# Methods of Hydrogeological Exploration for Design of Mine Dewatering

## By T. BOCKER and M. HEGEDUS

Hungalu Eng. and Dev. Centre
H-1389 Budapest P.O.B. 128.

Bauxite Prospecting Co.
H-8221 P.O.B. 31. Hungary

## 1. ABSTRACT

The Hydrogeological Survay of the bauxite mines in Hungary was establisned 30 years ago. The goal of the HS has been to collect the all available date 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 rock ie. the evaluation of drilling mud losses, the statistics of core samples evaluated by a special computer program for calculation the porosity and permeability of the rocks. An experimental injection test is presented together with the development of a new portable instrument to get signes of the water table change during the injection test in every two second. 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 date may be 1.2-1.6 time 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 Survay (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 benn situated under the karstic water level was the aim the establisn the HS. As a consequence of the outlined hydrogeological situation of bauxite reserves it turned out as early as the beginings of the undergraund working, that without regular hydrogeological observation, both the design and execution of any underground mining operation may be illusory.

**The Third International Mine Water Congress, Melbourne Australia, October 1988**

The goal the Hydrogeological Survay has been to collect the all
available date needed to solve the hydrogeological problems of bauxite
mines, ie.:

- the hydrogeological properties of baring and botton layers of
  bauxite,

- the water level situation the baring and bottom layers,

- the water enviroment on the surface and under the surface, in
  surrounding of bauxite areas,

- the mateorological 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 enviroment 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 30 th 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 enviroment.

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
interpretetion 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 measurment 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.

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### 3.1. Evaluate the drilling mud losses

The rate of drilling mud loss in different type of rocks have been usefull parameters for geting a preliminary picture of the permeability of separate layers. When the drilling muds had 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 yaars. 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 miocen layers ie. slake, 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 miocen layers above mentionded, 0.13 was given. A classification of rock types could be done due to the ip of different layers:

| ip | specific of permeabolity |
|---|---|
| < 0.05 | impermeable |
| 0.051 – 0.1 | poor |
| 0.11 – 0.3 | semi |
| 0.31 – 0.6 | good |
| 0.61 – 1 | exelent |

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

### 3.2. Statistics of core somples

The analyses of core samples on hydrogeological point of wiev can be based on the theoretical consideration. The length of core samples collecting during the drilling from fissured, karstic rocks can be usuelly 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 internetional research work can be replaced for the calculation with a theoretical rock where the fissuration has been a triortogonal 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 the each run out, or for the average one of optional numbers of run out, as well as, for the average one of the total lenght of the drilling. Taking into consideration the results of special hidraulic model experiment the permeality of fissured, karstic rocks can be calculated from the porosity due to the function as folows:

$$k = f(n)$$
where k = permeability,    n = rock porosity

## 4.   SPECIAL HYDROGEOLOGICAL EXPLORATION

The complex precess 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 datails 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 (abont 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 baing measured. The rest of the monitoring
wells has recorded the fluctuation of water table of Cretaceus, 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 cheeper 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 signes 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 pemeabitlity 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 whem 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.

Bisedes the methods of hydrogeological investigation mentioned in chapter 3 and 4 other world wide methods have been used by the Hydrogeological Survey ie

- 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 prepaire a feasibility studies on the complex water enviroment (surface and subsurface waters) of the expectable mine areas before the time of design for the purpuses of evaluating the effect of the designed drawdown on it.
A hydrogeological datebas system has been developed for the CAD/CAM system which can be process two millions of measured hydrogeological date 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 botton layer of the bauxite is upper triasic dolomite is situated in eastern dirrection 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 triasic dolomite and,

- then upper bauxite stage its bottem is upper cretaceous limestone.

According to the preliminary evaluation of the rock permeabilites based on the tml, the ip of dolomite is l, 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 triasic 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 tirasic aquifer is less than the water table of the cretaceous limestone. (See Figure No 4.). Within the scope of the hydrogeological investigtion

