THE ORIGIN OF GROUNDWATERS IN THE UPPER SILESIAN COAL BASIN (POLAND)

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ABSTRACT

The paper describes the environmental isotope investigation carried out in order to study the origin of groundwaters at the area of the Upper Silesian Coal Basin. Both chemistry and isotopic composition permit three groups of waters to be distinguished in the coal basin: meteoric waters of the last infiltration stage (1), mixed infiltration and relict waters (2), and relict (synsedimentary) waters (3). The artificial hydraulic interconnections created by mines activities and deep drainage cause changes in the natural isotopic composition of groundwaters. The isotopic investigations have given an indication that the depth of the extention of infiltration waters in the Upper Silesian Coal Basin is variable and depends mainly on the depth of mining, drainage activity and geological conditions of the area.

1. INTRODUCTION

The origin of groundwaters at the area of the Upper Silesian Coal Basin is still controversionally interpreted by specialists. New environmental isotope data of these waters permit to perform new interpretation (Różkowski and Przewłocki 1974, Przewłocki and Różkowski 1984, Grabczak and Zuber 1985). The isotope investigations have given an indication too that the depth of the extension of the infiltration waters in the Upper Silesian Coal Basin is variable and depends mainly on the depth of mining, drainage activity and geological conditions of the area (Różkowski 1985).

The environmental isotope studies of groundwaters in the Upper Silesian Coal Basin have been carried out also to determine the sources and zones of waters inflows to the mine workings.

2. GENERAL HYDROGEOLOGICAL CHARACTERISTICS

The Upper Silesian Coal Basin, the greatest coal basin in Poland, is situated within the Upper Silesian Variscitic intermontagne depression, the geological development of which has been effected by the Variscian and Alpine orogenies (A. Kotas, 1983).

The productive Carboniferous includes sandstones, conglomerates, mudstones and siltstones as well as coal banks. The thickness of the productive Upper Carboniferous reaches 8 200 m.

The Carboniferous deposits are covered ba the discontinuous series of Mesozoic carbonate rocks of about 150 m thickness in the northern and eastern parts of the depression and by clayly Tertiary rocks in the southern and western parts (Fig.1).

The northern hydrogeological region (I) is uncovered in hydrogeological sense. Palaeozoic deposits forming Variscian structures outcrop here directly or they are covered with permeable Mesozoic deposits. The feeding of the Carboniferous aquifers occurs at their outcrops and through the permeable capping.

The draining of aquifers in the productive Carboniferous occurs mainly artificially as the result of water pumping by coal mines which drain the orogen to the depth of ca 700 m in general.

The southern hydrogeological region (II) is hydrogeologically

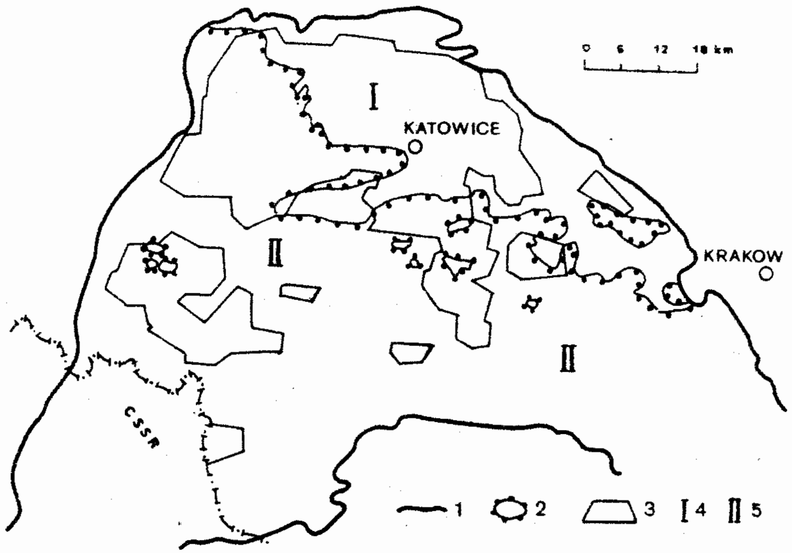

Fig.1 Upper Silesian Coal Basin

1-extension of the Upper Silesian Coal Basin, 2-extension of the isolating series of the Tertiary deposits, 3-coal mine area, 4- 1-st hydrogeological region, 5- 2-nd hydrogeological region

