Mine Dewatering Techniques and Technology Applied at SAKOG Brown Coal Mine

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ABSTRACT

The influence of the lateral variability of the protection layer lithology on the applicability of safety criteria for mining under the water bearing strata in the case of Salzach-Kohlebergbau-Geselschaft m. b. H. case (SAKOG) is presented. Well construction and drilling technology of the jet-in driven dewatering wells, as applied in the SAKOG's case is given and the effects of the applied dewatering techniques and technology are discussed.

INTRODUCTION

The brown coal mine of Salzach-Kohlebergbau-Geselschaft m. b. H. is located in Trimmelkam, some 30 km north-northwestward from Salzburg. The mining technology applied is underground mining with longwalls and caving. In its history, the mine was confronted with several flowing sand inflows, and in january 1985 a strong water inflow into the roadway occurred. After this a predewatering with surface wells was introduced in the Tarsdorf-Ost area and additional predewatering with in-mine drilled jet-in driven wells foreseen for the Weilhart area. Geological, hydrogeological and geomechanical situation and the applied criteria were already presented(2) in detail. We repeat here only their general features. The production with the application of the proposed criteria was undisturbed in the Tarsdorf-Ost area until, in july and in august 1989, two water inrushes into the producing longwalls inrushes occurred. Then, after a review of the local geological conditions, the criteria and the technology, proposed for the Weilhart area were applied also to the rest of Tardorf-Ost. Since then, the production in this area is undisturbed again and the criteria and the applied technology can be considered as tested.

HYDROGEOLOGICAL AND GEOMECHANICAL SITUATION

The general geological and hydrogeological situation of the Tarsdorf-Ost area is given on the Figure 1. Of the three productive coal seams, only the bottom coal seam is productive in this area. The following aquifers exist from the top downwards: 1. quaternary gravely to sandy aquifer, 2. upper sarmatian gravely to sandy aquifer, 3. lower sarmatian gravely to sandy aquifer, 4. badenian gravely aquifer of 3. Schotter, 5. badenian gravely aquifer of 2. Schotter and 6. badenian gravely aquifer of 2. Schotter. For the dewatering, only the 1. and 2. Schotter aquifers, which are closest to the coal seam and do not communicate with the upper ones are important. The coal seam is situated between the 1. and 2. Schotter horizons, the 1. Schotter constituting the underlying aquifer and the 2. Schotter the hanging one. Their hydrogeological data are given in Table 1.

