Influence of Karst Phenomena on Water Inflow to Zn-Pb Mines in the Olkusz District (S Poland)

J. Motyka and M. Czop

Abstract Lead and zinc ore deposits of the Mississippi Valley type (MVT), located in the Olkusz ore district (south Poland) are connected with strongly karstified Triassic carbonates, mainly dolomites. In this paper changes in the groundwater inflow quantities to the Zn-Pb mines in the Olkusz region are discussed: Boleslaw, Olkusz and Pomorzany. The mining activity in the Olkusz region is connected with probably highest groundwater inflows in the World. Occurrence of the karstic systems within Triassic rocks is a reason for extremely high water inflow to the underground mining workings, obtaining the value of 40 m^3/min in Boleslaw mine, about 95 m^3/min in Olkusz mine and about 300 m^3/min in Pomorzany mine. The main problem in the dewatering of the Triassic ground is the presence of the water-filled karstic systems. After the cutting of the karstic channels or caverns by the mining workings an abrupt increase of the water inflow to the mine dewatering systems is observed. Karstic forms, as an intrinsic drainage systems for fissures and matrix porosity, are responsible for enlargement of the recharge zone of mines.

1 Introduction

Lead and zinc ore deposits in the Olkusz region are occurring in the northeast part of the Upper Silesian Coal Basin periphery. These deposits belong to Mississippi Valley type (MVT) group of the Zn-Pb ores. According to Leach and Sangster (1993), MVT ores are epigenetic type, precipitated from dense basinal brines at temperatures ranging between 75 and 200 °C, typically in platform carbonate sequences and lacking genetic affinities to igneous activity. Hosted rocks for the Olkusz Zn-Pb ores are Middle Triassic strongly karstified carbonates, mainly ore-bearing dolomites.

J. Motyka, M. Czop
AGH – University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Department of Hydrogeology and Engineering Geology, Krakow, Poland, e-mail: motyka@agh.edu.pl; mariucz@agh.edu.pl

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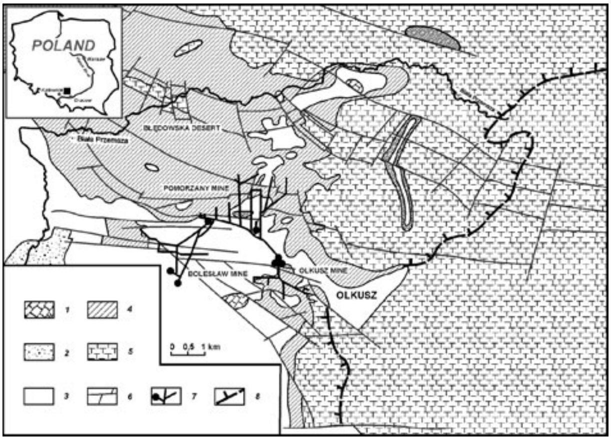

Fig. 1 Geological map of the Olkusz region Legend: 1) D-C1 carbonates; 2) P-conglomerates; 3) T1,2 – carbonates; 4) T3 – clays, claystones; 5) J3 – limestones; 6) main faults; 7) mine galleries; 8) range of T3 under J3

Mining of the ores in the Olkusz region has a very long tradition and according to historical sources dates back to the 12th century. Nevertheless, archaeological data indicate that exploitation of the lead ores with silver admixture was operating in late Neolith. After running the exploitation in the saturation zone, water was the serious factor, which make difficulties for execution of the underground mining workings. Drainage of the ore-bearing carbonate rocks was started in the 16th century, by using drain adits. The parts of these old workings are existing and still operating. Intensive drainage of the Triassic carbonates began at the end of the 19th century with application of the steam-driven dewatering pump in the few small mines. After 2nd World War the Boleslaw mine, which was flooded in the 1930s of the 20th century, was activate. Moreover, the two new mines: Olkusz and Pomorzany were built in the Olkusz region (Fig. 1).

2 Groundwater Flow Systems Within Triassic Aquifer

Four main groundwater aquifers are present in the Olkusz Zn-Pb region: 1) Quaternary, 2) Jurassic, 3) Triassic and 4) Palaeozoic (Devonian and Carboniferous). The Quaternary aquifer is of porous type, built up of fluvioglacial sands with gravels, debris or rarely dust, clays or silt clays insertions. Jurassic, Triassic and Palaeozoic aquifers are of the karst-fissures type, consisting of carbonate rocks: dolomites and limestones. Groundwater flow conditions within Triassic main groundwater aquifer require the consideration in the regional and local scales and also for the karstic system, including the voids, which form the hydraulic network. According to Motyka (1998), within the Triassic carbonates it is possible to separate four systems of the particular spaces with differences in geometry, mainly dimensions: 1) porous space (matrix), 2) fissures, 3) caverns and 4) filled forms.