- monitoring wells were drilled for the Triasic 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 measurments 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 desing the dewatering system of the mine
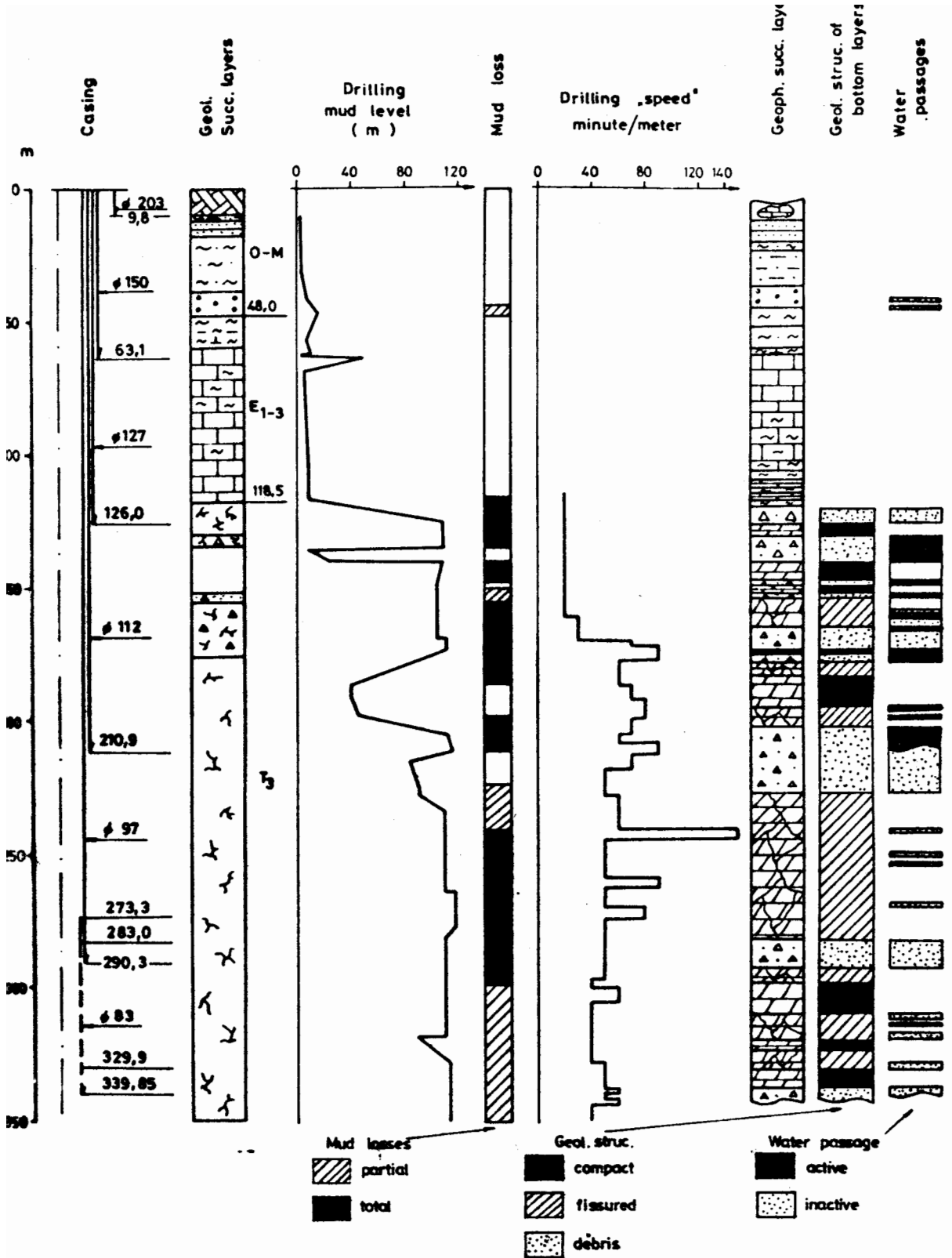and to forecast the water yield in the drift tunnel.
And analogous computer model was developed for the ferecasting which
has been able to compute for each time steps

- the reminder tunnel lenght,

- the reminder water pressure,

- the water pressure at the dean,

- the summarized water yield for the made lenght,

- the reminder deppression at the dean and,

- the water yield coming from the limestone in the roof
  of the tunnel.

