THERMAL SOURCE IN THE VRDNIK BROWN COAL MINE

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ABSTRACT

The Vrdnik brown coal mine, at the southern slopes of the Fruska gora mountain has been out of exploitation for a long time. Because of the insufficient knowledge of the tectonics and lithological of rock masses in the substratum of the Neogenic complex, the mine was overflooded. The thermal water came from the Middle Triassic limestones which are not involved in the fringes of the Neogenic basin. The Neogenic sediments 350 m thick, with two coal strata, was deposited in a tectonic depression of 4-12 km in width. The tectonic depression was formed between two the radial faults, and the reverse one. The tectonic depression edges are composed of serpentinites, Paleozoic shales, and silicificated rocks. In the Neogenic complex it is possible to single out penetrations of dacite-andesite and basalt. By series of parallel faults of the directions E-W and NW-SE the Neogenic basin, together with its substrate is divided into the tectonic blocks when is formed a tectonic graben. The spatial disposition of these tectonic blocks in the tectonic graben with karstified limestones in the substratum of the Neogenic complex was the cause of the mine flooding. Namely, by deepening the main outlet “South Shaft” and constructing a corridor along the coal layer, the limestones and coal layer were brought to the same level. As a consequence, the thermal water from the karstified limestones gushed to the mine at a rate of over 100 l/s. After mine flooding, substantial resources of thermal water were discovered. The waters from the “South Shaft” have been exploited for a number of years at a rate of 30 l/s, and used for spa purpose in a constructed health and recreational resort. This is by far a more favourable solution that mine exploitation as the Fruska gora mountain has been declared a National Park.

INTRODUCTION

The Vrdnik coal-bearing basin, although of small proportions, was considered to be a very prospective due to its favourable structure of coal layers with bentonic clays.

The objectives of the investigations were to define the tectonic structure of the coal deposits, spreading and hypsometric locations of karstic limestones, static volume of thermal waters, the thermal waters inflow and the conditions of flowing in.

METHODS

In order to reach the set aim, drilling of piezometric holes to sediments of the Neogene complex was performed, as well as the photo-geological observation of the terrain. Moreover, the drainage of the “South Shafts” was done quarterly and the following hydro-geological parameters were evaluated:

• k - coefficient of filtration,
• T - coefficient of transmissivity, and
• μ - coefficient of effective porosity.
At the end, the simulation of hydrodynamic behaviour of karstic aquifer was done by the mathematical modelling.

**REVIEW OF THE GEOTECTONIC CONSTRUCTION OF THE VRDNIK MINE AREA**

Vrdnik Neogene coal basin was formed on the southern slopes of mountainous massif Fruska Gora (in northern part of Serbia), as clearly profiled valley. The valley configuration is the result of the complex structural relationships since it had been formed along the tectonic fault in the terrain exposed to the constant tectonic movements (Ciculic and Dolic, 1960; Ciculic and Rakic, 1977). So after the Tertiary basin had been formed with the coal layers in the east-west direction the basin was divided into few tectonic blocks (Pavlovic and Mijatovic, 1988). The coal mine Oborac is located in one of these sunken blocks. The flooded southern pit is placed in its central part as presented in Figure 1.

The carte frontiers of the northern, western and southern coal deposit have been defined clearly by the faults while the southern one has preserved unclear. The geological form of the nearest surroundings of the deposit 'Oborac' consists of: serpentinites, metamorphic rocks, sericite, schists, quartzites, as well as Triassic sediments (sands, grauwacke, claystones and marlstones), diabase, the intrusion of dacite - andesite and Neogene deposits (Pavlovic and Mijatovic, 1988).

The Vrdnik coal-bearing series belongs to the Neogene age respectively to Lower Miocene, covering three particular horizons: underlying formation, coal bed and confining layer.

- **Underlying formation.** Lies over the rough paleorelief consequently creating very uneven thickness. That is why the depth is ranging from 9 to 100 m. It was determined by infrequent exploration boreholes drilled to the coal basal level. The underlying formation is composed of: conglomerates, breccia, sandstone, marlstone and claystone.

- **Coal bed.** Consists of two to four layers of coal interbeded by bentonite or coal clays. The total thickness of coal bed ranges from 4 to 17.5 m; the first one from 1.5 m to 5.0 m, and the second one from 0.4 m to 4.2 m. Both of them being characterized by continual distribution. The third and the fourth layer, range from 0.4 m to 3.8 m and 0.3-3.0 m, and they are of lenticulaire appearance.

