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HYDROGEOLOGICAL PROBLEMS OF CARBONIFEROUS COAL BASINS IN POLAND

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In Poland, Carboniferous coal deposits are exploited by mining in three coal basins: Upper and Lower Silesian and Lublin (Fig. 1). The first two basins are characterized by a large-scale exploitation whereas the third is still at the stage of mining-deposit and hydrogeological exploration. The Upper Silesian Coal Basin appears most important from the point of view of the scale of coal mining and quantities of waters pumped out of the mines.

Deformations and drainage of rock massif due to mining disturbed natural hydrogeological regime in the above mentioned basins. To a varying degree they also resulted in deggradation of natural water environment.

THE UPPER SILESIAN COAL BASIN

The Upper Silesian Coal Basin, 7500 sq. km in area (including 5500 sq. km situated in Poland), is situated in the Variscan Upper Silesian foredeep (fig. 2).

Coal-bearing Upper Carboniferous rocks occur beneath the Mesozoic in NE part of the basin, and clay Tertiary series in the southern and western parts (Fig. 2). Tertiary strata attain up to 1000 m in thickness in Alpine depressional structures. In that basin coal deposits have began to be intensively exploited as early as the XVIII century.

Three water-bearing formations have been identified in hydrogeological section of the Upper Silesian Basin: Quaternary, Quaternary-Mesozoic, and Carboniferous. Clay Tertiary sediments form here a separating, isolating formation. In NE part of the basin, rocks of the Carboniferous water-bearing formation crop out or are overlain by permeable Mesozoic and Quaternary rocks only (Fig. 2). In southern and western parts, the formation is overlain by impervious Tertiary strata, which results in decrease of its hydraulic conductivity and storage capacity.

The Carboniferous water-bearing formation is represented by a claystone-mudstone-sandstone complex. There is found a general trend to decrease of permeability and storage capacity of Carboniferous water-bearing horizons along with depth. Permeability coefficients decrease along with depth from 4.1×10^{-4} to 5.0×10^{-10} m/s and specific capacity from 16.6 to 0.00001 m^3/h (A. Różkowski, Z. Wilk, 1983). The horizons are built of semipermeable to practically impervious rocks in depth interval 700 – 1500 m, i.e. at depths at which especially intense exploitation is nowadays planned (A. Różkowski, 1981). Fissure porosity disappears at these depths, values of open porosity are varying from 0.05 to 12.0%, equalling 6.3% at the average, specific yield – from 0.001 to 0.092 and coefficients of permeability – from 5.0×10^{-10} to 7.7×10^{-7} m/s (5.1×10^{-8} m/s at the average). Low values of hydrogeological properties of sandstones is shown by specific capacity varying from 0.00001 to 0.03 $m^3/h/1$ m and equal 0.0071 $m^3/h/m$ at the average.

Piezometric head of deep-seated Carboniferous aquifers is ranging from 5.9 to 14.7 MPa.

Intergranular and fissured Carboniferous aquifers are isolated from one other by intercalations of impervious claystones, except for areas of mining works, fault zones, and zones of sedimentary wedging outs, where hydraulic connections are traced.

Aquifers are recharged in zones of outcrops or through permeable cover rocks. The recharge by water-bearing Quaternary sands of recent and burried river valleys has the major importance. Productivity of these aquifers suddenly decreases when they are covered by impervious Tertiary strata.

Aquifers of the productive Carboniferous were drain-

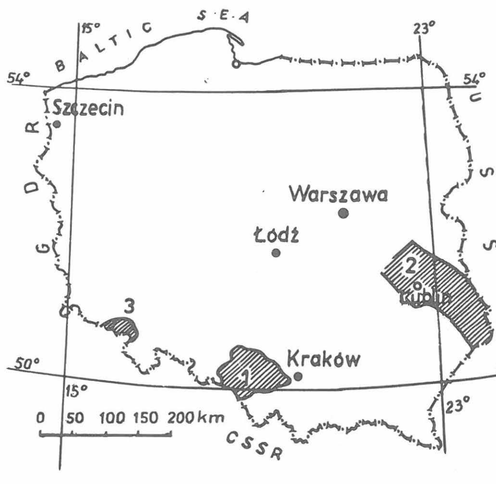

Fig. 1. Location of coal basins

1 – Upper Silesian Coal Basin, 2 – Lublin Coal Basin, 3 – Lower Silesian Coal Basin