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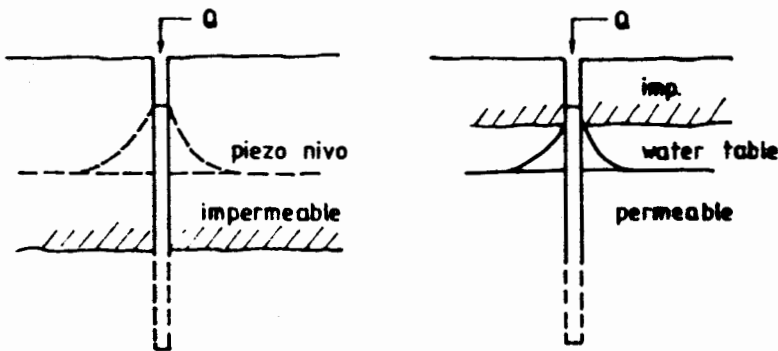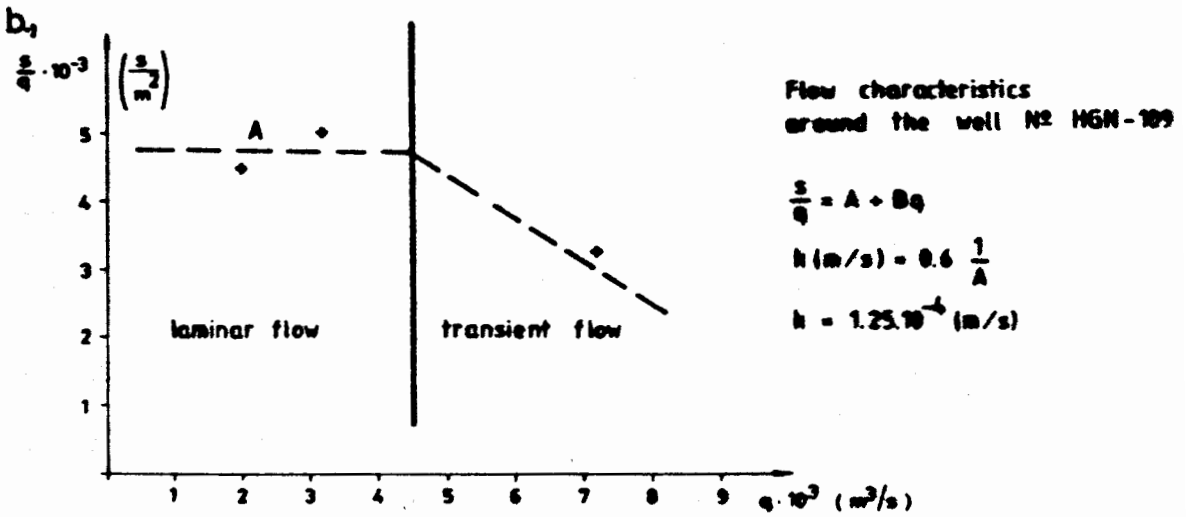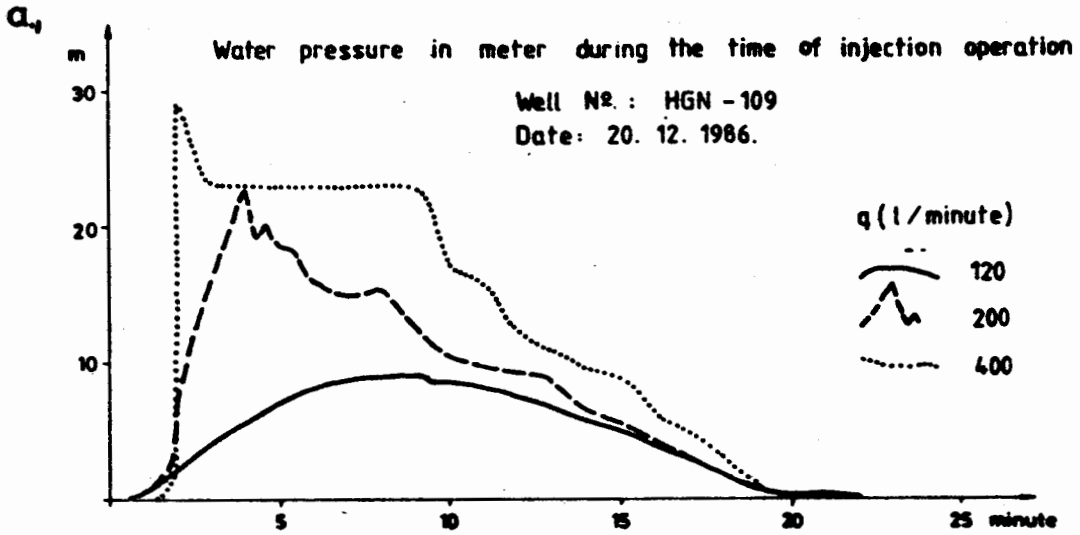5-10  m3 /minute (See Figure No 6.).
That was a suggestion to drill well which carries the creteseous water
off into the dolomite to make it be swallowed due to the above
