A COMBINED METHOD FOR DEWATERING THE MÁTRAVEREBÉLY MINE FIELD

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SUMMARY

The mining activity in the coal layer I /Miocene, Helvetian, Ottnangien/ of Kányás Mine in the Nógrád Coal basin, is exposed to ground water danger. Ground water is stored in the roof and floor sands of layer I and in the floor sand of layer II. The total thickness of the three ground water reservoirs is 30-40 m, the coefficient of seepage 4.10^{-6}-3.10^{-5} m/s, the delivery coefficient 17.10^{-6} - 22.10^{-5} m²/s, the gravitational void ratio is 10 per cent in the 25 m thick roof sand of layer I and the water pressure is 2-6 MPa with respect to the floor level of layer I. According to experience, the ground water reservoirs form closed systems in the structural units, without any supply. Layer I in the Mátraverebély region has practically no protection layer. Mining safety and economy can, therefore, only be ensured by dewatering the roof sand and relaxing the pressure of the water reservoirs in the floor.

The amount of water reserves to be lifted, is determined by the elastic deformation of the water and the rock, the reduction of the water level and the consolidation of rock. The elastic and consolidational reserves determined by mining and hydraulic parameters of the area planned for working, are less by two orders of magnitude than the gravitational reserves. The total amount of water is 15.10^6 m³ which gives 1,2 m³/min average flow rate assuming 25 years for the time of the mining activity.

A combined protection method is highly suitable for solving the ground water problems of the mine. Wells deepened from the surface can relax all three aquiferous layers and partially drain the water reservoir. Dewatering from surface can be combined with underground drai-

nage, pre-drilling and using roof-filters. Dewatering and mining have to be co-ordinated so that relaxation is carried out before drifting and draining before working. The capacity of the surface-based wells is 900 m^3/day and the time-requirement of pressure relaxation is 8-10 months with sufficient safety. An underground dewatering requires 10-12 months to empty the ground water reservoir in the roof. The maximum flow rate to be lifted from the mine is 2-2,5 m^3/min.

INTRODUCTION

Mining activities are influenced to a great extent by the geological environment and the natural conditions. In the Nógrád coal basin and especially in Kányás mine unfavourable geological and mining conditions can be experienced. One of the basic conditions of a successful production is, therefore, that the systems of development and working, the methods of protection against natural dangers and the technological solutions be carefully selected, based on a thorough analysis of the geological conditions. The special situation in the Mátraverebély region laid special emphasis on a detailed hydrogeologic investigation.

HYDROGEOLOGY OF THE MÁTRAVEREBÉLY REGION

The average cross-section characterizing the coal seam series is illustrated in Fig. 1. Ground water reservoir N° 1 is the roof sand of layer I whose average thickness in the region amounts to 25,4 m. Ground water reservoir N° 2 is the floor sand of layer I being 4,2 m thick in average. Ground water reservoir N° 3 is the floor sand of layer II with an average thickness of 5,7 m.

The thickness of the Congerian slate-bituminous slateous clay between layer I and ground water reservoir N° 1 is 0-0,9 m, it reaches 1,2-1,5 m only in certain points. Its protection effect is, however, strongly reduced by dense tectonic disturbances in this region. According to experience, the specific value of the protection effect of a bitumineous slateous clay layer is also smaller than that of a sandy clay.

Ground water reservoir N° 2 is directly in the floor of layer I, therefore, the protection layer thickness equals zero everywhere.

The average value of the protection layer between layer I and ground water reservoir N° 3 is 17,1 m. The thickness scatters between very great and very small values.

As regards the operational system and the pressure conditions of the ground water reservoirs, it can be stated that all three ground water reservoirs being dangerous for the mining activity in layer I contain pressurized water of fossil origin which is proved by chemical analyses. A very thick /200-500 m/, fine-grained, almost water-tight /k < 10^{-9} m/s/ streak is stratified in the floor that prevents surface water from entering the reservoirs.

The observed data about flow rates of water inrushes and drainage [1, 2] and the fact that the drifts become dry after a certain time, prove that water reservoirs lack any supply and form closed systems in the structural units. The static pressure of the water reservoirs was measured by allowing communication among the three layers. The static water levels were stabilized at +150 and +275 m above sea level, the water pressure was 200-600 m w.c. or 2-6 MPa with respect to the floor level of layer I. To determine the hydraulic parameters of the water reservoirs, pumping test was performed in three wells and geophysical measurements and calculations were carried out in seven others.

The grain size characteristic of the material from a sand inrush in ground water reservoir N° 1 was determined. The analysis lead to the conclusion that the coefficient of seepage is 3.10^{-4} m/s and the delivery coefficient is $4,5.10^{-3}$ m²/s in an unloaded state while under geostatic circumstances, i.e. at 6 MPa load a coefficient of seepage of $3,6.10^{-7}$ m/s and a delivery coefficient of $5,5.10^{-6}$ m²/s were obtained. Based on laboratory investigations, the coefficient of seepage can be given as $1,7.10^{-5}$ m/s for ground water reservoir N° 1 and as $3,5.10^{-5}$ m/s for ground water reservoir N° 2 [2].

Analysis of water balance provided 8 % [3] while grain size investigation 12,9 % [2] for the gravitational void volume of ground water reservoir N° 1 to be emptied prior to mining.