Ryc. 1. Położenie zagłębi węglowych

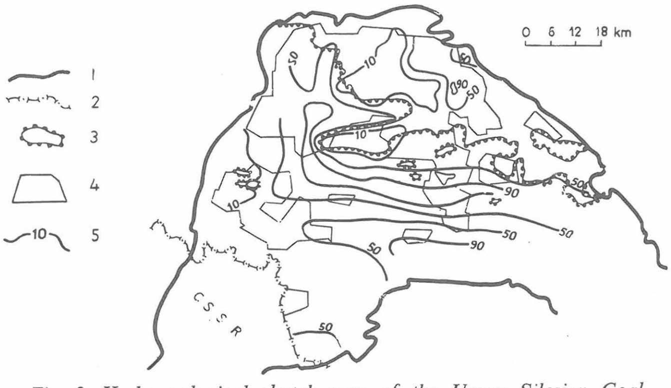

Fig. 2. Hydrogeological sketch map of the Upper Silesian Coal Basin

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 – isolines of the groundwater mineralization at the depth 500 m

Ryc. 2. Schemat hydrogeologiczny Górnośląskiego Zagłębia Węglowego

1 – zasięg Górnośląskiego Zagłębia Węglowego, 2 – granica państwa, 3 – zasięg serii izolującej osady trzeciorzędowe, 4 – obszary kopalniane, 5 – izolinie mineralizacji wód gruntowych na głębokości 500 m

ed by river valleys and zones of tectonic dislocations under natural conditions, undisturbed by the human activity. At present we often note inversion of water circulation routes and the base of drainage of the water-bearing horizons appears mainly related to mining works. The drainage of these horizons remains obscure in southern part of the basin, beyond the area of mining works. It mainly takes place along zones of regional tectonic dislocations which is shown by e.g. hydrochemical anomalies.

CHEMISTRY AND ORIGIN OF GROUNDWATERS

Studies on hydrogeochemical environment showed a normal vertical and horizontal hydrogeochemical zonality in the extent of the basin (19). This zonality is characterized by changes in mineralization (from 0.2 to 372 g/dm^3) and chemical composition of waters along circulation routes. The waters are varying in chemical composition. The hydrochemical types $HCO_3-SO_4-Ca-Mg$, HCO_3-Na. $Cl-HCO_3-Na$, and $Cl-Na$ predominate in the zone of water exchange and mixing. Strongly mineralized waters of isolated structures represent brines of the type $Cl-Na$ and especially $Cl-Na-Ca$. There is noted a general trend to increase of mineralization along with depth of occurrence of waters, independently of age of the strata. This general regularity is disturbed by phenomena of hydrochemical inversion. Hydrochemical gradients are varying from one geological structure of the basin to another and range from 8 to 25 g/dm^3/100 m in the depth interval down to 1000 m.

The present hydrochemical zonality is determined by geological structure and the state of mining management. This is best shown by the map of mineralization of waters at the depth of 500 m (Fig. 2), reflecting high spatial diversity in salinity and chemical composition. Water mineralization is varying from 1.8 to 117.7 g/dm^3. Waters characterized by low mineralization are multi-ion, and those with high mineralization – brines of the types $Cl-Na$ and $Cl-Na-Ca$. There is found a close dependence of mineralization of waters in the Carboniferous on character of overlaying rocks as well as the degree in which the rock massif is affected by mining works. The maximum salinity of waters, over 70 g/dm^3 was found in depressional structures under the cover of sealing Tertiary rocks. Horst structures not covered by the Tertiary and affected by mining works for over a hundred years are characterized by a marked freshening of waters in that depth interval. This phenomenon is further supported by graphs of changes in mineralization of mining waters along with depth (Fig. 3).

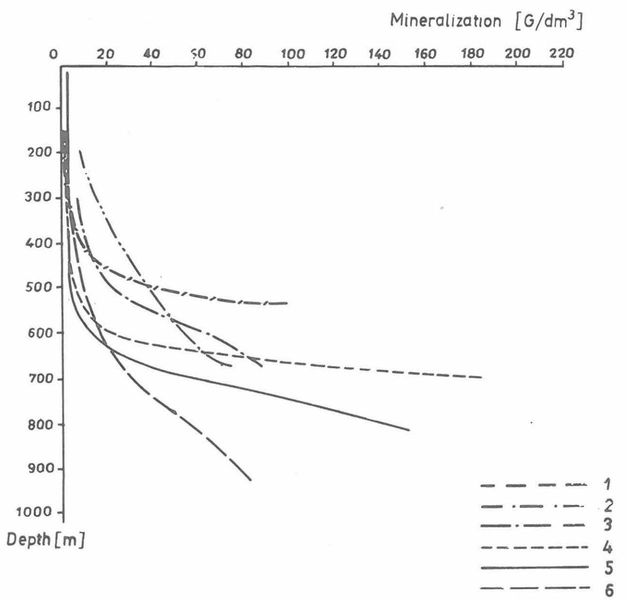

Fig. 3. Dependence of the groundwater mineralization on the depth

1 – 6 – groundwater mineralization of mine waters

Ryc. 3. Zależność mineralizacji wód gruntowych od głębokości

1 – 6 – mineralizacja wód kopalnianych

Precipitation waters from the last infiltrational stage (i.e. from the Sarmatian to Holocene, inclusively), shape the present gravitational system of circulation. They supply directly or indirectly Carboniferous water-bearing horizons in NE part of the basin and, locally, in the covered by Tertiary deposits part of the basin by hydrogeological windows. They percolate in accordance with dip of strata or along fault zones, expelling relict waters or mixing with them. Drainage due to mining leads to the advancement and acceleration of this process of water renewal.