mentioned hydrogeological situation of the upper bauxite stage.
The well for testing was drilled in the begining of this year and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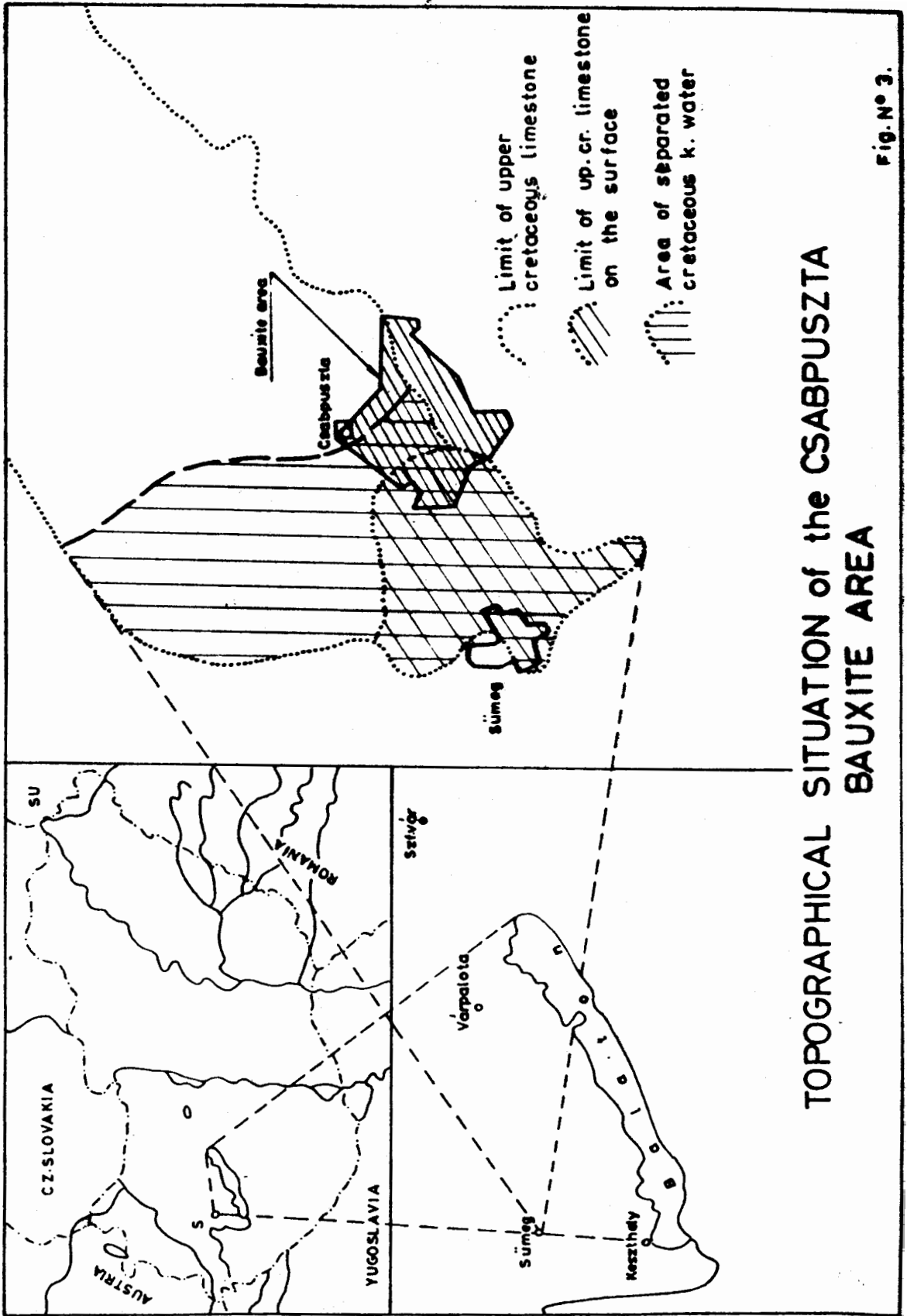drawdown result of the first 60 days can be seen on Figure No 4.

