HYDROGEOLOGIC PROBLEMS IN THE UPPER SILESIAN COAL BASIN

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ABSTRACT

The Upper Silesian Coal Basin covering the area of 7500 km^2 (including 5500 km^2 of the Polish territory) is comprised within the Upper Silesian variscitic intermontane depression filled with molassic sediments of Upper Carboniferous period having over 7000 m in thickness. In the northern-east part of the depression the Carboniferous sediments are occurring in outcrops or are covered with permeable formations of Quaternary and Mesozoic period, whereas in its southern and western zone the Carboniferous sediments are overlaid with impermeable Tertiary strata whereby their water-bearing capacity is lowere. The hydraulic conductivity of Carboniferous aquifers has been found to diminish as the depth progresses, from 4.1×10^{-4} m/s to 5.0×10^{-10} m/s. The piezometric pressures of the Carboniferous aquifers where the mining work is being conducted approach a level of 10 MPa. The Carboniferous aquifers are recharged by the infiltration of atmospheric precipitations through the outcrops or permeable overburden. Under natural conditions they were drained by river valleys and zones of tectonic dislocations. At the present time inversed paths of water circulation are often observed. As a rule the aquifers are being drained mainly by headings. The investigations of the hydrogeochemical environment have shown the occurrence of normal vertical and horizontal hydrochemical zones

within the Basin. The mineralization of waters show a general tendency to rise with the depth progress from 0.4 to 372 g/dm^3. This general regularity is disturbed by the phenomena of hydrochemical inversion. The total volume of water being pumped from hard coal mines every year is about 295 million m^3. The inflow volumes vary with time and are different for every mine. Apart from the "normal" water inflows, a sudden and generally unexpected inrush of surface or under-ground water to the mine can occur whereby the miners'life is imperilled. Mining of hard coal, zinc and lead ore as well as recovery of sand for back - filling purposes impoverish the Triassic and Quaternary formations in water, normally utilized by urban and rural communities. This impact consists either in the drainage of the aquifers by headings or in the pollution of Quaternary aquifers by their shallowing within the post-mining subsidence troughs. Saline Carboniferous waters pumped from the mines and discharged into rivers result in the salinity of river waters.

INTRODUCTION

Outline of geologic structure

The Upper Silesian Coal Basin (Fig. 1) covering the area of 7500 km^2 (of which 5500 km^2 is the Polish territory) is comprised within the Upper Silesian variscitic intermontane depression (Kotas 1982).

The tectonic dislocations occurring there consist mainly of faults and folds. The configuration of block tectonics was mainly affected by the Alpien orogeny.

The Upper Silesian depression is filled with molassic sediments of the Upper Carboniferous system whose thickness exceeds 7000 m in its central part. In the northern-east part of the depression the Carboniferous deposits are overlaid with Mesozoic, and locally with Permian, formations whereas the Tertiary strata

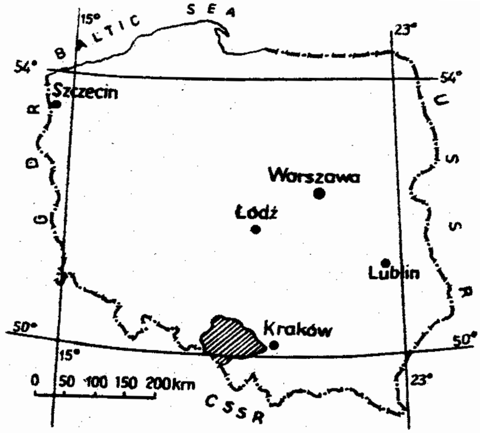

Fig. 1. Location of the Upper Silesian Coal Basin

are prevailing in the southern part (Figs.2 and 3). The depth of the Tertiary formations in the Alpine depression structures in the southern part of the Basin approaches 1000 m.

HYDROGEOLOGIC STRUCTURE OF THE BASIN

The hydrogeologic profile of the Upper Silesian depression includes the Quaternary, Mesozoic and Carboniferous aquifers. The insulating formations are created by silty Tertiary strata and, locally, by Lower Mottled Sandstone strata (Różkowski, Wilk - 1982).

