SOME RESULT OF KARSTIC HYDROGEOLOGY AND ITS UTILIZATION IN MINE WATER CONTROL

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SUMMARY

The following points are considered for inrush phenomena encountered during the mining of minerals located on karstic aquifers:

- the relationship between the degree of geologic fracturing and the number of inrush events;
- the relationship of the aquifer and the aquitard between minerals and the aquifer;
- the limit of validity of natural factors as controlling mine water;
- pilot settling experiments of the sediment carried by inrushes.

1. RELATIONSHIP BETWEEN INRUSH YIELD AND TECTONIC FRACTURING

Most of the following results has been reported in Hungarian but it is the first time of the English publication.

Mesozoic, mostly carbonate rocks deposited in the Hungarian paleozoic crystallic basins. These carbonate rocks are good aquifers due to karstic processes and have a thickness as great as several thousands meter. Sedimentary subbasins were formed on the kartic rocks, consisting of eocene, oligocene and younger deposits of depths higher than 1000 m. Amont these deposits valuable brown coal of several hundreds of tons, bauxite and manganese resources can be found and are deep-mined under water hazard.

The water hazard stems mostly from the underlying karstic aquifer, and karstic water can inflow into mining spaces with pressures up to 40-60 bar.

It was realized more than a decade ago that inrushes are connected to karstic rock fractures [4, 12, 13]. In order to quantify the phenomena, spatial configuration and sizes of tectonic elements were studied [1, 3, 14, 15].

More than 1000 inrushes of a total yield of almost 500 m^3/min have been observed during mining operations under various natural conditions.

The following principles were used in detecting the casual relationships:

a/ The total yield of inrushes is approximately proportional to the magnitude of the area [11, 16].

b/ The yield and frequency of individual inrushes can be considered only under the same conditions of protection layers between reserves and the aquifer.

c/ Inrush properties under constant protection layer conditions depend mostly on specific fracturing L/T [18], where T is the area and L is the total length of faults corresponding to T.

d/ A joint analysis of all main process is necessary for revealing natural phenomena governing inrush properties.

Various subbasins of the Transdanubian Mountain /TM/ were selected to investigate the following relationships between inrushes and natural conditions. For practically constant protection Figs 1a and 1b show the regressions. In Fig.1a the specific areal yield $\Sigma q_i/T$, and in Fig. 1b the specific areal number $\Sigma N_i/T$ are plotted against specific fracturing.

The following linear regression fits data [18]:

$$\frac{\Sigma q_i}{T} = C_q \frac{\Sigma L_i}{T} \qquad /1/$$

and

$$\frac{\Sigma N_i}{T} = C_N \frac{\Sigma L_i}{T} \qquad /2/$$

Regression coefficient C_q is 15 for the Dorog coalfield, 5 for Tatabánya and 4,5 for Iszkaszentgyörgy. The corresponding figures of C_N are: 7,8; 3,9 and 7,3.

The different performance of various regions - for instance in Dorog $\Sigma q/T$ is threefold as compared to the Tatabánya value - can be explained as follows.

The inrush process should be considered in the framework of and

$$\frac{\sum N_i}{T} = C_N \left(5{,}6 + \frac{3}{Y}\right) \qquad /5/$$

If Y is km, T is km², then q_i is m³/min and N_q is the number of inrushes. The ratio of the average total yield and the number of inrushes equals to the average yield of inrush events. The above equations can be used for sizing pumping stations provided the random error of regression is accounted for and a geologically analog area is considered. If these conditions are not met the general hydraulic model of inrushes /Schmieder [6 , 9]/ can be used, which results in the same linear equations after certain simplifications.

2. RELATIONSHIP BETWEEN PROTECTION LAYER AND INRUSH YIELD

Often a 0–40 m thick clayey aquitard is situated between the aquifer and mining openings in the Hungarian karstic eocene basins due to fresh-water sediment formation over the carbonate karstic rock. Those layers offer a protection against inrushes from the aquifer. The degree of protection depends on layer thickness and piezometric head. Physical processes in the protection layer have been revealed by Schmieder [5, 7], and are considered as known.

