HYDROGEOLOGY AND GEOTECHNICAL SAFETY OF AN OPENCAST MINE IN THE NORTH BOHEMIAN BROWN COAL BASIN

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ABSTRACT

Hydrogeological characteristics of the North Bohemian Brown Coal Basin is described. Specificity of this basin by the extent of mining and hydrogeological problems that can be divided into three problem spheres, i.e. protection of geotechnical security of opencast mine, protectiom of mineral springs in relation to the mining activity, formation of hydrological cycle of the landscape with the termination of mining activity is given. The hydrological model of underground-water circulation in hydrogeological massif of crystalline complex of Ore Mountains in the zone in the front of the face in opencast mine is being solved. Three types of underground-water circulation were defined. Hydrogeological function of debris deposits is corrected against previous opinions.

INTRODUCTION

North Bohemian Brown Coal Basin /SHP/ is of dominant significance in the energetics of Czechoslovakia. The history of coal mining in this basin has been associated with the formation of suitable hydrogeological conditions for reliable exploitation of underground mines and opencast mines. The principal attention is paid to the problems of dewatering, the solution of which happens to be more exigent in close relation to the development of mining activity in more complex deposit-geological conditions. The extent of dewatering works in SHP is substantially smaller than in similar basin structures in neighbouring states. The specificity of mining-hydrogeological problems in this basin appears in the width and variety of these problems, when faulty conclusions have deeper reach even beyond the scope of mining activity. The importance of the solution of mining-hydrogeological problems is in foreground with passing to opencast mining of coal with high capacity technics. This third period of coal mining in SHP has been passing through the history of mining activity in the last 35 years /Haas,1983/. The restriction of the negative influence of water upon coal extraction must be understood as a certain process where it is necessary to solve and fulfil a series of factors that stipulate the final result, i.e. safe operation.

Basic assumption for safe opencast mining of coal is to secure geotechnical safety of opencast mines /Strzodka, Fischer, 1983/. This conception includes a set of measures that among others prevent the negative influence of surface and underground waters upon the stability of lateral and front faces of opencast mines and dumps, prevention of water breakouts and floods, ultimate bearing value of working levels for excavating machines and conveyer plant. Geotechnical security is dependent on structural and lithological development of rocks, petrological composition, geomechanical properties and mining-technological conditions.

HYDROGEOLOGICAL CHARACTERISTICS OF BASIN

NorthBohemian Brown Coal Basin resulted from the Tertiary filling of the ramp valley oriented in the direction SW-NE. On NW side it is limited morphologically by the outstanding slope of massif of gneiss and granite of Ore Mountains. These rocks form the subbasement of Tertiary sediments of the basin that are of lacustrine and topset origin. At the junction of sediments of basin with the massif of crystalline complex of Ore Mountains the failure zone of crushed and altered rocks passes in the direction of basin axis. This zone has not a uniform course and is disturbed by transverse fractures in the direction NW-SE and fractures in the direction W-E. In the footwall of the basin there are rocks strongly kaolinized, up to the depth of 40 m. The border of the basin on the south-eastern side has an irregular course.

From the standpoint of coal extraction water-bearing aquifers are the most important, i.e. subjacent fissure water-bearing crystalline complex, sands in underlying rock and in the top wall of the group of beds, coal seam and Quaternary debris and gravel. All water-bearing aquifers are characterized by a low coefficient of permeability of the order 10^{-5}+10^{-6} $m.s^{-1}$. The permeability of Quaternary sediments oscillates from 10^{-4} up to 10^{-7} $m.s^{-1}$ according to the composition and place of attitude.

