HYDROGEOLOGY OF THE LUBLIN COAL BASIN (POLAND)

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ABSTRACT

The Lublin Coal Basin (LCB) is the area of the occurence of hard coal deposits in the eastern Poland (Fig. 1). Four main water-bearing horizons distinguishable in the hydrogeological profile of this area include Quaternary, Cretaceous, Jurassic and Carboniferous. The specifity of the hydrogeological conditions of the LCB results from the determining role of the highly water-bearing capacity of the Mesosoic cover of the Carboniferous and the advancement of the tectonics. The water-bearing sandstones and limestones of the Lower Cretaceous and Jurassic represent an enormous water reservoir with the pressure of 3.0 to 9.0 MPa being the main source of hazard for mining. The aquifers of the productive Upper Carboniferous are represnted by sandstones and coal seams. On the area where mining actually takes place these aquifers are under the pressure of 5.5 to 9.8 MPa.

The LCB is transit-flow artesian basin. The deep penetration of infiltrating waters is favoured by the block tectonics and active neotectonic movements. The regional grounwater flow is in the north-west direction. Hydrochemical vertical zonality of groundwaters is observed in the LCB. It is disturbed by the fault zones along which water sweetening of takes place.

So far within the LCB five mine shafts have been deepened and

two mines are under construction. Because of the occurence of water-bearing horizons within the overburden the shafts, ca 1000 m deep, had to be deepened by the freezing method.

While carrying out the vertical as well as the horizontal mine workings, started in 1975, it has been found that the hydrogeological conditions of the coal deposit are more complex than it was evaluated on the basis of drillings. The present inflow to the piloting mine amounts ca 7 m^3/min. The majority of it comes from the draining boreholes which are being drilled in order to improve the working conditions of the piloting longwall.

It has been found that the water-bearing capacity of the Carboniferous strata decreases with depth, while the mineralization of groundwater increases and its chemical composition changes. It is characteristic that the main water-bearing strata are the coal seams, and not the sandstone beds as one could expect. This phenomenon as well as the views concerning the origin of water entering the mine workings are discussed in the paper.

To protect the mines under construction against water hazard on the side of the Jurassic it is necessary to leave a 80 m thick safety shelf in the Carboniferous roof as well as a 20 m wide safety pillars along the main faults. Different concepts of an advanced, planned drainage of the Jurassic by means of drillings from the specially made workings have been proposed. They are shortly characterized in the paper. So far, first workings have been attempted aiming at introducing one of this methods.

INTRODUCTION

The Lublin Coal Basin (LCB) with the area of about 14000 km^2 (Porzycki, 1982) is the area of the occurence of hard coal deposits in the eastern Poland (Fig. 1). It is situated within the transition zone between the Precambrian and Paleozoic platforms (Żelichowski, 1972). From the beginnings of its discovery it has been the subject of intensive hydrogeological prospection the results of which systematically narrow and modify both the model of the hydrogeological conditions of the coal basin and the coal deposite occuring in it.

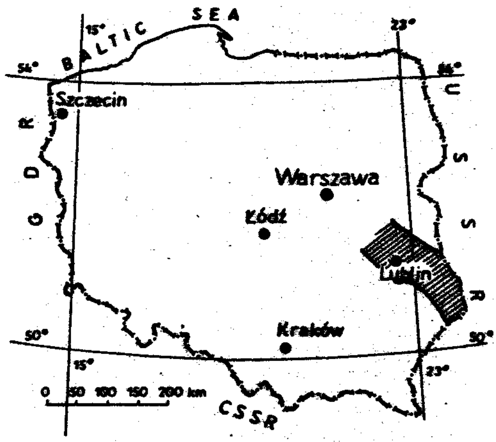

Fig.1 Location of the Lublin Coal Basin

The specifity of the hydrogeological conditions of the LCB results from the determining role of the highly water-bearing Mesozoic cover of the Carboniferous and the great advancement of the tectonics. In this situation designing of the mines as well as carrving out mining works safety and economically must be preceded by a detailed and complex identification of the hydrogeological conditions of the coal deposits.

