenovac(coal); 10. Strmosten(coal); 11. Nova Manasija(coal); 12. Senjski rudnik(coal); 13. Ravna reka-Pasuljanske livade(coal); 14. Podvis (coal); 15. Rtanj(coal); 16. Jerma(coal)

THE ORE DEPOSITS AND FACTORS OF THE WATER INFLOWS

In the region of East Serbia there are a number of ore deposits. The black and brown coal deposits with underground recovery as well as copper deposits are of special economic significance.

The major number of coal deposits occur in the external belt of Carpatho-Balkanides. They are genetically related to intensive tectonic and volcanic activity. Especially significant is the Laramidian orogeny. The major coal deposits with underground exploitation are: Senjsko-Resavski mines, Bogovina, Soko, etc. (fig.1.). Some of the mines were abandoned following their intensive exploitation.

The copper mineralization deposits occur within the eruptive zone of Timok, in the deep tectonic graben formed during the Upper Cretaceous, between the limestone mountain massifs in the peripheral parts. Intensive volcanic activity in this zone developed in a number of phases, giving rise to the formation of some of copper deposits. Major mines in this zone are: Bor, Veliki Krivelj and Majdanpek.

The major factors causing the water inflows for most of the deposits are the following:

-the presence of carbonate rocks, that is, the karst aquifer in the immediate vicinity of the deposits, often in the direct contact;

-the regional faults and fissure systems;

-the presence of river streams and aquifers with intergranular porosity in river alluviums, deposit roofs,

-some induced factors, above all, the method of expanding and exploitation as well as old mining works.

According to their size, all kinds of inflows are represented from relatively weak to the very big ones, in the course of one hydrologic cycle. The regime of karst aquifer brings about the unequal inflow intensity and enriched flows from the most active zones. In some mines the new flows have been recorded; they produced inundation of underground chambers. Besides the direct action of inflows, some deposits (copper deposits, in particular), are under the indirect impact of underground discharge from the karst.

SOME PRACTICAL EXAMPLES OF THE INFLUENCE OF KARST GROUND WATERS

Within the **Senjsko-Resavski** mines, annual inflow (pumped quantities of water) was from 0,003 x 10^6 m^3 to 1,2 x 10^6 m^3 during 1974 and 1975. The occurrence of sudden inflows which may cause catastrophic drowning of the deposits has been evidenced in the example of the new mine-Senjski rudnik-Lipov deo. Until 14.04.1980. the water inflow was insignificant. However, on that date the sudden inflow from karst overlying seam, occurred. This resulted in the drowning of mining galleries together with their mining machinery. The mean inflow was 67 l/s in the period from 14.04.-21.04.1980.

The mean inflow into the mining works of Senjsko-Resavski mines is about 100 l/s, with considerable fluctuations during the year. The largest quantities of these waters are directly due to karst aquifer and to a lesser extent, to fractured rock aquifer in andesite, Permian

sandstones and Tertiary sediments. Due to this, during the development of deposits, special attention has to be paid to the position of carbonate rocks, fault systems and old mining works.

Brown coal deposit of **Jasenovac** near Krepoljin is in a similar situation. Here, occasional enlarged inflows (such as those in 1984) result from direct underground discharge from Jurassic limestone. Under the conditions of "normal" exploitation, the deposit is characterized by low water inflow (mean inflow is 15 m^3/d).

Within the "**Bogovina**" coal deposit (southeastern Kucaj), based on detailed hydrogeological investigation and dye tests, it has been stated that the impact of karst aquifer waters on marl rock deposits was only indirect, as a consequence of the position of the impermeable barrier made of orbitoline sandstones. However, one part of waters probably outflows underground into the deposit. The mean inflow here is about 80 l/s (predominantly due to water infiltration from the Bogovinska Reka River and to waters from old mining works).