The parameters displayed in Table 1 have been accepted as basic data for the calculations.

The basic hypothesis of our calculations was that the ground water reservoirs of the area form closed systems, separated according to structural units and they lack any supply and are under gas pressure. The reservoir layers seperated by faults are independent hydrogeologic units. Two reservoirs may, however, directly communicate along fault planes in which case they form a single hydrogeologic unit. The reservoir layers dip at an angle of 6-12° thus a penetration at a higher level is combined with an intensive in-flow of gas.

AMOUNT OF WATER TO BE LIFTED

25-years of mining activity and a planar dranaige over the entire mining field have been assumed for the calculations. Mining may be regarded to be free of danger in view of the hydrogeologic situation if ground water reservoir N° 1 in the roof of the layer is drained and reservoirs N° 2 and 3 are relieved from pressure. The amount of water to be lifted is determined by

the elastic deformation of water rock,
the reduction of water level and
the consolidation of rock.

For the estimation of the water reserves, an average cross-section of layers, 300 m height of water column and a hydrostatic pressure distribution have been assumed, while changes in stratigraphy and pressure due to extremely varying tectonics have been ignored. The depth of ground water reservoir N° 1 is 284,40-308,40 m in the area investigated, that of N° 2 is 313,60-318,60 m and that of N° 3 is 336,90-345,90 m. The average depth limits of layer I are 313,60 and 318,60 m and the area planned for working is T = 6,2 km².

The amount of water due to the elastic expansion of water and rock is produced immediately after penetrating the layer. Consequently, the water reserves due to water and rock elasticity of reservoirs N° 1 and 2 affected by mining activity in layer I are removed and the layers relieved from pressure.

The neutral stress in water-permeable layers decreases after the beginning of development and working which is also combined with a temporary reduction of the effective stress in the roof and floor formations of small permeability. The floor and roof strata virtually swell into the drained water-permeable layer and after the gradual extrusion of their pore content the neutral stress becomes predominant and the layers become more compact due to the increased effective stress.

The reserves due the elastic expansion of water and rock were calculated with the help of relationships reprinted previously [4].

The amount of total reserves due to the flexible expansion of water and rock is $V^{/1/} = T \cdot \Delta V^{/1/}$. Using the values $z_1 = 384{,}40$ m, $z_2 = 318{,}60$ m, $\Delta u = 3$ MPa, $e_o = 1{,}0$, $M_o = 25$ MPa, $\sigma_o = 2$ MPa and those mentioned earlier, the reserves to be lifted become $V^{/1/} = 1{,}2 \cdot 10^5$ m³. The specific characteristic of these reserves is that they are drained very rapidly.

The reserves due to the reduction of water level are the amount of water in the gravitational void volume in the depressurized reservoir N° 1. Its value has been determined with relationship

$$V^{/2/}_{max} = T \cdot m_{average} \; n_o$$

with $m_{average}$ average thickness of ground water reservoir N° 1 and n_o gravitational void volume. On substitutiong, $V^{/2/}_{max} = 15.10^6$ m³ is obtained being greater by two orders of magnitude than the elastic reserves.

The amount of water reserves extracted by the consolidation of the rock is determined by the degree of rock compactness. The principle of the determination of the water amount due to consolidation is that the reduction of the neutral stress produced by depression, equals the increase of the effective stress and the amount of extruded water is determined by rock compactness:

$$V^{/3/} = T \; \Delta e \;,$$

with Δe being the change of void ratio caused by the reduction Δu of neutral stresses. The value of Δe depends basically on parameters e_o, M_o, γ_k, z and Δu [4].

The maximum amount of water extruded from unity section of depth under the effect of unity load, was determined graphically from a nomogramm. A multiplication of this value by the coefficient of consolidation provided the time function of the amount of extracted water. From a nomogramm [5]

$$\Delta \Delta V_{max} = 0{,}04 \qquad [l/m^2/m]$$

was obtained. Assuming a water level reduction of 300 m for the full drainage of ground water reservoir N° 1 of area T = 6,2 km², the amount of water is $V^{/3/}_{max} = 7{,}5.10^4$ m³, being again smaller by several orders of magnitude than the gravitational water reserves.

The total amount of water to be lifted is $V = V^{/1/} + V^{/2/} + V^{/3/} = 151{,}905.10^5$ m³ which corresponds to a steady flow rate of 1,2 m³/min assuming 25 years for the life of the mine. Taking into account the accessibility, location and shape of the area, the pattern of faults and the possible flow rate of surface-based drainage, a long-lasting initial flow rate of 2,0-2,5 m³/min has to be achieved.

SYSTEM OF DEWATERING

Based on the analysis of hydrology and the protection methods, a combined method of protection is suggested. All three layers endangering mining activity in layer I are intended to be depressurized by filter wells drilled from the surface in a pattern according to greater tectonic units, and where the dipping of the layer enables it, the ground water reservoir N° 1 can be partially drained. Dewatering from the surface is combined --according to practice-- with underground drainage, pre-drilling and the use of roof-filters.

The combined dewatering is suitably performed in two stages: /a/ pressure relief from the surface, /b/ underground drainage of the layer. Equipment to perform drainage are to be set up so that pressure relief should precede drifting and drainage carried out prior to working. Within the scope of this investigation, the dewatering pattern of structural units A and B is discussed with the help of map in Fig. 2.