covered. It comprises the southern and western parts of the Upper Silesian Basin. Here the Palaezoic is covered with an impermeable complex of Tertiary clayey deposits which isolates the underlying Carboniferous aquifers from atmospheric waters. The zones of regional dislocations are latent draining areas of the Palaeozoic aquifers. The aquifers of the productive Carboniferous are locally drained due to the mining activity.

There is observed in the Upper Silesian Coal Basin the increase of the total mineralization of groundwaters with depth from 0.2 until 372.6 g/dm^3 (Różkowski A., Rudzińska T., 1983).

Hydrochemical zonality recorded at present is marked by the sequence of chemical types of waters: $HCO_3 \rightarrow SO_4 \rightarrow Cl$.

Five hydrogeological cycles are recognized in the hydrogeological evolution of sedimentary basin in the Upper Silesia from Carboniferous to Quaternary inclusively (Różkowski and Przewłocki, 1978). Based on the result of the Oszczypko (1981) investigations the Alpine orogeny and related uplift of the Carpathian Mts, tectonic rebuilding of the depression and sedimentation in the Badenian sea played especially important role in formation of groundwater regime in this basin.

In the Sarmatian, simultaneously with the Badenian sea regression there started still lasting process of replacement of relictic waters by meteoric waters. Those infiltrated in the feeding areas on the northern part of the basin. Hydrochemical and hydrodynamic zonality recorded at present is the result of interaction of the present gravitational and deep sedimentational hydraulic systems.

3. ORIGIN OF THE GROUNDWATERS IN THE LIGHT OF THE ENVIRONMENTAL DATA

Meteoric waters of the last infiltration stage lasting on from Sarmat to Holocen inclusively form contemporary gravitational system of circulation. They recharge directly or indirectly Carboniferous water-bearing strata in the whole I-st open hydrological region and locally, through the hydrological windows in the II-nd region. They are also filtering along down the formation squeezing out relictic waters or mixing with them themselves.

This process illustrates dependence between $\delta^{18}O$ and δD (Fig. 2). On the diagram at the background of precipitation line described by the equation: $\delta D = 8\delta^{18}O + 10$, one can distinguish 3 groups of waters: meteoric waters of the contemporary infiltration stage, mixed and synsedimentic ones varying among themselves in the stable isotope composition. Abundance of those waters in the frames of particular groups determine their position in the dynamic system of the Upper Silesian Depression.

4. METEORIC WATERS OF THE LAST INFILTRATION STAGE

Meteoric waters of the last infiltration stage recharge directly or indirectly Carboniferous aquifers in the whole I-st region and locally, through thy hydrogeological windows, in the II-nd region. They also filter along down the formation squeezing out the conate waters or mixing with them. This process illustrates the dependence between $\delta^{18}O$ and δD (Fig.2).