Isotopic studies (10, 16) showed the presence of waters of the last infiltrational stage in NE part of the basin down to 600 m at the most. These are Holocene and Pleistocene as well as pre-Pleistocene waters. Contents of stable isotopes $\delta^{18}O$ are varying from -12.1 to $-8.8°/_{oo}$, and those of δD – from -77.1 to $-62.0°/_{oo}$, which indicates a fairly high changes in climatic conditions in these times.

Positive values of tritium (from 110 ± 10 to 8 ± 3 TU) are generally noted down to the depths of 150 – 250 m (or locally 300 m). Point datings of mining waters from the depth of 400 m showed contents of ^{14}C from $11.1 \pm 1.3°/_{oo}$ to $30.5 \pm 0.6°/_{oo}$ and the lack of tritium (14). Waters formed in earlier hydrogeological cycles occur beneath the extent of those from the last cycle. They represent highly mineralized brines. Their $\delta^{18}O$ values range from -7.8 to $-0.89°/_{oo}$, and δD – from -62.0 to $-15.0°/_{oo}$, which indicates different origin. Synsedimentary brines with $\delta^{18}O$ and δD values close to SMOW were found in the zone of hydrodynamic stagnation in the extent of Tertiary depressions.

MINE WATERS

In the Upper Silesian Coal Basin, coals are exploited by underground mining, mainly by the longwall system, down to the average depth of 650 m (1050 m at the most). The steadily growing depth of exploitation and opening of new mining levels increase the extent of drainage by mines and amounts of pumped out water. Inflows to mines range from about 1.0 to 42.7 m^3/min. and are directly related to the recharge conditions of the productive Carboniferous aquifers and their permeability. Mines characterized by high inflow of water (of the order of 25 – 42 m^3/min) are concentrated in the areas where the Carboniferous is overlain by Quaternary strata of large thickness and high water content. Water-production index range from 0.17 to 4.4 (afflux 1 t. output). These mines are shallow and they pump out waters of mainly dynamic resources. The studies carried out by Z. Wilk (24) showed a correlation between inflow and area and depth of mining works. The lowest inflows (of the order of a few m^3 per min) are noted in regions where Carboniferous rocks are covered by Tertiary ones, insulating them from the influence of infiltrational waters, and where the Carboniferous crop out at the surface, not being covered by water-bearing Quaternary and Triassic strata. Water-production indices for these mines range from 0.26 to 0.44 m^3/T. The mean index of unit afflux for the Upper Silesian Basin equals 1.1 m³/min/km², and mean water-production index – 3.3 m³ per t of exploited coal (5). It should be noted that the inflows to deep-seated (800 – 1000 m) levels in both the mines being deepended and those under construction are small, independently of geological structures of the area, usually ranging up to 3.0 m³/min.

The total quantity of waters pumped out of rocks coal mines equals 724 m³/min (in 1984). The waters are highly varying in chemistry. Mineralization of natural mine waters ranges from 0.2 to 372 g/dm³ but that of total mine waters is up to 110 g/dm³ (16). Waters with total mineralization up to 1.5 g/dm³ are multi-ion and are pumped out in quantities of the order of 275 m³/min. Those with mineralization over 1.5 g/dm³ and representing the mixed type from the point of view of chemistry, are pumped out of mines in quantities of the order of 449 m³/min. Waters with mineralization up to a few g per dm³ belong to the hydrochemical types $HCO_3 - Cl - Na$, $HCO_3 - SO_4 - Na$, and $Cl - SO_4 - Na$. Waters with increased mineralization are usually of type Cl – Na, and strongly mineralized brines represent the hydrochemical type Cl – Na – Ca. For the characteristics of chemistry of mine waters see e.g. E. Posyłek, M. Rogoż and W. Zimny (9).

THE INFLUENCE OF MINING WORKS ON WATER ENVIRONMENT

Mine waters are pumped out of coal mines in quantities of about 1,000,000 m³/d, which results in origin of giant (over 2000 km²) areas characterized by lowered piezometric pressure of waters in the productive Carboniferous in the basin. The drainage also affect (but on a smaller scale) Tertiary and Quaternary strata. The drainage due to mining resulted in lowering of the natural base of drainage down to depth of 300 – 800 m (or locally even 1050 m). A high index of underground outflow, generally ranging from 4.5 to 11 l/s/km² in mining areas in NE part of the basin may be treated as the measure of intensity of drainage of the rock massif.