The debris prevail on the slopes of Ore Mountains and cover the interface of Tertiary sediments with the crystalline complex. At the mouth of water streams from mountain valleys into the basin the cones of proluvial dirty gravel were created. The recharge area of the Tertiary water-bearing aquifers is delimitated by the ledge of this formation at the foot of Ore Mountains slopes. The general streaming of underground water passes upright to the direction of basin axis, i.e. from the Ore Mountains slopes to the south-eastern border of the basin. In last years the coal seam had been extracted in border regions of the basin at the foot of Ore Mountains. Mining activity raised secondarilly the permeability of coal seam that nowadays has the function of drainage aquifer for intook waters. In the centre of the basin the movement of underground waters is limited by pumping underground waters. The average annual pumped quantity of mine waters is $31.2.10^{6}$ m^{3}. Opencast mines share in this quantity with 43 %, i.e. incl. pumped waters in their foreland /Haas,1983/.

HYDROGEOLOGICAL PROBLEMS IN SHP

From the hydrogeological point of view SHP can be characterized as a complex hydrogeological structure, even if the coefficient of water-bearing capacity /the quantity of pumped water per unit of extracted raw material/ is relatively slow. 0,56 $m^{-3}.t^{-1}$. From the point of view of the geotechnical security of opencast mines the main attention is concentrated upon dewatering of water-bearing aquifers, aquitards in the hanging wall and footwall of the coal seam. This multilateral activity that interferes with a series of technical spheres is closely connected with a series of purely hydrogeological problems, the solution of which is important not only in the relation to mining activity, but has influence even upon the period after the termination of coal extraction.

The hydrogeological problems of the extraction of coal seam in SHP can be divided into the following problem spheres:

a/ geotechnical security of opencast mines with regard to the stability of slopes and dump bodies;
b/ the release of blocked coal reserves in relation to the protection of mineral springs;
c/ formation of hydrogeological cycle of the landscape with the termination of mining activity.

a/ The problem is concentrated on the assurance of the stability of high slopes. The basic presumption of higher stability of slopes in the basin structure is the limitation of negative effects of the hydrostatic, stream and pore-water pressure of the underground water. Effective solution consists in the dewatering of rocks with low coefficient of permeability of order $10^{-6} m.s^{-1}$. Nevertheless, the pumped quantities of water are not neglectable, as they represent 23 % of the annual volume of pumped water /Haas,1983/.

The independent problem consists in the stability of slopes of dump bodies. The basic presumption of the protection of dumps from the effects of underground and surface waters consists in the dewatering of the dump space with long-termed effect even during the formation of the dump body. Good knowledge of hydrogeological conditions of dump space is inevitable for the preparation and construction of the dump in concrete conditions. These requirements have not been always fulfilled in necessary extent, and it becomes evident by landslides with frequent stops in the dump formation. Inside of the dump bodies specific hydrologic regimens are being formed, the regularity of which is not quite clear. On dump bodies there are known constant springs, uplift water is being ascertained by bore holes and water inside of the dump proves delay relatively for a long time. At one dump with the area 10 km^2 the time of delay of water in its body was ascertained for 6 years /Hanzlík, Morevec,1986/.

Actual problem consists in the security of the stability of front and leterel slopes of the opencast in the outcrop part of the basin structure at the junction with the massif of Ore Mountains.

b/ Mineral healthing springs represent the source of natural richess of unrecoverable value, therefore they must be the object of protection at any time. This protection is very actual in territories with mining activity that more or less devastates the ecosystem of landscape. This problem is specific and actual in SHP. In the north-eastern part of the basin it concerns the release of blocked coal reserves in relation to thermal waters in the paleorhyolite in the geothermal structure of Teplice. The connection between the coal extraction and occurrence of thermal waters was previously proved by a series of catastrophic breakouts of thermal waters into mine excavations, associated with the destruction of flowing openings of these waters. Nowadays the opening of big opencast mine is being solved, it is dependent on deep drawdown of the outward forcing level of underground waters that are in a certain relation to waters of geothermal structure. The extent and mode of protection of thermal waters are dependent on the level of knowledge, as to the milieu of the origin and circulation of these waters, as to the knowledge of the deposit and the perspective of its utilization. The degree of the level of knowledge appears practically as by releasing the blocked reserves, as by announcing new limits. The solution of the protection of natural healthing springs, utilized in spa, is therefore very important for the development of coal extraction of blocked coal reserves that are not neglectable.

