Changes in mine-water hydrology during the shut-down process of the zinc-lead ore mines in the Bytom region (S Poland)

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Abstract

Mine exploitation of zinc-lead ore deposits within the Triassic Bytom Trough lasted from the 12th century until 1989. Its zinc and lead ore deposits are related to the so-called ore-bearing dolomites series of the Middle Triassic. In the mid-seventies of the 20th century, five zinc and lead ore mines were exploited. Water flowing into the mines when still active was 32.5-47.8 m^3/min during 1975-1988. The end of the exploitation in 1989 and the final closure of the mines (1990-1991) did not mean the end of their drainage, because this would cause flooding. Water from the Triassic rock mass would endanger the still active hard-coal mines underneath. The main role in the centralised draining system for the abandoned ore mines is played by the central pumping station at the Bolko shaft (CPSB). It was predicted that the average inflow to CPSB would amount to approximately 36 m^3/min. Throughout the 15-year-period (1989-2003) of ore workings drainage, major changes in water inflow occurred. A significant decrease in mine water inflow is connected with at least four events that accompanied the shut-down of main pumping stations and with the influence of hard-coal mining in the underlying Upper Carboniferous on the dense network of inactive ore workings. In 2003 the average water flow into CPSB was 23,1 m^3/min, which amounts to approximately 64% of the total estimated inflow.

1 Geology, hydrogeological-dewatering and mining conditions in the central part of the Bytom Trough

The Bytom region of ore mining is situated within the so-called Triassic Bytom Trough and within the western part of the Silesia-Cracow area of Zn-Pb ore deposits (Kropka 2003; Wilk et al. 1990). In the period of the most intense development of ore mining, in the second half of the 20th century, five mines were actively working: Miechowice, in the western region, and Piekary, Bytom, Brzeziny and Dąbrówka in the eastern region (Fig. 1). The subjects of mining were galmei deposits (oxidized ores), zinc blende and galenite (sulphide ores) (Gałkiewicz 1980; Piwowarski and Żeglicki 1977). The thickness of the exploited deposit ranged from 2.0 to 6.5 m. Exploitation levels of ore mines were situated at depths (below the local surface) from 64 m to 100 m. All closed mines are still interconnected underground.

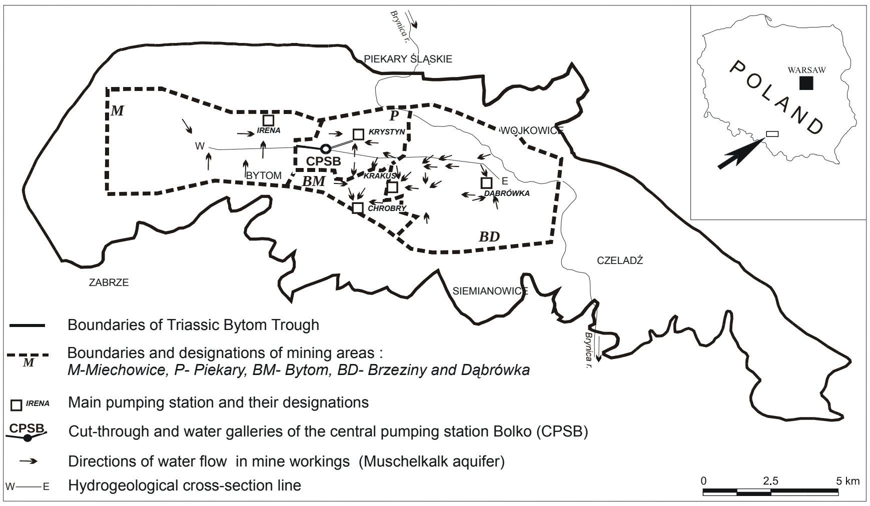

Fig. 1. Hydrogeological sketch of the Triassic Bytom Trough (state for 1988)

Hard-coal deposits have been long-lasting and intensively exploited since the 1870s in the productive Carboniferous deposits lying below the ore workings and within the influence of Zn-Pb ore exploitation. In the years 1989-2003 the number of active hard-coal mines under ore workings decreased from 10 to 4 (Fig. 3).