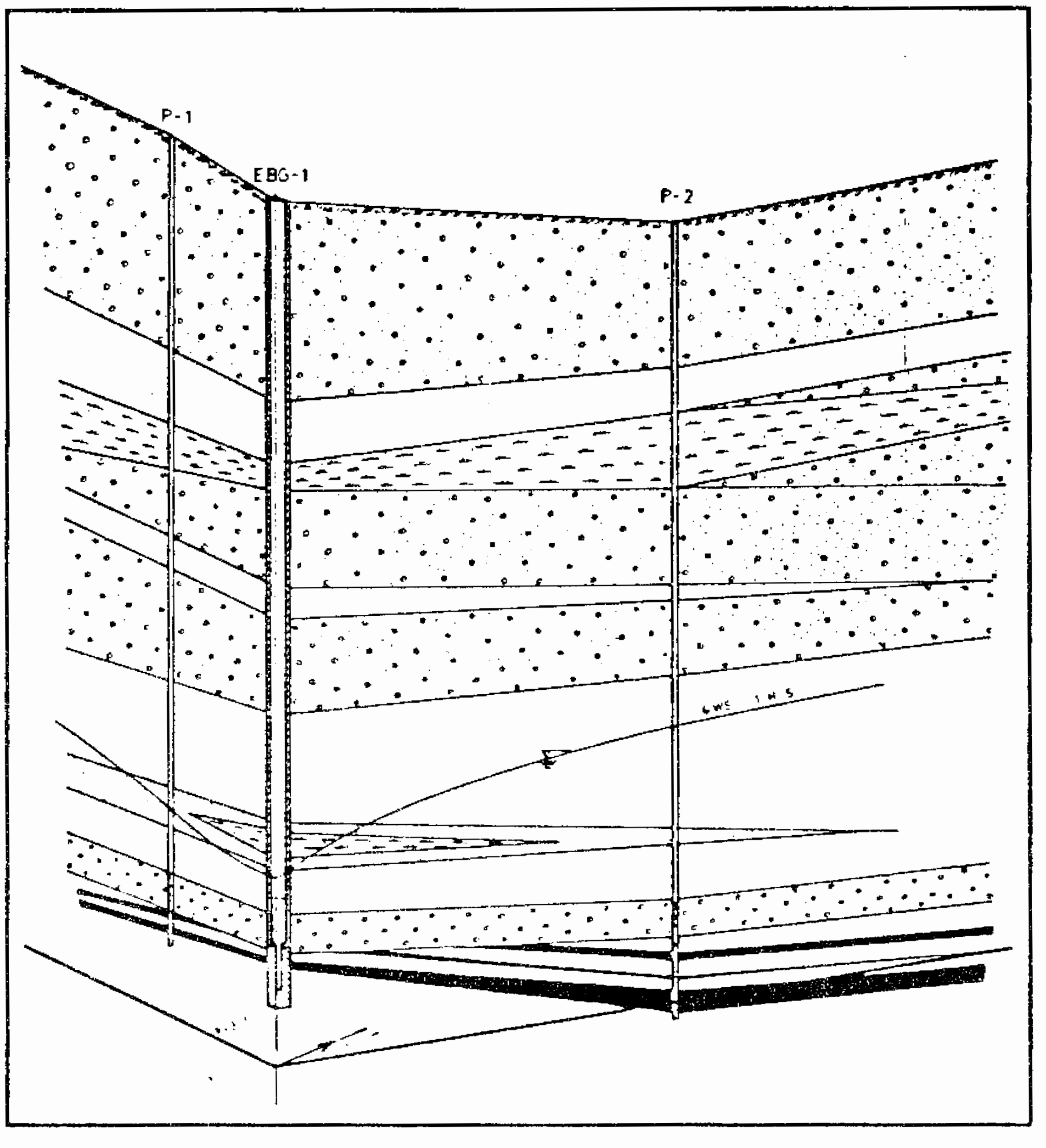

Figure 1: Cross-section of the area of Tarsdorf-Ost close to the 1985 inrush

Legend: 1 - coal seams, 2 - gravelous to sandy gravelous aquifers, 3 - impervious to semipervious alternating layers of clays, silts ,silty sands, with interbedded coal seams in the immediate top wall layer, 4 sandy aquifer, 5 - semipervious silt to silty sand

Table 1: Hydrogeological parameters of 1. and 2. Schotter aquifers

PARAMETER	Aquifer of 1st Schotter	Aquifer of 2nd Schotter	
	Weilhart	Weilhart	Tarsdorf-Ost
Permeability	4.75×10^{-6} m/s	5.79×10^{-5} m/s	3.47×10^{-5} m/s
Transmissivity	4.00×10^{-5} m²/s	3.74×10^{-4} m²/s	3.00×10^{-4} m²/s
Storativity	1.97×10^{-4}	4.17×10^{-5}	7.82×10^{-5}
Specific storativity	3.01×10^{-5} m^{-1}	6.51×10^{-6} m^{-1}	9.05×10^{-6} m^{-1}

The aquifers, endangering the production are separated from the coal seam by top wall and bottom wall layers, presenting an alternating series of silts, clays and coal. By their geomechanical values, they can be ranged into weak rocks. Table 2 shows the parameters, used in safety criteria definition, based on the similarity with the Velenje lignite mine case.