Now some mining experience on protection layers is summarized. A specific protection of some 0,3 m/bar offered by intact layers can prevent inrushes from the underlying aquifer.

There is, however, a sudden decrease if the protection layer is disturbed by tectonic and atectonic movements. In this case, the necessary specific protection is about 4 m/bar, that is a tenfold increase as compared to intact layers.

Observation data were used for analyzing the effect of various specific protection /0–4 m/bar/ on the yield and number of inrushes. Results show /Fig. 3/ that the effect of increasing protection is greater for the number than for the yield of inrushes. These regression lines can be applied to forecasting inrush properties under different protection.

3. SEDIMENT IN THE INRUSH WATER

The former studies have also contributed to the discovery that secondary sedimentary rocks located between the aquifer and mining openings can be carried with inrush water into the openings.

These sedimentary rocks contain also cohesionless dolomite particles of 0,06–0,5 mm.

geomechanical forces forming geological elements. Fractures in the Dorog region have larger average dilatation, leading to higher aquifer conductivity. It is just the Dorog region where bed rock bedding direction E-W changes to NW-SE direction general to TM. The direction and intensity of geomechanical forces had to be changed in order to accumulate the necessary energy increment for the change of bedding direction. This local excessive loading of the base rock could have caused the increased fracturing of fault elements controlling water conductivity.

This local variability of geomechanical effects is evident also over other parts of TM [3].

Fig. 1 shows that despite the greater insensitivity of dolomite to karstifying along faults, the specific yield increases linearly and reaches the yield pertaining to some limestone area. This can be explained by the increased degree of cataclasm, following the degree of tectonic fracturing. This increase would balance the decrease of less-karstic parts.

Fig. 1 also indicates that N_Q/T is higher for limestone basins reaching almost the value pertaining to the heavily loaded Dorog basin. This is a natural consequence of the cataclastic structure, where inrush is possible without faults.

The various slopes of the regression lines in Fig. 1 indicate the relationship with aquifer conductivity which can be estimated after Schmieder /1970, [5]; 1975, [8]/.

Values of specific fracturing range between 3-36 km/km² in TM. This tenfold change highly influences the forecasting of the yield and number of inrushes. As a result, the spatial situation of fracturing was also studied. It was demonstrated that the more remote we are from the edge of the aquifer the smaller is the degree of fracturing. This hyperbolic change can also be explained by geomechanical reasoning. Results are shown in Fig. 2, where observation data corresponding to mines are indicated. The linear regression is [17]:

$$\frac{\sum L_i}{T} = 5,6 + \frac{3}{Y} \qquad /3/$$

where Y is the distance from the edge of the aquifer.

The combination of equations /1/, /2/ and /3/ results in expressions for the average specific yield and number of inrushes:

$$\frac{\sum q_i}{T} = c_q \left(5,6 + \frac{3}{Y} \right) \qquad /4/$$

There is proved methodology to size elements of drainage, collecting, and conveying as well as spaces for machinery in mine water control. Also, the advance of pumping technology permits to select and apply the proper type and capacity of pumps. The task remains to receive and treat sediment in a controlled way. First, sediment conveying elements are needed, then one part of total sediment harmful to pumping operation is to be removed. The sediment is removed by in-mine settling basins whose selection and operation were reported at the Granada conference on mine water.

A precondition of sediment treatment design is to forecast the amount and quality of inrush sediment.

In addition to the dolomite particles mentioned the sediment material may contain other rock particles carried by mine water through operating and abandoned workings.