In the middle part of the Bytom Trough, in the natural hydrogeological profile of the Triassic multiaquifer formation, three independent aquifers have been distinguished: Muschelkalk, Roetian and Middle and Lower

Bunter sandstone. The Muschelkalk aquifer consists of dolomites and limestone; it has a fissured-karstic character and is of significance for flooding the workings of closed Zn-Pb ore mines (Baranowski 1980; Kropka 2003; Kropka and Respondek 2000). Long lasting ore exploitation in the central part of the Bytom Trough caused that water table to be lowered to the level of ore workings, i.e. to the ordinate of 170-240 m above sea level and the Triassic formation was drained above the level of ore workings (Kropka 1996).

The deposits ran out quickly, leading to the cessation of mining activity in the period between December 1978 (Miechowice mine) and December 1989 (Dąbrówka mine). The end of ore mining in the Bytom Trough was not accompanied by flooding of ore workings and the creation of a big water reservoir in the profile of the Triassic deposits. This reservoir would be a real water danger to the still active hard-coal mines situated below. In such a situation it would be necessary to drain the former workings of Zn-Pb ore mines until exploitation of coal deposits lying below would be completed (probably ca. 2020).

In the early 1980s it was decided to centralize ore mine drainage. The decision was preceded by a detailed mining-hydrogeological analysis of influence and results of previous and already planned hard-coal exploitation on ore workings, as well as experiences of drainage services in ore mines. The basic conclusions resulting from the analysis follow:

- the bottom of ore-bearing dolomites during hard-coal exploitation planned till ca. 2020 will be formed in such a way that it will enable general water flow towards a central pumping station situated at the Bolko shaft,
- arranging one centralized system of draining all ore workings in closed mines was technically possible and economically justified, since it prevented all hard-coal mines situated under these workings from being endangered by water and, simultaneously, made the work of drainage services easier in following years,
- the Bolko shaft, which, after deepening, was foreseen to be used for this task, is located in the area of dense and consistent infrastructure of the northern part of the Bytom city, where already recorded and planned surface subsidence, as estimated, will not exceed a few metres; the last fact was the guarantee for long working life of the central pumping station.

The central pumping station Bolko (CPSB) was built in the years 1985-1991. It consists of the Bolko shaft, 129.3 m deep, two cut-throughs, western and eastern, two water galleries, western (1100 m long) and eastern (1225 m long) and the pumping station with a sump and water headings

Nos. 1 and 2, with a total capacity of 15300-17500 m³. The total discharge capacity of all 13 pumps installed in the pumping station is 106.6 m³/min.

2 Water inflow to active zinc-lead ore mines in the years 1945-1988

Reliable data concerning water inflow to Zn-Pb ore mines in the Bytom Trough come from the period after 1945. The total water inflow to all mines in the years 1945-1988 ranged from 22.0 m³/min (1970) to 56.3 m³/min (1948). The total inflow was characterised at that time by big fluctuations. They resulted from the fact that important sources of water flowing into mines were, apart from atmospheric precipitation, waters of anthropogenic origin: among others, water infiltrating from watercourses and surface reservoirs and water and sewage infiltrating as a result of breakdowns in water supply and water mains systems in the cities (Kropka 2002). In the years 1945-1988 at least 3 periods can be distinguished. These differ in the amounts of inflow and their credibility as well:

- in the years 1945-1950 water inflows (36.4–56.3 m³/min; 45.8 m³/min on average) were not credible because of the occurrence at that time of deflooding and reconstruction of Miechowice mine (in the western area) and, among others, a very high share of water infiltrating from surface reservoirs and from still natural beds of watercourses in water flowing to mines,
- in 1951-1974, completed or highly advanced regulation of surface watercourses and elimination of many artificial surface reservoirs caused inflow of anthropogenic waters to mines to be reduced significantly; this 24-year-period was characterised by water inflow of 22.0-38.8 m³/min (30.6 m³/min on average),
- in the 14-year-period 1975-1988, directly preceding the completion of CPSB, some of the water flowing to mine workings was again from anthropogenic sources. This included water infiltrating from surface watercourses and water directed from drainage of surface reservoirs into mine workings by means of boreholes. As a consequence, the total water inflow to mines was increased. Total inflows ranged from 32.5 to 47.8 m³/min (41.8 m³/min on average.