## COMPLEX HYDROGEOLOGICAL INTERPRETATION

Fig. Nº 1.

**a₁**

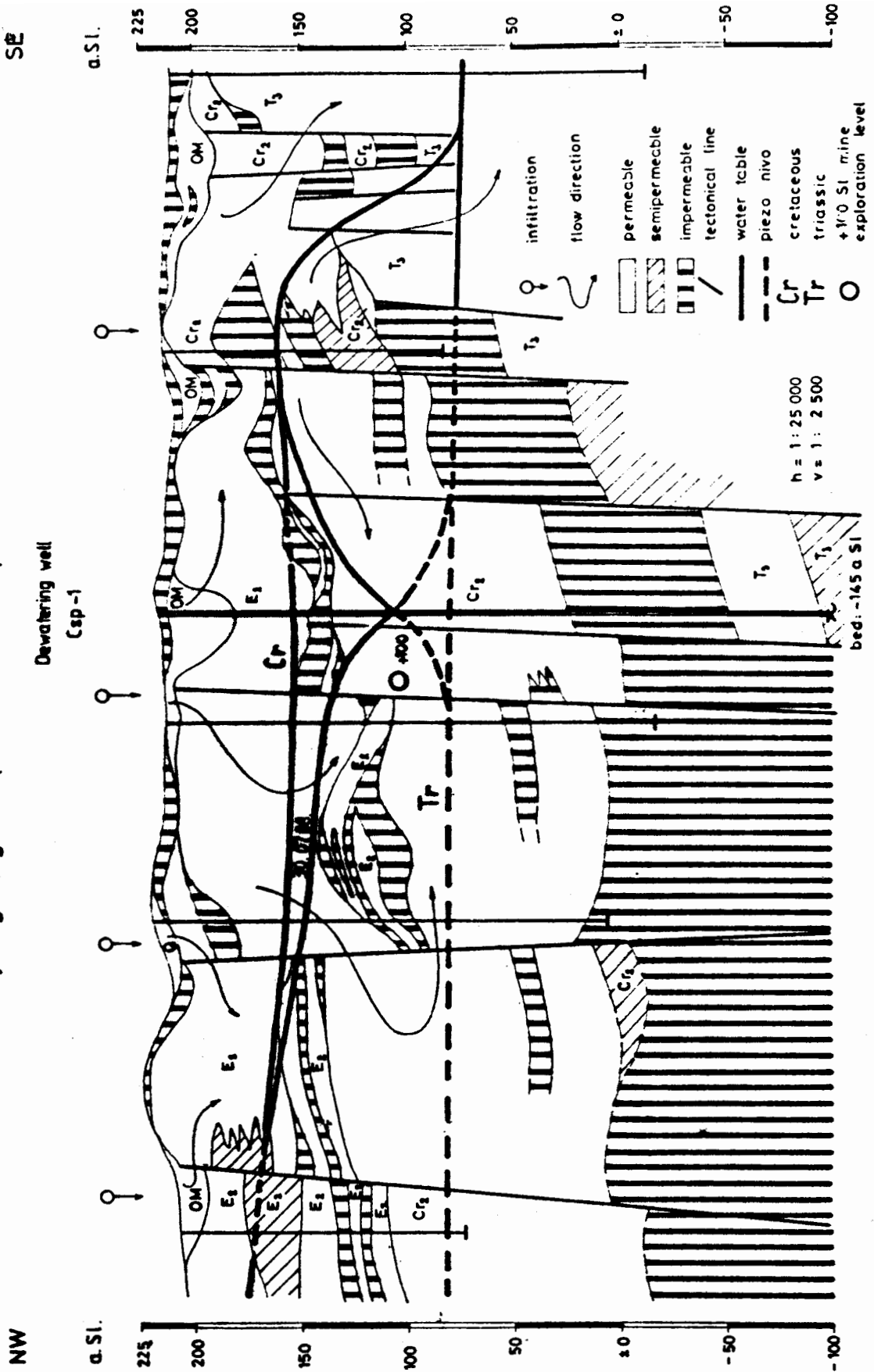Water pressure in meter during the time of injection operation

Well N≗: HGN – 109
Date: 20. 12. 1986.

q ( l / minute )

—  120
／\  200
·····  400

**b₁**

$\frac{s}{q} \cdot 10^{-3}$  $\left(\frac{s}{m^2}\right)$

Flow characteristics
around the well N≗ HGN-109

$\frac{s}{q} = A + Bq$

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

$k = 1.25 \cdot 10^{-4} \ (m/s)$

laminar flow        transient flow

$q \cdot 10^{-3} \ (m^3/s)$

Q

piezo nivo

impermeable

Q

imp.

water table

permeable

Experimental injection test

Figure N≗ 2.

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TOPOGRAPHICAL SITUATION of the CSABPUSZTA BAUXITE AREA

Fig. N° 3.