PRESSURE RELIEF FROM THE SURFACE

The section of structual unit A is illustrated in Fig.3. The layer, ground water reservoir N° 1, the static water level, the proposed well and the pair of ground drifts are also indicated. It can be seen that roughly 290 m water level reduction is required to ensure safe conditions for drifting. The area of the structural unit is 87.10^4 m^2. The bottom of the dewatering well is about 500 m deep, the filter-approximately in the depth range of 420-480 m- is 35 m long and 300 mm in diameter and consists of three sections according to ground water reservoirs N° 1, 2 and 3.

The capacity of the well amounts to 630 l/min, approximately 900 m^3/d as calculated with well-known relationships [1,6,7]. This value seems to be in good agreement with data about water resources in the area.

The well drains a pressurized closed system lacking any supply and produces the elastic reserves in its first period of operation, i.e. during pressure relief. The 11^o of layer dipping and the drainage of the layer caused by this inclination parallelly to pressure relief in the third stage of pumping, are also taken into account.

Assuming a pumping with constant flow rate, on substituting the actual data /$n = 0,35$, $B_w = 5,33.10^{-4}$ /MPa, $k = 1,15.10^{-5}$ m/s, $r_o = 0,15$ m and $R_k = 1400$ m/ it has been obtained that the depression reaches the contour even in the point at the greatest distance from the well after a 10-day long pumping with a constant flow rate.

Correspondingly, the equivalent effect equals 530 m and the maximum water level reduction in the first stage of pumping is $s_{o1} = 60$ m.

In the next stage of pumping the depression space sinks parallelly to its original position, the pressure distribution is illustrated in Fig. 4. It can be seen from the figure that the value of $\Delta s = s_{o2} - s_{o1}$ can be as high as 245 m without beginning to drain the highest parts of the structural unit in the West, although the deeper area of the layer undergoes properly to depressurization. The second stage of pumping with constant flow rate lasts for $t = 18{,}6 \approx 20$ days, thus the points in the most favourable position on the West contour are relieved from pressure in about a month. By this time a water level reduction of $s_{o2} = \Delta s + s_{o1} = 305$ m is achieved which requires pumps with 310-320 m heads taking into account the surface and pressure conditions around the well. The further pressure relief /areas lower than the West contour, in dipping/and the beginning of drainage near the west contour have to be carried out with a constant flow rate in the third stage of dewatering because of the limits in the heads of pumps.

When starting pumping with constant flow rate, the water level stands at -130 m in the well and at -55 m from sea level on the contour. This means that the starting pressure difference of the combined /open and closed/ production system is 75 m.

To ensure safe conditions for the drifting of the ground drift pair, the water level in this point is reduced to -100 m from sea level. Consequently, the pressure difference between the well and the farthest point in the depression area decreases to 40 m while elastic reserves ΔV_1 and stored reserves ΔV_2 are drained. The elastic reserves were calculated as $0{,}8.10^4$ m³. The stored reserves ΔV_2 originate from the layer drainage near the west contour.

Taking into account an average layer thickness of 25,4 m and a pressure reduction of 35 m on the contour the drained area amounts to approximately $3{,}25.10^4$ m², the volume of drained water is $8{,}3.10^4$ m³ thus a total amount of $9{,}1.10^4$ m³ has to be lifted to the surface in this stage of pumping. According to our calculations, the time requirement of the third stage of pumping is 130 days during which time the initial flow rate of the well, i.e.900 m³/d decreases to 500 m³/d.

Therefore, after a 30-day pumping with constant flow rate of 900 m³/d and a further 130-day pumping with a decreasing flow rate at a constant depression of $s_{o2}=305$ m, i.e. after an approximately 6 months pre-drainage period the drifting of the ground drifts can be started.

These results are, however, to be corrected because of the inhomogeneity and inclination of the aquiferous layers: the pressure relief in the structural unit A has to be started 8-10 months prior to the drifting of ground drifts.

The well drilled to relieve pressure is also suitable to drain the layer, its long-time economic use is, however, limited by the head of the pump built in the well. Analysis of the characteristics of the pump and the effect of layer dipping and pressure reduction proved that the dewatering of a further 100-m section requires a further reduction in the contour pressure of $\Delta s_k = 14$ m and a water production of 6.10^4 m³. 220 days are needed to drain this further 100-m section, during this time the flow rate decreases to 310 m³/d. A further 50-m section is drained only in 190 days and the flow rate of well reduces to 230 m³/d. Thus the effectivity of the drainage performed from the surface considerably decreases with increasing depth, therefore, the second factor of the combined system, i.e. underground dewatering has to be applied in the next period.

The effectivity of draining the tectonical unit by a single well from the surface can be characterized as follows: pumping the water for a period of 2 years removes $2,1.10^5$ m³ out of the total $2,2.10^6$ m³ of the water reserves in the structural unit with an area of 87.10^4 m². This fully protects an area of 9.10^4 m² /draiining the layer/ and partially solves the depressurization of the rest of the area /to the level of -110 m/ i.e. 2/3 of the elastic reserves are lifted from the layer.