The average total inflow to ore mines in the years 1951-1988 was 34.7 m³/min. It was assumed in estimations made in the 1980s for closed ore mines that, after the direction of water flow was changed as a result of shut-down of the 5 central pumping stations, total inflow to CPSB would be ca. 36.0 m³/min (Table 1).

3 Analysis of water inflows to the closed mine workings

CPSB started to work in March 1989. The central pumping station allowed the process of successive shut-down of particular main pumping stations to be commenced (Figs. 1,2). The shut-downs occurred in the period between 31.03.1989 and 30.04.1990.

Table 1. Water inflow to active Zn-Pb ore mines (1951-1988) and to the central pumping station Bolko (1990-2003)

Period	Total			Western region		Eastern region	
	m^3/min	%	%	m^3/min	%	m^3/min	%
1951-1974	22.0-38.8	-	-	3.6-6.4	-	17.6-34.5	-
1975-1988	32.5-47.8	-	-	3.7-10.3	-	28.5-40.3	-
Forecast	36.0	-	100	-	-	-	-
Sept 1990-July 1991	29.1-31.6	100	81-88	6.5-8.0	20-27	22.6-23.6	73-80
Sept 1991-Mar 1996	25.6-35.9	100	71-100	2.1-6.1	9-16	23.0-30.7	84-91
Apr 1996-June 1998	27.6-56.8	100	77-158	3.3-13.1	13-23	23.9-43.7	77-87
July 1998-Dec 2003	20.5-39.7	100	57-110	0.6-0.9	2-3	19.9-38.8	97-98

The main pumping station at Irena shaft (ca. 2200 m north-west from the Bolko shaft) was shut-down on 31.10.1989. Water from the area of Miechowice mine reached CPSB in the next month, i.e. November (Fig. 2). It is supposed that in the period between December 1989 and July 1991 in the western water gallery of CPSB all of the water that previously, in years 1975-1988, used to flow to Miechowice mine were registered (in the amount of ca. 6.5-8.0 m^3/min; 7.14 m^3/min on average). As early as August 1991 however, in the northern part of the mining area lying below Centrum hard-coal mine, an intensive exploitation of coal deposits lying at the outcrops caused strong deformations of theTriassic formation. As a consequence, the insulating shelf lying at the bottom of the ore workings was locally damaged and water escaped from Triassic carbonate deposits at a rate of 4.0-5.0 m^3/min into the mine workings in the Centrum mine (Fig. 4). In the period between September 1991 and March 1996 ca. 2.1-6.1 m^3/min of water flowed through the western gallery. The increase of inflow up to ca. 3.3-13.1 m^3/min in the period April 1996 to June 1998 (Table 1) resulted from very high precipitation within the discussed area. Precipitation was 813 mm in 1996 and 955 mm in 1997. In the following months of 1997 and in 1998, water accumulated in mine workings took advantage of intensive fissures in the Triassic formation and again intensified seepage to the Roetian aquifer and probably further into the deposits of productive Carboniferous. This once more caused a decrease in inflow to the western water gallery. From the second half of 1998 until now, the amount of water inflow from the western region (formerly Miechowice) has remained at the level of 0.6-0.9 m³/min (Table 1, Fig. 4).