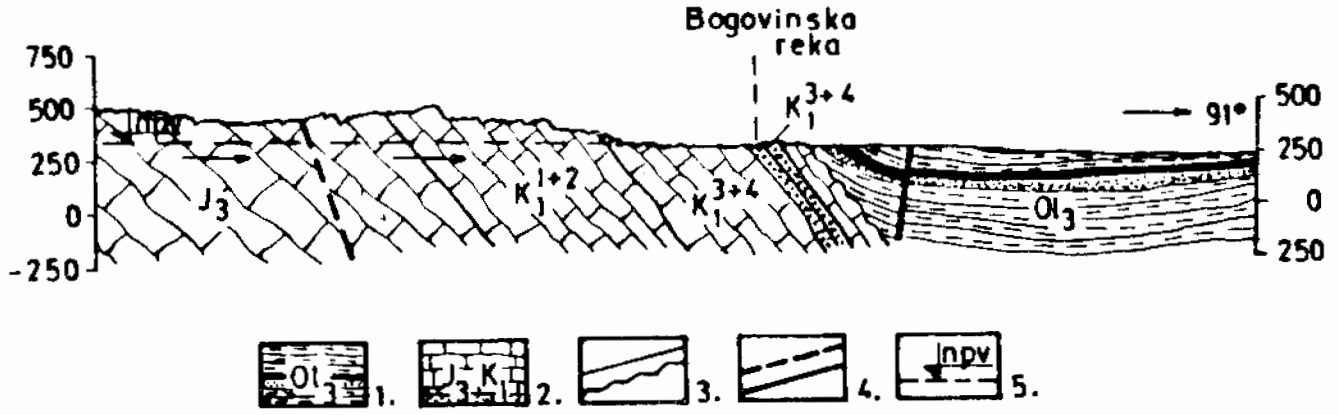

Fig.2. Schematic hydrogeological cross section of Bogovina mine
1. Oligocene deposits, marlstones, sandstones coal; 2. Limestones of Upper Jurassic and Lower Cretaceous; 3.Geological boundary; 4. Fault; 5. Ground water level

The "**Soko**" coal deposit in the eastern peripheral part of Sokobanjski basin near Citluk, also belongs to the group of deposits with low inflow under present conditions. However, since the main factors of inflow are the Urgonian limestones (in the periphery and substratum of the deposit), as well as surface waters of the Izgara River (by indirect infiltration through karst aquifer), under the conditions of prospective mining this could result in the increase of inflow in "active" zones of the contact of "productive" deposits and limestones.

The "**Lubnica**" coal deposit is beyond the zones of possible influence of karst aquifer. The "**Tresibaba**" and "**Podvis**" mines have not had any major problems in the course of mining either. Similar conditions prevail in the black coal deposit of "**Avramica**"-**Vrska Cuka**, although the Middle and Upper Jurassic limestones are significantly represented in a broader zone of the Liassic sediments to which the deposit is primarily connected. In a number of coal exploratory boreholes or boreholes for water supply of the surrounding provisional settlement, artesian aquifers have been discovered beyond the zone of direct mining works. The abandoned mines of "**Rtanj**" and "**Jerma**" are in similar condition as well. During exploratory work with the "entrance" into limestones, considerable quantities of water with increased

hydrostatic pressure were obtained.

Example: By exploratory drilling in the "Nova Jerma" mine at the depth of 57 m, the water outburst some 18 m above the surface. The hydrostatic pressure declined later on with steady flow of 3 l/s during 1955.

Filtration characteristics of fractured rock aquifer formed in gneiss, in the wider zone of **"Majdanpek"** copper deposit, do not allow for the possibility of infiltration of larger quantities of water from karst aquifer. However, exploratory works in deeper parts of the deposit at the entrance into limestone horizons have increased the aquifer water inflow up to 18 l/s.

Within the **"Veliki Krivelj"** deposit, along the system of fractures and fissures and younger cross faults, karst aquifer waters inject into volcanic and hydrothermally altered volcanic rocks. During the production of two prospecting galleries trough the deposit which were vertically positioned to the Kriveljska hydrothermally altered zone and the direction of the limestone of the Krs mountain massif, the increase in inflow of ground water was recorded with the coming of the tunnel closer to limestones, with resulting sudden inflows of ground water in the immediate vicinity of the contact.The karst aquifer waters in the substratum of "Veliki Krivelj" cooper deposit, influence the continuous ore wetting and the occurrence of sliding of ore mass. In addition to increased inflows, this makes the process of mining ever more complex and expensive. The outflow under pressure has occurred in the course of geological test drilling within this deposit, some 50-80 m above the base level of erosion.

In exploratory geological works for the needs of investigation of copper mineralization in eastern parts of the eruptive area of Timok, subsurface discharge of a part of karst water into fractured volcanic rocks has been proven in a number of localities as well.

In the localities of **Bozina Reka River-Pogare** (foothill of Veliki Krs), three boreholes were drilled during 1977. The B-320 borehole was drilled up to the depth of 381,80 m through the hydrothermally altered volcanic rocks.

