THE HYDROGEOCHEMICAL ZONES OF THE CARBONIFEROUS FORMATIONS OF THE K-1 MINE IN RELATION TO THE REGIONAL HYDROGEOLOGICAL SURVEYING OF THE LUBLIN COAL BASIN /LCB/

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ABSTRACT

The results of several-year studies on the water chemistry of the inflows of the Bogdanka K-1 piloting mine allowed for vertification and precising of the hydrogeochemical zone pattern of that part of the Lublin Coal Basin, recognized earlier in the regional aspect, basing on the surveying of bore-holes. Water chemistry of borehole waters was examined and found to show the regular vertical hydrochemical zones, typical of coal basins.

Shaft and horizontal mine workings as well as the exploitation of the first and second longwalls permitted a through sampling of waters flowing out from the Carboniferous formations.

The occurence of vertical hydrochemical zones was found, being manifested in the water mineralization increasing with depth (from ca. 2000 mg/dm^3 at 754 m, through 4500 mg/dm^3 at 920 m, to ca. 10.000 mg/dm^3 at 960 m) and determined by a succession of chemical types of water. The types alter from the Na-Cl-HCO_3 through the Na-Cl to the Cl-Na. Hydrochemical indices to change as well, from among which the rNa : rCl index changes most (from 1.84 to 0.93).

The hydrochemical zones pattern obtained from a mine workings survey differs from that obtained from a boreholes survey.

INTRODUCTION

Studies on the water chemistry of water samples taken from bore-holes in the LCB showed the occurence of the regular hydrochemical zones, typical of artesian basins (Różkowski, Rudzińska 1978). The zonation is manifested mainly in the water mineralization growing with depth, the determined succession of the chemical types of water, and alterations in values of the hydrochemical indices, mainly of the rNa : rCl index. Results of water analyses of effluents, outflows and outdroppings in mine excavations allowed for precising of the pattern of the distribution of waters of various mineralization and chemical composition in the Carboniferous and its overburden.

The description of the vertical and horizontal hydrochemical zones presented in this paper is based on more than 200 chemical analyses of water samples taken during in the boring deeping of shafts and in the first horizontal workings in the K-1 mine (Table 1). Since no results of the chemical analyses of the upper part of the shaft profiles (the Quaternary and Upper Cretaceous) were available, to characterize that zone the authors used the results of the analyses of water samples taken from bored wells of the Cretaceous formations of the mining area of the K-1 mine.

Since a detailed characteristics of the water chemistry of water-bearing horizons opened by mine workings is presented by the authors in other paper : (Adamczyk, Smuszkiewicz in Różkowski, Wilk (ed.) in press). Hence, only the points of it being essential for the subject of this paper are presented below.

RESULTS OF STUDIES AND DISCUSSION

Confirming the bore-hole data of Różkowski and Rudzińska (op. cit.), the results of the studies on mine workings allow three hydrochemical zones to be distinguished in the vertical profile of the LCB. The first one, i.e. the active water exchange zone, is

Table 1
Essential characteristics of the water chemistry of waters from water-bearing levels splitted by mine workings of the K-1 mine

Stratigraphic affiliation of the sampled effluents and outflows		Number of analyses	Mineralization	Concentration of main ions (mg per dm^3)					
				Ca	Mg	Na + K	HCO_3	SO_4	Cl
				minimum mean maximum					
Lower Cretaceous		16	864 1273 1583	1 4 15	1 5 10	241 306 537	159 382 603	30 84 135	205 333 546
Jurassic		46	788 1375 2384	1 5 15	0 6 9	216 460 854	226 448 854	4 19 142	175 337 1060
Carboniferous	The level of 754 m.	34	1240 1630 2169	0 6 36	2 7 36	395 565 726	342 438 520	5 17 48	370 616 925
	The level of 864 m.	30	1545 3508 4006	1 14 36	1 12 23	493 1157 1416	482 842 1180	0 46 281	413 1120 1880
	The level of 920 m.	34	2622 4490 7060	14 27 102	6 29 81	902 1553 2576	67 802 1457	0 36 228	809 2040 3800
	The level of 960 m.	23	6555 8430 10260	9 107 141	52 87 119	2388 3106 3703	119 353 501	0 20 89	3400 4689 6000