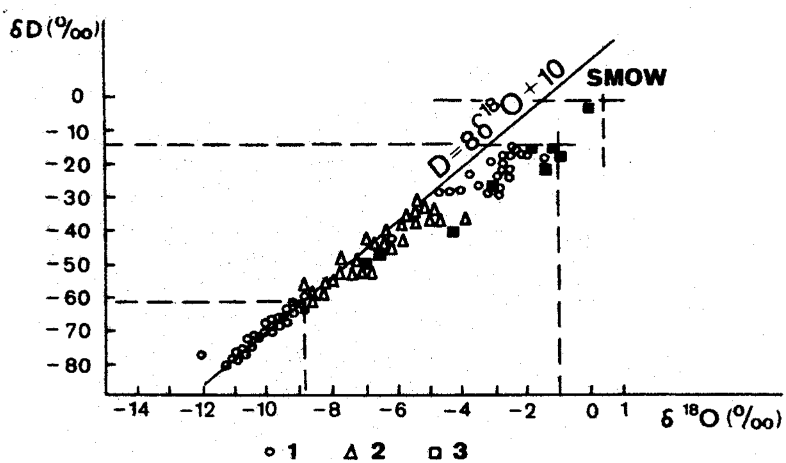

Fig.2 $\delta^{18}O$ plotted against δD for Upper Silesian Coal Basin waters

1 - waters from the Carboniferous under permeable cover (I-st region), 2 - waters from Carboniferous under the impermeable Tertiary (II-ud region), 3 waters from the Tertiary formation

In the diagram at the background of precipitation line, described by the equation: $\delta D = 8\delta^{18}O + 10$, one can distinguish infiltration waters which all measuring points fall at the precipitation line. To the infiltration group of waters belong those which the $\delta^{18}O$ values vary from -12.1 per mille to -8.8 per mille and δD from -81.0 to -62.0 per mille. Waters from the permeable upper-lying Carboniferous have been sampled together with the natural seepages to the mining works in the I-st hydrogeologic region, locally in the II-nd region. Total mineralization of these waters ranges from 0.2 to about 20 g/dm^3. Generally they belong to the HCO_3-SO_4-Ca-Mg, SO_4-Ca-Mg, Cl-SO_4-Mg, Cl-HCO_3-Na and Cl-Na types of waters. The total range of their appearance reaches about 400 m, locally 600 m, below the day surface due to the active drainage of the Carboniferous orogen by the coal mines. (Fig. 4)

According to Grabczak and Zuber (1983) the closer specification of age of the infiltration waters may be done by estimate of the tritium and ^{14}C contents as well as the stable isotope content. In the Mesozoic formations recharging directly Carboniferous aquifers tritium concentration was found to vary from 5.0±2 TU to 18.2±2 TU, stable isotope composition: $\delta^{18}O$ from -9.5 per mille to -9.0 per mille and δD from -69.0 per mille to -67.9 per mille. These data point out the contemporary infiltration.

In the productive Carboniferous formation, in the I-st hydrogeological region, over 200 mining water samples were analyzed at tritium content and few of them at ^{14}C. Tritium presence varying from 110±10 TU to 8±3 TU was found till the depth 150 to 250 m, locally even up to 300m. On the other hand at the depth 400 m the mining waters investigated by Jureczko (1974) show no tritium presence at all and ^{14}C at the level between 11.1±1 per cent to 30.5±0.6 per cent of modern carbon. Dispersion of the stable isotope composition, $\delta^{18}O$ varying from -12.1 per mille to -8.8 per mille and δD from -81.0 to -62.0 per mille point out at the high climate differentiation at the time of these waters ali-