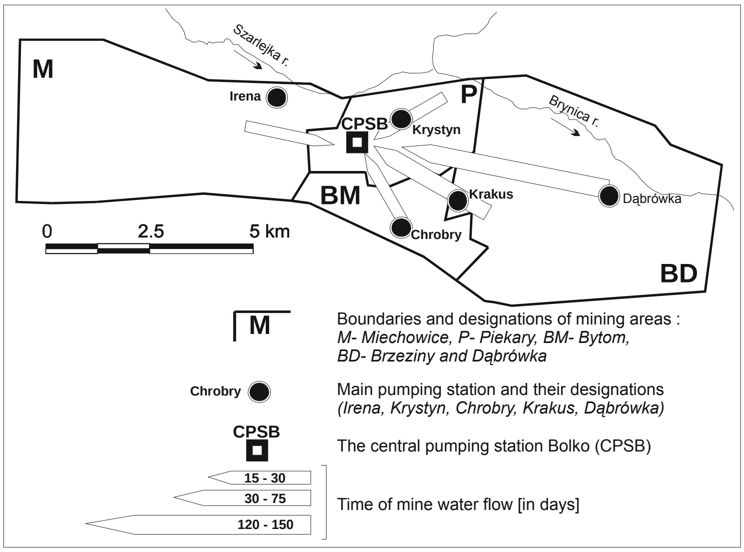

Fig. 1. Time of mine water flow from the mining areas to the CPSB after stopping main pumping stations (1989-1990)

A completely different situation occurs on the other, eastern part of the system. Total water inflow to the eastern water gallery should result from the sum of inflows from 4 main pumping stations located, until 1989-1990, at the already mentioned shafts: Krystyn, Chrobry, Krakus and Dąbrówka dip headings (Fig. 1). Total water inflow to the eastern area in periods analysed previously was characterised by huge fluctuations:

- in years 1951-1974 inflows ranged from 17.6 to 34.5 m³/min (25.9 m³/min on average),
- in years 1975-1988 total water inflows were higher and remained between 28.5 and 40.3 m³/min (34.6 m³/min on average).

The main pumping station at the Krystyn shaft, located ca. 1250 m east-north-east from the Bolko shaft (Figs. 1,2), was shut-down on 31.03.1989. It was the first one to be shut in the eastern region. The small distances between pumping stations as well as the possibility of fast water flow through the eastern water gallery caused that water inflow into CPSB to be stabilised in May 1989. Inflow to CPSB suddenly increased from 8.9-10.3 m³/min to 17.5 m³/min. The increase did not, however, account fully for the earlier total water inflow to Piekary mine, at which the Krystyn shaft is located. After the flow direction had been changed towards the CPSB 4.0-5.0 m³/min "disappeared". The difference could have been the result of simultaneous superposition of three factors. These are remarkably decreased precipitation, cessation (or significant decrease) of flow from some anthropogenic source of supply to ore workings and possible seepage of a part of the water into the Roetian aquifer lying below.