UNDERGROUND DRAINAGE IN THE AREA PRE--DRAINED FROM THE SURFACE

Underground drainage in area A is preceded by a pressure relief performed from surface by a well. The preparatory drifts are driven to the NW from the ground drift pair upwards in dipping between the drained ground water reservoirs after 2 years of operation of the draining well. For the case of drifting downwards in dipping, roof wells lined with 8-10 m long filters, at distances of 5-6 m and with diameters of 60 mm are suggested in the roof sand to reduce the residual water pressure and to drain ground water reservoir N° 1. Because of their closeness the sets of wells built in the parallel pair of drifts are regarded as galleries. To determine the flow rate of unit length, two stages of the drainage have been investigated.

In the first stage the height of inflow in the gallery decreases at nearly constant flow rate and the depression radius increases. In the second stage the height of inflow and the depression radius become steady while the flow rate and the height of water level between the galleries continuously decrease. The initial flow rate of the system has been calculated and 3,5 l/min/m has been obtained for one side of the gallery and 7 l/min/m for both sides [8] . 270 days have been found for the time of full drainage, i.e. the depressurized ground water reservoir N° 1 can be drained in 270 days.

The most unfavourable value can be expected in the deepest /SE/point of the layer where the roof has to be drained and two reservoirs in the floor have to be depressurized. Using the assumption of galleries again 6 l/min/m has been found for the initial flow rate from the elastic reserves and 20 days for the maximum time of pressure relief. The results mean that the flow rate for 1 m length of the gallery lies between 7 and 13 l/min and the retreating longwall mining can start 270+20=290 days or with somewhat greater safety 10-12 months after the advancing drifting is finished.

Depressurization of ground water reservoir N° 3 has to be started in the point where the height of the water column above layer floor is as high as 85 m if 17,1 m average thickness of the protection layer is taken into consideration. Since the water level in ground water reservoir N° 3 has been reduced by the well in average to -110 m measured from sea level depressurization with floor filters will be required only if mining activity reaches -200 m layer depth. The floor filters can be placed at distances 20-30 m because of the more favourable coefficients of seepage and need for pressure reduction in layers 2 and 3.

Further pairs of drifts can be drifted under more favourable conditions because the pressure relieving effect of the first panel extends to the boundary of the structural unit.

UNDERGROUND DRAINAGE WITHOUT PRE-DRAINAGE

Protection of areas of type "B" is proposed according to the order of the drainage of areas of type "A" but using underground drainage only. Drainage of areas of type "A" provides access to structural units lying upwards in dipping without risking water inrushes. Areas of type "B" enable the layers to be drained by draining boreholes drilled from faces of drifts.

To approach areas of type "B" pre-drillings can clear existence of faults. If faults are indicated, three drainage boreholes have to be drilled from each of the three development drifts in area "B" illustrated as an example. These boreholes drain ground water reservoir N°1 and can be drilled by Kassai-Halász's drilling-filtering tool. The middle one of them can lay in the plane of the drift axis and the two others in planes inclined at 30° to the middle one. During the drilling of the drainage boreholes and the depressurization and drainage of the area, the drifting is suspended. A drainage borehole of 114 mm diameter lined with a 10-m long filter can produce a maximum flow rate of 60-65 l/min, thus a maximum san-free flow rate of 0,6 m³/min can be expected from the three drifts.

The surface of area "B" is 12.10^4 m², the elastic-consolidational reserves are $0,4.10^4$ m³ and the static reserves to be drained amount to 3.10^5 m³. The depth of the layer floor varies between +50 and -40 m measured from sea level, its direction of dipping is SE and the angle of inclination equals 10,5° . The average static water level of the three reservoirs is 220 m from sea level, the average height of water column above the layer floor amounts to 170 m on the west border of the area and 260 m near the east limit fault.

Pressure relief of the area is carried out also here in two stages and it needs 5-6 days to depressurize the layer. A substantially longer period is required to drain a closed inclined ground water reservoir that lacks any supply.

Assuming a full drainage for the layer, the calculated curve of q/t/ is plotted in Fig. 5. a. and that of l/t/ in Fig. 6.a. Curve q/t/ gives the total flow rate of the 9 drainage holes in the three drifts as a function of time and l/t/ the length of undrained section of the layer measured in dipping. q_{01} denotes the maximum flow rate /water absorbing capability/ of the system at the beginning of the drainage, its value being 580 l/min l_o stands for the actual length of drifts to be driven in area "B" /l_o = 610 m/.

The process of drainage can be greatly accelerated if a cross-cut is driven parallelly to the NW fault at a distance of 40-50 m to connect the three drifts. This cross-cut can be used for drilling the drainage holes to form a drainage gallery. 21 drainage holes drilled by Kassai-Halász's drilling-filtering tools can be made at 10-m distances their total flow rate being approximately 2000 m³/d. The function flow rate-time of the drainage holes drilled from the cross-cut is illustrated in Fig. 5.b. and the length of the undrained section of the layer is shown in Fig. 6.b.

The cover layer thickness 5 m/MPa required to ensure safe conditions for drifting can be achieved in 370 days if 9 drainage holes are used in the three drifts while a drainage gallery provides the same result in 160 days.

To relieve pressure in ground water reservoirs N° 2 and 3 a simple method can be applied. Drainage holes have to be drilled from the side drifts to depressurize ground water reservoir N° 2 and from the middle one to relieve ground water reservoir N° 3. Through these holes reservoirs N° 2 and 3 are depressurized during the time of partial drainage of reservoir N° 1 or even in substantially shorter time because of the high rate of the drainage of the elastic reserves.