In the northern-east part of the depression the groundwater formation of the Upper Carboniferous period has its outcrops or underlies the permeable and strongly water-bearing Quaternary and Mezosoic strata (Fig. 3). In the southern and western part of the depression the Carboniferous groundwater formation is overlaid with impermeable Tertiary strata which renders the re-

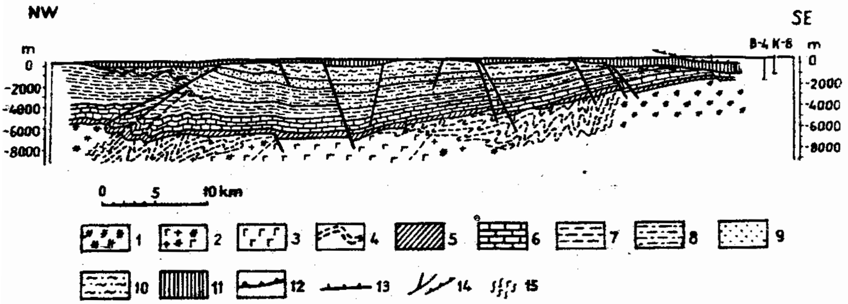

Fig. 2. Cross-section (I - I') of the Upper Silesian Coal Basin (A. Kotas, 1982)
1 - metamorphic rocks of the Cieszyn and Bytom areas, 2 - metamorphic and magnetic rocks of the central area, 3 - basic and ultrabasic rocks of the central area, 4 - Precambrian formation, 5 - Cambrian formation, 6 - Devonian-Lower Carboniferous formations, 7 - kulm formation (Visean-Namurian), 8 - Paralic series (Namurian A), 9 - Upper Silesian Sandstone Series (Namurian B-C), 10 - Siltstone Series (Westphalian A), 12 - Tertiary formation, 13 - overthrust, 14 - fault, 15 - breaching zone

change of Carboniferous deposits by precipitations or surface waters eiters difficult or impossible.

The profile of the Upper Carboniferous groundwater formation may be divided into four basic water-bearing complexes characterized by different hydraulic conductivity and water-bearing capacity (Fig. 3). In general, two water-bearing complexes with good permeability are distinguished, being separated by those of weak hydraulic conductivity. The first water-bearing complex occur within the profile of Cracow Sandstone series and covers C and D Westphal links consisting almost exclusively of thick sandstone shoals. Its thickness varies from dozen to over 1000 m. This complex represents the Carboniferous strata with the highest water-bearing capacity due to a high hydraulic conductivity of the rock and advantageous recharge conditions.

The second water-bearing complex includes the B - C Namurian

Strata and A - Lower Westphal links which together form the Upper Silesian Sandstone Series. Also within this profile sandstone prevails over siltstone and mudstone. The remaining strata of the Upper Carboniferous formations, i.e. the lower part of B - Westphal strata and A - Westphal strata form the mudstone complex whereas the A - Namurian strata are comprised within the Paralic series. Within the profile of the two complexes predomination of impermeable silt-rock over sandstone and mudstone is observed. These rock complexes of the Upper Carboniferous system show the lowest hydraulic conductivity and water-bearing capacity.

The Carboniferous aquifers show a general tendency to reduce their hydraulic conductivity and water-bearing capacity as the depth progresses. Thus the coefficient of permeability, open porosity and specific capacity drop from 4.1×10^{-4} m/s to 5.0×10^{-10} m/s, from 28% to 0.05 % and from 16.6 to 0.00001 m^3/h, respectively per every meter of depression. Within 700-1500 m depth range, i.e. where an intensive mining work is planned in future the aquifers are formed of semi-permeable and practically impermeable rocks (Różkowski, 1981). At this depth the fissure porosity was observed to decline.

The values of open porosity vary from 0.05 to 12 % with an average value of 6.3 % whereas the specific yield factors range from 0.001 to 0.092, being generally lower than 0.01. The coefficients of permeability remain within the range from 5.0×10^{-10} to 7.7×10^{-7} m/s, with an average value of 5.1×10^{-8} m/s. Low values of sandstone permeablity influence their low water-bearing capacity which is indicated by the specific yields ranging from 0.00001 to 0.03 m^3/h per one metre of depression, the average specific yield being 0.0071 m^3/h per one metre of depression. The piezometric pressure of the deep-situated Carboniferous aquifers under discussion vary from 5.9 to 14.7 MPa.