Matrix porosity of Triassic limestones is 0.002–0.08, with arithmetic mean of 0.017. The hydraulic conductivity of the matrix range from 3.42×10^{-12} to 1.21×10^{-8} m/s, with a geometric mean of 3.8×10^{-10} m/s. The porous space in limestones has a very low specific yield, ranged from 0 to 0.0091, with the arithmetic mean equal to 0.00064. The fissures porosity range from 0.00023 to 0.044 with arithmetic mean equal to 0.0052. The mean hydraulic conductivity of the fissures network and interbedding planes of the limestones massif is 8.7×10^{-4} m/s for the saturated zone. Mean cavern porosity in these rocks is estimated at about 0.002 and the hydraulic conductivity of the cavern space is about 1.6×10^{-1} m/s (Motyka 1998). The same author estimates mean porosity of filled forms in Triassic carbonates which is about 0.01 for limestones and about 0.015 for dolomites. Mean value of hydraulic conductivity filled forms in these carbonates in the natural conditions is estimated as 2.8×10^{-9} m/s.

Matrix porosity of the Triassic dolomites in the same area ranges from 0.0054 to 0.34, with an arithmetical mean value of 0.109. Hydraulic conductivity of the matrix ranges from 2.1×10^{-11} to 4.9×10^{-6} m/s, and specific yield ranges from 0 to 0.15 with an arithmetic mean equal to 0.028. The fissures porosity in the dolomites range between 0.004–0.016 with the mean value of 0.0037. The mean hydraulic conductivity of the fissures network and bedding planes is 1.03×10^{-3} m/s for the shallow weathered zone and 5.5×10^{-4} m/s for the saturated zone. Mean cavern porosity of dolomites is estimated at about 0.006, and the mean hydraulic conductivity is about 1.5×10^{0} m/s. The hydraulic properties of filled forms are not known; however, Motyka (1998) estimates the porosity of filled forms for dolomites is about 0.015.

3 Water Inflow to Zn-Pb Mines

After 2nd World War in the Olkusz area three Zn-Pb mines were active: “Bolesław”, Olkusz and Pomorzany.

Boleslaw mine was built at the beginning of the 19th century. Archival data indicate that water inflow to underground workings of the Boleslaw mine range from 22 m^3/min to 39 m^3/min. The mine was closed and flooded in 1931 due to economic reasons connected with the Great Depression. After 2nd World War, at the beginning of the 1950s of the 20th century, Boleslaw mine was dewatered. Systematic measurements of the water inflow to the Boleslaw mine were started in the second half of 1958. Temporal changes in the water inflow to the Boleslaw mine were strictly connected with opening out of the adjacent Zn-Pb ores. Dewatering of the Olkusz mine, which was started in August 1958, has only the insignificant influence on the water inflows to the Boleslaw mine. From November 1973 the rapid and significant decrease in the amount of the water inflows to the Boleslaw mine was observed. The reason for these changes was the beginning of the Pomorzany mine dewatering.

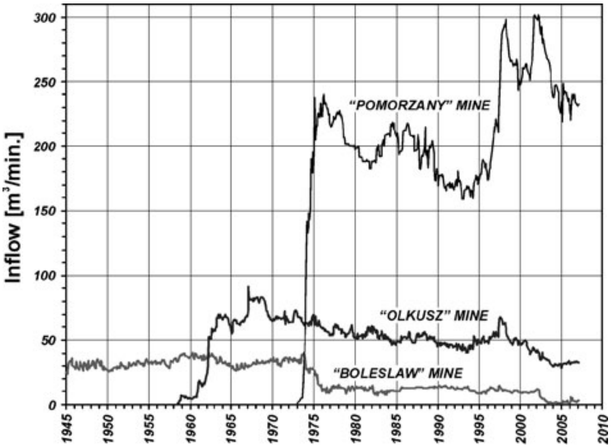

Fig. 2 Groundwater inflows to the Zn-Pb mines in the Olkusz region

Inflow to the Boleslaw mine from about 30–34 m^3/min observed at the beginning of the 1970s in the 20th century was dropped to the value range from 8 m^3/min to 15 m^3/min in 1990 and only about 6–8 m^3/min in 1995. In 1995, the liquidation process of the Boleslaw mine was started and actually the mine underground workings are partly flooded and the main shaft is used as an intake of water for technological purposes. Depending on the requirements, the intake discharge ranges from 0.7 m^3/min to 5.6 m^3/min (Fig. 2).

