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 substrate 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 quartely 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 interbedded 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.

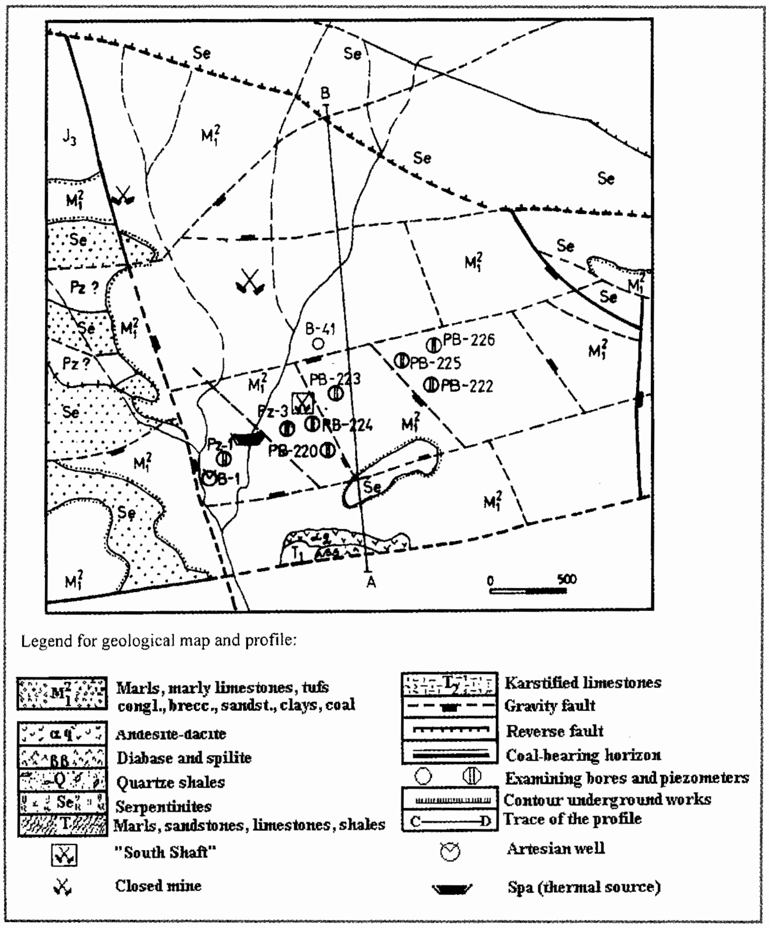

Figure 1. Geological – tectonic map of coal basin Vrdnik (Pavlovic and Stojiljkovic, 1998).

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 dug in of the main southern pit, have caused the unusual slightly intensified thermal waters outflow (approximately a few l/s) originating from the bedrock of the coal layer composed of sandstone and pebble, initiating the change of the previous state. The southern pit was characterized by dampness, dropping and leakage of water in insignificant amounts before the occurrence.

From the southern pit which was already dug, an exploiting pit is directed to the NW along the coal bed horizon which has unexpectedly led to the solid barrier composed of karstified limestone (Figure 2).

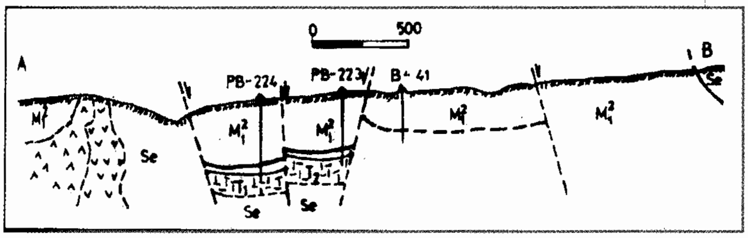

Figure 2. Thermal source and limestone position into the tectonic graben (Pavlovic).

The removal of the impervious coal bed together with its immediate cover and bedrock which have been underlain the limestone, thermal water of 32-34 °C temperature has occurred like intrusion. Thermal water has completely flooded entire southern field together with the pit mine of 270 m depth, in less then 48 hours. Since water was under the pressure it had outflowed for a while. The capacity of groundwater flow as well as piezometric pressure have not been recorded.

The coal horizon have been sunken by the tectonic movements at the level of karstified limestone along the faults between Gustav pit and Krcevina, that was proved by the borehole 131 presented in the Figure 1.

The sunken of the exploiting horizon to deeper parts without precise knowledge about the geology-tectonic structure, increases the risk. It is particularly the case if the damaged solid rocks are visible on the surface along the Neogene basin ridge. The practice has proved that even tectonised serpentinites sometimes could be water bearing layers as well as other solid rocks. That is the reason one has to follow the consistency of the coal levels distribution. The relief of bedrocks, faults and blocks structure have initiated the discontinuation or folding of coal bed inside the basin. In these cases the projection of the exploiting flours need to be preceded by the exploring boreholes up the bottom. The rock type, its fissured degree, elevation head of the coal basin as well as possible fault direction, have to be verified by the exploring boreholes. The aim is to determine the spatial position of the coal bed.

Therefore, all the measures of the safe exploitation could be predicted by an exact project. It could be the positioning of the safeguarded columns made of impermeable coal layers in front of the contact with the potential water bearing strata.

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 m^3s^{-1}, 0.115 m^3s^{-1} and 0.126 m^3s^{-1}.

Prior to the non-stationary drainage regime of the capacity of 0.126 m^3s^{-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/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 i0,5 is 0.074 (for turbulent flow), T is 2.44 x 10^{-3} m^3s-1 (transmissivity), L is 250 m (length of the inflow zone).

$$Q = T \times L \times i^{0,5} = 0.00244 \times 250 \times 0.074 = 0.045\ m^3s^{-1}$$

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 $S \neq 0$. It was determined that the water reserve under the conditions of flowing in amounted to 343,713 m^3. Based on this, the order of magnitude of the unit inflow from the calcareous aquifer substratum was evaluated to be 0.040 m^3s^{-1}, which is in accordance with the previous estimation.

CONCLUSION

The skilful 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 m^3, estimated by the mathematical modelling, with the inflow of 0.045 $m^3\ s^{-1}$, 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

Ciculic, M. and D. Dolic, 1960. The Report on Investigations of Coal in the Vrdnik Tertiary Basin. Ed. Fond Geozavoda, Belgrade, Yugoslavia. (in Serbian).

Ciculic, M., and M. Rakic, 1977. Legend for the Elementary Geological Map. Ed. List Novi Sad, scale = 1:1.000.000, Belgrade, Yugoslavia.

Pavlovic, P. and B. Mijatovic. 1988. Hydro-geological Conditions of Underground Exploitation of "Oborac" Deposits of Brown Coal and Bentonite in Vrdnik. Ed. Fond Geozavoda, Belgrade, Yugoslavia. (in Serbian).

Pavlovic, P., and D. Stojilkovic. Hydrogeological characteristic and investigation degree of the thermal source in the base of the Vrdnik coal basin. XIII Geological Congres, pp. 119-130, Herceg Novi, Yugoslavia.