c/ From the standpoint of the formation of the new ecosystem of landscape after the termination of the coal-seam extraction the attention is concentrated upon proper reclaming interventions. From the hydrogeological standpoint the conditions of the formation of hydrogeological cycle, disturbed by the previous mining activity, have not yet been contemplated. The significance of the circulation of underground waters for the metabolism of ecosystems has not yet been quite appraised, especially the balance of pumped natural waters, the weight balance in relation to the streamflows from the drainage area, the contamination of waters. These questions gradually become more actual.

From the short survey we see the width and variety of hydrogeological tasks in close and broader connection with mining activity and they concern the geotechnical security of the opencast mine.

RESULTS DISCUSSION

The advance of working face of the big opencast mine Čsl. armáda /Czechoslovak Army/, the mining area of which is in the central part of the basin near the town of Most, is directed to the random part of the deposit at the foot of Ore Mountains slopes. The morphology of slopes in the region of Jezerka reaches slopes up to 35°. The dip of the slope of crystalline complex in the footwall of Tertiary sediments is more steep and reaches the values 60-75°. The extraction of coal reserves represents the exposure of the steep slope that is high 250+300 m. The solution of the stability of slopes is therefore very important, incl. hydrogeological aspects, especially the dewatering of the crystalline complex.

The hydrogeological massif of Ore Mountains is characterized by the discontinuous fissure water-bearing system. The large anisotropy and heterogenity of the milieu and the morphological exposure of steep slopes impose limitation on the utilization of boring exploration methods that have mostly point character without broader generalization. It is therefore useful to utilize methods, the results of which enable to apply them in regional range /Hanzlík,1982/.

A certain idea of impermeability of hydrogeological massif of crystalline complex has been generally accepted. Nevertheless, qualified hydrological estimates and synoptical balance evaluations of inflows of mine waters demonstrated that it is necessary to correct the view on tightness and impermeability of fissure system of crystalline complex. Attention was paid to the formation of the model of circulation of underground fissure water in the region of the zone in front of the face.

The evaluation of results of multispectral sensing supplied relatively reliable knowledge of the extent of water-bearing debris deposits in area. At the same time some spring lines were distinguished that dewater covering deposits in the slope and at the crest of Ore mountains. Important knowledge consists in the statement of hydrogeological function of debris sediments at the foot of the slope of Ore Mountains that cover outcrop fronts of Tertiary or series or strata. These sediments have been evaluated as flood pools or shallow underground water, i.e. as water-bearing aquifers. From the evaluation of pictures followed that debris deposits appear as "dry". This presumption was verified by results from geophysical measurement /oral statement Hrách,1985/. On the contrary, the hydrogeological function of debris has the character of temporary water accumulations, i.e.as equalizing reservoir for underground water that inflows from the slopes of crystalline complex, before infiltration into sandy equivalents of outcrop fronts of Tertiary series of strata. The results of drilling works in the debris piller of Jezerka and neighbourhood proved also the small extent of water-bearing debris deposits and a certain dependence of levels of underground waters on meteoric waters. No formation of larger accumulation of underground water in debris has been observed.

Hydrological measurement on the system of 15 springs at the slope of upper part of Ore Mountains demonstrated their unlikeness according to the steadiness and unsteadiness of water discharges. The morphological position of watched springs is unique, but the differencies in water discharges indicated further aspects that influence the yield of springs during the year. Mutual diversity appears also at the springs, flowing opening of which occur close together. While one spring has stabilized discharge with current annual oscillation, the second one gets dry during the rain-less period.