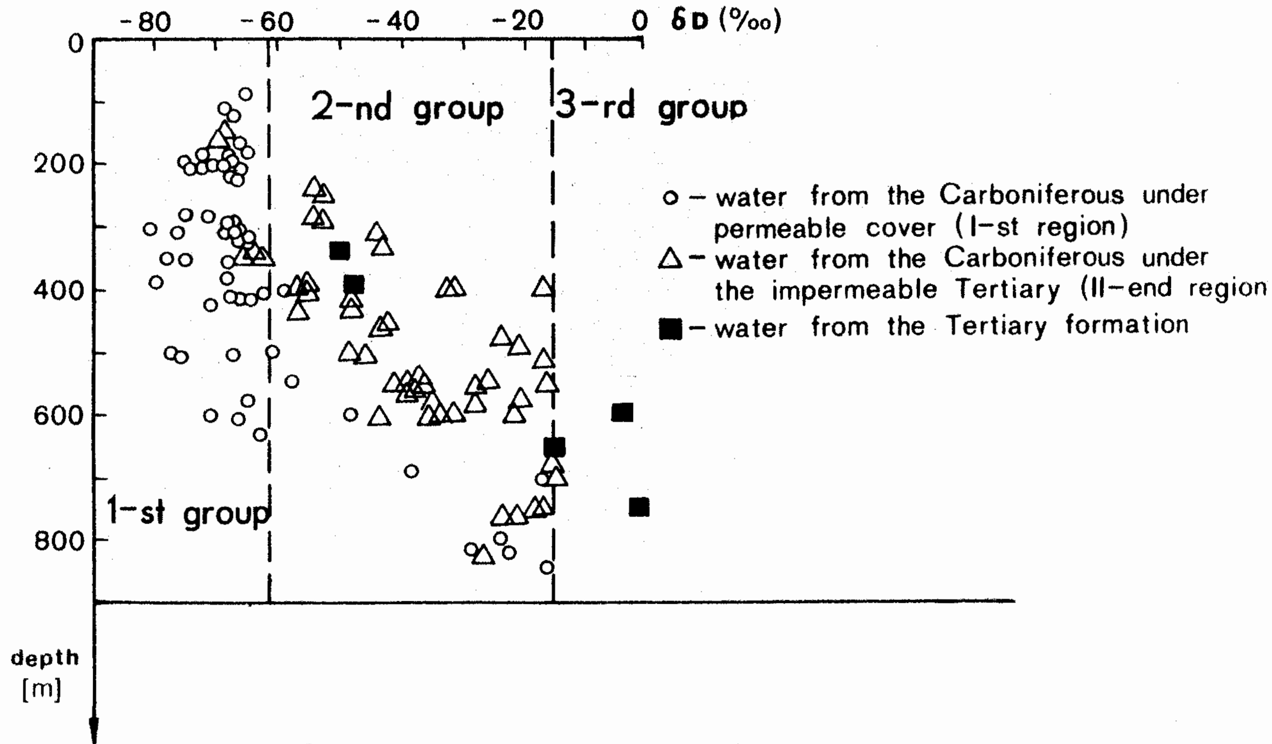

Fig. 3 δD values of groundwaters versus depth

mentation. Utmost low values are characteristic for the could climate. At the basis of all these data one can conclude that the examined waters of the last infiltration stage are of Holocenian and Pleistocenian age, may be partly of the Prepleistocenian age.

A close correlation among the groundwaters mineralization, their isotope composition in the Carboniferous deposits and the permeability of the Carboniferous overburden as well as mining drainage activity is observed. In the first hydrogeological region (I), where the Carboniferous deposits are covered with well permeable stratas and where the intensive coal extraction is carried out above 100 years, the minewater mineralization on the depth of 500 m ranges very often from a few until ten g/dm^3 only. The $\delta^{18}O$ values of this group of waters range from -10.85 per mille to -9.59 per mille and δD from -77.1 per mille to -67.8 per mille. At the basis of the tritium, ^{14}C and stable isotope data one can conclude that these waters are of Holocenian and Pleistocenian age.

The results of the hydrochemical and isotope investigation have shown that in the first region the groundwaters freshening process may exceed locally the depth of 500 m. (Fig. 3).

In the second hydrogeological region (II) where the coal extraction has been carried out mainly about 25 years only and where the Carboniferous deposits are under a capping of the Tertiary clays, the groundwater mineralization on the depth of 500 m varies from 70 to 117 g/dm^3 and $\delta^{18}O$ value range from +0.7 per mille to -4.93 per mille and δD from -3.6 per mille to -37.3 per mille. According to Przewłocki and Różkowski (1984) these waters are mainly the mixture of relict waters of different origin.