The basin's hydrogeological conditions have been the subject of research work since 1964. The research was concentrated first of all in the eastern (the Central Coal Region, Fig. 2) - most favourable in terms of coal deposits - part of the basin (Porzycki, 1982). Hydrogeological identification of the central part of the LCB has started to widen and deepen since 1975 in connection with the beginning of the building of the first coal mine K-1. The western part of the LCB, situated to the west of the Kock structure is hydrogeologically poorly identified.

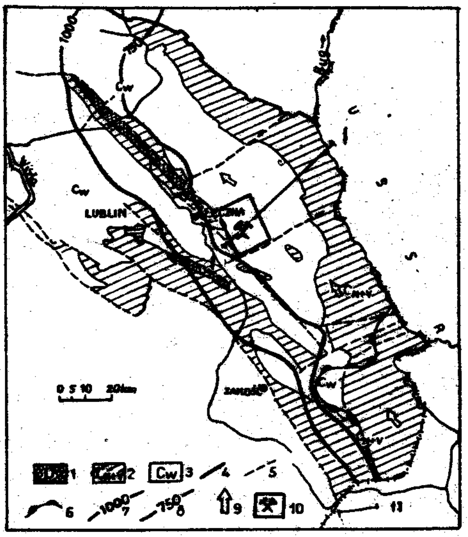

Fig.2 Geological Sketch map of the Lublin Coal Basin without rocks younger than Carboniferous (after J. Porzycki)

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-faulta, 6-present, erosional boundary of Jurassic rocks, 7-1000m isopach of cover rocks, 8-750m isopach of cover rocks, 9-direction of regional flow, 10-coal fields, 11-cross-section line

The summing up of the results of hydrogeological research of the LCB is to be found in the hydrogeological monograph of the Lublin Basin being printed at the moment (Różkowski, Wilk, ed. in press).

HYDROGEOLOGICAL CONDITIONS

In the LCB the Jurassic formations lie on the erosion surface of the Carboniferous, higher lie the Cretaceous formations, locally the Tertiary and the Quaternary sediments (Fig. 3, 4). The total thickness of the Carboniferous overburden ranges from about 340 m in the eastern part of the basin to over 1000 m in the western part (Fig. 2).

The diversified geological structure of the LCB enables to distinguish several water-bearing and isolating horizons in its profile (Rudzińska, Różkowski, 1984). There are two water-bearing complexes in the productive Carboniferous cover: Quarternary-Tertiary-Upper Cretaceous and Lower Cretaceous-Jurassic divided by the separating series built of the lower marl elements of the Upper Cretaceous period. The stratification of the permeability of the cover formation and the deposit series is illustrated by Fig. 4.

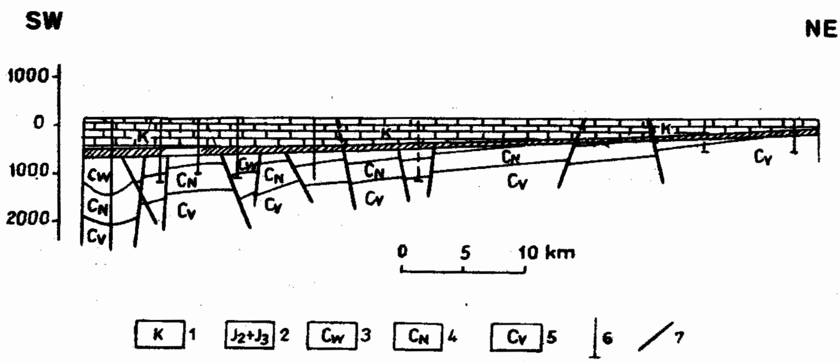

Fig.3 Geological cross section I - I
1- Cretaceous, 2-Jurassic, 3-Westphalian, 4-namurian, 5-Visean, 6-bore-hole, 7-faults