The amount of these two types of sediment was calculated for the planned mines in the Eocene Program. This was the basic data of designing a full-scale model of settling basin [2]. The full-scale model was warranted by the difficulties in forming underground openings and the uncertainties inherent in smaller-scale modelling. Literature values of settling velocity were used for determining the sizes of the basin. Constraints of underground opening sizes required to deviate from a ratio of 1:20 - 1:30 /depth-width/ used in the surface to a ratio of 1:10 - 1:15. As a result, the residence time of sediment is much shorter than in surface basins. On the other hand, no biological effects are to be accounted for. The design should consider the fluctuating sediment loading and the maximum inrush yield for safety reasons, The experimental basin /Fig. 4./ was designed with due regard to the previous considerations, according to the classical Hazen method. The flow velocity was calculated on the basis of the residence time and the areal loading, as well as the Dobbins-Camp method. Settling velocity was modified by the methods of Szaljev, Ivicsics, and Zsegzsda-Velikanov, as well as the Sudry diagram. The final modified settling velocity was taken as the average of the results arrived at by the former methods. Various discharge of 10-20 m^3/min and varoius sediment loading of 2,5-7,5% /weight/ were applied and settling efficiency was measured. Next, the case of fluctuating discharge but constant sediment loading was studied. Fig. 5. shows that the efficiency is satifactory if sediment loading ranges up to 6%. On the other hand the upper limit of the predicted value is hardly greater than 5%.

Hydraulic efficiency of the basin was also investigated /Fig. 6./, using the methods of Muszkalai, Ivicsics and Müller-Neuhaus /through-flow wave and through-flow curve/.

Measurement data agree with or in some case give better values than the calculated ones.

Naturally these results hold for real-life settling basins characterized by similar sizes and loading. Since the in-mine solution may require several restrictions such as non-vertical walls, smaller width, larger loading of weir crest, a pilot-model corresponding to such an alternative was also constructed. Experiments on this basin are going on. Hopefully, a more advanced sizing method will be developed.

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LIST OF FIGURES

Fig. 1. The specific areal yield /a/ and specific areal number /b/ of inrushes as plotted against specific tectonic fracturing

Fig. 2. Tectonic fracturing of cratogenic basins as plotted against the distance Y from the edge of the aquifer

Fig. 3. The effect of disturbed protection layer on the yield and number of inrushes

Fig. 4. Cross section of the experimental settling basin

1. Inflow mine water /Q m^3/p/
2. Inflow into the settling basin
3. Inflow gate
4. Changable inflow elements /Geiger, Stengel, Stuttgart/
5. Rough settling part of the basin
6. Sediment collector shaft
7. Sediment treatment space
8. Operational water level
9. Settling part of fine sediment
10. Floating garbage collector
11. Outflow weir, controllable crest
12. Outflow channel