connected with the formations of the first water-bearing Quaternary-Cretaceous complex. These are freshwater of a medium hardness their mineralization usually up to 800 mg/dm^3, and the chemical type HCO_3-Ca-Mg or HCO_3-Ca-Na. The water chemistry of the zone is determined mainly by the processes of dissolving of components of the rocks the waters circulate within. The processes depend mainly on the carbonate balance of the waters.

The second hydrochemical zone distinguished by the authors comprises the water-bearing complex connected with the formations of the Lower Cretaceous, Jurassic and the upper part of the Carboniferous to the mine level of 754 m down. It is separated from the first, upper zone, with a complex of almost 400 m thick, poorly permeable and impermeable Cretaceous formations. In respect of the main hydrochemical index used for the distinguishing of hydrochemical zones, i.e. the r Na : r Cl index whose mean value reaches more than 1.3 in the waters of the discussed zone, these waters should also be included to the upper zone of the active exchange. However, the difficult conditions of the water feeding and exchange as well as the chemical type being different from that of the waters of the mentioned above upper zone, were the reason for the distinguishing of this zone in the present paper. The mean value of the sodium-chloride index is yet lower in this zone.

The waters occuring within the Lower Cretaceous, Jurassic, and Upper Carboniferous formations show a very similar chemical composition; sodium (sodium and potassium), hydrogen carbonate and chloride ions predominate. These are mainly waters of the Na-HCO_3-Cl, Na-Cl-HCO_3, and HCO_3-Cl-Na types. A marked increase of mineralization with depth becomes observable in this zone (Fig. 1).

The value of the r Na : r Cl index within the second hydrochemical zone charges in a rather wide range even in waters of the same lithostratigraphic link (Fig. 2, Table 2).

Table 2. Values of the rNa : rCl index in the K-1 mine inflows

Stratigraphic affiliation of the sampled outflows and effluents	Index value		
	the lowest	mean	the highest
Lower Cretaceous	1.35	1.78	1.93
Jurassic	1.23	2.01	2.92/5.2
Carboniferous mine, level of 754 m	1.31	1.44	1.65
Carboniferous mine, level of 864 m	1.16	1.33	1.84
Carboniferous mine, level of 920 m	0.97	1.10	1.19
Carboniferous min, level of 960 m	0.93	0.95	0.98

The inflows of the mine level of 864 m show a higher mineralization and a higher concentration of the main ions determining the chemical type of water, than the inflows of the horizontal mine workings at the mine level of 754 m. (Fig.1). However, they represented the same chemical type as the waters occurring above, i.e. the Na-Cl-HCO_3 one.

While the mine working inflows of the mine level of 846 m can be included to the second hydrochemical zone distinguished by the autors, the ones of the region of the longwall at the mine level of 920 m, despite that they are connected with the same coal bed, represented the intermediate type, between this and the third zone.

The chemical type shifts from Na-Cl-HCO_3 (characteristic of the mine level 864) to Na-Cl and Cl-Na, and except the outflows of the goaf zone the values of the rNa :rCl index approximate to 1.0, in single samples being less than 1.0 (Table 2, Fig. 2).