Table 2: Specific weights of the top and bottom wall layers at SAKOG

PARAMETER	Mean value (kN/m^{-3})	Standard deviation (kN/m^{-3})
Specific weight (U,T)	27.5	0.23
Natural volumetric weight (U,T)	21.4	1.04
Natural volumetric weight (K)	13.3	0.56
Splinter volumetric weight (U,T)	10.5	0.28

Legend: U - silt, T - clay, K - coal

From the geotechnical aspect, the top wall and bottom wall layers consist of weak to medium hard rocks. Values of rockmechanical parameters of the individual samples vary within a broad range as it can be seen from the Table 3. This is due to the vertical lithologic variations, with individual layers of clay, silt or silty sand being from some centimetres to some meters thick. Coal layers some centimetres to some decimeters thick function as reinforcement, adding to the variability of the data values.

Table 3: Rockmechanical parameters of top and bottom wall layers at SAKOG

PARAMETER	Range of variation of sample values
Uniaxial strength (kN/m^2)	156 - 1624
Tensile strength (kN/m^2)	116 - 507
Elasticity modulus (kPa)	67.1 - 457
Friction angle (°)	21 - 31 (clays&silts) 27 - 48 (coal)
Swelling pressure (kN/m^2)	4 - 70

APPLIED SAFETY CRITERIA

For the safety criteria definition, there was no possibility of in-situ measurements. The criteria were therefore applied on the basis of similarity with the other mine cases. The height of caving was defined as

$$h_o = (X+1)xV = \frac{\gamma_p}{\gamma_p - \gamma_r} x\ V$$

where h_o denotes height of the caving-in area(m), V height of excavation, x ratio of caved-in and excavation heights, γ_p natural volumetric weight and γ_r splinter (broken material) volumetric weight. The x ratio was found in the SAKOG case to be slightly smaller than 1.2, which was adopted as the applied ratio. Above the caved-in area, a protective layer of thickness M_h, with maximum allowable critical hydraulic gradient of i_c = 0.05 MPa/bar was required on the basis of similarity with Jyhomoravska panva coal basin and the criteria applied there. On this basis the allowable hanging wall aquifer pressure was defined as (with the symbols as previously defined):

$$p_h\ (MPa) = (M_h - 1.2\ x\ V)\ x\ 0.05\ MPa/m$$

Where this criterion could not be met with surface predewatering only, as in the Weilhart area case, additional predewatering with underground boreholes was required. For this predewatering, the critical height of water over the excavating longwall with quasi horizontally lying aquifers was defined as:

$$H(L,t) = 0.47 \times H_o/(1+1.12 \times (t \times k \times H_o)/(n_e \times L^2)))$$

where the symbols denote: L length of the longwall, H_o height of the water in the aquifer, k aquifers permeability, n_e aquifers effective porosity, t time from the start of inflow.

EXPERIENCES WITH THE APPLIED CRITERIA

A sudden water inrush into the roadways heading from Tarsdorf area into the newly developing Weilhart area was at the start of the above criteria. With the criteria applied, the roadway advance into the Weilhart area was preformed without any problems. When entering into the Weilhart area, additional dewatering from the mine was applied, according to the technology which was jointly developed by S.P. GZL and SAKOG.

Also the coal extraction according to the above criteria in the area of Tarsdorf-Ost was without any problems until june 1989. By then, the excavation entered into an area, where the hanging wall layer contained layers of silty sand, sometimes lying directly above the coal seam. Within the hanging wall layer several relatively thick (up to some decimeters) layers of coal acted as reinforcement, thus augmenting the caving-in height a&1bove the longwall face. Such situation led to two water inrushes, both starting as minor inflows from the old workings and finally shifting to the longwall face, as wet coal and clay production problems caused long wall advance to slow down and, eventually, to stop.

