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ENERGY TRANSPORT AND POTENTIAL OF AN ABANDONED MINE

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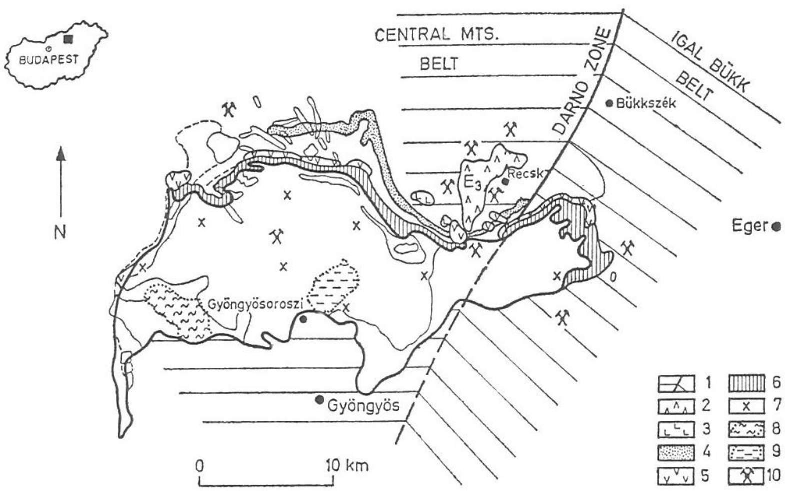
Abstract: In the '70s an important copper ore mine was implemented in Recsk, Northern Hungary. Unfortunately as soon as the use of the roadways were finished the activities were suspended, because the decreasing price of the copper on the international market. The mine then was abandoned the roadways and the shafts were flooded by mine water. The abandoned mine has a substantial geothermal potential. The terrestrial heat flow is anomalously high: 0.108 W/m^2, the temperature is 59.5 ^{0}C at the lower level in the depth of 1160 m. The heat transfer surface is more than 150,000m^2. Using a heat pump this potential is suitable for heating of the nearby area.
Keywords: Abandoned mine, energy source, energy transport

1. Introduction

The Recsk copper mine is an unfortunate implementation of the Hungarian ore mining industry. Recsk, as it can be seen in the Fig. 1. is situated in the Mátra Mountains, Northern Hungary.



1. Basement formations. 2. Upper Eocene biotite-hornblende andesites. 3. Eggenburgian andesites. 4. Lower Rhyolite Tuffs. 5. Carpathian pyroxene andesites. 6. Middle Rhyolite Tuffs. 7. Badenian pyroxene andesites. 8. Diatomites. (Caldera stage sediments) 9. Hydroquartzies (Caldera stage). 10. Mining area (after Földessy)

Figure 1. Geology of the Mátra Mountains

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The Mátra Mountains belongs to the Inner Carpathian volcanic arc. It is the highest (1014 m) and the largest Tertiary volcanic range of Hungary. In the last century detailed geological and geophysical surveys have been made, providing a great number of data for both the surface and subsurface geology. The most informative contributions to our knowledge about this area are the works of Szabó (1875), Mauritz (1909), Noszky (1927), Rozlozsnik (1934), Szádeczky-Kardoss (1959), Kubovics (1970), Varga (1975), Földessy (1988), and Zelenka (2000). More than 1200 ore exploratory drillings have been drilled to find and evaluate the important copper deposit of Recsk.

2. Geological background

The pre-Tertiary basement of the Mátra Mountains is separated by a regional scale deformation zone, the so-called Darnó line. Two essentially different basement structure can be recognized: the folded Mesozoic of the Eastern Mátra and the faulted Mesozoic structural belt of Western Mátra. The structural differences between the two units separated by this zone have been maintained throughout the Tertiary period.

The first Tertiary volcanic activity belonged to the vertical movements along the Darnó line, and four substage of volcanism resulted. The first was entirely subaqueous volcanism in the Upper Eocene. The rocks are typically biotite-hornblende andesites. The second substage developed by step-by-step assimilation and contamination as well as the build up of a stratovolcanic character. The originally andesitic character was shifted toward the more acidic range, producing dacites. In the third substage the eruptive centre was shifted northward, produced a stratovolcanic sequence of biotite partly overlapping the earlier volcanic sequences. The fourth stage was the development of a central explosive caldera of the strato-volcano, and resulted in the formation of radial and irregular dyke-patterns. The quickly subsided volcanic area was filled with reef limestones.

This subsidence, reached its maximum by the middle Oligocene, when the largest part of the Eocene volcanics was covered by marine sediments. The Upper Eocene volcanic activities is associated with very significant mineralizations in connection with shallow intrusive porphyric body and its skarn environment producing porphyric copper ores, skarnous copper ores in the intrusives and altered country rocks. The third substage of volcanism has produced intensive hydrothermal alterations as well as formation of stockwork copper ores. In the caldera area exhalative-sedimentary copper mineralization developed during this stage.