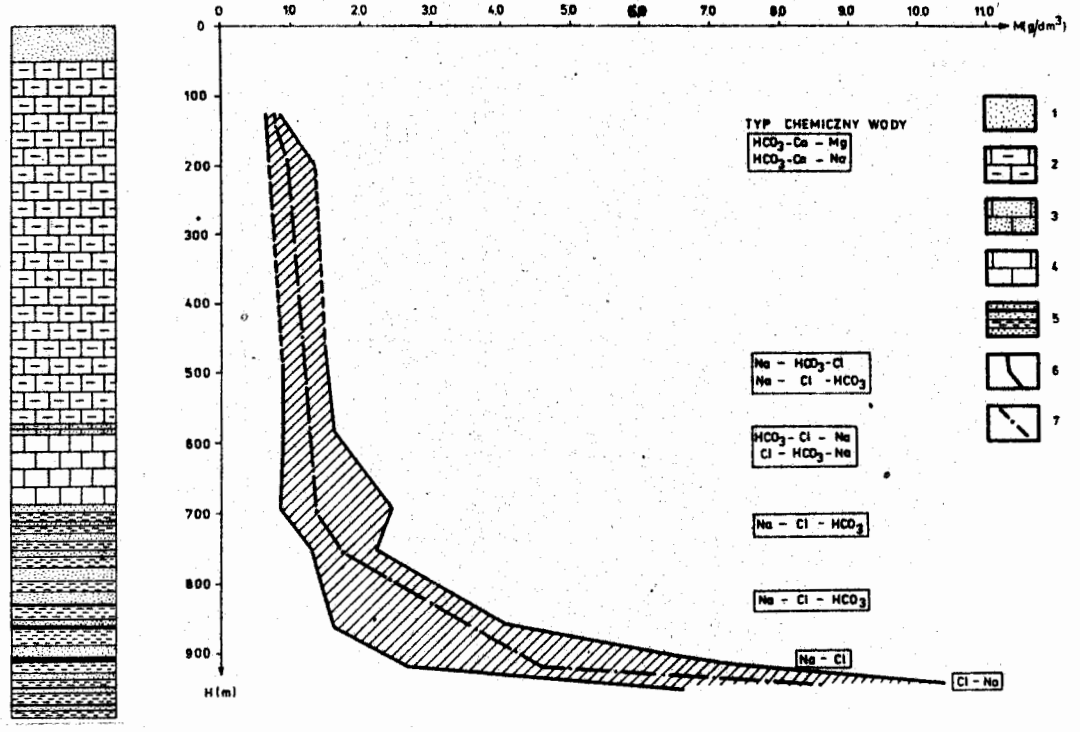

Fig.1. Variations in mineralization and chemical types of the waters of Bogdanka mine with depth
1 - Quaternary, 2 - Upper Cretaceous, 3 - Lower Cretaceous alb., 4 - Jurassic, 5 - Carboniferous, 6 - bondaries of the area of variations in waters mineralization, 7 - statistically averaged diagram of mineralization variations with depth.

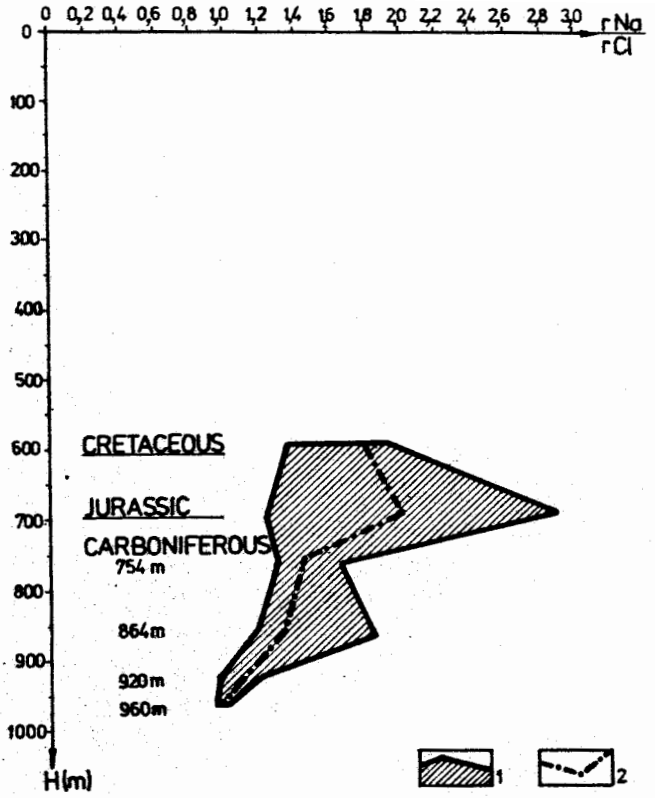

Fig.2. Depth changes in the rNa : rCl value in water inflows of the K-1 mine 1 - area of the alterable index value, 2 - mean index value.