The supply of mineralized mine waters leads to increase in salinity of almost all the creeks in the basin. The mine waters are discharged to the Vistula and Odra rivers and their tributaries.

The mean mineralization of mine waters discharged to the creeks is about 10.9 g/dm³, concentration of ions $Cl + SO_4$ – about 5.63 g/dm³, and mean mineralization of mine waters discharged to individual creeks (tributaries of the Vistula and Odra rivers) ranges from 0.8 to 31.5 g/dm³. Mine waters discharged to rivers carry salts in amounts about 11 800 T/d, including about 5980 T/d of sulfates and chlorines. So great amounts of salts clearly result in degradation of river water quality.

It should be noted here that the mean total mineralization of waters pumped out of coal mines clearly increases in connection with opening of new exploitation levels in active mines and construction of new deep mines in southern parts of the basin. It rised over 100% in relation to the year 1970 when it was equal 4.9 g/dm³ (7), and a further increase is expected in the future (11). A number of creeks became pratically turned into collectors of mine waters. In the area of the Upper Silesian Coal Basin waters in majority of rivers fall beyond the water purity classes or are assignable to the IIIrd., i.e. the lowest class.

The results of studies on the Vistula River, the major collector of mine waters from the basin, well illustrate the dynamics of the process of increase in salinity of river waters (20). In the light of studies from the year 1986, mean annual values of salinity of the Vistula River waters in the area of the basin increase from 0.2 in the upper course to 2.8 g/dm³ in the lower, under conditions of mean flow. The total load of salts increases from 90 T/d to about 7560 T/d, and that of $Cl + SO_4$ – from 40 T/d to 3890 T/d, respectively. It should be noted that about 80% of the total load of salt in the Vistula River waters comes from those discharged from coal mines.

A special program aimed to minimize effects of discharge of mineralized mine waters to rivers has been elaborated by the Ministry of Mining and Energy. This is planned to be achieved by the use of method of evaporation in the case of brines and construction of retentional reservoirs and collectors to discharge salt waters in the lower course of rivers (11).

Pollution of underground and surface waters in the Upper Silesian Coal Basin also increases due to leaching of salts from dumped barren rocks. The amounts of dumped barren Carboniferous rocks recently rise up to 30 – 40% of the output, which means that the dumps increase at the rate of about 70 – 80 million t per year. Moreover salinity of the waste steadily increases along with depth of exploitation, because of the presence of highly mineralized pore

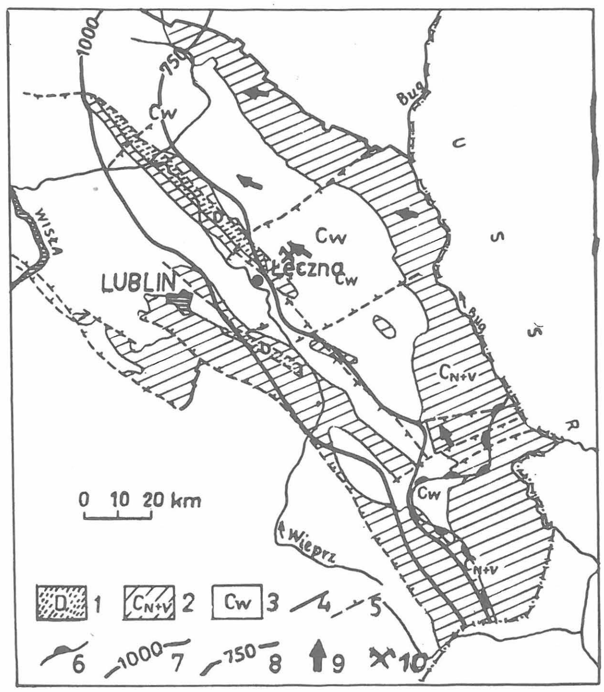

Fig. 4. Geological sketch map of the Lublin Coal Basin without rocks younger than Carboniferous (geological setting after J. Porzycki)

1 – area of distribution of Devonian rocks, 2 – area of distribution of Visean and Namurian rocks, 3 – area of distribution of Westphalian rocks, 4 – extent of Carboniferous – erosional and tectonic boundaries (boundary of Lublin Coal Basin), 5 – main faults, 6 – present, erosional boundary of Jurassic rocks, 7 – 1000 m isopach of cover rocks, 8 – 750 m isopach of cover rocks, 9 – direction of groundwater flow, 10 – mine area