Legend:
- Limit of upper cretaceous limestone
- Limit of up.cr. limestone on the surface
- Area of separated cretaceous k. water

Hydrogeological profile of Csabpuszta mine area

compiled by: Gy. Höriszt

T = Transmissibility
( $m^2/s$ )

AREAL DISTRIBUTION of the TRANSMISSIBILITY

Fig.N° 5.
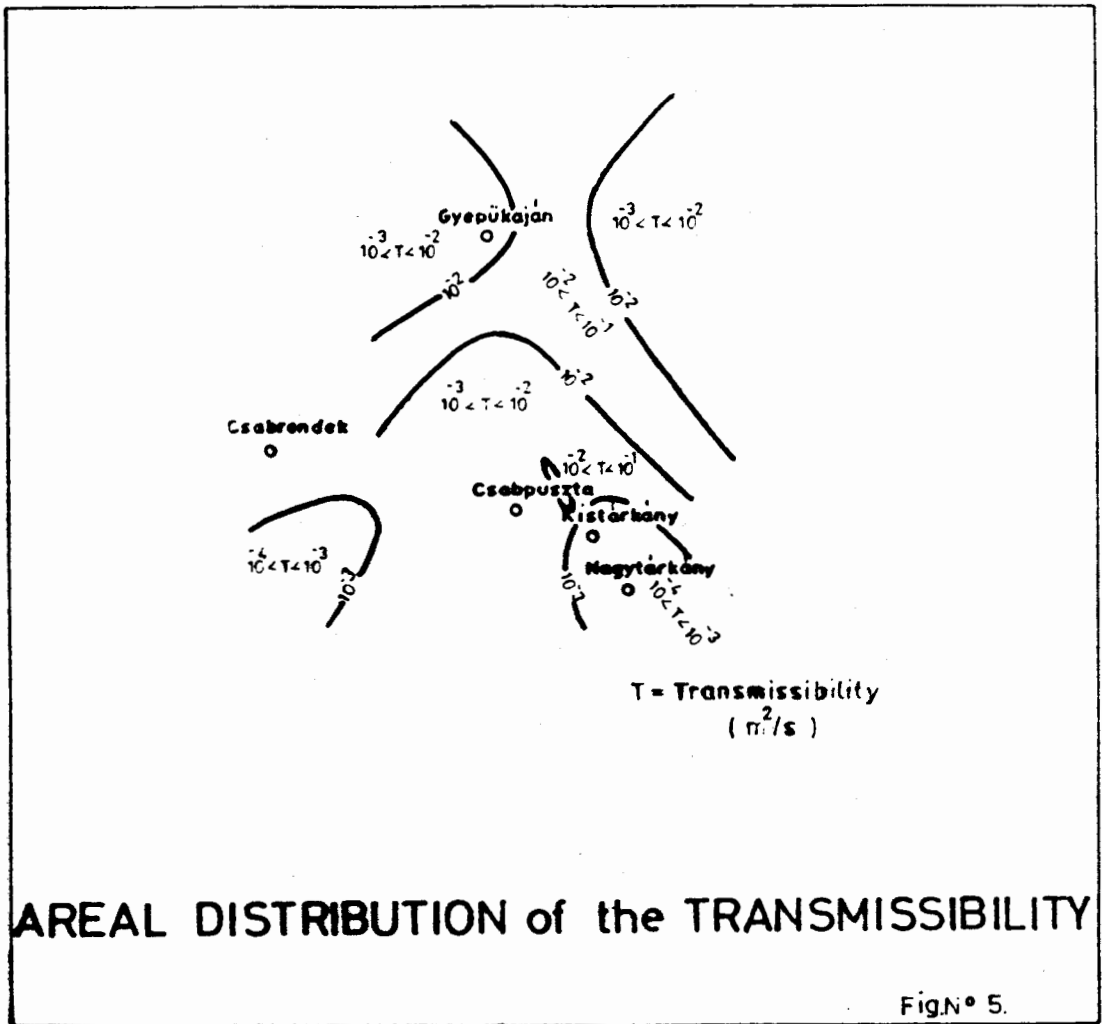
SKETCH of the DRIFT TUNNEL in CSABPUSZTA

h = 1:10000
v = 1:2000

T = Transmissibility (m²/s)
Q = Forecast Yield (m³/min)
—— Water table
– – – Piezo nivo
Cr = Cretaceous
Tr = Triassic