Methods of Hydrogeological Exploration for Design of Mine Dewatering

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1. ABSTRACT

The Hydrogeological Survey of the bauxite mines in Hungary was established 30 years ago. The goal of the HS has been to collect all available data needed to solve the hydrogeological problems of bauxite mines. The results of activity of the HS have been summarized in the annual reports. This report is going to present a few methods to evaluate the hydrogeological properties of fissured, karstic rocks, i.e., the evaluation of drilling mud losses, the statistics of core samples evaluated by a special computer program for calculating the porosity and permeability of the rocks. An experimental injection test is presented together with the development of a new portable instrument to get signs of the water table change during the injection test in every two seconds. It can be proved that the flow around the well may be a transient one if the yield of the injection exceeds a definite one (Figure 2.). It was observed that the permeability calculated from the pumping test data may be 1.2-1.6 times higher than it coming from the injection test.

A practical example is presented also how to use the results of the HS for designing the dewatering of a new mine together with an analogous computer model to forecast the yield expectable for making the drift tunnel. A suggestion based on the hydrogeological feature has been done for the dewatering without using electric energy (see Figure 3.-6.).

2. INTRODUCTION

The Hydrogeological Survey (HS) of the bauxite mines in Hungary was established 30 years ago. Due to the fact that the 60-70% of the resources of bauxites have been situated under the karstic water level was the aim the establishment of the HS. As a consequence of the outlined hydrogeological situation of bauxite reserves it turned out as early as the beginnings of the underground working, that without regular hydrogeological observation, both the design and execution of any underground mining operation may be illusory.
The goal the Hydrogeological Survey has been to collect the all available date needed to solve the hydrogeological problems of bauxite mines, ie.:

- the hydrogeological properties of baring and bottom layers of bauxite,
- the water level situation the baring and bottom layers,
- the water environment on the surface and under the surface, in surrounding of bauxite areas,
- the meteorological situation,
- the recharge and discharge areas of the subsurface (karstic) waters.

The other task of the HS has been to collect and evaluate the experiences of dewatering of mines, ie.:

- the yield of dewatering,
- the extension and form of the depression cones,
- the effect of the dewatering on the environment comparing with the situation being before the mine operation.

The results of activity of the HS have been summarized in the annual reports. The first in the line had been the year book from 1958 and the 30th of this line was brought to light in 1988. The mine of hydrogeological experiences can be found in these series of annual reports. The methods and phasis of hydrogeological exploration could be cristallized during the past 30 years and a reliable basis has been made for design the dewatering of new mines and the foresacting the possible effect of one on the environment.

3. THE INTERPRETATION OF RESULTS OF THE GEOLOGICAL EXPLORATION FOR HYDROGEOLOGICAL PURPOSES

The main method of the geological exploration of bauxite layers can be done by the drilling operation based on the results of geological mapping. Due to the geological exploration the date for hydrogeological interpretation are as follows:

- the successive layers including the evaluation the permeable and impermeable ones,
- the number and directions of tectonical lines and their statistics,
- the measurement of drilling mud level,
- the places of the drilling mud losses,
- the statistics of core samples for estimate the porosity and permeability of fissured, karstic water bearing layers.
3.1. Evaluate the drilling mud losses

The rate of drilling mud loss in different types of rocks have been useful parameters for getting a preliminary picture of the permeability of separate layers. When the drilling muds had consisted of water only, the loss rates of them gave us more valuable parameters than the other cases we had. A statistics of mud losses for each layers have been made by the Bauxite Prospecting Company for more than 30 years.

To evaluate the permeability of different layers the cases of total mud losses (tml) had been taking into account. For example the tml in dolomites were observed in 36.2% of the all mud loss cases, however this value was 4.7% only in the miocene layers i.e. shale, dawk and clayey gravel. Comparing the percentage of total mud losses in a given layers to the percentage of the tml in dolomite (which has been the highest rate) an index of permeability (ip) could be given. For example for the value of the ip of miocene layers above mentioned, 0.13 was given. A classification of rock types could be done due to the ip of different layers:

<table>
<thead>
<tr>
<th>ip</th>
<th>specific of permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.05</td>
<td>impermeable</td>
</tr>
<tr>
<td>0.051 - 0.1</td>
<td>poor</td>
</tr>
<tr>
<td>0.11 - 0.3</td>
<td>semi</td>
</tr>
<tr>
<td>0.31 - 0.6</td>
<td>good</td>
</tr>
<tr>
<td>0.61 - 1</td>
<td>excellent</td>
</tr>
</tbody>
</table>

Using the ip of each layers given by the geological drilling investigation useful informations could be got for the preliminary description of the hydrogeological characters of the rocks.

3.2. Statistics of core samples

The analyses of core samples on hydrogeological point of view can be based on the theoretical consideration. The length of core samples collecting during the drilling from fissured, karstic rocks can be usually depended from the distance of the individual fissures, the abrasive hardness of rocks and the time of drilling. The real fissured karstic rocks due to the results of international research work can be replaced for the calculation with a theoretical rock where the fissuration has been a triorthogonal one.

A special computer program was developed to evaluate the porosity of fissured karstic rock based on the core statistics. The calculation of porosity can be done for each run out, or for the average one of optional numbers of run out, as well as, for the average one of the total length of the drilling. Taking into consideration the results of special hydraulic model experiment the permeability of fissured, karstic rocks can be calculated from the porosity due to the function as follows:

\[
k = f(n)
\]

where \( k \) = permeability, \( n \) = rock porosity
4. SPECIAL HYDROGEOLOGICAL EXPLORATION

The complex process of hydrogeological research includes the analysis of all available stratigraphical, structural geological, geophysical and hydrogeological information and by synthesizing them its ultimate goal is up of the hydrogeological model of the area in question.