Ryc. 4. Szkic geologiczny Lubelskiego Zagłębia Węglowego bez skał młodszych od karbonu (geologia według J. Porzyckiego)

1 – obszar występowania skał dewonu, 2 – obszar występowania skał wizenu i namuru, 3 – obszar występowania skał westfalu, 4 – zasięg karbonu – granice erozyjna i tektoniczna (granica Lubelskiego Zagłębia Węglowego), 5 – główne uskoki, 6 – obecna, erozyjna granica skał jury, 7 – izopachyta 1000 m skał przykrywających, 8 – izopachyta 750 m skał przykrywających, 9 – kierunek przepływu wód gruntowych, 10 – obszar kopalni

waters in rocks. Contents of chlorines in these rocks are varying from 0.15 to 1% (3, 26). The mechanism of leaching of mineral components from dumped waste of Carboniferous rocks is discussed in the paper by I. Twardowska (26).

Pollution due to deformations of mining areas also markedly contributed to deterioration in quality of groundwaters. This phenomenon takes place in result of damage of creeks and industrial water reservoirs, lack of mechanism of self-purification in the case of waters occurring close to terrain surface, and increase in physical pollution of waters due to mechanical suffosion (25).

THE LUBLIN COAL BASIN

The Lublin Coal Basin, about 14 000 km^2 in area (J. Porzycki 1978), is a region of occurrence of coal deposits in eastern Poland (Fig. 1). Erosional surface of the Carboniferous is here overlain by the Jurassic, covered, in turn, by Cretaceous and (locally) Tertiary, and Quaternary. Summative thickness of the cover increases from about 340 m in eastern part of the basin to over 1000 m in the western (Fig. 4).

Hydrogeological conditions in the Lublin Coal Basin were the subject of studies from 1974. The studies were mainly focussed on the eastern part of the basin, most adventageous from the point of view of coal resources, thickness of the overburden, and depth of occurrence (8). The konwledge of hydrogeology of central part of the basin became markedly increase from 1975, in connection with construction of the mine K-1. The western part of the basin, situated west of the Kock structure, still remains poorly known from the point of view of hydrogeology.

A summary of results of the above mentioned hydrogeological studies is given in the monograph on hydrogeology of that basin (21).

HYDROGEOLOGICAL CONDITIONS

Geological structure of the Lublin Coal Basin appears diversified, which makes possible differentiation of a number of water-bearing stages and those separating them (22). In the cover of the productive Carboniferous, there occur two water-bearing stages, Quaternary-Tertiary-Upper Cretaceous and Lower Cretaceous-Jurassic, separated by a stage built of lower marly members of the Upper Cretaceous. Figure 5 shows stratification of permeability of rocks of the cover and deposit series.

Two major water-bearing horizons may be differentiated in the hydrogeological section of the upper water-bearing stage: Quaternary and Upper Cretaceous. The horizons usually remain in hydraulic contact. Active fissurity is traced in Upper Cretaceous rocks down to the depth of about 170 m (Fig. 5). Permeability of rocks is found to be increased in fault zones (4). Filtration coefficients of that horizon generally range from 5×10^{-4} to 1.1×10^{-5} m/s, and unit outputs – from 4.0 to 12.5 m^3/h/m.

Lower members of the Upper Cretaceous are practically impervious and form a separating formation because of advanced diagenesis and presence of marly intercalations (Fig. 5). Thickness of that formation increases from 140 m to about 820 m in the west. Permeability coefficients of these strata fall within the range $10^{-8} - 10^{-9}$ m/s to increase in fault zones. Mining works confirmed the isolating character of that formation.

The Jurassic-Lower Cretaceous water-bearing formation changes in thickness from 30 m in the Bug River area to 120 m in central part of the basin and about 350 in the western part. It comprises Albian water-bearing horizon and Jurassic water-bearing complex. They form a huge water reservoir under pressures of 3.0 – 9.0 MPa, creating the major hazard for mining works. The Lower Cretaceous (Albian) aquifer is related to sands, sandstones and conglomerates, varying in thickness from 0.5 to 37.0 m (from 0.5 to 7.0 m in the Central Coal Region). Permeability coefficients of that horizon fall in the range $2.28 \times 10^{-7} - 5.57 \times \times 10^{-5}$ m/s, and specific capacity in the range 0.0009 – 0.854 m^3/h/1 m. Sandy Albian sediments are characterized by quicksand properties, creating the major water hazard in the course of construction of shafts.