SUGGESTION FOR DEWATERING THE MÁTRAVEREBÉLY REGION

A combined method is suggested to solve the dewatering of the region. Wells drilled from the surface can be used to depressurize and partially drain the closed structural units of type "A" /to the east and south-east from the planned pair of ground drifts/. The suggested number of wells is 8, their pattern considered as suitable is outlined in Fig. 2. The number of the wells also indicates their order of drilling. The pair of ground drifts can be driven under the protection of the drainage performed from the surface. The preparatory drifts to prepare twin fronts can be made under the same protection.

In the drifts advancing downwards in dipping in areas of type "A", roof wells and floor filters can drain ground water reservoir N° 1 and depressurize N° 2 and 3. The distance among roof wells of 60-mm diameter is 5-6 m,the length of the filters have to exceed 4-5 m but they are the most suitably 8-10 m long.

Depressurization of ground water reservoirs N° 2 and 3 has to be started in a depth of seam I. where the floor protection layer of seam II. does not provide the specific thickness of protection layer of 20 m/MPa against the residual pressure after depressurization from the surface. Because of the rapid drainage of the elastic reserves, the floor filters can be placed at essentially greater distances than those of roof wells: a pitch of 30 m is suggested for the floor filter pattern.

Structural units of type "B" are proposed to be worked under the protection of underground drainage. The stratigraphy of these units being beneficial from the point of view of drainage allows for the majority of drifts to be driven mainly among ground water reservoirs already drained or depressurized and for the winning to be started after drifting.

REFERENCES

[1] Kertész, R.: Hydrogeology of Kányás coal reserves. BKL Bányászat. Vol.109.1976.N° 2. P. 115-122. /In Hungarian/

[2] Possibility of combatting down Kányás ground water danger. BÁKI Research Report. 1977. N° 13-23/76. /In Hungarian/

[3] Ground water drainage in Nógrád coal basin. Nógrád State Coal Mines. 1978. /In Hungarian/

[4] Juhász,J.: Hydrogeology. Publishing House of the Hungarian Academy of Sciences. Budapest 1976. /In Hungarian/

[5] Kézdi, Á.: Soil Mechanics. Tankönyvkiadó. Budapest 1969. /In Hungarian/

[6] Schmieder-Kesserü-Juhász-Willems-Martos: Ground water danger and water economy in mining. Müszaki Könyvkiadó. Budapest. 1975. /In Hungarian/

[7] Kovács Gy.: Seepage hydraulics. Publishing House of the Hungarian Academy of Sciences. Budapest. 1972. /In Hungarian/

[8] Schmieder, A.: Planning of active ground water protection in mining. Doctor's thesis. 1965. /In Hungarian/

Table 1.

Aquiferous layer	1	2	3
Average layer thickness m	25,4	4,2	5,7
Coefficient of seepage m/s	$8,5.10^{-6}$	4.10^{-6}	3.10^{-5}
Delivery coefficient m²/s	$21,6.10^{-5}$	$16,8.10^{-6}$	17.10^{-5}
Gravitational void volume %	10	-	-

FIGURES

Fig. 1. Average section in Kányás mine
1: layer depth, m
2: cross-section
3: layer thickness, m
4: denomination of layer
5: humus
6: brown clay
7: streak
8: shell sand /Chlamys/, sandstone, water reservoir N° 1
9: brownish gray slateous clay
10: bituminous slateous clay
11: bituminous coal layer I. under working
12: micaceous sand, water reservoir N° 2
13: micaceous sandy clay
14: bituminous coal layer II.
15: micaceous sand, water reservoir N° 3
16: micaceous sandy clay