The third hydrochemical zone distinguished by the authors comprises the Carboniferous formations below the depth of 920 m. There occur only waters of the Cl-Na type. The value of the r Na : r Cl index is lower than 1.0 and ranges from 0.93 to 0.99. It is the zone of a difficult water exchange and a poor contact with atmospheric waters.

In a commonly accepted division into hydrochemical zones this zone would belong to the second (medium) zone, whereas the ones described above should be included to the upper zone.

The Carboniferous formations, and partly their overburden are characterized by reductive conditions. The sulphate-chloride index ($r\ SO_4 \times 100$) : rCl in most cases does not extend the value of 1.0, decreasing continuously with depth within the Carboniferous.

Depth changes in mineralization (Fig. 1) can be divided into two intervals. Its value is growing relatively slowly up to 900 m deep, altering from about 1.5 to 4.0 g/dm^3 at the depth of 500 m and 900 m respectively. Deeper than 900 m a rapid increase of mineralization can be observed, its values ranging from about 4.0 to over 10.0 g/dm^3 at 900 m and 960 m respectively. The value of the mean hydrochemical grade in the studied interval of Carboniferous formations and their overburden (i.e. from ca. 500 m to 960 m) is about 65 m per gramme per dm^3, that of the hydrochemical gradient being about 1.5 gramme per dm^3 per 100 m.

The pattern of the vertical hydrochemical zones (Fig. 1) indicates that the waters of the Jurassic formation represent the chemical type being characteristic of the higher hydrochemical zone. The values of the r Na : r Cl index are higher than in the overlying Cretaceous (Fig. 2). It would indicate better conditions of water flow and exchange in the Jurassic than in the lower part of the Cretaceous.

In general, especially within the Carboniferous formations, it is observable that the conditions of water exchange are getting worse with depth. This is indicated by the values of the r Cl : r HCO_3 index increasing from about 1 - 4 in the Cretaceous, Jurassic and the upper part of the Carboniferous, to more than 10 at mine level of 960 m, with the simultaneous Jurassic in the values of the r HCO_3 + r SO_4 : r Cl index, from 0.4 - 0.5 to 0.05 respectively.

Fig.3 shows a diagram of depth changes in mineralization, elaborated on the basis of all chemical analyses of the water inflows of the Bogdanka mine workings. The curve illustrating the changes has been statistically determined by means of a regression analysis. Its formula for the studied depth interval is y = a + b : x. The correlation coefficient between H (depth) and M (mineralization) for this model of fitting is r = 0.91. The course of mineralization is typical of the process of freshening of a sedimentary basin. It is comparable with the typical of the Upper Silesian Coal Basin (USCB) diagrams of depth changes in mineralization- presented in Fig. 3B. The areas of the USCB that are covered with Miocene formations, where the processes of freshening are poorly marked, are characterized by a "convex" curve, as in Fig. 3B (region of the Silesia mine-I, region of Rybnik - II). The hydrogeologically uncovered regions the central and eastern parts of the USCB are characterized by a "concave" curve, being similar to that characteristic of the LCB. It is well to add, however, that unlike in the LCB, in no part of the USCB waters of the mineralization of about 10 g/dm^3 can be found 1000 m deep. In general, even in areas hydrogeologically uncovered disturbed by a long-lasting mine exploitation, the occurence of strong brines is observed at 500 - 700 m. The data presented above suggest that the USCB and LCB differ in respect of the conditions that determined the chemical composition of the waters occurring within the Carboniferous formations.