The Neogene volcanism includes andesitic and rhyolitic phase. Through these phases the initial rhyolitic predominance was changed toward the andesitic character.

The entire ore forming process was restricted to the hydrothermal temperature range. Its complexity is due to its temporally multiphase nature and the variety in the environmental controls of localization. Two stages of mineralization can be distinguished. The main stage comprises mineralization related to the intrusive host rocks. A second, less important stage is coupled to the latest effusives. The ore formation began at 400 ^{o}C, and ended at about 150^{o}C.

The most important ore type is the porphyry copper mineralization, in the form of disseminations, micro veinlets and veins throughout the inner alteration zones within intrusive bodies. The porphyry copper ore reserves total several hundred million tons at 0.4% copper cut off grade, with a 0.77% average copper grade. From the low grade central core a gradual enrichment occurs, 0.4-0.6% values in the phyllic region and 0.9-1% Cu maxima in the propylitic zone.

The highest concentrations of copper can be found in the limestone skarns, with an average 1.5% Cu content. Two main localizations of these skarn ores have been recognized: one of them is stratabound and parallel to the original bedding of the skarnified sediments, the other is represented by cross cutting steep lenses and veins. The ores related to the skarn zone represent 30% of the economic ore reserves of the deposit.

There are two main ore zones in the Recsk area. The so-called upper ore zone is situated at the depth interval between -490 and -690 m above the sea level. The lower ore zone can be found between -690 and -890 m above the sea level. The two ore zone are separated by a quartzit layer without any ore content.

3. The story of the mine

Recognizing the existence of the important copper ore reserves in 1969, it has been decided to deepen a shaft directly instead of further exploratory drillings. The first shaft – Recsk I – was deepened with an internal diameter of 8 m, to a depth of 1202 m. It was completed in the year of 1974. During the same year the second shaft was deepened: Recsk-II. During the deepening of it, there was some serious water inflow. The largest one happened at the depth of 770 m, with a flow rate of 0.95 m^3/min. The salinity of the inflowing water was very high, 9000 g/m^3. The scale deposit was steadily removed from the shaft wall.

To connect the two shafts, two horizontal drifts were driven at the depth of -700 and -900 m above the sea level. The cross section of the drifts is 20 m^2. Generally the drifts have proven to be consistent, but mainly were supported roofbolts of 1.8 m length. The drifts system of the mine is shown in Fig. 2.

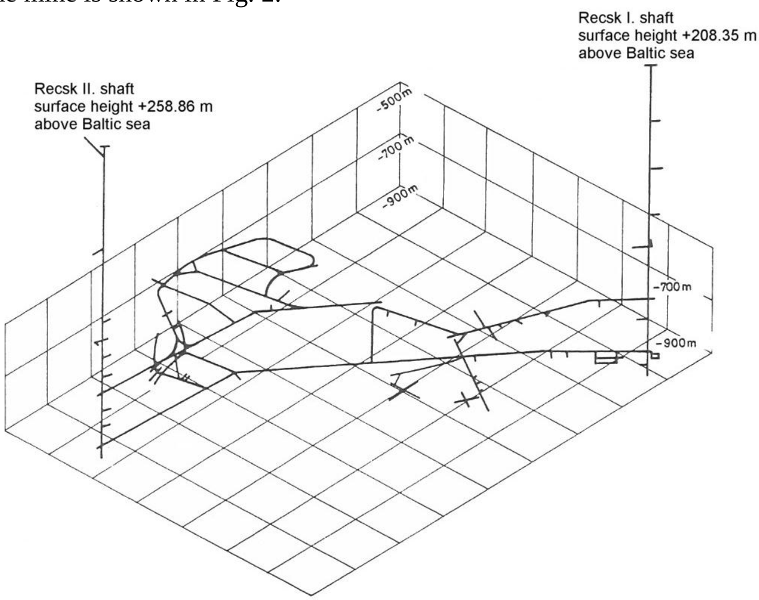

Figure 2. The roadway system of the Recsk mine

There was a water inflow during the drift construction too. It happened at the lower -700 m level with a flow rate of the 2 m^3/min. The inflowing cross-section was cemented with difficulties, because the pressure of the water was as high as 70 bar. In the lower drift at the level of -900 m there was not any problem with the water, because of the upper drift drained the water, its pressure at the -900 m depth was 25 bar only.

