Grouting of Mine Workings in the Josef Seam of the Mary Mine

By Tomáš VYLITA[1]

[1]Geoindustria - GMS Praha
Přistavni 24
170 04 Praha 7
Czechoslovakia

ABSTRACT

The system of galleries in the Josef Seam, as well as two shafts of the Mary Mine, Czechoslovakia, affected by the critical inrush have been grouted using so-called "comprehensive grouting" method. The method consists in a step-by-step filling in of mine workings with an environment-friendlyclay-cement mixture, using special boreholes drilled from the surface.

The grout curtains have succeeded in eliminating the infiltration of hot, gas saturated and mineralized water into the Mary Mine.

INTRODUCTION

The Mary Mine is now the only reminder of the formerly extensive underground brown coal mining in the Sokolov Basin, Northwest Bohemia. The region is renowned for its abundant resources of curative mineral waters used mainly at the spa towns of Karlovy Vary, Františkovy Layne and Marianske Lazne.

Owing to the setting of the mining areas of the Sokolov Basin with respect to structures bearing thermal and gas-saturated springs in the nearby spa of Karlovy Vary, underground and now prevailing open-cut mining operations are accompanied by many problems connected with the efficient protection of the spa site. In Karlovy Vary, a thermal mineral spring (temperature 40 to 73°C, mineralization 6.4 g/l, of a $NaHCO_3SO_4Cl$ hydrogeochemical type, supersaturated with carbon dioxide) is located and inrushes of hot water of a similar nature had been known to occur in the Mary Mine District even before 1876. In that year, upon reaching down to the lower of the two seams developed here in the Julia Shaft, powerful hot water inrushes were encountered. A 1901 inrush at the Mary Shaft allegedly affected the yield of Karlovy Vary springs in a negative manner (there was a sudden drop of the yield, which continued well into 1908). In 1908, the State Mining Bureau (pursuant to a decree of the Commission for Spring Protection stating that the drop of the yield of Karlovy Vary springs had been caused by mine water pumping at the Mary II Shaft beyond any doubt) ordered lower levels of the Mary Mine to be flooded and the level of mine water at the Mary V Shaft to be reduced. Even after a few weeks the drop was stopped and some three months later the yield started increasing again. The protective measure had survived until 1990, when a decision to liquidate the

draining system of the mine was taken because of a project to work out this section of the basin. Pursuant to requirements of the mine's operator and because of local geological conditions, Geoindustria Praha, cooperating with the Soviet company "Spetstamponazhgeologiya", sealed the Mary II and Mary V Shafts and the system of galleries affected by the critical inrush, using the so-called "comprehensive grouting" method. The method consists in a step-by-step filling of mine workings draining thermal waters of the basal aquifer of the basin with a clay-cement mixture, using single-purpose boreholes drilled from the surface.

GEOLOGICAL AND HYDROGEOLOGICAL SETTING OF THE SURROUNDINGS OF THE MARY MINE

Geological Seeting of the Region

The Sokolov Basin is founded on a fault structure constituting a borderline between two geological units of the Bohemian Massif - the Ore Mts. Region and the Central Bohemian Region.

The basin area of the weakened zone built of Tertiary sediments comprises several conspicuous faults, striking approximately SW - NE. The main role in the tectonic setting and preserving the filling prior to denudation has been played by postsedimentary faults with a jump height of 100 to 200 metres. Relicts of Tertiary sediments constitute a northeast-bound belt the maximum thickness of which is 400 m (near the Mary Mine).

The **basin bedrock** consists of medium metamorphed rocks of the Karlovy Vary Granite Pluton mantle, or the pluton proper. The rocks constituting the bedrock have been affected by weathering processes of a variable intensity. Metamorphites are jointed, occasionally silicified and mineralized with pyrite.

The basal **Stare Sedlo Formation** was formed in early stages of the destruction of a Paleogene paleoplain. It is represented by rather unsorted fluviatic sands, often affected by secondary silicification and converted into quartzites. Indication of organogenic sedimentation are relatively frequent. The rocks of the formation are massive, solid, with relatively insignificant tight joints occasionally healed with pyrite. The thickness of the formation at the point of the 1901 inrush is approximately 25 metres.