The Carboniferous aquifers are separated from one another by

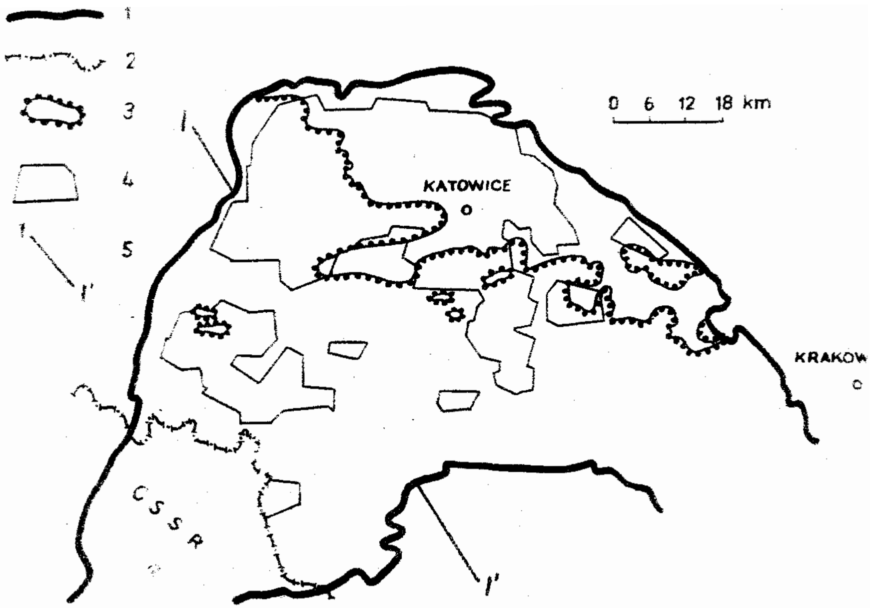

Fig.3. Upper Silesian Coal Basin
1 - extension of the Upper Silesian Coal Basin, 2 - state boundary, 3 - extension of the isolating series of the Tertiary deposits, 4 - mine areas, 5 - cross-section line

the inserts of impermeable siltstone. Hydraulic connections between the aquifers are observed where the mining work, fault dislocations or sedimentation lensing occur.

The aquifers are recharged by the infiltration of atmospheric precipitations through outcrops or permeable overburden. Local recharging of Carboniferous strata by rivers and streams is also observed at mine-drained sites. The water-bearing capacity of the Upper Carboniferous sediments is predominated by their hydraulic conductivity and by the indirect recharge from strongly water-bearing Quaternary formation of presently existing and burried river valleys. When overlain by impermeable Tertiary sediments the aquifers in question show a drastic drop in their water-bearing capacity.

Under natural conditions undisturbed by the man, the Upper Carboniferous aquifers were drained by river valleys and tectonic dislocation zones. At present the inversion in water circulation paths is often observed. The basic reason of the drainage of aquifers are the headings.

The chemistry and general mineralization of waters occurring within the hydrogeologic profile of the Basin are variable (Różkowski, Przewłocki, 1985). Waters occurring in the Quaternary formations are fresh and exhibit differentiated ionic composition. Waters of Tertiary formations are characterized by general mineralization from 0.5 to 150 g/dm^3. These are mostly of Cl-Na type within the zone where chemical sediments rich in SO_4^2 occur. Tertiary brines are weakly radioactive and distinguish themselves by high concentration of specific components J^- and Br^- with methane predominating in their gaseous composition. The Triassic series contain fresh water of HCO_3-Ca-Mg type.

The general mineralization of water within the Upper Carboniferous formations varies from 0.4 to 372 g/m^3. The chemistry of these waters is variated. In the zone of exchange and intermixing of waters the hydrochemical types: HCO_3-SO_4-Ca-Mg, HCO_3-Na, Cl-HCO_3-Na and Cl-Na are predominating. Strongly mineralized waters of isolated structures are brines of Cl-Na and Cl-Na-Ca type. The brines of Carboniferous formations distinguish themselves by an elevated concentration of specific components such as: Ba^{2+}, Sr^{2+}, F^-, HBO_2, J^- and Br^-. The gaseous composition of brines is predominated by methane coming mainly from coal beds degassing. In strongly mineralized waters an elevated level of radioactivity was observed (Różkowski, et al, 1985).