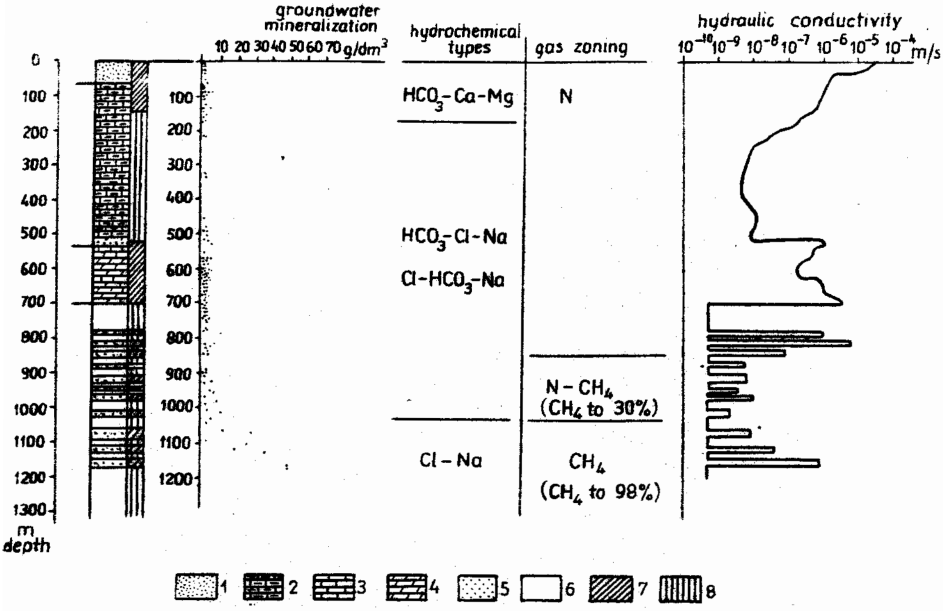

Fig.4 Hydrogeological diagram

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

There are two basic aquifers in the hydrogeological profile of the upper water-bearing complex: Quaternary and Upper Cretaceous. They are generally in a mutual hydraulic relationship. The depth of the range of the active cleavage in the Upper Cretaceous formations are observed to the depth of about 170 m (Fig. 4). The increased water-bearing capacity is observed in the dislocation zones (Krajewski, 1984). The hydraulic conductivity of the described aquifer usually cover the range of 5.0×10^{-4} to 1.1×10^{-5} m/s and the specific cap. from 4.0 to 12.5 m^3/h.

The lower layers of the Upper Cretaceous formation, because of the influence of the diagenesis processes and the marl inserts, are practically impermeable and make the isolating horizon (Fig. 4). The depth of this horizon increases from 140 to about 820 m towards the west. The hydraulic conductivity of the described rocks cover the range of 10^{-8} to 10^{-9} m/s. Their values increase in the tectonic dislocation zones. The isolating character of the separating horizon was confirmed by the mine workings.

The water-bearing complex of the Lower Cretaceous and the Jurassic has the thickness from 30 m in the Bug region to 120 m in the central and about 350 m in the western part of the basin. It covers the Albian and the Jurassic aquifers. They make an enormous water reservoirs with the pressure of 3.0 to 9.0 MPa in the natural conditions. The Lower Cretaceous Albian aquifer is represented by sands, sandstones and conglomerates. Its thickness vary from 0.5 to 37.0 m, within the range of the Central Coal Region - from 0.5 to 7.0 m. The hydraulic conductivity values of the described aquifer vary from 2.28×10^{-7} to 5.57×10^{-5} m/s and specific cap. from 0.0009 to 0.854 m^3/h.

The Jurassic aquifer is built of the carbonate, secondarily, the sandstone-mudstone formations. The sediments of the Middle Jurassic represented by sandstones, mudstones and limestones have the thickness of about 50 m and fill the erosianal forms in the roof of the Carboniferous formations (Szydeł, Szydeł, 1984).