By the time drift had been completed, the price of the copper in the world market fell radically in spite of the forecasts. While the IBRD prognosticated 6,090 USD/tons for 1995, the actual price on the international market was 2,000 USD/tons only. Since the price of the copper was permanently low the development of the Recsk mine has not continued from 1981. The Hungarian Council of Ministers ordered the steady interruption of any activity in the mine. The pumping of the water was also suspended. Thus the road way and the shafts of the mine are flooded by this time. The rise of the water level with time is shown in Fig. 3. The shafts are plugged, but a monitoring pipe having a diameter of 250 mm makes possible the measurements of the level, concentration and temperature of the water.

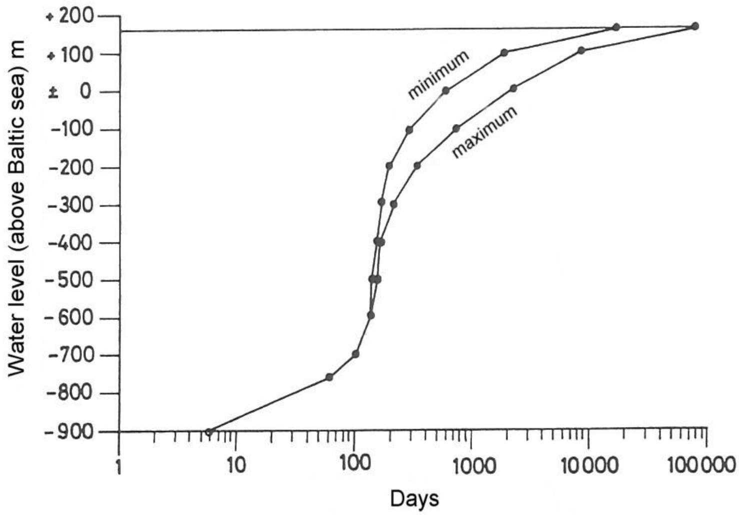

Figure 3. The rising water level on time

4. Geothermal conditions

High underground temperatures were observed in the Recsk mine during the drift construction. Intensive ventilation was necessary in the whole period of the implementation. Numerous temperature data have been obtained in exploratory boreholes. Most data are measured by mercury thermometers after a few days of finishing the drilling operations. Apparently these values are lower at least by 10-20% according to measurements than the undisturbed rock temperatures. The corrected temperature data of the rock obtained an average value at the upper drift level 960 m under the surface of 51.8 ^{o}C. The geothermal gradient based on these data is 0.0435 ^{o}C/m. The average temperature obtained at the lower roadway level 1.160m depth from the surface is 59.5 ^{o}C. The geothermal gradient calculated by these temperatures is 0,0427 ^{o}C/m. The comparison of these gradients seems to be in rather good agreement. The rock mass around and above the drift is mainly andesite and limestone. The overall heat conductivity of the cover layers is obtained as 2,53 W/m ^{o}C. Thus the terrestrial heat flow calculated by these data is 0,108 W/m^2. The heating of the area is slightly greater than the Hungarian average of the terrestrial heat flow (0,095 W/m^2). The supply of the water flooding the drift and the shafts is a deep water bearing rock mass surrounding the mine. The temperature of the water essentially is the same as the rock temperature. Temperatures measured on the occasion of water flows are in agreement with rock temperatures.

The water filled mine has a large geothermal potential. The volume of the flooded mine is more than 200,000 m^3. At the free surface of the water in the shaft the temperature of the water is 29 ^{o}C. This temperature increases with the depth. The walls of the drift are in thermal equilibrium with the water. In the shafts some free convection occurred deforming the linear geothermal temperature distribution along the depth.

A submersible pump can be lowered to the bottom of the shaft to produce warm water. Assuming 1.2 m^3/min flow rate and 30 ^{o}C temperature, the obtainable thermal power is 2,512kW. After utilization, the produced warm water can be discharged without any back-pressure into the other shaft.

5. Summary

The utilization may be primarily district heating. It seems necessary to built in suitable heat pumps to increase the temperature of the produced water. Another possible use for the large diameter shaft, is to built in a hairpin-type bore-hole heat exchanger without any water production. Both methods can be economic. The area close to the mine is a wooded recreation area. There are some health resorts with medicinal springs and hotels with medical treatment facilities. The produced water is suitable to supply spas and swimming pools. The clean geothermal heating provided can maintain the clean healthy air. The produced geothermal energy is sustainable for a long time. The heat transfer surface of the drifts and the shafts is more than 150,000 m^2. Assuming a temperature difference of 4 ^{o}C between the rock and the water, and a heat transfer coefficient is 4.8 W/m^2 ^{o}C, the thermal power supply of the system is 2.880 kW. Thus the planned thermal power can be enlarged. The geothermal energy is really renewable in this area.

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