The investigations of hydrogeochemical environment have shown the occurrence of normal vertical and horizontal hydrochemical zonation in the Basin. Said zonation is characterized by changes in mineralization and chemistry of waters along their circulation paths. The mineralization of waters shows a general growth with the increase of depth, irrespective of the age of formations (Fig.4).

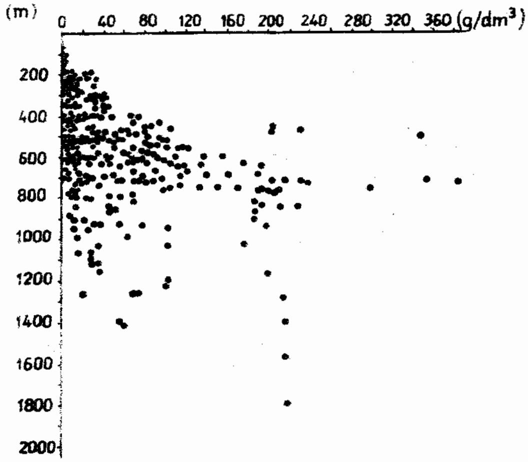

Fig.4. The dependence of groundwater mineralization on depth

This general regularity is disturbed by the occurrence of hydrochemical inversion. Hydrochemical gradients are different in main hydrogeologic structures of the Basin and they vary from 8 to 25 g/dm^3 per every 100 m at the depth interval up to 1000 m.

The regularities as observed indicate that where the Carboniferous formations are outcropping ot overlain by permeable overburden the zone of fresh water within Carboniferous formations can exceed 500 m (Różkowski, 1985). Mining-induced deformations of rock-mass combined with an intense drainage of aquifers by mines facilitate the exchange and intermixing of underground and atmospheric waters at the final stage of infiltration. In the depression areas the isolating Tertiary overburden makes an obstacle for waters exchange whereby the Carboniferous formations occurring there show highly mineralized waters.

VOLUME OF INFLOWS AND WATER HAZARD TO HARD COAL MINES

According to the latest data the general volume of water pumped out from hard coal mines attains about 395 mil.m^3 per year which means that every ton of gotten coal is charged with about 2.1 m^3 of pumped out water and an average inflow to the mine is about 11.9 m^3/min. (Wilk, 1985). These inflows, however, vary with time and show a high degree of diversification in individual mines. Nonetheless they show a steady growth tendency which was illustrated by Wilk (1985) with the following figures. In the year 1947 the coal minning from, and the water inflow to, the mines of the USCB were about 56 mil.tons and 261 mil.m^3 respectively, whereas these two values recorded in 1968 were 120 mil. tons and 384 mil.m^3. It can be seen that the growth of water inflow is smaller than that recorded in coal output. In the recent years the general inflow growth was very low.

The inflows to the individual mines, however, are showing different tendencies, systematically growing in one group of mines, decreasing in another group or oscillating about a constant level in still another group (Wilk, 1967).

The diversification of the volumes of inflows to individual mines is evidenced by the data quoted by Wilk (1963). In the year 1956 there were 73 operative mines of which one pumped about 0.2 m^3/min., and another one - about 27 m^3/min. Similar diversification has been seen this year as far as other indices are concerned. Thus, the inflows per one gotten ton of coal ranged from 0.05 m^3 to 31 m^2 whereas expressed in terms of area they varied from 0.05 to 5.9 m^3/min per 1 km^2 of mined surface. The investigations carried out by Wilk (1965) indicate that such large differences in water inflows to individual mines can be attributed to a high deversification of natural and technological conditions prevailing in the mines under investigation.

The natural conditions cover the geographic environment (atmospheric precipitations, configuration of the ground in the vicinity of the mine, lay-out of surface waters, surface management methods) and geologic structure (lithology of the bed rock, bed-surrounding rock and overburden as well as the tectonics).

The technological conditions cover the size of the mine represented by the extent of headings, rate of growth of post-mined surface, mine depth and its growth rate, spatial arrangement of headings, winning method, types of lining , etc.

Since all the above conditions are acting at the same time with their effect degree being variable with time the inflows to the individual mines are different and they are changing according to different patterns.