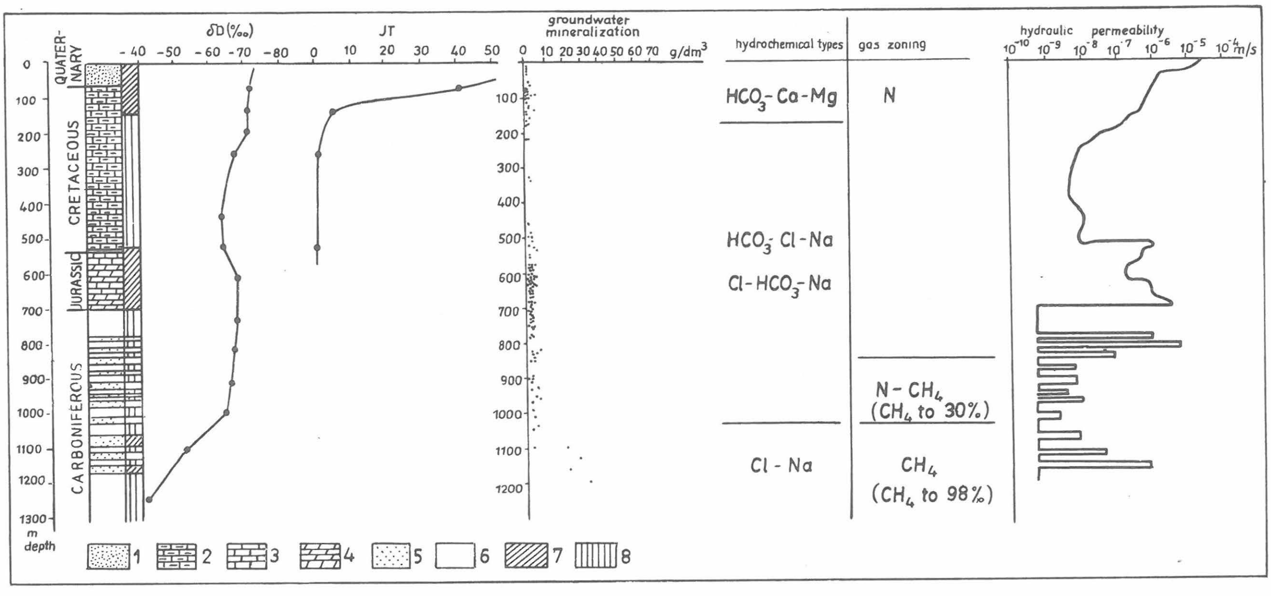

Fig. 5. Properties of the hydrogeochemical environment of the Lublin Coal Basin

1 – sand, 2 – marl, 3 – limestone, 4 – dolomite, 5 – sandstone, 6 – mudstone and siltstone, 7 – permeable complex, 8 – slightly or non – permeable complex

Ryc. 5. Cechy środowiska hydrogeochemicznego Lubelskiego Zagłębia Węglowego

1 – piasek, 2 – margiel, 3 – wapień, 4 – dolomit, 5 – piaskowiec, 6 – mułowiec, 7 – kompleks przepuszczalny, 8 – kompleks słabo- lub nieprzepuszczalny

The Jurassic water-bearing stage is here built of carbonate and, on a smaller scale, sandstone-mudstone rocks. Rocks of the Middle Jurassic (?), represented by sandstones, mudstones and limestones, are about 50 m thick and infill erosional forms in the top of the Carboniferous. They create a serious water hazard for the mining works because of their physico-mechanical properties. The section of the Jurassic displays a marked stratification of permeability and aquifer productivity in the vertical. Permeability coefficients change from 6.49×10^{-8} m/s to 5.90×10^{-5} m/s, and specific capacity – from 0.036 to 8.43 $m^3/h/m$ in eastern part of the basin.

The Upper Carboniferous water-bearing formation is formed of Westphalian deposits series and Namurian C rocks. It comprises alternating water-bearing horizons and isolating claystones. Reservoir rocks here include sandstones, mudstones, and coal seams, with waters under the pressure 5.5–9.8 MPa in the Central Coal Region. Permeability coefficients of sandstones of the Lublin Beds range from 9.04×10^{-9} to 6.27×10^{-6} m/s (but lower values usually predominate – see Fig. 5), and specific capacity – from 0.0002 to 0.288 $m^3/h/m$. Claystone rocks of the Namurian A and B here form a separating and underlaying stage.

The Lublin–Volhynia Basin, within which the Lublin Coal Basin is situated, is of the flow-through type. Migration of infiltrational waters to large depths is facilitated by both block tectonics and active neotectonics. A general outflow of waters to NE depends on origin of potential high pressures in morphologically elevated Podole and Roztocze area. It is also facilitated by geological structure of the basin, direction of fault zones, and open flow-through character of the basin. The discharge of the groundwater systems takes place in the Mazowsze basin probably.