From july 1989, the technology of the additional dewatering, originally foreseen and developed for the Weilhart area was applied also to Tarsdorf area. It was decided, when necessary, to dewater also the flowing sands. For the spacing of the dewatering boreholes over the progressing longwall or advance gate, the combined dewatering effects of a series of boreholes, positioned either on roadways, or at an advancing gate or at two advancing gates and starting to function at different times were calculated with two computer programmes. First, suitable for quick calculations, was based on a simple algorithm constituted of the following formulas:

$$s[p,t_k] = \sum_{i=1}^{n}\sum_{k=1}^{m}((0.183 \times ((Q_b)_i)_k / T_p) \times \log((2.25 \times T_p \times t_k)/((r_{pb})_i^2 \times S_p)))$$

with:

$$((Q_b)_i)_k = \{s[b_i,t_{k=0}] - \sum_{k=1}^{k-1}(\sum_{j=1}^{i-1}(0.183 \times ((Q_b)_j)_k / (T_b)_i) \times \log((2.25 \times (T_b)_i \times t_k) / (r_{ij}^2 \times (S_b)_i)))$$
$$+ \sum_{j=i+1}^{n}((0.183 \times ((Q_b)_j)_k / (T_b)_i \times \log((2.25 \times (T_b)_i \times t_k)/(r_{ij}^2 \times (S_b)_i))))\} \times$$
$$\times (T_b)_i / (0.183 \times \sum_{k=1}^{m}\log((2.25 \times (T_b)_i \times t_k)/(r_{ii}^2 \times (S_b)_i)))$$

In the above equations, according to the standard Jacob-Lohman[1] notation, the symbols denote: s drawdown, Q discharge, T transmissibility, S storativity, r distance of the point of drawdown calculation from the discharging borehole (with r_{ii} equivalent to the borehole radius) and t discharging time. Subscripts p and b denote point of drawdown calculation and dewatering borehole, respectively. Indexes denote: k time increment, i&j discharging boreholes i and j respectively.

The second approach to the longwall face dewatering problem was based on SUTRA finite elements model. There, the aquifer was considered unconfined by previous surface dewatering, with a more or less constant border inflow into the excavation area and with the discharged water coming from this border inflow and from the depletion of the aquifer over the excavated area.

From these calculations it was possible to augment the spacing between the dewatering boreholes along the gates from the initial (at the start of the longwall face), being 10 - 15 m, to the final (after about 100 m of longwall face advance), being 40-50 m.

Jointly with the additional dewatering from the advancing gates, some other measures, resulting in a quicker and a more steady long wall face advance (7 productive days per week) were also introduced. The combined action of both resulted that the production in this area is now continuing. Unfortunately, the coal seam in this area is close to depletion.

DEWATERING TECHNOLOGY APPLIED

Surface wells

Predewatering with a line of surface wells, blocking the inflow into the mining area is applied as an initial predewatering measure. Well construction is a standard one and they are equipped with submersible pumps. With these wells, the aquifer pressure over the mining area is reduced from the initial 13 - 16 bars to 2-4 bars only. Pumped water is of drinking quality, yet, for environmental reasons, it is discharged into the Salzach river and not infiltrated locally into the more pervious and from the pumped aquifers hydraulically separated quaternary aquifers.

Dewatering boreholes drilled from the mine

For the purpose of in-mine dewatering, it was necessary to develop a system, which would enable a quick and effective additional predewatering. The system should capture the water in such a way to keep the roadways and advance gates free from flowing water and mud. It should enable the road advance crew to drill and install a dewatering borehole within a shift in order to maintain the required advancing pace. Given the very thin hanging wall protective layer in the Weilhart area and the monorail transportation technology applied, and given the necessity of the depressurization of the underlying aquifers, the system should allow for drilling in all directions in galleries with 2.2 m diameter.

To comply with the above demands, the technology of jet driven wells was adapted to the specific conditions met in SAKOG mine, and an underground electro-hydraulic powered rotary drilling rig was designed and constructed by S.P. GZL. This rig has two hydraulic motors - one for rotation and one for the advance of the drilling rods - and is designed basically to allow for drilling to a depth of 150 m. Specific conditions in SAKOG demanded a strict control of the drilling mud pressure, when taken into account the small thickness of this layer and its disturbance by the roadway driving. If uncontrolled, the mud pressure itself could lead to a hanging wall protection layer collapse. Therefore, and this is specific, the mud pressure can be controlled separately from the mud throughflow, thus allowing for the low pressure drilling when necessary. Specific for this system is also that not only the functions of the rig, but also of the mud pump can be operated from the control panel.