On the basis of the tritium investigation results it is possible to define more detailly the turn-over process of groundwaters in the mining areas. It was recorded that before the mining activity groundwater with the tritium content above 5±2 TU extended

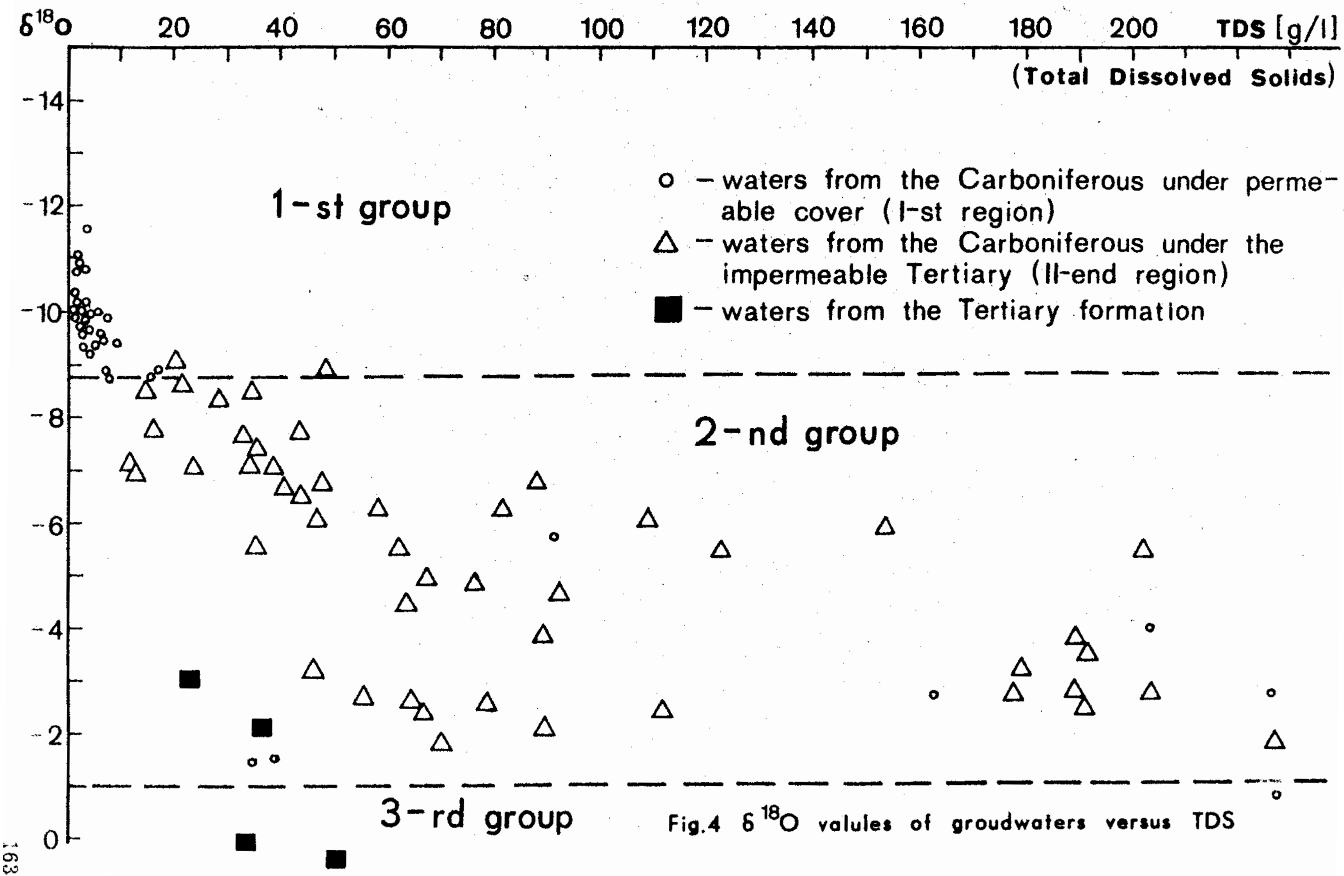

Fig.4 δ^{18}O valules of groudwaters versus TDS

to the depth 60-150 m. Recently mine waters with such tririum content have been recorded to the depth of 200-300 m. It indicates that the zone of young water distribution, of age below 30 years, was enlarged about 100-150 m.