4.1. The hydrogeological observation network

In order to reveal the details of hydrogeology of the bauxitiferous areas a hydrogeological observation network was established. The first monitoring wells were made at the center of the mining concentration. Later on as the depression grew larger, additional wells were established along the periphery of depression, yet with in the expectable area of influence of the drawdown.

From 1953 on in all 510 observation wells had been established. 210 of them are being in operation even now. In the majority (about 90%) of the observation wells the variation of the water table of main karstic reservoir (upper triasic dolomites and limestones which are the bottom layers of the bauxite) are being measured. The rest of the monitoring wells has recorded the fluctuation of water table of Cretaceous, Eocen and Pliocene stratas.

4.2. The experimental injection in monitoring well

The most of the observation wells mentioned in chapter 4.1. were developed from the geological discovery well and it is the reason that the diameter of the monitoring wells are small, not wider than 80 mm. This well diameter does not allow to run the pumping test therefore an experimental injection probe method has been developed to get informations for the permeability or transmissibility of the aquifers. The method can be used under the confined or unconfined circumstances. The experimental injection tests take a sort time (not more than two hours) therefore the cost of it much more cheaper than the one of the pumping test and their results meet the demand of the mining design.

A new portable instrument had been constructed and developed for the automatic measurement the change of the water table in the wells during the time of the injection test which could get the signs in every two second.

On the Figure No 2. can be seen the results of an injection test made with three different water yield. The permeability can be evaluated by using different assumptions and one of them are shown on the Figure 2. It can be proved that the flow around the well is a laminar one if the yield of the injection less than about 270 liter/minute. In the cases whom the flow feature around the well was not analyzed, the calculated rock permeability may be less than one given from using the laminar flow stage.

It was observed that the permeability calculated from the date of the pumping test had been 1.2.-1.6. time higher than the permeability coming from the injection test.
Besides the methods of hydrogeological investigation mentioned in chapter 3 and 4 other world wide methods have been used by the Hydrogeological Survey i.e.

- pumping test in single wells or in well groups,
- geophysical measurement on the surface and in the wells etc.

It is special task for the Hydrogeological Service to prepare feasibility studies on the complex water environment (surface and subsurface waters) of the expectable mine areas before the time of design for the purposes of evaluating the effect of the designed drawdown on it.

A hydrogeological database system has been developed for the CAD/CAM system which can be process two millions of measured hydrogeological data per year.

5. THE PRACTICAL EXAMPLE

The topographical situation of the Csabpuszta bauxite area can be seen of Figure No 3. Nyírád operated bauxite mine area, where the bottom layer of the bauxite is upper triassic dolomite is situated in eastern direction from this new bauxite area. The geological setting of the Csabpuszta area departs form the Nyírád one due to the results of the geological exploration.

The bauxite reserves can be found in two different stages an follows:

- the lower bauxite stage its bottom is upper triassic dolomite and,
- then upper bauxite stage its bottom is upper cretaceous limestone.

According to the preliminary evaluation of the rock permeabilities based on the tml, the ip of dolomite is 1, as well as the ip for cretaceous limestone is 0.2-0.5 only. There has been pointed by the geological investigation that an impermeable cretaceous marl was deposited between the dolomit and the cretaceous limestone. In the eastern part of the Csabpuszta area the impermeable layer becomes thin and it ends off.

In the NW part of the Csabpuszta area the cretaceous water system seems to be separated from the triassic water system which has been the object of the dewatering activity of the operated bauxite mines for 30 years. That is the reason that the piezo nivo of upper tirsac aquifer is less than the water table of the cretaceous limestone. (See Figure No 4.).

Within the scope of the hydrogeological investigation

- monitoring wells were drilled for the Triassic Cretaceous Eocen and Pliocen aquifers,
- 6 groups of wells were made for the new undulating tests to evaluate the hydrogeological connections among the aquifers of different stages,
- special geophysical measurement were done.
The transmissibility of the upper cretaceous limestone was estimated by the results of undulating test (see Figure No 5.). In this case the areal transmissibilities were related to structural zones in the NW-SE and NE-SW directions. The new mine has been to open the upper bauxite stage up and the task was to design the dewatering system of the mine and to forecast the water yield in the drift tunnel. And analogous computer model was developed for the forecasting which has been able to compute for each time steps

- the reminder tunnel length,
- the reminder water pressure,
- the water pressure at the dean,
- the summarized water yield for the made length,
- the reminder depression at the dean and,
- the water yield coming from the limestone in the roof of the tunnel.

The forecasted water yield for the total length of the drift tunnel was 5-10 m³/minute (See Figure No 6.). That was a suggestion to drill well which carries the cretaceous water off into the dolomite to make it be swallowed due to the above mentioned hydrogeological situation of the upper bauxite stage. The well for testing was drilled in the beginning of this year and the drawdown result of the first 60 days can be seen on Figure No 4.
COMPLEX HYDROGEOLOGICAL INTERPRETATION

Fig. №1.
Water pressure in meter during the time of injection operation

Well No.: HGN-109

Flow characteristics around the well No. HGN-109

\[ \frac{S}{Q} = A + Bq \]

\( h \) (m/s) = 0.6 \( \frac{1}{A} \)

\( h = 1.25 \times 10^{-4} \) (m/s)

Experimental injection test

Figure No. 2.
AREAL DISTRIBUTION of the TRANSMISSIBILITY

Fig. No. 5.