Parallel to this, a construction of jet driven dewatering borehole was designed, allowing for drilling upwards and equipped with an appropriate preventer. The system is presented in the Figure 3. For the conditions met at SAKOG two types of screens were designed - one for the gravelous aquifers and the other for silty sands.By this system, after the drilling and installation of a conductor tube, the borehole is combined rotary and jet driven until the screened portion of the drilling rods enters the aquifer. During this operation the screen is plugged in order to allow for proper circulation of the drilling fluid. Preventer head prevents water and drilling fluid from entering the roadway and allows for controlled outflow of the drilled material. After the installation of the screened portion into the aquifer, the screen is unplugged and the borehole activated.

A specific problem presented the grouting of the conductor tube, which is installed into a previously disturbed coal seam. This grouting should be quick and effective and as inexpensive as possible. It must be stressed that a quick grouting of the conductor tube is vital for the quick progress of the drilling operations and of resulting roadway advance. This problem was solved by SAKOG team of experts by the application, first of chemical grouts, and, finally, of cement grout. The latter was found to be cheaper and to allow, with proper additives, an equally quick installation of the conductor tube.

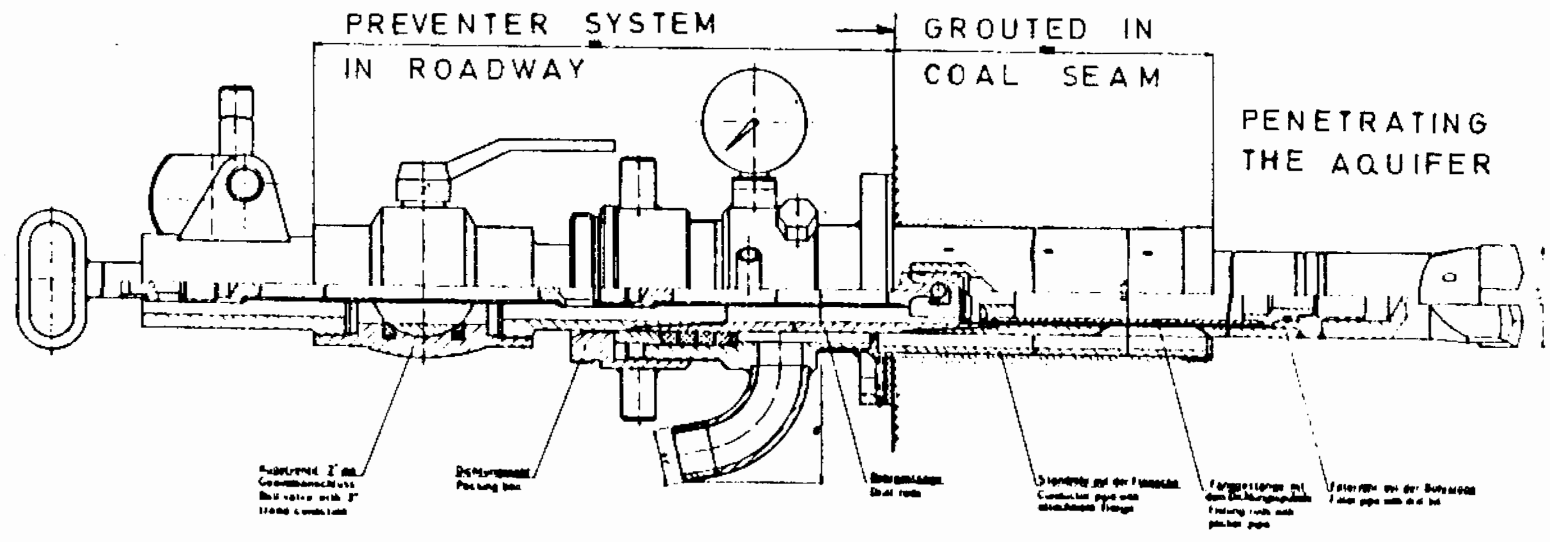

Figure 2: System for drilling and equipment of dewatering boreholes at SAKOG mine

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