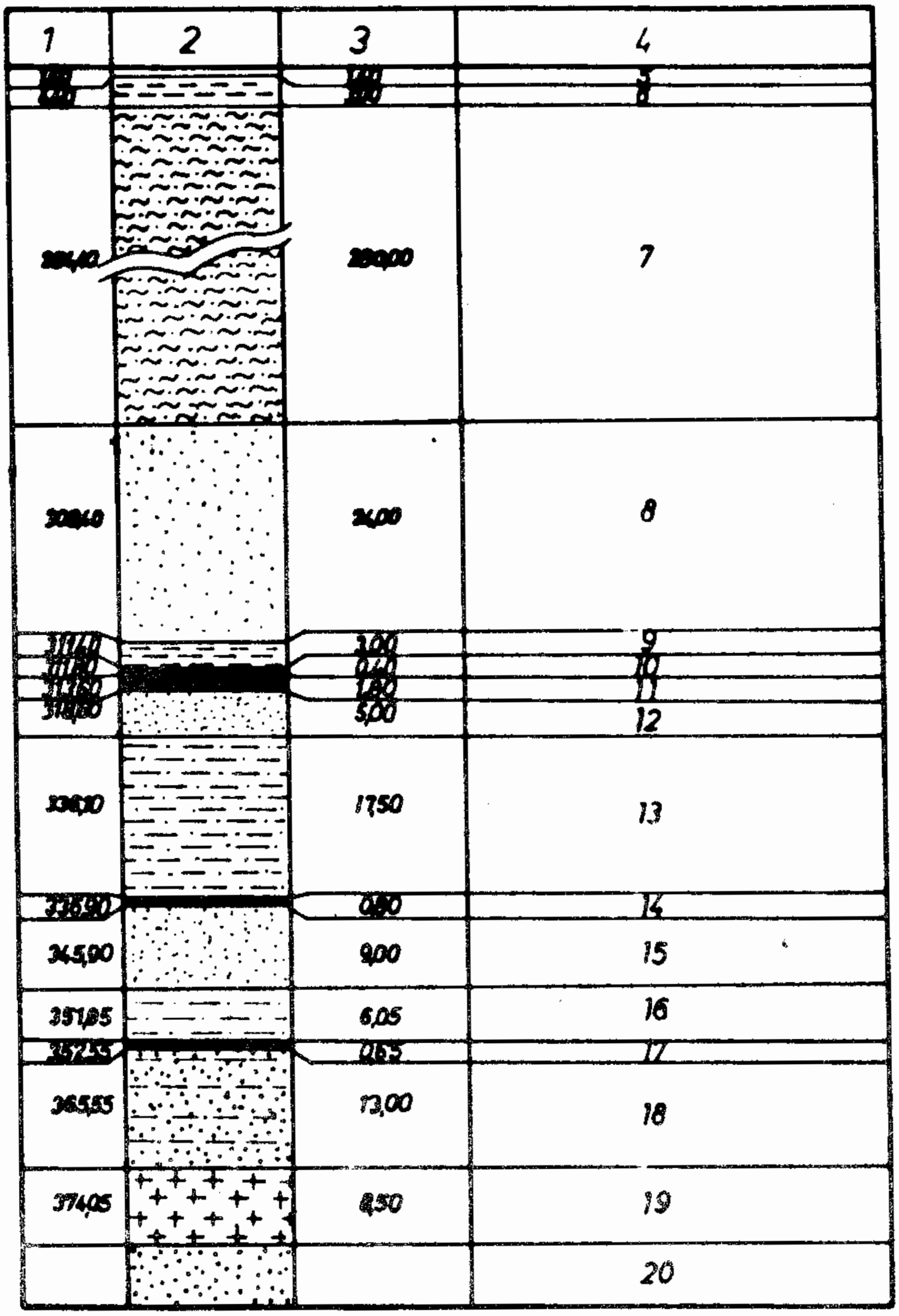
Fig. 2. Map of Mátraverebély region
KD: South panel of Kányás mine
Df: South mean-line
D : South air-heading
Fv: development drift
Bh: mine ground boundary
Vk: dewatering well

Fig. 3. Cross-section of structural unit "A" to determine the parameters of depressurization from the surface
Fv: development drift
Vk: dewatering well
1: measured static water level
2: water reservoir N° 1
3: bituminous coal layer I under working

Fig. 4. Cross-section to dermine parameters of pumping with constant flow rate
Fv: development drift
Vk: dewatering well
1: initial water level
2: water level after pumping for time t_o
3: water level after pumping for time $t_o + t_1$
4: water reservoir N° 1
5: bituminous coal layer I. under working

Fig. 5. Flow rate of drainage as function of time
a: total flow rate of drainage holes in development drifts
b: total flow rate of drainage holes in cross-cut
t: time of drainage /dewatering/ of layer d
q: total flow rate of drainage holes l/min

