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CARBONIFEROUS AQUIFERS OF THE MAIN SYNCLINE IN THE UPPER SILESIAN COAL BASIN, POLAND

Jadwiga WAGNER[1]

A b s t r a c t . The paper presents the results of ten years hydrogeological studies carried out on 190 exploration boreholes drilled from 1953 to 1990 year. The study area covers the Main Syncline situated in the Upper Silesian Coal Basin in the Southern Poland. Hydrogeological conditions of the Carboniferous sequence are controlled by geological and anthropogenic factors.

K e y w o r d s : Carboniferous aquifers, Upper Silesian Coal Basin.

The Main Syncline is located in the central part of the Upper Silesian Coal Basin (USCB). It forms an extended syncline with gently declining flanks and is composed of the Carboniferous deposits covering the area of approx. 1715 sq. km. Its tectonic framework was developed during the Variscan orogeny and rejuvenated during the Alpine orogeny (Kotas, 1982). The main fault zones follow the East–West trend with some inclinations towards NWW–SEE (Buła, Kotas ed., 1994). The geologic profile of the Main Syncline consists of depositional sequences formed during three orogenic cycles: Caledonian, Variscan and Alpine, which are underlain by Precambrian basement and overlain by Quaternary deposits.

The Variscan cycle deposits are composed of carbonate, flysch and molasse lithological association. The molasse association, which is built of the polyfacial Carboniferous coal-bearing strata, reaches the thickness of 4,000–6,000 m. This association can be divided into the following lithostratigraphic formations: Paralic Series (PS), Upper Silesian Sandstone Series (USSS), Siltstone Series (SS), and Cracow Sandstone Series (CSS). The lithostratigraphic series comprises of interbeded sequences of clastic rocks: conglomerates, sandstones, siltstones and coal seams. These series can be differentiated based on the varying proportions of coarse to fine-grained sediments, varying thickness and development of coal seams. The Carboniferous overburden consists of Triassic carbonate rocks and Quaternary sands and gravels in the North-Eastern part of the Main Syncline whereas Tertiary clay deposits occur additionally in the southern and north-western parts of this syncline.

The hard-coal mining in the Main Syncline has taken place for over two hundred years. Due to considerable over exploitation of proven coal seams in the zone between the depth of 100 and 600 m, prospects for coal extraction are connected with deeper horizons. Mining areas of mine collieries, which are situated within the Main Syncline, cover in total as much as 840 sq. km. Natural inflow of groundwater to hard-coal mines at the Main Syncline area is approx. 460 thousand cu.m. per day (1999 year).

This study is based on a great number of papers and unpublished projects, such as: Różkowski (1971a, b, 1995), Różkowski, Wilk (1982), Różkowski, Wagner (1986), Rogoż, (ed. 1987, 1995), Witkowski (1988), Różkowski *et al*. (1990, 1992), Pluta, Zuber (1995).

The Main Syncline covers two hydrogeological regions (Różkowski, Wilk, 1982). Regions I-st and II-nd are distinguished according to the recharge conditions of the Carboniferous aquifers. In the I-st region, the Carboniferous aquifers are recharged in the outcrops or through permeable overburden, whereas in the II-nd region the recharge is through the erosional structures. The Carboniferous groundwater is drained mainly by the coal mine workings, fault zones and locally stream valleys. The underground water regime of the Main Syncline is controlled by geologic factors such as: synclinal rock configuration, lithology of the Carboniferous coal-bearing strata and its overburden, fault block arrangement, increasing with depth rock diagenesis as well as human industrial activities such as mine drainage induced by coal exploitation (Wagner, 1998).

The Carboniferous aquifer contains fractured-porous groundwater horizons separated by impermeable claystone intercalations. The interconnections between groundwater horizons have frequently been recorded within each individual lithostratigraphic series. These are associated with each individual lithostratigraphic series, which in turn are associated with

[1] Upper Silesian Branch of Polish Geological Institute, Królowej Jadwigi 1, 41-200 Sosnowiec, Poland