Overlying the Stare Sedlo Formation is the **Josef Seam Zone** (Upper Oligocene), in which most of the grouting operations have been located. It is a part of a coal-bearing sedimentary process, suppressed by fluvio-lacustrine sediments and pyroclastics during the early Miocene. The Josef Seam proper, developed within the lower part of the lithologically rather variable sequence, contains black-brown coal with a considerable amount of ashes and ferruginous sulphides, belonging to xylitic detritus of a lignite orthophase. At the Mary Mine, the thickness of the sequence ranges from 9.7 to 11.2 m, that of the seam proper being 4 m or so. The Josef Seam, where the fatal inrush of thermal waters occurred in 1901, comprises some 800 metres of 2.0 x 2.2 m gates and has been opened by two circular shafts 4.0 m in diameter.

The Lower Miocene brings about the advant of volcanic sedimentation, which is designated as the **Volcanodetritic Formation.** In the area of interest, it is represented by fluvio-lacustrine materials consisting of variable persontages of sediments of a volcanic origin (tuffaceous agglomerates, tuffs weathered into clays etc.). The thickness ranges from 44 to 70 metres.

Overlying these sediments is the **Main Coal-Bearing Formation** (Burdigalian), here represented mainly by the Antonin Seam exploited by the Mary Mine. An open-cast extraction of the Antonin Seam should commence in this area by 1995. The coal-forming sedimentation was terminated by a sudden water level increase and the sedimentation of the **Cypriss Formation** (Helvetian), consisting of pelitic sediments originating in a lacustrine, low-aerated environment (blue-gray bituminous claystones).

Hydrogeological Conditions of the Site

There are three important aquifers developed in this part of the Sokolov Basin, namely the basal aquifer, the Josef Seam aquifer and the near-surface Cypriss Formation aquifer. The situation in the Main Coal-Bearing Formation, which initially had its own groundwater, has been changed significantly by mining operations in most of the area of the basin.

The **Basal Aquifer** comprises the Stare Sedlo Formation with a joint, partly porous permeability, which maintain direct hydrodynamic communication with the underlying metamorphites or granitoids, which have a joint-type permeability. In the central part of the basin, around the Mary Mine, the aquifer comprises an accumulation of thermal, gas-saturated water of the Karlovy Vary type ($NaHCO_3SO_4Cl$). The areal extent of the accumulation has been affected in a significant manner by a pressure drop in the basal aquifer resulting from the inrush and a long-term draining operation taking place at the mine.

Inrushes of hot water upon reaching the Josef Seam in the vicinity of the Mary Mine had been known even before the sinking of Shaft II, one of the two shafts reaching down to the Josef Seam, began in 1898. However, the largest and in terms of its consequences the best-known inrush occurred in October 1901, when a new gateway was being driven from the new shaft. Mineralized (0.3 g/l), gas-saturated (CO_2) and hot (30.3°C) water of the $NaSO_4HCO_3Cl$ chemical type burst out of underlying sandstones at an altiktude of 236 m a.s.l. at a flow rate in excess of 4,200 l/min. The temperature dropped fairly quickly to 27°C, but, on the other hand, the content of minerals started climbing steeply, from the initial 0.3 to 4.22 g/l (in 1908).

The groundwater pressure drop thus meant an increased inflow of the thermal mineral water and its mixing with the original less mineralized and cooler water. In spite of efforts to put the inrush under control using then modern equipment, mining operations in the Josef Seam were not recommenced and in 1908 the lower levels of the Mary Mine were flooded, as there was a suspition the situation had been affecting the yield of springs of the Karlovy Vary Zone.

Remedial measures required a concrete curtain at Shaft II and a partial sealing of Shaft V, the other shaft reaching down to the Josef Seam. Until last year, approx. 1 cu.m/min of hot (28.5°C), gas-saturated (2.1 g/l of free carbon dioxide) and highly mineralized (5.6 g/l) water of the Karlovy Vary type had been discharged from Shaft V via a separator, the flow rate being determined by the required water level in the shaft.

Until the grouting was completed, the basal aquifer groundwater regimen had thus been significantly affected by the remedial measures at Shaft V, which represented the focal point of drainage in this part of the Sokolov Basin.