Analysing of the water samples taken from the airway and from the region of the Ist longwall allowed for the recognition of

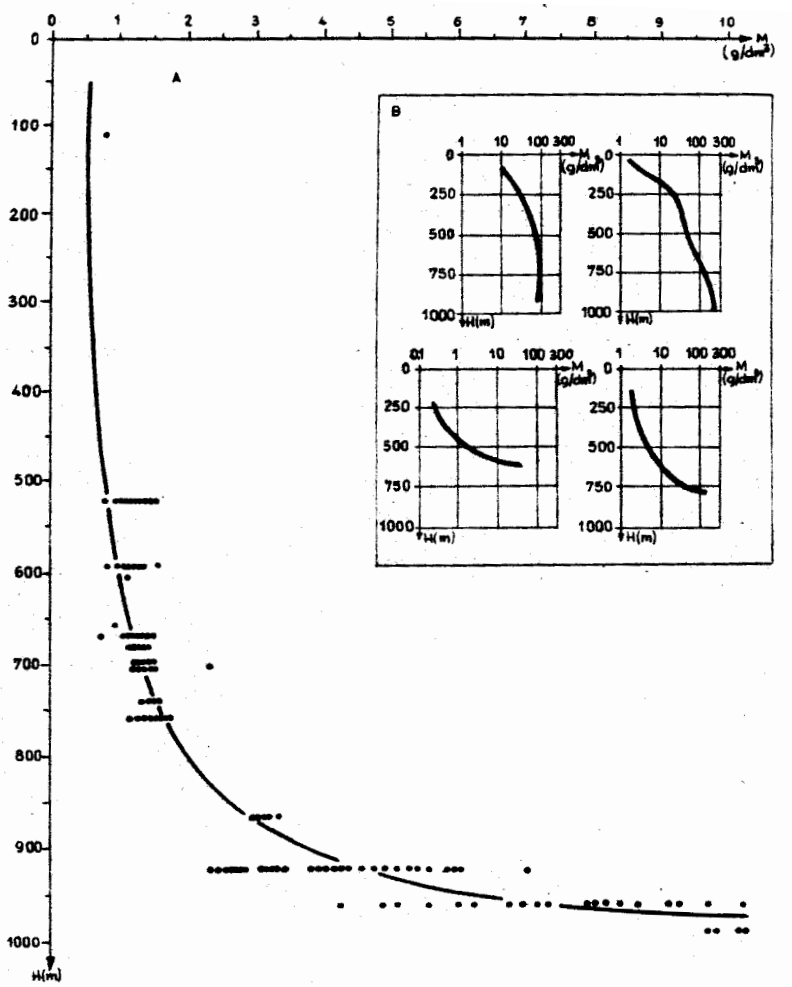

Fig. 3. Diagram of depth changes in mineralization of water inflows of the K-1 mine (A) related to chosen profiles of depth changes in mineralization in the Upper Silesian Coal Basin (B) - I-region of the Silesia mine, II - region of Rybnik, III - eastern part of the USCB, IV - basin of Bytom.