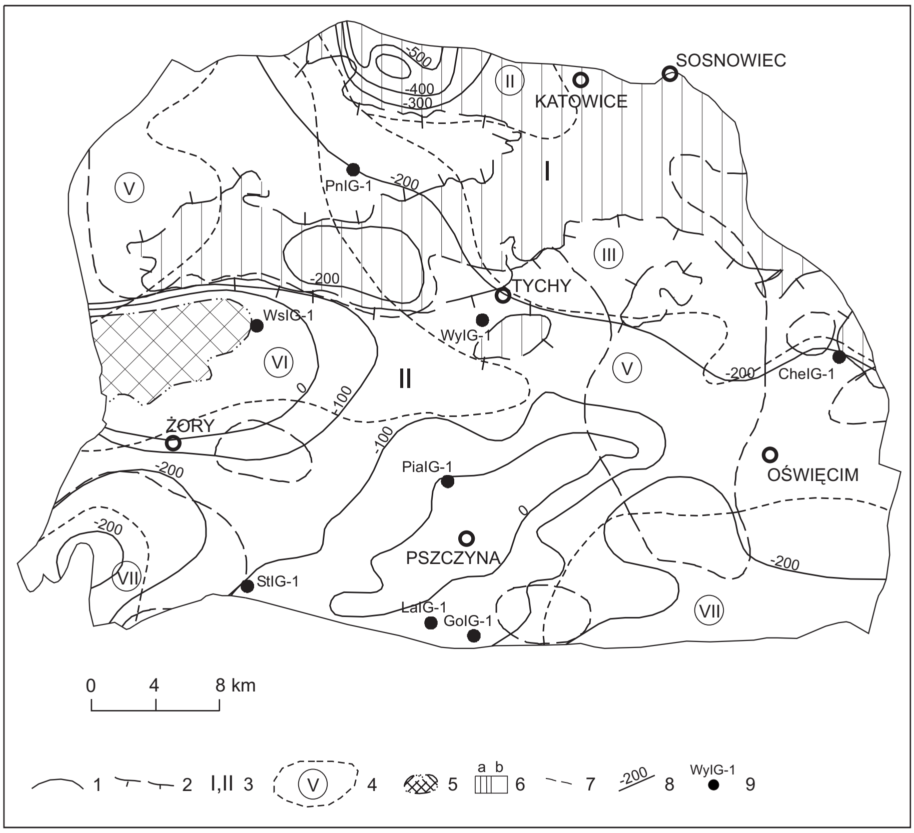

Fig. 1. Hydrogeological sketch of the Main Syncline

1 — boundary of the Main Syncline, *2* — extent of Tertiary formation, *3* — ground-water regions (after Różkowski and Wilk, 1982), *4* — hydrochemical subregions (after Różkowski *et al.*, 1993), *5* — salt deposit, *6* — zone of recharge to aquifers in the Carboniferous productive sequence; recharge: a) direct and indirect, b) retarded, *7* — extent of draining effect of collieries (after Wilk *et al.*, 1990, supplemented by Wagner, 1998), *8* — datum of top of brine horizons (35 g/l) (after Różkowski *et al.*, 1990, supplemented by Wagner, 1998), *9* — boreholes subject to hydrogeological testing

certain areas such as: coal mining, faulting and the zones of pinching out of sediment layers.

The Main Syncline is located within five hydrochemical subregions: II, III, V, VI, VII (Fig. 1). These were distinguished according to the occurrence of the main geological structures of the USCB, the occurrence of Tertiary sealing beds in the overburden of the Carboniferous aquifers, spatial variations of groundwater TDS, groundwater conditions subjected to alteration due to pumping accompanying the long-term coal mining, the occurrence of rock salt deposit, and the presence of hydrochemical anomalies.

The description of the hydrochemical regions has been elaborated with the contribution of the author of the present paper (Różkowski *et al.*, 1990). Three hydrochemical regions (III, V, VI) are enclosed completely, and two others (II, VII) only partially within the area of the Main Syncline. The boundary of the region V follows the contour line of the 250 m below s.l. elevation of water containing 50 g per liter TDS, and locally in the south, it runs along the Ruptawa fault zone. Region VI, which is enclosed within region V, contains the Tertiary salt deposit with the accompanying envelope of highly mineralised groundwater. The boundary of this region was assumed to be identical with the contour of the 250 m below s.l. elevation of water containing 110 g per liter TDS. Region VII encompasses the area of occurrence of a hydrochemical anomaly in the Carpathian Foredeep, which is characterized by reduction of mineralization at the upper part of the Carboniferous deposits. The boundary of region VII coincides with the previously described boundary of region V.

The author characterized selected hydrogeological parameters of the aquifers within the Carboniferous coal-bearing strata based on the research conducted in the years 1953–1990. The data from 190 boreholes were collected using direct and indirect techniques, field and laboratory testing procedures. The type and number of tests in each individual lithostratigraphic formation of the Carboniferous coal-bearing sequence are shown in Table 1. The objective of laboratory tests was to determine hydrogeological rock properties such as: effective porosity measured with a mercury porosimeter, storage capacity using a centrifuge method, and permeability using a low-pressure method (Table 2). Field-testing by direct methods consisted of pump testing, bailing and drill stem testing (subsurface sampler — discharge coefficient, Table 3). The author estimated the reliability of water chemistry analyses assuming the following potential sources of error: analytical errors, water contamination with drilling fluid and cement, mixing of waters from different aquifers due to hydraulic contacts which occurred by drilling of a well. The analyses were considered reliable if a value of an estimated error was less than 5%.