Changes of contents of tritium and oxygen 18 have been traced on the basis of a series of springs. The determination of δ oxygen 18 shows that waters infiltrated during winter period prevail. The time of delay of infiltrated water according to activities of tritium amounts to 3 + 5 years, i.e. at springs

that don´t get dry. Sample analyses of fissure water from the depth of crystalline complex, i.e. from inflows in exploration galleries and from the overflow of water in the bore hole from the depth 93 m/l 1.s^{-1}/ presented uncorrected radiogenic age 5000 years, let us say 8-10 000 years. It was very interesting to recognize at the inflow of water from the bore hole in the face of the gallery Jezerka that in water with high radiogenic age, according to the tritium analysis, water from relatively actual circulation of underground water on conductive fissure systems was stated. This information regressively enabled to determine the tectonic structure as conductive, in accordance with previous measurements.

It was possible to determine the model of circulation of fissure underground waters in the region of the foreland of opencast mine on the basis of the total summary of knowledge. We distinguish three types in the hydrogeological massif:

- Shallow circulation of underground water that is concentrated into subsurface zone, consisting of covering sediments and upper mouldered part of underlying rocks.
- Hypogene fissure circulation of underground water that is bond on conductive fissure zones with depth and regional reach. The motion of underground water is very slow. The infiltration territory is supposed to have linear course at larger distance. Underground water of this circulation dewaters from the footwall of the Tertiary basin.
- Fissure-crack circulation of underground water. This third type of underground-water circulation in the fissure system takes place along small conductive fissures not very deep inside of the crystalline complex. The underground water of this circulation is dewatered by spring flowing openings and forms substantial part of contribution of water discharge in dry period of the hydrological year.

In the studied region of the foreland of opencast mine the monitoring of underground-water levels is being realized as a part of studying warning states before the slide of debris sediments. Direct juncture between movements of debris and higher level of underground water in studied bore holes was proved. Pumping of water from the shaft 55 m deep with the supposed dewatering function of debris sediments is also joined into the monitoring. During the year 1986 no perceptible changes of underground-water levels in observation wells dependent on water pumping have been observed. According to the model of underground-water circulation in the hydrogeological massif the presumption of other source of pumped water was pronounced. This presumption was ackonwledged by the proof of water origin from the water stream that disembogues from distant neighbouring glen into the basin /oral communication, Hrubý 1986/.

The dewatering of hydrogeological massif of crystalline complex is difficult. Gradual development of knowledge on the basis of application of further methods, e.g. system structural-tectonic analyses of the territory, thermometry of springs and water streams etc. show the necessity of prospecting conductive ways of circulation that were created in dependence on failure and fissure zones. This task is long-termed and has broader importance.

CONCLUSION

The assurance of geotechnical safety of opencast mine contributed to the determination of the model of underground-water circulation in the hydrogeological massif of crystalline complex of the slope of Ore Mountains in the foreland of opencast mine. Three types of the circulation of fissure underground water were defined, i.e. the shallow, hypogene and fissure-crack one. The unlike hydrogeological function of debris deposits at the foot of slopes that have the washing regiment and not the accumulative one was proved. The gained knowledge is being utilized as the basis for the assurance of geotechnical safety of opencast mine.

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References

Haas,K.,1983, Odvodňování povrchových dolů, základní podmínka spolehlivého provozu, Uhlí, 31: 369-375

Hanzlík,J.,1982, Evaluation of the groundwater circulation in the forefield of an open pit mine according to the analyses of tritium, In: Proc.A of I.Inter.Mine Water Congr.IMWA,Budapest: 66-83

Hanzlík,J.,Moravec,J.,1986: Hydrology of spoil banks and protection of groundwater, In:Memoires of the 19th Congress of IAH, Karlovy Vary 8.-15.9.1986

Strzodka,K.,Fischer,M.,1983, Vliv odvodňovacích prací na zajištění geotechnické bezpečnosti v povrchových dolech NDR, Uhlí,31: 264-267