5. MIXED WATERS (II-nd GROUP)

Second group of waters creating separate cluster at the precipitation line (Fig. 2), characterizes itself by the higher concentration of heavy isotopes and significantly differs from isotopic composition of the atmospheric waters of the last infiltration period. $\delta^{18}O$ values ranges here from -7.8 per mille to -0.9 per mille and δD from -62.0 per mille to -15.0 per mille. Within the I-st hydrogeological region this type of waters was sampled at the depth 550 to 850 m, whereas in the II-nd region at the depth 240 to 850 m. Waters discussed here come from the Tertiary and from the productive Carboniferous formations. The total mineralization of waters amounts from 14 to 229 g/dm^3. They belong mainly to the Cl-Na and Cl-Na-Ca type, locally Cl-SO_4-Na type of water. Within the Carboniferous formations no correlation between water mineralization and heavy isotope content has been observed. (Fig. 4).

These waters are a mixture of relict and meteoric water of the last infiltrational stage as well as a mixture of relict water of different ages.

In the zone of dynamic stagnation one meets relictic brines of the Cl-Na and Cl-Na-Ca type. They are characterized by the Na/Cl ratio factor below 0.85 what points out at their high level of methamorphism and their isolation from the influence of infilt -tion waters of the last infiltration period.

Separate points for these waters at the precipitation line (Fig. 2) drive toward SMOW. That suggests that infiltration waters mix with other pore waters squeezed out from the thicker series of the argillaceous marine deposits which had been released as a result of compaction and dehydratization processes. These processes are expected to take place during few hydrologic cycles starting from Carboniferous to the Quarternary periods.

Within the group of mixed waters influence of waters from the last infiltration period is alternate; the value of hydrochemical factor Na/Cl which exceeds 0.85 confirms this statement. This influence in the I-st hydrological region is locally observed even at the depth 600-700 m, particularly at the area of the intensive mining exploitation.

According to Oszczypko (1981) mixed waters occuring in the roof link of the Carboniferous in the hydrodynamic stagnation zone, at the most part of the Upper Silesian Depression are mainly Tertiary epigenetic ones. Chemical composition, anomally high mineralization (351 g/dm^3) in the vicinity of the Tertiary salt deposit grip at the favour of this conclusion.

Kleczkowski et al. (1968) by means of the He-Ar method estimated age of these brines coming from the southern part of the Upper Silesian Depression at 33-105 milion years. So, this suggests possibility of migration of the pore waters to the Carboniferous from the indigenous Tertiary formation as well as from the Carpathian Flych deposits.

Pore waters from the argillaceous Badenian formations were squeezed out into the Carboniferous as a result of compaction and geodynamic pressures during Carpaths lifting up.

According to Jacquin and Poulet (1973) mathematical model compactional pressure distribution within the argillaceous profile of Badenian conditioned the depth of the pore water migration range. As a result of different thickness of Badenian deposits in the Tertiary depressions the compaction flux ranges at the level 700 to 1300 m. These waters parameters such as mineralization, chemical and isotope composition are significantly scattered. Stable isotope composition for $\delta^{18}O$ values varies from -0.9 per mille to -5.7 per mille and δD from -15.0 per mille to -37.2 per mille.

Occurence of the mineralization and isotopic ratio gradients seem to result from the facial differentiation of the Badenian deposits from which pore waters were squeezed out.

In the reservoirs of the Badenian sea at the time deposits from the normally salted sea were sedimenting simultaneously with the chemical deposits from lagoons. Results of observations of the evaporating processes at the Black Sea (Waliashko and all. 1977) confirm the possibility of differentiation of the stable isotope composition in a sea waters.