Table 1

Hydrogeological testing of the Carboniferous productive sequence in the area of the Main Syncline of the USCB

Lithostratigraphic series	CSS*	SS	USSS	PS
Number of boreholes with laboratory tests	71	54	36	20
Investigated interval [m]	50–1345	20–2190	100–1990	495–2130
Number of boreholes with pumping tests	46	64	26	6
Investigated interval [m]	40–980	20–1418	510–1792	175–1982
Number of water analysis	34	52	10	1
Investigated interval [m]	40–980	40–1418	152–1972	1556–1982

* CSS — Cracow Sandstone Series, SS — Siltstone Series, USSS — Upper Silesian Sandstone Series, PS — Paralic Series

Table 2

Selected hydrogeological properties of the Carboniferous rocks in the area of the Main Syncline of the USCB (the results of laboratory investigations)

Hydrogeological properties	Porosity [%]				Specific yield [%]				Permeability [mD]			
Lithostratigraphic series	CSS	SS	USSS	PS	CSS	SS	USSS	PS	CSS	SS	USSS	PS
Number of samples	954	1321	729	284	472	923	487	78	916	1204	699	200
Average	15.21	11.58	5.82	4.09	3.82	2.69	0.81	0.72	54.08	34.61	0.41	0.18
Geometric mean	14.14	9.79	4.70	3.08	2.97	1.85	0.69	0.67	10.69	1.31	0.03	0.08

Table 3

Selected hydrogeological characteristics of the Upper Carboniferous aquifers in the area of the Main Syncline of the USCB (the results of field tests)

Hydrogeological properties	Permeability [mD]			Hydraulic conductivity [m/s]			Discharge coefficient [m^3/h·1 m]			Specific discharge [m^3/h·1 m]		
Lithostratigraphic series	CSS	SS	USSS	CSS	SS	USSS	CSS	SS	USSS	CSS	SS	USSS
Number of samples	35	47	22	118	133	22	19	24	8	132	153	10
Average	25.90	16.67	4.57	$8.45\text{x}10^{-6}$	$1.36\text{x}10^{-5}$	$1.34\text{x}10^{-7}$	0.051	0.019	0.007	0.271	0.210	0.002
Geometric mean	13.51	5.12	0.61	$4.50\text{x}10^{-7}$	$4.27\text{x}10^{-7}$	$1.34\text{x}10^{-8}$	0.021	0.002	0.0009	0.041	0.027	0.0008

The author analysed changes of the TDS of groundwater, expressed by dry residue at 200 m depth intervals (Table 4). The groundwater circulating at the depth interval of 0–600 m is extremely differentiated with respect to their chemical composition and properties. Fresh and mineral waters occur to the depth of 600 m. Brines occur at the depth greater than 600 m. These are typical for deeper parts of Carboniferous aquifer. The author shares common view that the profile of deep-seated Carboniferous aquifer contains palaeo-infiltration waters. Two genetic types of waters have been distinguished: connate palaeo-infiltration brines and infiltration waters. Waters of the mixed type have been found in the zones between these waters (Wagner, 1998).

Table 4

Average values of Total Disolved Solid [g/l]

Investigated interval [m]	CSS	SS	USSS	PS
0–200	5.758	8.779	0.743	10.620
200–400	16.685	10.948	44.420	7.318
400–600	46.182	43.365	0.796	16.695
600–800	84.493	90.432	51.094	77.435
800–1000	126.685	101.340	123.980	82.820
1000–1200	—	138.590	128.814	105.532

Evaluation of results of the tests confirmed that reliable data were obtained from well *in situ* tests such as: pumping or water removal tests for the aquifers. Laboratory tests provided the largest amount of data on hydrogeologic properties of the rocks that form the deep strata of Carboniferous coal-bearing deposits. The research performed by the author confirmed that the results of laboratory tests are representative and reliable for the deep horizons of the Carboniferous coal-bearing strata at depth greater than 600 m. The permeability values obtained for sandstones and siltstones using laboratory techniques are comparable with the data of the *in situ* well tests, which were performed for the deep horizons of the Carboniferous coal-bearing strata. Values of porosity and storage capacity coefficients seem to be representative for *in situ* reservoir conditions.

The author presented the results of the investigations in several publications, and characterized values of hydrogeological parameters of the Carboniferous aquifers (Wagner, 1998). Variations of hydrogeological rock properties and hydrogeological parameters of aquifers were analysed for each of the four lithostratigraphic series of the Carboniferous. The results of these investigations were presented in separate papers (Wagner, 1997) The analysis of mean values of selected hydrogeological parameters of the aquifers which was performed by the author for 200 m depth intervals confirmed the validity of the existing data obtained from testing the Carboniferous aquifers (Wagner, 1998).

The results of this study confirmed the regularities in the occurrence of groundwater in Carboniferous aquifers of the Main Syncline, which have already been observed in the USCB.

This study confirmed the groundwater conditions within the Carboniferous aquifers of the Main Syncline as affected by both geologic and anthropogenic factors, consisting mostly of coal mining and associated drainage of mine waters through underground workings.

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