Fig. 5. Settling efficiency of the experimental basin

Fig. 6. Hydraulic efficiency of the experimental basin

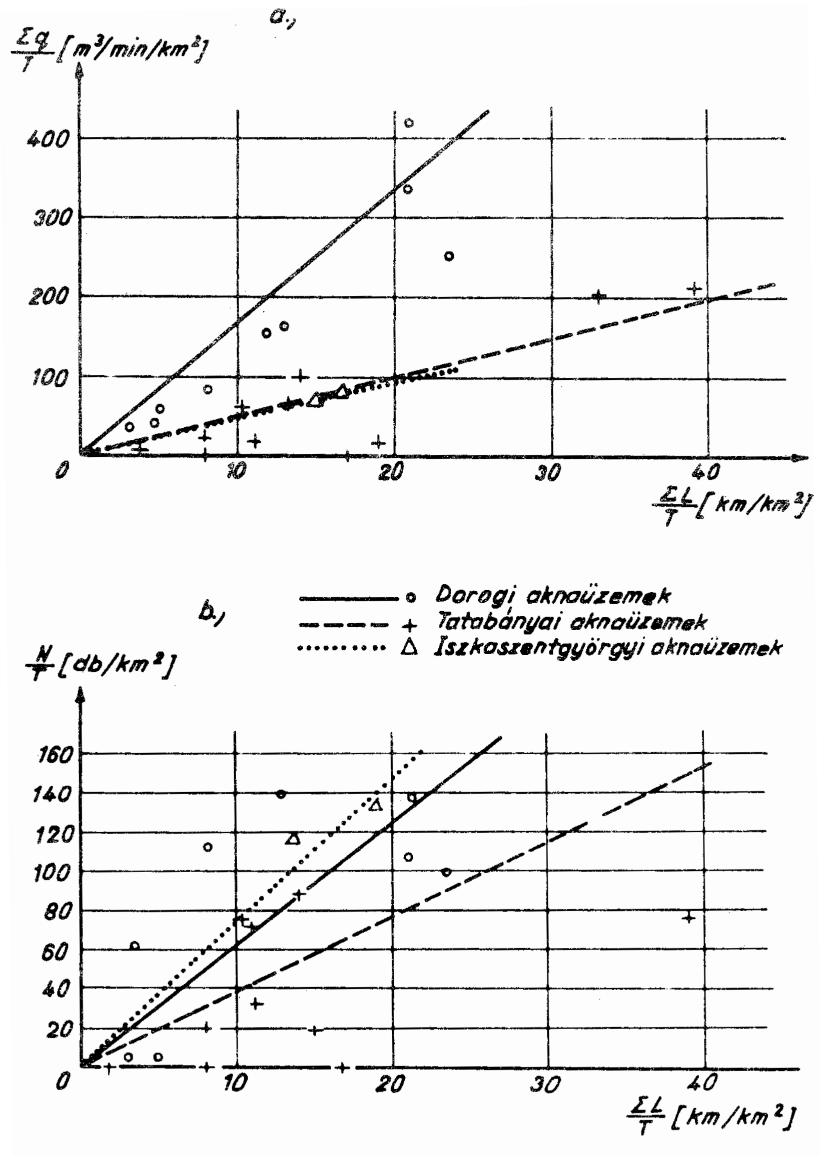
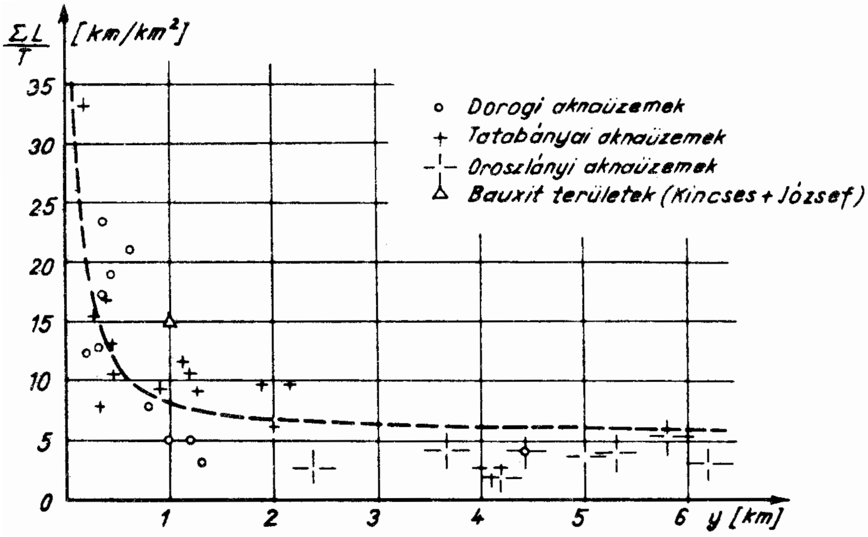

a.)
Σq/T [m³/min/km²]
400
300
200
100
0
10
20
30
40
ΣL/T [km/km²]
b.)
———— ○ Dorogi aknaüzemek
– – – – + Tatabányai aknaüzemek
········ Δ Iszkaszentgyörgyi aknaüzemek
N/T [db/km²]
160
140
120
100
80
60
40
20
0
10
20
30
40
ΣL/T [km/km²]