One can observe a distinct stratification of permeability and water-bearing capacity of the Jurassic formations in their vertical profile. The hydraulic conductivity varies from 6.49×10^{-8} to 5.90×10^{-5} m/s and the specific cap. from 0.036 to 8.43 m^3/h in the eastern part of the basin.

The Upper Carbonifeorus water-bearing complex is made of the Westfalian productive series and the formations of the Namurian C. The described complex consits of the aquifers and separating shale layers. The water-bearing rocks are sandstones, mudstones and coal seams. On the area of the Central Coal Region they carry waters under the pressure of 5.5-9.8 MPa. The hydraulic conductivity of the Lublin beds sandstones varies from 9.04×10^{-9} to 6.27×10^{-6} m/s with the lower values dominating (Fig. 3). The specific cap. vary from 0.0002 to 0.288 m^3/h. The separating subjacent horizon are shale formations of the Namurian A and B.

The Lublin-Wołyń groundwater basin to which the LCB belongs, is of a transit-flow character. The deep penetration of infiltrating waters is favoured by the block tectonics and active neotectonics. The regional groundwater flow towards NW is forced by the formation of the high potential pressures of waters in the morphologically uplifted area of Podole and Roztocze. It is also favoured by the geological structure of the basin, directing of the dislocation zones and the transitflowing character of the reservoir. The discharge of the potential pressures of the basin takes place probably in the Mazowsze trough, it means in the Central Poland.

The differentiating speed of flow and water resources regeneration within the range of particular water-bearing horizons made it possible to determine the vertical hydrodynamic zones in the discussed basin. The disturbances of the hydrodynamic zones are observed as local anomalies of piezometric pressures in the fault zones and within the range of the mining drainage.

The fault zones are probably the privilaged routes of water infiltration from the active exchange zone, through the separating horizons. The transmissivities of the fault zones, having their extensions in the Palaezoic formations are observed in the Lvov-Wołyń Basin by the Soviet hydrogeologists (Shirokov, ed. 1984, Babinjec and others, 1979). Basing on the analysis of the interdependence of water level in the Carboniferous and Cretaceous formations on the territory of the above mentioned basin they proved the process of water infiltration through the separating horizon. The infiltration velocity varies from 1×10^{-3} to 1×10^{-5}

m/d depending on the thickness of the Upper Cretaceous formations and the degreeof their dislocations. The transmissivity of the dislocation zones in the separating horizon of the Upper Cretaceous in the LCB was shown, among others, basing on the geothermic research by Błaszczyk, Zarębski (1980) and recently it has been discussed in the regional scale by Zwierzchowski (1986). This problem has been widely presented in the Lublin Coal Basin monograph (Różkowski, Wilk, ed., op. cit.). The water infiltration time through the separating horizon in the area of the Central Coal Region varies from 10^3-10^5 years. It is confirmed by the results of the research on the water isotopic composition (Różkowski, Przewłocki, 1974; Zuber, Grabczak, 1981). It is necessary to stress the fact that in the conditions of depression caused by the mining drainage the water infiltration time in the dislocation zones may be much shorter.

In the LCB one can observe the vertical and horizontal hydrochemical zones (Różkowski, Rudzińska, 1978, 1983). These zones undergo local disturbances in the fault zones where one can generally observe water sweetening of (Zwierzchowski, 1986). The upper water-bearing horizon carries sweet water. Waters of the Lower Cretaceous-Jurassic horizon are characterized by mineralization varying from 0.4 to 2.0 g/dm^3 in the eastern part of the basin, reaching 31 g/dm^3 in the western part. In the formations of the productive séries of the Lublin beds, within the reach of the Central Coal Region, water mineralization varies from 0.6 to 10.0 g/dm^3. These are HCO_3-Cl-Na, Cl-HCO_3-Na and Cl-Na types of water.