An estimation of diversity in velocities of flow and possibilities of renewal of waters in individual water-bearing stages made it possible to trace hydrodynamic zonality in the vertical section of the basin. Disturbances in that zonality are reflected by local anomalies of piezometric pressures in fault zones and within the extent of drainage related to mining works.

Fault zones are the priviledged percolation routes for waters coming from zone of active exchange through separating – insulating formations. Soviet hydrogeologists (23, 1 et al.) noted water-bearing fault zones extending into the Paleozoic, in the course of analysis interrelationship of water table in the Carboniferous and Cretaceous in the Lvov-Volhynia Basin. They also evidenced percolation of waters through the separating formation. The rate of percolation ranges from 1×10^{-3} to 1×10^{-5} m/d, depending of thickness of Upper Cretaceous and intensity of faulting of the strata. The question of hydraulic permeability of fault zones in the Upper Cretaceous separating stage in the Lublin Coal Basin was shown by some authors, including A. Błaszczyk and K. Zarębski (2) in analysis of results of geothermal studies, and more recently in regional scale by A. Zwierzchowski (28). It is also widely discussed in the monograph of the basin (21). The time of percolation of waters through the separating stage in the Central Coal Region is estimated at 10^3 to 10^5 years. This is further supported by results of studies on isotopic composition of waters (15, 27). It should be noted that the rates may be greater under conditions of a depression due to drainage by mines. That question is important for estimations of water inflow to mines.

In the Lublin Coal Basin there is also found hydrochemical zonality in the vertical and horizontal (17). The zonality appears locally disturbed in fault zones, where waters usually display effects of freshening (28). Waters occurring in the upper water-bearing formation are fresh, and those of the Lower Cretaceous-Jurassic formation are characterized by mineralization ranging from 0.4 to 2.0 g/dm^3 in eastern part of the basin and up to 31 g/dm^3 in the western. The mineralizations ranges from 0.6 to 10.0 g/dm^3 in waters occurring in the deposit series of the Lublin Beds in the Central Coal Region. The waters are of the types $HCO_3-Cl-Na$, $Cl-HCO_3$ and $Cl-Na$.

The last stage of infiltration, continuing from the Miocene to the present, exerted especially strong influence on the shape of the present hydrogeochemical zonality and hydrodynamic field in the Lublin Coal Basin. The influence is recorded down to the depth of about 1000 m in eastern part of the basin, being reflected by distribution of potential head and chemistry and isotopic composition of waters (Fig. 5) (15, 22). Waters occurring at larger depths appear isolated from influence of that stage and the degree of insulation increases along with depth. The latter waters may be interpreted as heterochroneous, buried ones.

Isotopic studies carried out by A. Zuber and J. Grabczak (27) showed a regional variability in zonality of isotopic waters of the Lower–Cretaceous–Jurassic and Carboniferous (Lublin Beds) water-bearing formations. Taking into account the results of identifications of tritium, ^{14}C, and stable isotopes, the age of the above described waters has to be interpreted as varying from one structure to another, from the Early Pleistocene to Tertiary, inclusively.

INFLOW OF WATERS TO MINES AND THEIR MINERALIZATION

The hydrogeological model of the Lublin Coal Basin and the growing experience from mining works show that mining works will result in drainage of both water-bearing horizons of the Carboniferous deposits series and Albian and Jurassic water-bearing formations. It cannot be excluded that the decrease of piezometric pressure of waters in the drained rock massif will intensity percolation of waters from the Upper Cretaceous horizons through the separating stage, as well as ascensional inflow from the Kumów Beds, directly underlaing the Lublin Beds.

Inflows of waters to mining works are related to mining of static resources: gravitational waters and waters released from overall aquifer compressibility. Inflows from dynamic resources should take place in the future, under conditions of development of depressional zone.

Inflows of waters to mining works in the Central Coal Region were estimated by various teams (13), taking into account both drainage from the overburden and the Carboniferous aquifers. According to the prognoses of the Main Mining Institute, the inflows should range from 18 to 32 m^3/min (21). The total mineralization of total mine waters for individual deposit units, estimated taking into account the planned drainage of waters from the overburden and deposit series, will range from 1.0 to 2.5 g/dm^3 (18). The load of salts in these waters should range from 21 to 52 T/d.

The prognoses of water hazards and inundation of mining works are verified by observations made in the Bogdanka (K-1) pilot-exploitational mine where the first test wall (level 960 m) began to operate in 1982. A total inflow to that mine was found to be equal 5.4 m^3/min, according to data for 1985. The inflow was due to drainage of the water-bearing overburden strata by mine shafts only (3.8 m^3/min) and drainage of Carboniferous water-bearing horizons by mining works (1.6 m^3/min).

Total mine waters pumped out of the mine are characterized by total mineralization of 2.5 g/dm^3. There is noted an increase in mineralization of mine waters along with depth of sampling, from 1.6 g/dm^3 at depth of 754 m to 10 g/dm^3 at depth of 960 m.