The **Josef Seam Aquifer**, especially the brown coal seam itself, is supplied both from the underlying Stare Sedlo Formation and by the infiltration of relatively cold, low-mineralized water from the surface. Although there is a distinctive hydraulic relation with the basal aquifer, the Josef Seam has its own groundwater regimen (chemical type - $NaHCO_3$ to $CaSO_4$, mineralization 0.5 g/l, maximum temperature 26.1°C, low content of free carbon dioxide). The Josef Seam groundwater regimen was also affected in a significant manner by the discharge operation going on at Shaft V.

The watertightness of the Miocene filling of the basin has been disturbed by coal-mining operations. The water content of the Volcanodetritic Formation is generally very low and the groundwater circulation of the Main Coal-Bearing Formation has been affected in an essential manner by historical and current mine works. The overlying Cypriss Formation constitutes the top aquifer, with a slightly confined of free groundwater table.

Grouting Operations

The problem of the relation between the thermal water inrush and the Karlovy Vary Zone of thermal springs has been here for a long time and has not been completely cracked until now. The most probable theory in this respect is one advocating a common deep-seated carbon dioxide sources for two relatively independent spring zones. The protection of natural curative springs of Karlovy Vary was the principal reason why the final sealing of gateways driven in the Josef Seam and related shafts was undertaken in the spring of 1990. Another argument supporting the operation was the planned advance of open-pit mining operations in the Antonin Seam toward the Mary Mine.

The risk of high infiltration to the bottom of the future quarry and rock deformations above gateways in the Josef Seam, as well as other factors, led to the application of the so-called comprehensive grouting method.

The method is based on an acturate calculation of the entire sealing process and the filling of the worked-out gateways in the Josef Seam, making use of all available information on hydrophysical and mechanical properties of the rock mass, which was obtained by means of a broad range of analyses and tests.

The worked-out spaces in the Josef Seam, as well as Shafts II and V, have been grouted using environment-friendly glay-cement grout mixtures blended with the hydrogeology of the site in mind. The grout was inserted by means of 13 vertical and 4 inclined boreholes from the surface: the boreholes were equipped with perforated casings, or solid casings perforated at certain intervals.

The grout, which was prepared from local Cypriss Formation claystones, was fed into the boreholes at a rate of approximately 100 cu.m/day. Process parameters (pressure, flow rate, density) were measured on the manifold. The total grout consumption was 8,160 cu.m. At the same time, the grout was checked for its specific density, viscosity and shear strength at a field laboratory.

Initial conditions of the grouting process were determined by hydrodynamic tests in the boreholed (pressure equalization and rheometric measurements). Effects of the grouting measures have been illustrated by rheometric measurements taken in boreholes redrilled after the completion of the process.

In addition, daily measurements of the grout levels in the different boreholes and groundwater level measurements in the grouting boreholes and hydrogeological boreholes in the vicinity of the Mary Mine were conducted.

Laboratories of "Spetstamponazhgeologiya" were engaged in long-term tests aimed at determining the grout resistance against corrosion and, consequently, the useful life of the grout curtain established. The testwork has proven that no corresion processes take place in the grout mixtures. It has been confirmed that the grout - water system is in an equilibrium state, which means that the sealing curtain will be capable to fulfil its task for a virtually unlimited period of time, unless exposed to direct mechanical interventions. The grouting mixture is naturally resistant to seismic and other shocks which are relatively frequent in this part of the Bohemian Massif.

CONCLUSIONS

The grout curtains have succeeded in eliminating the infiltration of hot, gas-saturated and mineralized water of the Karlovy Vary type into the Mary Mine.

The filling of gateways and shafts in the Josef Seam has been proven by grout level measurements in the different boreholes and by the grout oozing out in Shafts II and V at the level of the upper Antonin Seam. The grout's sealing effect has been confirmed by rheometric tests and regimen measurements in hydrogeological boreholes and wells in the vicinity of the Mary Mine, as well as by monitoring the discharge from Shaft V, which is now practically nil. The water now running away from Shaft V comes originally from the overlying Cypriss Formation claystones.

Groundwater level measurements in boreholes indicate a significant increase of the pressure in the Josef Seam aquifer and in the basal aquifer. At the same time, the pressure increase closely correlates with the advance of the grouting operations.

The filling and sealing of the Josef Seam gates and shafts using a total of 8,160 m^3 of grout made from natural materials have succeeded in almost restoring the hydrogeological situation existing there before the commencement of mining operations. In addition, the risk posed to the regimen of Karlovy Vary natural curative springs by mining operations in this region has been eliminated.