Particularly intensive influence on the shaping of both the present hydrogeochemical zones and the hydrodynamic field in the LCB was exerted by the last infiltration stage lasting from Miocene to the present times. The range of its influence in the eastern part of the basin reaches the depth of about 1000 m what is observed in shaping the potential pressures, water chemistry and its isotopic composition (Fig. 4) (Różkowski, Przewłocki, op.

cit.; Rudzińska, Różkowski, op.cit.). Below this depth appear waters isolated from the influence of the last infiltrational stage, the degree of isolation growing with depth. These are waters of various age.

The isotopic research carried out by Zuber and Grabczak (1981) proved the existence of the regional changes of the isotopic zones of the Lower Cretaceous-Jurassic and Carboniferous horizon waters (the Lublin beds). Taking into account the results of tritium, ^{14}C and stable isotopes determination one should accept the various age of the described waters within the range of particular structures. It varies from early Pleistocene to Tertiary inclusive.

HYDROGEOLOGICAL PROBLEMS OF THE MINING

The territory of about 4730 km^2 with the resources of about 32 milliard tons, has been delimited in the LCB which, according to the present detailed geological prospecting and at present technico-mining and economic conditions may be the subject of mining development.

The original intentions anticipated the building of 6-7 mines which were to produce 6.3.million tons in 1985 and 24.6 million tons in 1995. At the moment the building of only 3 mines is planned. So far 5 mine shafts have been or are still being deepened, out of which one was flooded.

While carrying out the building of the vertical and then horizontal mine workings started in 1975 it has been observed that the mining-geological and particularly hydrogeological conditions of the deposit are more difficult and complex than it was evaluated on the basis of the drillings. A dozen or so such drillings were carried out on the area of the first designed mines.

The shafts of the first piloting K-1 mine and the following K-2 mine with the depth of about 1000 m had to be deepened by means of a deep-freezing method and a cementation method due to the occurence of the above mentioned two water-bearing complexes in the Carboniferous overburden. Particularly difficult was the shafts' going through the sandy Albian strata. Though they are only a few meters thick, however, in the conditions of the undrained rock mass they are under big pressure of water occuring in the overlying Upper Jurassic fissured limestones. In such a situation the sandy Albian sediments are of the swimming sand character. Among others, the difficulties resulting from the occurénce of this thin stratum of the swimming sands at the depth of about 600 m were the reason of flooding of the shafts of the piloting mine.

The hydrogeological examination by means of drillings from the surface did not provide all the necessary information to work out quite reliable predictions of the magnitude of water inflows to the buit mines. In concerns in particular the coefficient of hydraulic conductivity and the coefficient of storage. Also the problem of hydraulic contacts between particular waterbearing complexes and the possibilities of exchanging water in the conditions of mining drainage as well as the hydrogeological role of faults are still not recognized. These unexplained problems as well as differntly accepted technical data concerning the magnitude of the predicted water inflows to mines including the ones obtained by means of the electric modelling method (Haładus, Kulma and Wilk, 1982) differ to a large extent. The summing up of the results of carried out calculations is to be found in the work by Różkowski (1983).

Depending on the accepted assumptions and parameters the evaluated by different authors inflows to the first mine K-1 were to be from 5 to about 19 m^3/min. At present for the purpose of dewatering designing it is accepted that in the first period of the existence of mine covering the extraction of the lower bundle of coal seams the inflow will be about 10 m^3/min., and in the second period, when the upper bundle of coal seams will be extracted and the advanced mining drainage of the Jurassic strata will be carried, the inflow will be about 16 m^3/min.

The present inflows to the K-1 mine are not great because they are below 7 m^3/min. Including the inflow from the horizontal mine workings of the total length of about 23.5 km and from one piloting longwall at the depth of about 200 m below the Carboniferous roof is about 4 m^3/min. The remaining amount of water comes from the shafts. Only a small part of water flowing into the horizontal mine workings comes from natural outflows, its dominating part comes from the dewatering of mass rock by means of specially drilled boreholes. Introducing the drainage of Carboniferous strata was to improve work conditions in the area of the piloting longwall as well as to eliminate the difficulties in preserving the mine passages. The advanced dewatering covered the strata occuring above and below the horizons of 920 and 960 m as well as the strata deposited between these horizons.