- **Confining layer.** Has the maximum thickness. The western tectonic blocks confining layer caprock thickness ranges from 27 to 67 m and in deposit Oborac from 175 to 289 m. Immediate confining layer is presented by coal clay, clay and marl, being of 10 m thickness. In the upper layers they are succeed by clays and marls interstratified with the sand, gravel and fine grade sandstone. Large depth of confining layer in the deposit Oborac area had been caused by the sinking of the blocks along the trace faults in EW direction where the coal deposit lies between the blocks.

**THE UNDERGROUND EXPLOITATION RISKS**

The underground exploitation risks always exist, but the exploitation could be safe if one follows the exact mine rules strictly.

The pits dug built in the intergranulaire porosity rocks are not always jeopardized by underground water. That is why the exploitation has been done without any consequences in the mine field Vrdnik for number of years. The coal bed depth was defined by the numerous exploration bores only, so they have been drilled up to its very underlying formation. The blocks structure as a consequence of radial tectonic and a type of hard rocks in the basis of Neogene deposits, has been neglected in this case.

Since the fissured karstified limestone as a favourable water bearing formation does not appear on the surface of the Vrdnik valley i.e. Neogene basin, it have not been expected to be found in the basis. Nevertheless, the further dig in of the main southern pit, have caused the unusual slightly intensified

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**Figure 1. Geological – tectonic map of coal basin Vrdnik (Pavlovic and Stojiljkovic, 1998).**
POSSIBILITIES OF DRAINAGE OF FLOODED SOUTH COAL BEARING BASIN

A planned 3-month drainage of the “South Shaft” was reduced to 54 days. The pumping was performed continuously in 10-17 day intervals with the capacity of 0.080 m³/s⁻¹, 0.115 m³/s⁻¹ and 0.126 m³/s⁻¹.

Prior to the non-stationary drainage regime of the capacity of 0.126 m³/s⁻¹, SWL of 34.79 m was registered and then the pumping was done ceaselessly from November 23 to December 10, 1987, with a relatively stable dynamic level of 83.0 m (ΔS = 48.21 m).

Parameters k, T and μ were estimated on the basis of the plots S = f (log t) and S = f (log t') obtained from the data on pumping and level measurements in six observation wells.

The determination of the water inflow by the measurements of the level restoration time, the restored water volume, the area of limestones blocks and the volume of the rock mass was not reliable due to the gas factor, unknown static volume of water in the underground works and the different anisotropy of the hydraulic conductivity. The inflow could be more reliably determined over the gradient on the interpreted isoclinic map of positions of aquifer levels, where gradient 0.5 is 0.074 (for turbulent flow), T is 2.44 x 10⁻³ m²/s⁻¹ (transmissivity), L is 250 m (length of the inflow zone).

Q = T X L X i0,5 = 0.00244 x 250 x 0.074 = 0.045 m³/s⁻¹

Assuming that the length of the inflow zone is only 250 m, the amount is significant. If flowing in is done from the west along the border gravity fault, the length of the inflow is much longer, and due to it the process of drainage is more complex.

The evaluation of water reserves by calcareous aquifer modelling was done when there was no flowing in on the surface contours delimited with the gravity faults with the gradient S = 0, and where there was flowing in with the gradient S ≠ 0. It was determined that the water reserve under the conditions of flowing in amounted to 343,713 m³. Based on the basin, the order of magnitude of the unit inflow from the calcareous aquifer substratum was evaluated to be 0.640 m³/s⁻¹, which is in accordance with the previous estimation.

CONCLUSION

The skillful research of the isolated coal basins that have been formed in the depressions (originating in the solid rock mass by folding) is necessary indeed. That is particularly the case if they had been exposed to radial tectonic after the final phase of its origin. Insufficient knowledge of this type of basins structure, due to sudden penetration of mine waters in to the pit rooms, may produce the catastrophic consequences during the exploitation. The possibility of groundwater intrusion increases in the case of block structure of coal basin bedrock when the position of tectonically damaged bedrock and the coal bearing horizon had been...
brought at the same level. The fissured rocks are the water bearing layers, particularly karstified limestone can accumulate immense amount of groundwater. The consequence of the inadequate knowledge of the coal basin structure as well as exploration boreholes drilled to the coal bearing horizon bedrock only, was the flooding of the southern field of the Vrdnik coal mine.

Although the Vrdnik coal bearing basin has a favourable structure of coal layers, the obtained results indicate that the drainage is not economically justified. The drainage of the static volume of 343,713 m³, estimated by the mathematical modelling, with the inflow of 0.045 m³ s⁻¹, without the appropriate equipment, is hard to carry out. If the rehabilitation costs of underground corridors is considered, then the better solution will be an already established spa “Thermal” with its recreation center.

REFERENCES