The construction of the Olkusz mine was started in 1957 by shafts sinking. The water inflows at this beginning stage of mine dewatering were about 8 m^3/min. In 1960, the horizontal mine galleries were drifted for opening out and exploitation of the Zn-Pb ore. After cutting of the Lower Triassic dolomites, underlying ore-bearing carbonates, water inflows to the Olkusz mine increased to the value of about 10 m^3/min. As a consequence of the Middle Triassic limestone cutting the further increase of water inflow to about 30 m^3/min was observed (Fig. 2). In April 1962, the main exploratory drift cut the system of the caverns in the Middle Triassic limestones. The inflow of water from these karstic forms reached the value of about 20 m^3/min and the total inflow to the Olkusz mine increased to about 52 m^3/min. As a consequence of the progress in mining exploration in the next 2 years, further increase of the water inflow to the Olkusz mine was observed. Between May 1963 and August 1964, the amount of the water inflowing to the dewatering system of the described mine reached the value of about 70 m^3/min. In the following period, the inflow was changed with both short duration decrease and also increase. In February 1967, the extremely large water inflow to the mine workings occurred from the karstic cavern system. The measured discharge of this inflow was about 37 m^3/min and total inflow to the Olkusz mine increased to the value of about 90–95 m^3/min. After draining of the water gathered in the cavern system, total inflow decreased rapidly to about 82 m^3/min and after the next year was stabilized in the interval between 68 m^3/min and 72 m^3/min. With effect from 1972, in spite of significant fluctuation of about 10 m^3/min, the distinct trend of the total inflow decrease was observed. The reasons for these changes were the starting of the drainage of the Pomorzany mine and long-term hydrological drought in Poland for the period 1984–1996. The minimal total inflow for this time interval of 41 m^3/min was measured in August 1993. In July 1997, the extreme rainfall was the reason for the serious flood in South Poland. This phenomenon has an impact on the increase in total inflow to the Olkusz mine, which in September 1997 reached the value of about 68 m^3/min (Adamczyk and Motyka 2000). The peak-inflow decreased rapidly to the value of about 50 m^3/min. In the last time sequence, the decreasing trend of the total inflow to Olkusz mine was observed, from the second half of 2003 to the present inflow which dropped to the value of about 28–33 m^3/min.

Construction of the Pomorzany mine was started in 1969 by the drifting of the opening-out heading within Permian conglomerates, underlying Triassic carbonates. In the beginning phase of the mine construction, the inflows from Permian rocks were insignificant, with discharge of about a few litres per minute. That is why the measurements were not started before July 1972. Maximal inflow from Permian conglomerates of about 5 m^3/min was observed in August 1973. In October 1973, the underground workings were drifted within karstified Triassic carbonates. During the next seven months the total inflow to the Pomorzany mine increased from about 5 m^3/min to above 100 m^3/min (Fig. 2). The increasing trend was continued and in October 1975 total inflow reached the maximal value of about 240 m^3/min. Rapid increase of the inflows was connected with the opening of the following water-bearing karstic channels and caverns. In the next years, after attained maximum, the total inflow to Pomorzany mine decreased and the minimal value of about 185 m^3/min was measured in July 1983. Opening the new region of the Zn-Pb ore in 1983–1984 was connected with a decrease of the inflow to the value of about 220 m^3/min. Long-term hydrological drought in Poland in the period 1984–1996 was the reason for the systematic decrease of the water inflow to Pomorzany mine. In April 1994, inflow reached the minimal measured value, only 160 m^3/min. Heavy rainfalls in the second half of 1996 and extreme rainfall amounts in July 1997 had a strong influence on the amount of water inflowing to the dewatering system of the Pomorzany mine. This situation was similar to the previously described example of the Olkusz mine. In Pomorzany mine the maximal measured inflow, about 300 m^3/min, was observed in May 1998. After this peak point in inflow, the stabilization of the inflow was observed on the level of about 250 m^3/min. The situation with rainfall-induced increase of the inflows to the mine was observed also at the turn of years 2001 and 2002. As a consequence of heavy rainfalls in the summer of 2001 after 1 year, in August 2002, the total inflow to the Pomorzany mine attained the value of about 300 m^3/min the situation observed after this peak point was analogical to the stated in the period 1997–2000. In February 2004, the inflow decreased to the value of about 230–250 m^3/min and is holding in this level to the present.

4 Conclusions

Occurrence of the water-bearing karstic channels and caverns within Triassic carbonates is a reason for the extremely high inflows to the Zn-Pb mines in the Olkusz region. the necessity of the pumping of large amounts of water has a significant impact on the Zn-Pb deposit exploitation costs. Discharge and characteristics of the inflows to the Zn-Pb mines in Olkusz region are strongly influenced by occurrence of the karstic forms. In a stage of the deposit opening any situation of the karstic system incision was connected with abrupt increase of the inflows to the mine. Discharge of the individual inflows from caverns were reached about 40 m^3/min for Olkusz mine and about 100 m^3/min for Pomorzany mine.

Temporal changes in the inflows from karstic systems are dependent on the type of groundwater aquifer, which is a recharge source for particular inflow. A fissured-karstic aquifer is a source for the extremely large inflows with rapid decrease of the discharge and following stabilization on the value result from recharge of the cavern system by fissures. A porous-karst-fissured aquifer has an additional source of water, which is gathered in pore spaces. Inflows from this type of aquifer have a relatively longer period of high discharges. A typical feature of the porous-karst-fissured aquifer with occurrence of the filled forms is an initial low discharge, which increases gradually according to the intensity of the tunnelling process. After draining of the water accumulated within karstic systems and porous space, the inflow discharge decreased slowly to the level resulting from the conductivity of the fissure system.

The prognosis of the discharge of the particular inflow (up to 1.6 m^3/s), especially from the mine face, is extremely difficult. The best methodology, and also very expensive, for safe mining exploitation is the drilling of the exploratory, protection hole. But this method results only in determination of the existence of karstic channels without any information about volume of the connected system and also volume of water gathered within system. In the past, the geophysical and isotopic methods were used, but it was found that they are completely useless for these purposes.

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