Fig. 1. ábra



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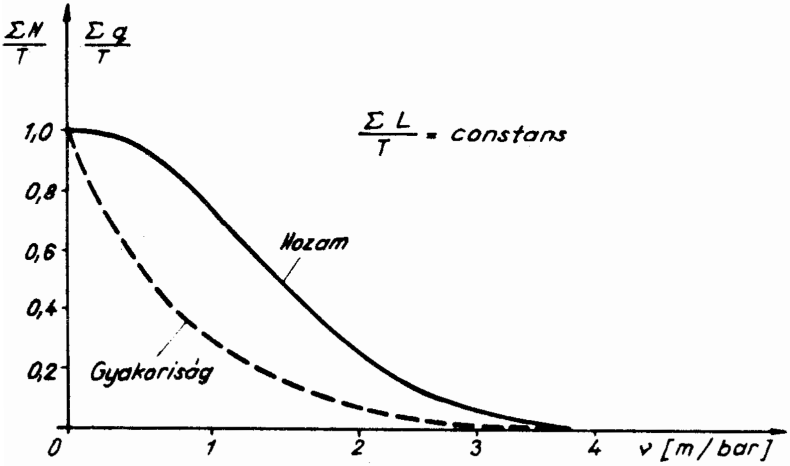

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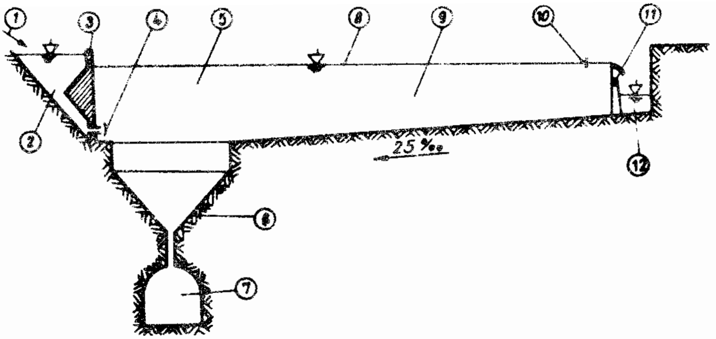

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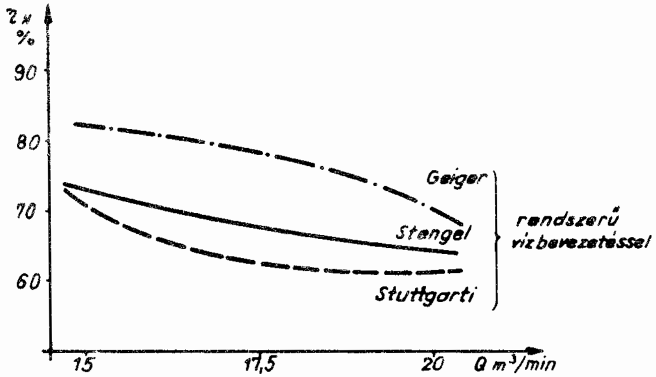

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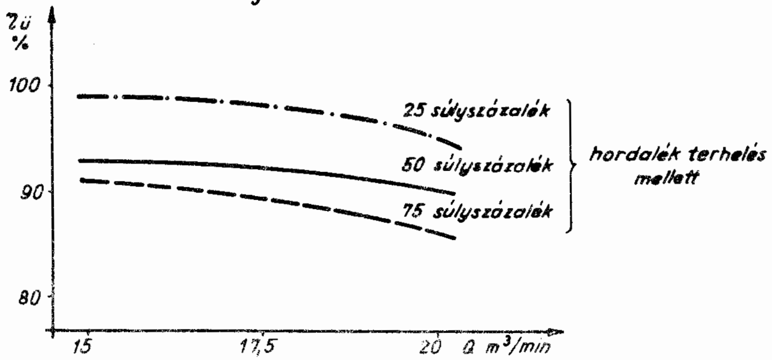

Fig. 6. ábra