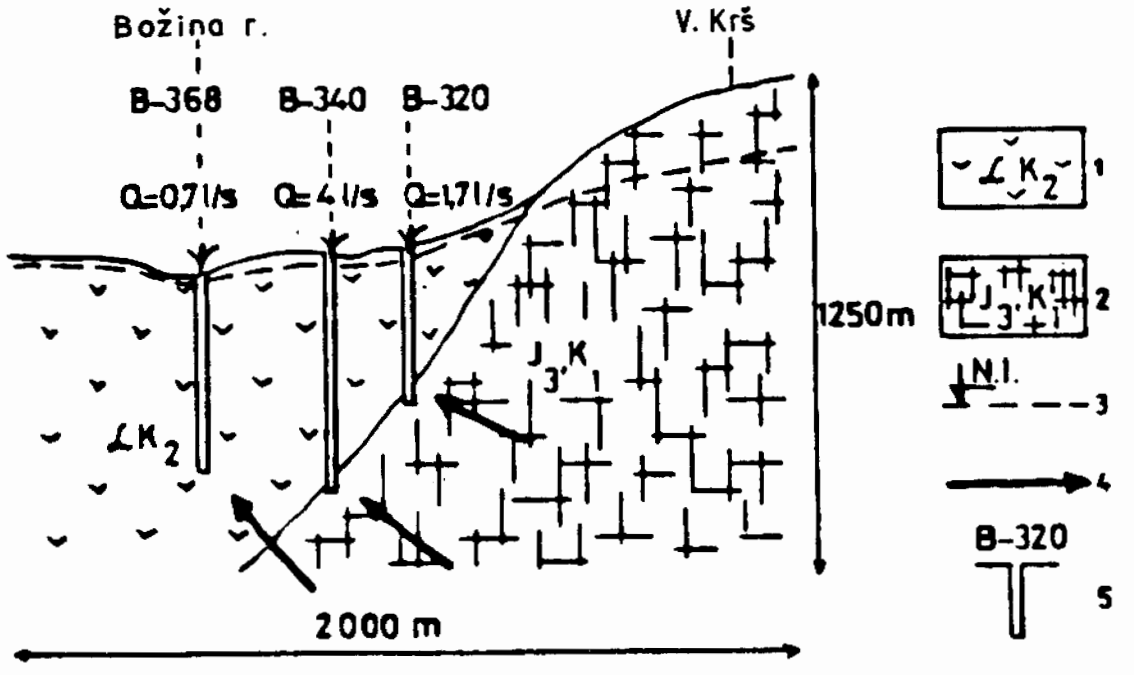

Fig.3. Schematic hydrogeological cross section of zone of Bozina Reka

1. Volcanic rocks of Upper Cretaceous; 2. Limestones of Upper Jurassic and Lower Cretaceous; 3. Ground water level; 4. Direction of circulation of ground water; 5. Borehole.

At 381,80 m marble limestones were tapped. From these, some 1,7 l/s of water discharged with the temperature of 20 °C. The B-340 borehole went up to the depth of 477,40 m from the surface of the field through the hydrothermally altered volcanic rocks finally tapping the marble limestone. Here also the outflow of 4 l/s occurred with water temperature of 21 °C. The B-368 borehole was drilled up to the depth of 478,0 m. Along its whole length it passed through andesite, volcanic breccia and volcanic agglomerates and ended there. Between 425,0 m 427,0 m the outflow of 0,7 l/s occurred. The water temperature was 21 °C.

In the locality of **Ujova Reka River** (foothill of the Kriveljski Kamen limestone), the B-2 borehole was drilled in 1980, up to the depth of 500,0 m. Along its whole length, the borehole tapped the hydrothermally altered volcanic rocks. At 130 m, the outflow of 2,5 l/s occurred. The water temperature was 17 °C. In all of the above boreholes, the outflow of water occurs even today.

CONCLUSION

Although the ore deposits of eastern Serbia have a relatively low inflow, the occurrences of sudden inflows of karst ground water are frequent. This has resulted in a number of catastrophic drowning of mining works. Special attention should be paid to these conditions in the course of exploratory work during the development of deposits. Systematic and detailed hydrogeological investigation is necessary as well as the monitoring of the regime of mine water with the aim of providing all necessary protection measures.

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