The largest inflows are recorded in the case of newly huilt, shallow mines, where caving system is employed and the output shows a steady growth. Such mines are located within sandstone area close to a river and are deprived of silty overburden.

Low inflows are observed in old and very deep mines where the coal occurring within the clump series under a thick silty Miocene overburden is won with the use of roof protection method, and the output is low.

Taking into consideration the geologic structure and hydrogeologic conditions prevailing at the Upper Silesian Coal Basin it becomes easily understandable that the mines with the largest inflows are situated in the northern-east part of the USCB whereas those with low inflows are encountered in its southern and southern-west zone.

Besidesof the "normal" water inflows to the mines one sometimes has to do with sudden, more or less unexpected inflows or e- ven inrushes of underground or surface waters and waters with suspended solid material. The possibility of such an inrush which may endanger mine workings and crew is defined as "water hazard". With this term the concept of the "source of water hazard" is strictly connected.

Two classes of water hazard sources can be distinguished (Kon- stantynowicz and al., 1974): 1 - characterized by unlimited fre- edom of water movement, 2 - characterized by limited freedom of water movement. To the first class there belong: a) surface stre- ams and water reservoirs, b) abandoned water logged mine wor- kings, c) karst caves, channels, etc., d) open fault zones. To the second class there belong: a) water-bearing consolidated host and surrounding rocks, b) water-bearing consolidated overburden strata, c) tight fault zones, d) unproperly sealed off old bore- holes.

As an example, there are given below, according to Konstanty- nowicz (1970), the data illustrating the sources of 225 water i- nrushed to the Upper Silesian coal mines, which took place du- ring the period of 25 years between 1944 and 1969: fault zones - 30 %, water-bearing Carboniferous strata - 27 %, water-bearing overburden - 22 %, old flooded mine workings - 18 %, surface stre- ams and water reservoirs - 2 %, old surface bore-holes - 1 %.

The distribution of the inrush debit was the following: less than 1 m^3/min - 33 %, between 1 and 3 m^3/min - 25 %, between 3 and 5 m^3/min - 12 %, more than 5 m^3/min - 30 %. The most disas- trous results were caused by water inrushes from abandoned water logged mine workings and from surface waters.

The evaluation of mine water hazard is a very complex problem since the hydrogeological and mining situation which decides on the possibility and on the debit of a sudden water inflow varies in space as well as with time.

According to the Polish safety rules all underground mines or their portions are classed among one of the three categories of water hazard. The detailed requirements for a mine or its portion to be classed to a certain category of mine water hazard are cited a.o. by Wilk (1985).

Among the coal mines or their portions one can find in the USCB all categories of mine water hazard. In mines and their zones classed to different water hazard categories the mining operations have to be carried out according to specific and detailed principles and rules.

Concluding it should be noted that thanks to strict observation of safety rules and introducing of the preventive and precaution measures the number of water inrushes to the coal mines in the last years distinctly decreased, and no catastrophic water inrush has happened.

IMPACT OF MINING ON WATER RESOURCES

The impact of mining on the water environment has been discussed in a separate paper included in this volume (Rogoż, Staszewski and Wilk, 1987). Which is why this problem will be presented here in a very general manner.

The concentration of the mining industry within the USCB territory adversely affects the water resources of the region. These disadvantageous effects are manifested by decay of water in both community and individual well-intakes as well as by the pollution of underground and surface waters. Thus the mining work will markedly increase the deficit of water that has been occurring in the USCB for years which in confrontation with the large water demand due to highly concentrated population and industry makes the problem very serious (Posyłek, Rogoż and Zimny, 1981).

The impact of mining work on the water resources is of very complex nature and the scale diversification of occurring phenomena (these latter being to a large extent irreversible) is very large. The mining work results in the changes in hydrogeological conditions prevailing over the given territory. The kind, size and extent of these changes is conditional mainly upon the geologic structure of the territory as well as upon the type and development of the mining work. The main phenomena causing the changes in hydrogeologic conditions includes the drainage alteration of size and direction of hydraulic gradients in water-bearing formations as well as changes in the hydrogeological characteristics of the rock mass. These phenomena result in the reduction of underground water resources by lowering the water volume in the aquifers being mined and by water pollution.

The total mining activities within the USCB territory may be classified by mining method and product as follows:

- exploitation of sand pits,
- underground mining of zinc and lead ores,
- underground mining of hard coal.