Depletion of $\delta^{18}O$ and δD values in the group of mixed waters coming from the hydrodynamic stagnation zone may result also from mixing of the Badenian pore waters enriched in heavy isotopes with the highly mineralized paleoinfiltration waters.

Relictic waters formated during the older hydrologic cycles appear within the low Carboniferous links. According to Grabczak and Zuber (1985) stable isotope investigations they are paleoinfiltration waters of Permian age. Partially it may be waters resulting from the compaction and dehydratisation of the thick argillaceous marine Namurian and Visenian.

On the example of the Tertiary formation, at the basis of the stable isotope composition one can observe mixing processes of waters of different origin. Waters from the last infiltration stage mix here with the Tertiary sediment waters with the stable isotope composition corresponding to SMOW (Fig. 2). Mixing rate of these processes is differentiated and depends mainly on the permeability of the Tertiary formation.

Presence of tritium in this group of waters was reported till the depth 100 m. Waters sampled at the depth intervals 160 m to 240 m characterized themselves by mineralization not exceeding 10 g/dm^3 correspondingly ^{14}C content 40.2±0.9 per cent to 31.6± 3.0 per cent of modern carbon, and absence of tritium.

Highly mineralized waters and brines with TDS 15-50 g/dm^3 sampled from the depth 346 m to 750 m revealed no tritium and no ^{14}C content. Stable isotope content in the samples picked up from the same depth intervals varies for $\delta^{18}O$ from -7.1 per mille to +0.3 per mille and for δD from -50.3 per mille to -0.2 per mille. All points fall into precipitation line (Fig. 2).

At the basis of the quoted data dominating role of waters coming from the last infiltrational period within the Tertiary water-bearing formation till depth of 240 m seems to be evident.

Contribution of these waters in the total amount of the mixed waters grows smaller with depth; at the level of 600 m it disappears entirely what confirms stable isotope composition close to SMOW.

6. SYNSEDIMENTARY WATERS

The III-d group of waters separated at the precipitation line (Fig. 2) contains Cl-Na brines, mineralized within limits 35 g/dm^3 to 50 g/dm^3. They were formed as a result of compaction and dehydratisation of the marine Tertiary clays. These waters occur in the sandy inserts of the Badenian argillaceous deposits in the depression zones, at the depth around 600 m. (Fig. 3).

Depression zones are isolated from the influence of infiltration waters what values of hydrochemical indicators, anomalous water pressure, presence of methane and lack of ^{14}C point at (Różkowski 1971). $\delta^{18}O$ and δD values for this group of waters corresponds to SMOW (Fig. 2) what once again confirms their synsedimentic origin. Różkowski (1971) and Dowgiałło (1973) had previously pointed at this. Tertiary age of these waters was also confirmed by means of He/Ar factor for gases dissolved in brines (Różkowski, 1971).

7. CONCLUSIONS

Within the hydrologic profile of the Upper Silesian Depression up to 900 m deep at the basis of environmental isotope data three groups of waters of different age and origin were distinguished.

Subsurface waters coming from the last infiltration period belong to the I-st group. Tritium and ^{14}C dating as well as characteristic stable isotope composition made it possible to prescribe these waters to Holocenian and Pleistocenian age. Mining activity artificially deepens the range of their occurence.

Highly mineralized mixed waters of different origin belong to the II-nd group. At the basis of ^{14}C dating, scattered both stable isotope composition and hydrochemical indicator values inside this group two zones have been distinguished: depleted replenishment zone and hydrodynamic stagnation zone. Inside the 1-st zone the atmospheric waters of the last infiltration stage mixed with the relictic waters occur, whereas relictic waters of different origin occur in the stagnation zone.

Synsedimentic waters occuring solely in the Tertiary depressions belong to the III-d group. Stable isotope composition for those brines correspond to SMCW values.

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