Fig. 6. Length of undrained section of layer as function of time
a: effect of drainage in development drift
b: effect of drainage in cross-cut
t: time of drainage /dewatering/ of layer d
ℓ: length of undrained section of layer m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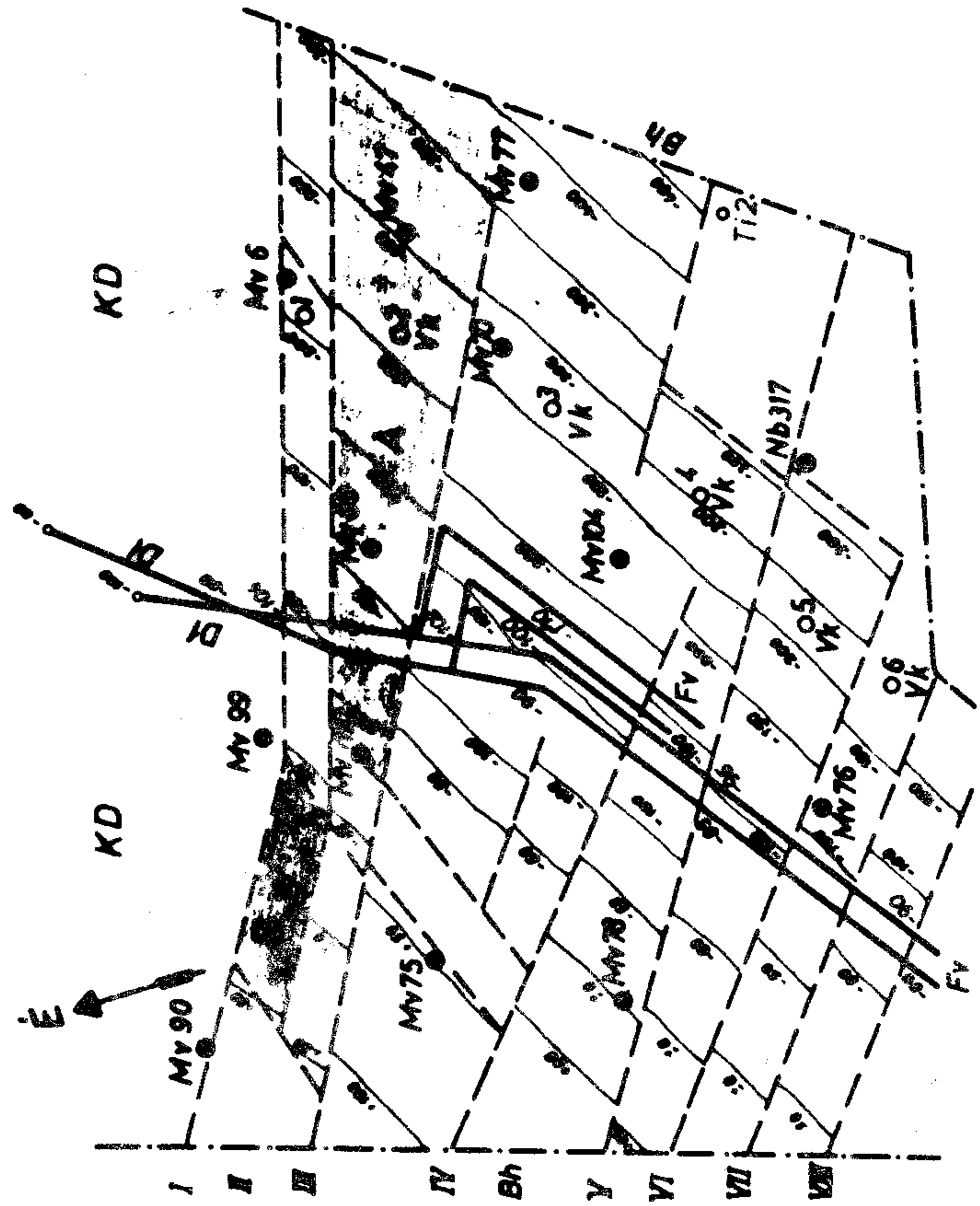
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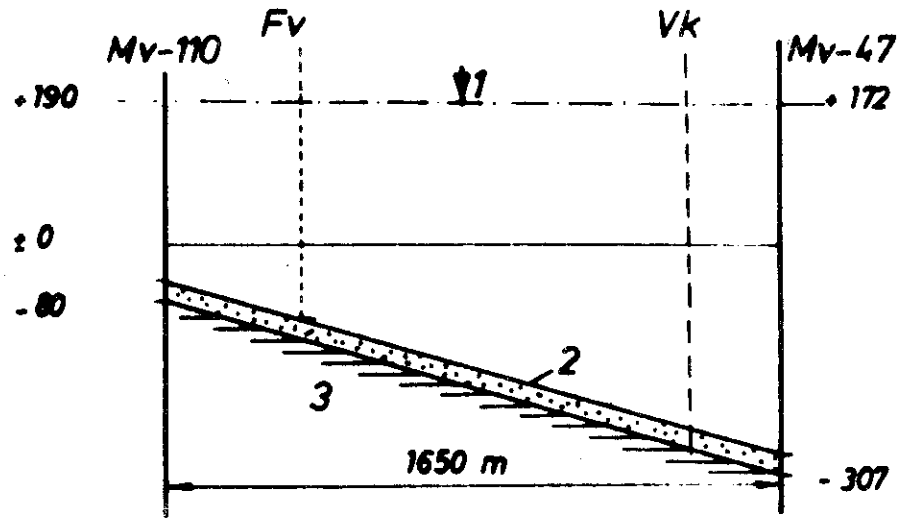

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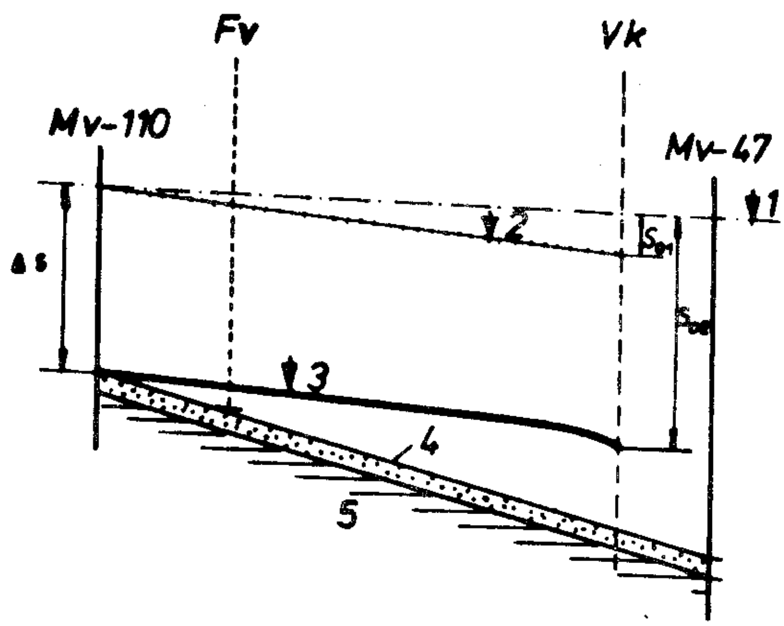