In the sand pits mainly the Quaternary sand deposits are extracted causing the drainage of the subsurface Quaternary aquifers which constitute the main source of forming wells supply. This phenomenon reaches a large scale particularly in the area of backfilling sand pits characterized by a large excavation area.

Underground mining of zinc and lead ore is run in the northern and northern-east zone of the USCB, viz. within the Bytom trough as well as Chrzanów and Olkusz regions. The headings in the floor portion of ore-bearing dolomite are draining highly aquaeous strata of fractured and karstified limestone and dolomite constituting the basic aquifer of the Triassic formations. In consequence of zinc and lead ore mining combined with coal mining effects a permanent drop of water table occurred in Triassic deposits in the Bytom trough. The example of this situation can be seen at the "Rozalia" pit intake within the Siemianowice region where the water table dropped by 60 m during 75 years with the intake output being diminished by several times. The occurrence of vast and deep depression cones in the aquifer in question can also be observed in the Olkusz and Chrzanów regions.

Winning of hard coal predominates on the USCB territory because of both extent and amount of this mineral. The direct impact of coal mining on the water resources being manifested in the form drainage of Carboniferous overburden aquifers occurs mainly where the Carboniferous sediments outcrop at the surface or are overlain by the Quaternary or Triassic strata, with an insufficient isolation being provided between the Carboniferous strata and younger formations. Under these circumstances the mining work being run within the Carboniferous strata results in the drainage of not only the Carboniferous rock mass but also the overburden strata whereby the water table of the Quaternary and Triassic aquifers gets lowered over the large areas.

In the northern part of the USCB and particularly within the Bytom trough the draining impact of the coal mining on the Triassic aquifer (mottled sandstone level) is manifested by post-mining gobs at the coal beds situated close to the outcrops. The caving methods being employed under the Triassic strata close to the outcrops result in frequent breaking of the ledge constituting the Triassic floor, accompanied by outflows of water which are sometimes very intensive. Such phenomena did occur in the cavings of the mines situated mainly in the eastern part of Bytom trough (Wałęcki, 1985).

In the USCB zones where the Triassic and Quaternary aquifers are not subjected to a direct drainage due to the occurrence of an impermeable stratum in the Carboniferous overburden, the cases of degradation of water resources at the Quaternary aquifers can occur within subsidence troughs. The mechanism of this depletion consists either in the increase of hydraulic gradients at the subsidence trough edges or in the shallowing and pollution of the aquifers within the troughs. The uplifting of the free water table in relation to the site surface intensifies the pollution of water with organic matters. Changes in the direction of underground run-off due to site deformations can also change the chemistry of water coming from the given intake if the zone of the latter's supply has been displaced. In addition to the above the post-mining deformations of the rock mass can break the isolating strata or make them permeable thus causing the waters from different aquifers to mix with one another. Consequently, potable waters can get polluted by mineralized subartesian waters occurring at greater depths.

SALINITY OF RIVERS WITH WATERS FROM HARD COAL MINES

The protection of rivers against the salinity caused by mine waters constitutes a very serious problem in the Upper Silesian Coal Basin. An intensive coal output on this territory involves a massive amount of saline mines waters being pumped out onto the surface (Wilk, 1985, Rogoż, Posyłek and Szczypa, 1986). Said waters are evacuated into the tributaries of Odra and Vistula Rivers whereby the rivers get saline. This phenomenon is followed by the degradation of the natural water habitat and determination of river biota. Rivers can not provide water for the needs of urban or agricultural communities, industrial plants utilizing the river water have to bear massive costs of their demineralization, and hardly controllable losses are incurred due to increasing agressiveness of water against to steel and concrete structures. All these problems do not close the list of disadvantages connected with water salinity.

The amount of salts discharged together with mine waters into Vistula and Odra Rivers every day was about 6.800 tons in 1980 and is estimated to rise to 19.300 tons/day in the year 2000. This rise will be attributable to the increase in water-dissolved salts since the amount of pumped water is expected to increase very moderately, from 960 to 1015 thousand cubic meters per day.

A program targeted toward the protection of rivers against salinity has been described in the separate paper included in this volume (Rogoż, Staszewski and Wilk, 1987).

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