The Lower Cretaceous-Jurassic water-bearing formation has been intensely drained by shaft works during the last few years. This resulted in origin of a vast area of lowered piezometer pressures. The value of piezometer pressures decreases for about 3 MPa in the center of that depression and the extent of depressional cone began to extend beyond of the Central Coal Region.

LOWER SILESIAN COAL BASIN

The Lower Silesian Coal Basin is situated in a deep, strongly faulted syncline, in marginal part of the Intra-Sudetic Basin (SW Poland – see Fig. 1) but only a part of the basin (about 500 km^2/in area) is situated in Poland. Only two areas, Wałbrzych and Nowa Ruda, are practically important from the point of view of economy. The areas are situated within the zone of outcrops of the Carboniferous. Mining began here in the XIX century but the perspectives for further developments are rather low.

The productive Carboniferous water-bearing formation is formed in that region by a complex of claystone-sandstone-mudstone rocks, and individual water-bearing horizons are separated by horizons of non-permeable rocks. The water-bearing formation of the overburden, also separated by horizons of non-permeable rocks, comprises the Permian, Cretaceous and Quaternary. Its thickness is reduced in the Wałbrzych region to increase in the Nowa Ruda area to 300 m. The present hydrogeological regime of the basin is determined by geological structure and drainage connected with mining.

MINE WATERS

In the Lower Silesian Basin, coal mines pump out about 67 000 m^3 per day. Inflows to individual mines are varying from 5.7 to 16.0 m^3/min. According to S. Opyrchał and others (6), the unit afflux index ranges from 0.8 to 1.2 m^3/min/km^2. The water inflow to mine proceeds under conditions of stabilized depressional cone and are determined by the magnitude of atmospheric precipitations.

In accordance with the data of S. Opyrchał and others (6), the correlation of the magnitude of precipitations and inflow is very clear in the Wałbrzych region, where surface of direct infiltration is very large and the rocks massif strongly faulted and cut by mining works. In turn, the correlation is much less clear and observable with delay in the case of the Nowa Ruda region, characterized by thick overburden, smaller surface of recharge area, and less advanced dismembering of the deposit.

Waters flowing into the mines of the Lower Silesian Coal Basin are characterized by mineralization from decimals to about 8 g/dm^3, and only small quantities of them are strongly mineralized. Low mineralized waters of the types $HCO_3-SO_4-Ca-Mg$ and $SO_4-Cl-HCO_3-Na$, predominate here. Waters flowing through porphyry intrusions represent the type $HCO_3-Ca-Na-Mg$ or HCO_3-Na, with the content of free CO_2 up to 1.8 g/dm^3.

Translated by W. Brochwicz-Lewiński

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STRESZCZENIE

Eksploatacja złóż węgli kamiennych, występujących w utworach karbonu produktywnego, prowadzona jest w Polsce metodą głębinową w trzech zagłębiach węglowych: górnośląskim, dolnośląskim i lubelskim. Dwa pierwsze zagłębia cechują się rozwiniętą na szeroką skalę eksploatacją, trzecie zaś jest w fazie rozpoznawania hydrogeologicznego.

Deformacje górotworu i jego drenaż, wywołane eksploatacją górniczą, doprowadziły do zakłócenia naturalnego reżimu hydrogeologicznego, zwłaszcza w zagłębiu górnośląskim i dolnośląskim. Spowodowały one również, w różnym stopniu, degradację naturalnego środowiska wodnego.

Ilość i jakość pompowanych wód przez kopalnie węgla kamiennego zależne są od takich czynników, jak: budowa geologiczna złóż, parametry hydrogeologiczne serii złożowej i jej nadkładu, położenie w systemie przepływu wód oraz od głębokości, metod i czasu eksploatacji.

РЕЗЮМЕ

Эксплуатация месторождений каменного угля, находящихся в отложениях продуктивного карбона, проводится в Польше глубинным методом в трёх угольных бассейнах: Верхнесилезском, Нижнесилезском и Люблинском. Два первые бассейны характеризуются эксплуатацией проводимой в крупном масштабе, третий бассейн находится в фазе гидрогеологической разведки.

Деформации горных пород и их дренаж, вызванные горной эксплуатацией, привели к нарушении естественного гидрогеологического режима, особенно в Верхнесилезском и Нижнесилезском угольных бассейнах. Они вызвали также, в разной степени, деградацию природной водной среды.

Количество и качество вод накачиванных шахтами каменного угля зависит от таких факторов, как: геологическое строение месторождений, гидрогеологические параметры пластовой серии и её вскрыши, положение в системе течения вод, а также от глубины, методов и времени эксплуатации.