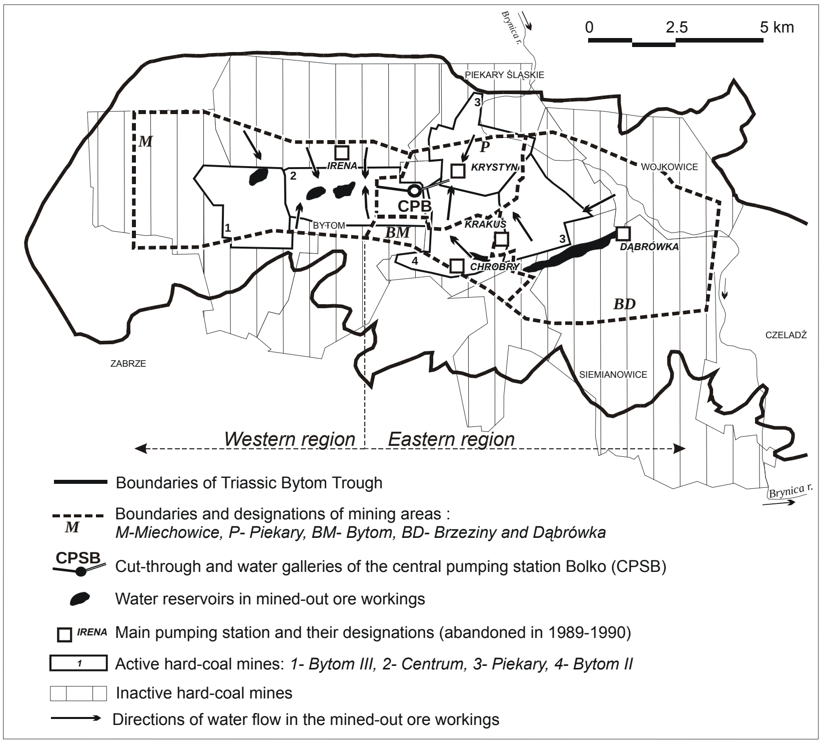

Fig. 2. Hydrogeological draft of the former ore field (state for 2003)

On 31.03.1990 the next two main pumping stations at the Krakus shaft and Dąbrówka dip headings were shut down. These are situated respectively 2900 m south-east and 6200 m east-south-east from CPSB (Fig. 2). In the following month of April, the total water inflow to CPSB did not change, despite the redirection of water from the shut-down pumping stations. This fact is attributed to the considerable distances for water flow from these areas to the central pumping station, the probable partial filling of old workings with water and reconstruction of pressures in the Triassic carbonate rocks. Some of the water played a particular role in filling a fault graben and creating a huge reservoir there, with a size ca. 1600 000 m³. These factors caused water from the Brzeziny mine (ca. 10.0-10.5 m³/min in total), at which the Krakus shaft is situated, to flow into CPSB in 2 parts: first, 7.0-7.5 m³/min after ca. 30-60 days in May, while the remaining water from this area, i.e. ca. 3.0 m³/min arrived at the Bolko pumping station after ca. 60-75 days, in June. Water (ca. 0.5-1.0 m³/min) from the last closed (30.04.1990) main pumping station at the Chrobry shaft mixed together with waters coming to CPSB from the closed Brzeziny mine.