The boreholes of the diameter of 65 mm are drilled either vertically or at different angles to the height from 25 m to about 100 m. The outflows obtained from these boreholes were quite different, from about 1 to maximally about 400 l/min. The biggest outflows came from the longest boreholes, draining the strata disarranged by the coal extraction with roof caving of the piloting longwall.

The drainage of the floor strata is carried out by means of the vertical boreholes of the diameter of 150 mm drilled downwards from the beds on the 920 and 960 m levels. The depth of the boreholes is no more than 10 m. They are situated in mutual distance from 50 to 100m.

The yield of these boreholes is small, from 5 to 20 l/min. Their aim is the disposal of water margins in beds and protecting against the increase of claystones humidity which causes the swelling of the gallery bottom.

The measurements of the outflows from the drainage boreholes carried out in the workings on the 920 m and 960 m levels in the K-1 mine show that the waterbearing capacity of the Carboniferous strata decreases from the Carboniferous roof towards the more deeply deposited strata. It is also proved by comparing the general magnitude of the inflows, which at the level of 920 m with the length of the workings of about 13.5 km are almost 2.5 times bigger than at the level of 960 m, where the length of the workings is about 10 km.

The decrease in the waterbearing capacity of the strata with their depth is accompanied by the increase of water mineralization and the change of its chemical character. Since this problem is discussed in a separate article from this volume (Adamczyk, Smuszkiewicz, 1987), here we shall only briefly characterize the quality of water flowing into particular levels of the K-1 mine.

The 754 m level: water of the $Na-Cl-HCO_3$ type, mineralization from 1.26 to 1.78 g/dm^3 and pH from 7.5 to 8.6. These waters having been examined during the last 8 years do not change their mineralization. As far as the chemical content and mineralization are concerned they are similar to the waters from the Jurassic waterbearing horizon.

The 864 m level: water is of chemical character and pH analogous to the 754 m level. It differs only in mineralization which ranges from 1.54 to 4.00 g/dm^3.

The 920 m level: water of the Na-Cl or Cl-Na type, thus differing from the water of higher levels. Mineralization is also higher because it ranges from 2.62 to 7.10 g/dm^3. Water flowing out of the caving zone over the piloting longwall in the 382 measure is of the $Na-Cl-HCO_3$ type, thus, in this respect it is similar to the waters of the 864 m level.

The 960 m level: water from this level clearly differs from higher level water. It is only of Cl-Na type and its mineralization is from 6.5 to 10.2 g/dm^3.

Changes in the yield of boreholes and the decrease of total inflows with the depth of workings as well as changes in the chemical contents of water and its mineralization both in time and in space throw some light on the problem of the origin of waters flowing into mine workings. They point to the fact that these waters come mainly from draining of static resources. Certain part of the volume of the inflowing water is connected with elastic properties of it and of the host-rocks. It is released due to the existence of the distressed zones forming round the new mine workings. Fine cracks appearing in these zones drain the water contained in the pore spaces. Bigger cracks, e.g. these which occur above the caving zones of the piloting longwall in the 382 measure and the zones of rock loosing connected with the local tectonic-structural phenomena are certainly ways of water migration from further distances.

It is characteristic that not the sandstones beds, as one could expect, but coal seams are the main waterbearing strata in the K-1 mine. It can be explained in this way that coal has smaller tensial strength than sandstones and shales and that is why it undergoes stratification most easily due to the extraction of the lower bed. Thanks to it can become a better water collector than the surrounding rocks.