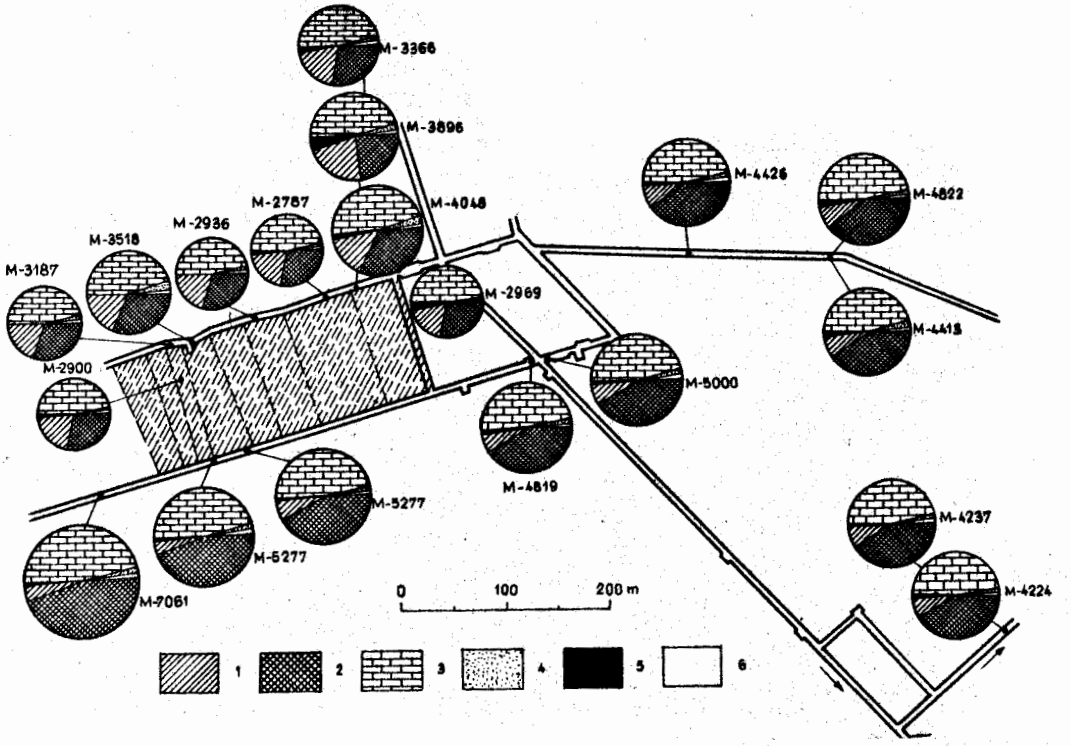

Fig.4. Map of the water chemistry of the inflows of the extraction gallery (longwall) region of the K-1 mine (the level of 920 m) drawn according to the strate in the end of 1983, 1 - HCO_3, 2 - Cl, 3 - Na + K, 4 - Mg, 5 - SO_4, 6 - Ca.

the pattern of the horizontal hydrochemical zones of coal seams 382 in its part opened by mine workings. The zones are illustrated by a map (Fig. 4). It should be explained, that the pattern presented by the map concerns coal seam 382, whose deposition depth ranges from about 884 m (region of shaft 1,4) to 920 m (region of shaft 1,2). Hence, the map presented in Fig. 4 does not strictly correspond to the horizontal hydrochemical zones of a particular depth profile, but is a map of the chemistry of the waters occurring within coal seam 382.

The vertical hydrochemical zones described above permit the correct interpretation of the pattern presented in Fig. 4.

The observed higher mineralization values of waters in the region of shaft 1.2 than of those of the region of shaft 1.4 resulted undoubtedly from the fact, that in the previous region samples were taken from the effluents located about 60 m deeper. However, in the region of the long-wall waters showing a relatively low mineralization value (ca. 3 g per dm^3) and high values of the r Na : r Cl index are found. These are mainly the waters of the goaf zone, that is, the ones that shifted from upper parts of the Carboniferous. Hence, a relatively rapid "freshening" of the waters occurring at the level of 920 m is observed as a result of disturbance of the rock mass. The process of freshening of waters within Carboniferous formation, that is caused by technological factors, is probably overlapping the considerably slower process of the natural freshening, whose lasting is measured in terms of the geologic time. The natural freshening is associated with the regional descending flow of waters within the Jurassic and Westfalian formations, from SE to NW.

The available data amount does not allow for a more detailed discussion on this problem as well as for the decision whether the regional direction of the water flow and the resulting process of freshening of the Carboniferous formations is distinctly reflected in the water chemistry of the Bogdanka mine waters.

Further studies on the chemical composition of gravitational waters coupled with studies on pore solutions unable to be gravitationally bleeded, should provide interesting data on the subject.

In spite of the short, about 3-year period of observations on the level 920 m, some tendencies are observable in the effluents and outflows of this level. For instance, the total water mineralization has been found to decrease with time. This will be noticeable, if we compare the maps illustrating the chemical composition of the waters of the level 920 in the particular years.

Now it is difficult to foresee the further course of the changes with time. No doubt they would be dependent on the vertical range of the mining impact and the resulting inflow of waters from upper parts of the Carboniferous.

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