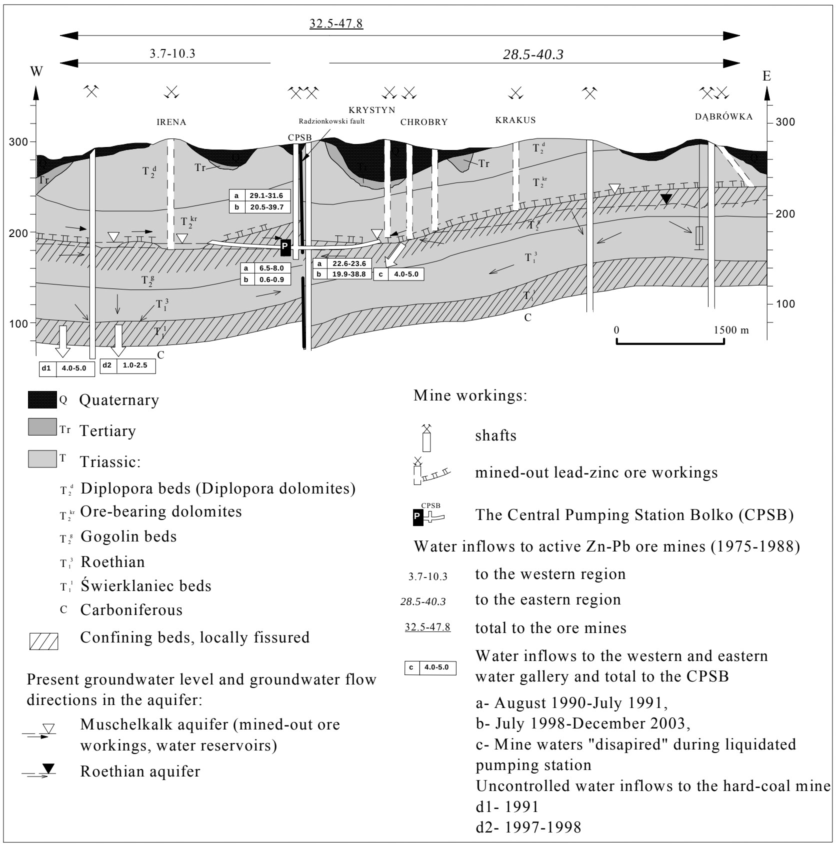

Fig. 3. Hydrogeological cross-section

Water from the region of the Dąbrówka mine (4.0-4.5 m³/min) reached the area of the Bolko shaft after ca. 5 months, causing flow from the east to increase from ca. 19.9 m³/min (July 1990) to 23.6 m³/min (August 1990).

The above analysis shows that water (a total amount of 13.5-16.0 m^3/min) from three main pumping stations (Krakus, Dąbrówka, Chrobry) reached CPSB in the amount of ca. 14.0 m^3/min, i.e. ca. 88-100%. The possible small water loss (ca. 1.0-2.0 m^3/min) could have been due to reduced precipitation or anthropogenic supply, and also small and practically unobserved increases in water inflows to workings of two hard-coal mines Siemianowice and Barbara-Chorzów lying below.

After the waters finally changed direction, total flows from the eastern region in the period August 1990-July 1991 stabilised at the level of 22.6-23.6 m^3/min (Table 1).

4 Conclusions

The shut-down of main pumping stations in five closed Zn-Pb ore mines in the Bytom Triassic Trough was completed on 30.04.1990. Changing direction of water flow in mine workings connected with the stations, and accompanying filling of old workings and Triassic formation (first of all establishing a water reservoir in the fault graben) can be considered to be completed in August 1990.

In the period August 1990 to July 1991, water inflows to the central pumping station at the Bolko shaft (CPSB) remained at the level of 29.1–31.6 m^3/min, which was ca. 81-88% of the estimated value (36.0 m^3/min; Table 1). During the shut-down of the main pumping stations and changing the direction of water flow in the eastern part of the system, ca. 5.0-7.0 m^3/min “disappeared”, i.e. 14-19% of the estimated value. Inflows from the two regions, western and eastern, were 6.5-8.0 and 22.6-23.6 m^3/min respectively, ca. 22-25% and 75-78% of the total inflow to CPSB at that time (29.1-31.6 m^3/min). Water “escapes” from inactive ore workings that occurred in the western part of the system in 1991 and 1997/1998 led to decreases in water flow into CPSB from 6.5-8.0 to 0.6-0.9 m^3/min. Such an inflow was only ca. 8-14% of the value from the period August 1990 to July 1991. At the same time the share of inflow from the western area of the total inflow to CPSB declined from ca. 20-27% to a value ca. 2-3%. Simultaneously, the share of inflow from the eastern area increased from ca. 73-80% in the period August 1990 – July 1991 to ca. 97-98% at present (20.5-39.7 m^3/min; Table 1).

Approximately 5.0-7.5 m^3/min, i.e. ca. 85-90%, of water flowing to inactive mine workings in the western area seeps through fissured Triassic and Carboniferous formations, including layers isolating ore workings from the bottom (total thickness ca. 120-210 m), and reaches mine workings of the Centrum hard-coal mine lying below. The contribution of water from flooded inactive workings in the western area to inflow to mine workings in the hard-coal deposit increased from less than 1.0 m^3/min in the years 1985 to 1988 to ca. 4.2-5.2 m^3/min in the years 1992 to 1995 and 5.7-6.4 m^3/min after 1998.

In the period between August 1990 and December 2003, inflows to the eastern area ranged from 19.9 to 43.7 m^3/min, but the values above 25.0-30.0 m^3/min resulted from increased atmospheric precipitation. The analysis of the inflow amount in the eastern area at that time does not provide clear proof that water escapes from this region into Roetian and productive Carboniferous aquifers.

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