The source of water hazard for the K-1 mine is a very rich groundwater reservoir in the fissured Jurassic formations (Wilk, 1985) characterized by high water pressure. In the non-lowered water pressure state it is about 7 MPa on the Carboniferous roof. The direct hazard from the side of the Jurassic waters for the workings driven in the Carboniferous near its roof surface (the upper bundle of coal seams) is even higher because the lower part of the profile of the Jurassic is characterized by high hydraulic conductivity (of about $3.7x10^{-5}$ m/s). The lower section of the profile of the Jurassic is represented by a series of weak rocks (mudstones, claystones and weak sandstones) which under the conditions of great hydraulic gradient may enter the state of swimming sand. Besides, there are buried erosional valleys in the Carboniferous roof filled with the above mentioned weak sediments. The localization and depth of these valleys is not exactly known. The highest section of the profile of Carboniferous strata is also weathered. The depth of the weathering zone counted from the Carboniferous roof is evaluated between 20 and 50 m.

Water hazard on the side of the Jurassic strata practically makes it impossible now to start extracting the upper bundle of coal seams. To protect mines against water hazard on the side of the waterbearing Jurassic formations it is necessary to leave safety shelf in the Carboniferous roof. It has been established (Opinia ...., 1981) that thickness of this shelf (counted from the roof of the compact non-weathered Carboniferous strata) should depend on the Jurassic water pressure on the level of the Carboniferous roof. With water pressure begger than 1.5 MPa the thickness of the protection-shelf should be 80 m and after total dewatering of the Jurassic until its floor, the thickness of the safety-shelf can decrease to 20 m. Horizontal safety pillars of the width of least 20 m are to be left along the main faults. It is dictated by the fact that with the so far made mine workings no hydrogeological role of the faults with big amplitude of throw and regional range which limit the mining fields of the first mines has been discovered. One should, however, take it into account that in case of opening such a fault-zone with the working driven in the roof part of the Carboniferous system big hydraulic gradient will occur in this zone. In consequence, water flowing in it out of the Jurassic strata may cause erosion of the primarily weak and cracked in the fault zone Carboniferous rocks. It could lead to difficulties and even disaster.

The current experience with crossing small tectonic dislocations with mine workings prove that the cracks of these faults are tight or filled with clay and do not carry water. The big depth of the currently carried out works and the claystone character of the rocks surrounding coal beds enable to suppose that cracks of the faults with big amplitude will also be tight.

Due to the character of the source of water hazard and, so far, their not full identification, the K-1 mine coal deposit was classified entirely into the highest, i.e. the third degree of water hazard. In the K-2 mine the Carboniferous formations to the depth of 150 m from its roof were classified to the third degree of water hazard, and the remaining part of the mine deposit was classified to the second degree of the water hazard (Opinia ..., 1981). In this situation, in order to obtain the permission of the mining authorities to extract the coal seams situated within the above mentioned safety shelf, it would be earlier necessary to dewater the Jurassic formations lying above the Carboniferous ones. Having established the hydraulic the between water occuring in the Jurassic and Carboniferous formation, one should take into account the fact that under the influence of the extraction of the lower bundle of the coal-seams a very drainage of the Jurassic may follow. The total dewatering of the Jurassic horizon would, however, last very long. Thus, in order to make it possible earlier to extract the coal-seams of the upper bundle, the planned Jurassic drainage is expected with the drillings from the specially made workings. Different concepts of such an advanced, planned drainage have been taken into account. One of them would consist in making the system of galleries and pump chambers in the Carboniferous system within the above mentioned safety shelf and drilling in them the boreholes upwards, to the Jurassic strata . Another version of the way of the Jurassic dewatering worked out in the Central Mining Institute, anticipates the drainage of the lower part of the Jurassic from the workings made in its middle, least permeable part. For this purpose, short galleries were suggested to be driven from the existing 3 shafts several kilometers apart, the building of the pump chamber with the capacity of 10 m^3/min and then drilling the boreholes askew downwaters. The number and length of the boreholes and spontaneous water outflow capacity from the boreholes should be selected in such a way as not to exceed the pump chamber capacity. The evaluation of the effectiveness of such a method of doing away with water hazard of the K-1 and K-2 mines will be possible only after some time of its functioning. So far, the first works have been attempted aiming at introducing this method on one of the shafts at the depth of 640 m.

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