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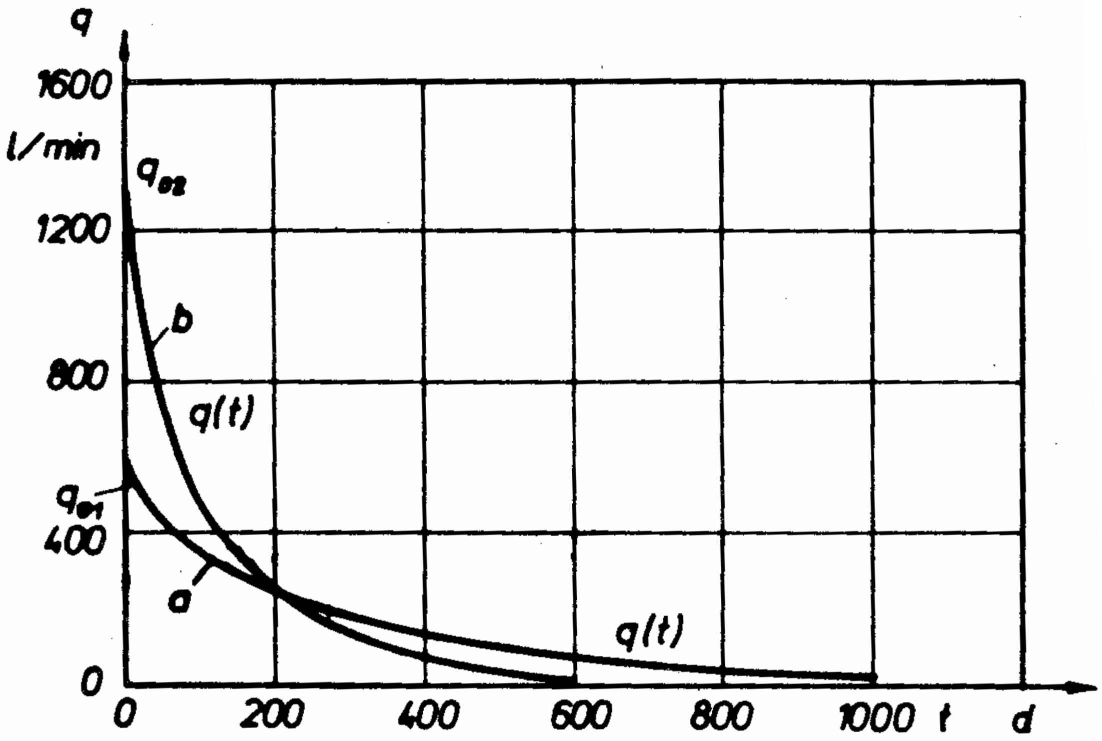

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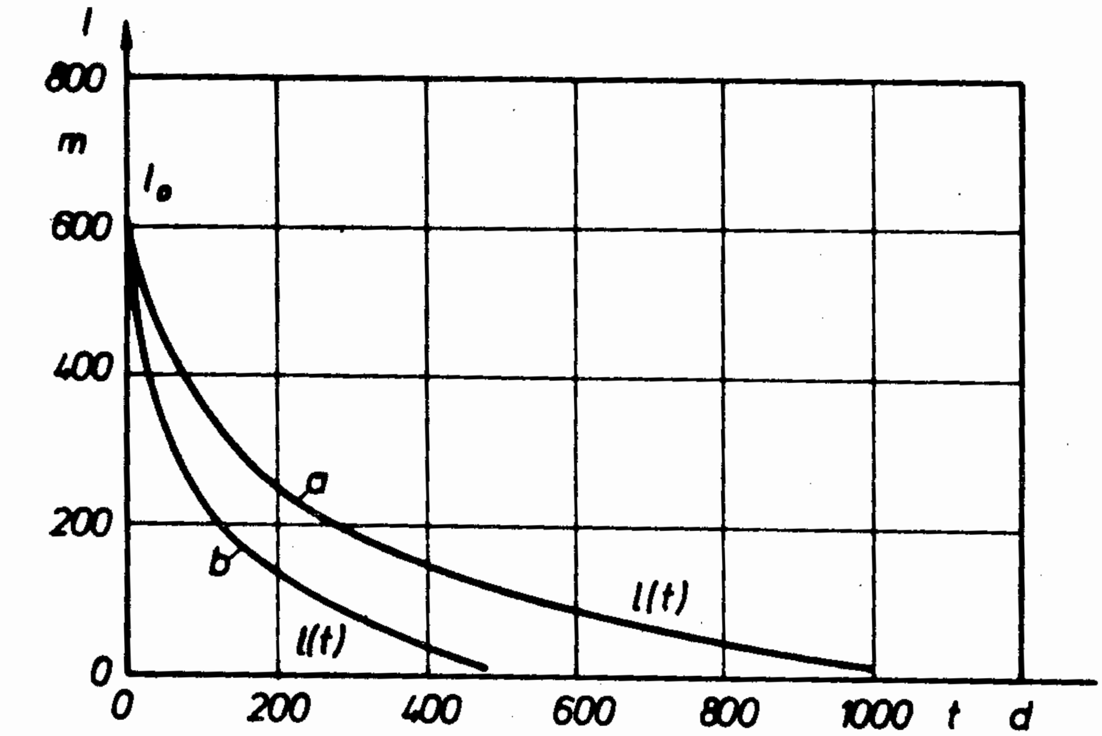

6. ábra Fig. 6.