Part II–3 Karst and its correlation with other geological processes (with reference to the zone of influence of Bratsk Reservoir)

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The Bratsk man-made reservoir is situated in the central area of the Irkutsk amphitheatre; it is considered to be peculiar among other reservoirs of the Angara cascade of hydro-power stations. Within the influence zone of Bratsk reservoir numerous exogenic processes develop, both inherited and activized, and newly-forming, which occur in the areas formerly not affected by deformation; the latter were not typical of this region. Analysis of the data concerning the exogenic geological processes (EGP) in the area of artificial reservoirs, and the on-location observations have led to the opinion that the combination of processes produces definite geodynamical conditions, which are more complicated than those caused by single-type processes. Besides, each process developing in the shore area is studied in the light of anthropogenic influence, the Bratsk reservoir with its specific regime of exploitation being considered to be one of the main technogenic factors which contribute to activation and intensification of processes.

In the shore area of the southern part of Bratsk reservoir there is a wide occurrence of soluble rocks such as a gypsum-saliferous-carbonate formations of the Angara and Litvintsev Member of Lower-Mid Cambrian (dolomites, limestones, anhydrite-dolomites and gypsum) (Trzcinski 1996).

Under natural conditions (before the Bratsk reservoir has been made) the superficial forms of paleokarst were presented by large collapse sinkholes and pits (up to 60 m in diameter and 25 m in depth), karst outliers, trenches, blind creeks etc. The subsurface karst forms were presented by caves; the largest of them is Balaganskaya cave, the access to which is now flooded by reservoir water. Substantial deformations of the surface were induced by suffosion.

The construction of the Bratsk reservoir has eminently changed the dynamics of karst processes, especially in the areas of sulphate rock occurrence (Wika et al., 2000; Trzhtsinsky 2002). Here the intensive development of collapse, subsidence and trough forms can be observed. In some settlements (such as Khadakhan and Novonukutsk) the deformations have caused damage to buildings and constructions; some shore zone areas have become unsuitable for industrial and even for agricultural use. It should be noted that in many territories marked by the occurrence of gypsum-anhydrite rocks, the suffosional deformations have been replaced by karst processes, accompanied by formation of new collapse sinkholes of 20 to 38 m depth (Fig. 1). During the period of reservoir filling (1963-1966), up to 200 sinkholes per 1 km^2 (2 to 30 m in diameter and 5 to 28 m in depth) appeared each year in some areas (now flooded). Origination of large-size sinkholes is typical of the early period of reservoir's existence, which was due to the rejuvenation of paleokarstic features; development of sinkhokes in later years has been caused mainly by water table fluctuations, induced by the changes of water level in the reservoir.

Fig. 1. Karst holes on the arable field in the area of Russian Melkhitui.

The main role in activation of gypsum karst belongs to the change of the hydrogeological conditions, which followed the construction of the reservoir (Pavlov, 1978). The highest backwater level is 401.6 m (stated backwater mark), that corresponds to the 30 m-rise of the level in the discussed southern areas. Accordingly the hypsometric level of ground waters has been changed, which entailed the redistribution of cavern water in hydrodynamical zones. The zone of variable water saturation increased in the extent, accompanied by the inundation of the former aeration zone (presented by the heavily cleaved rocks with high penetrative quality). Thus, the zone of vertical circulation decreased in thickness, with the increase of the horizontal circulation zone, which is more dynamical; this has its effect on the development of karst. New hydrogeological conditions determine the resistance of the territory to karst processes; by present time, the area of the Khadakhan-Melkhitui massif is marked by the 16%~18% affection by karst. The resistance of the shore area to karst depends on the distance from the reservoir: the larger is the distance, the higher is the resistance of rocks composing the area. The zone of karst activation in the region is now 6 km wide; maximum rate of origination of new collapses is stated in the inshore zone.

The southern part of the area is marked by a wide occurrence of landslide deformations induced primarily by karst. This territory is the subject of definite apprehensions in terms of the risks of effects of exogenic geological processes, because it is rather densely populated (about 70 persons per 10 km^2) and intensively used for agricultural purposes.

The typical case of the karst landslide development of slopes is the Kazachinsky landslide (The Problems of protection …, 1993). This is the block-type landslide, with depth-creep of slopes; separate blocks of the massif subside into caverns (Photos made in 1969 and 1996). Under the conditions of backwater, the rate of displacement of landslide blocks twice (and even more times) exceeds the natural movements. The maximum rates of displacement time to the periods of reservoir's draw-down (1968-1969; 1975-1982; 1990; 1996-1997).

Displacements of sliding elements of landslides (almost of identical geological profile) ranging from the settlement Svirsk to the Unga-bay, occur by clayey material, which has been formed at the contact of gypsum-anhydrite rocks with limestones and dolomitized gypsum. Several cycles of level variations during the exploitation of reservoir have led to the erosion of diluvium, which resulted in the outcrops of karsting rocks. This increased the infiltration of fresh water into the shore massif and caused the intensive karst processes within the rock mass. The view in plan shows the circles of sliding, which generally do not have the typical round form, rather the landslide blocks are of a rectangular form (Fig.2.). The dynamics of their development depend on the rate of leaching of carbonate rocks (Kozyreva, 2001). Deformation of slopes manifested itself as newly-occurring fissures, trenches and circles. Activation of karst-landslide deformations manifests itself by the yearly rejuvenating collapses, karst and suffosional sinkholes of apparently small size but of considerable depth (> 3 m). At the foot of the slope the horizontal leaching caverns appear, filled with loose material (dolomite powder). During the period of low level the karsting rocks crop out, so that the loose material-filled caverns can be seen. The data of laboratory studies evidence that the alternating inundation leads to the decrease of the unit weight of soil, increasing porosity and water saturation; moistening of the rocks causes the 3.5-time decrease of its strength.

The outcrop of soluble rocks just near the water line causes the formation of definite karst-abrasion types of coast area, which also leads to lowering of the slope stability due to the foot undercutting. The size of cavities depends upon the composition of the cliff's rocks and varies considerably: from 10 cm to 1.2 m in width (wave-cut notch) and 50 cm to 6 m in depth. Gypsum is subject to formation of ephemeric caverns of 30 m-depth and about 2 m in outside diameter.

At present the investigations are carried out at the Laboratory of Engineering Geology and Geoecology of the Institute of the Earth's Crust to evaluate the state and development of processes and their interaction; here the comprehensive technique of instrumental survey and computer data processing is used.

In the area of the Angara-river, below the settlement Bykovo, the interaction of exogenic geological processes has been revealed. A section of the developing slope is presented here, in which the intensely eroded bedrocks are overlain by the channel facies of the structural-aggradational terrace of Quaternary. The landslide displacements have affected the western slope extending for 200~250 m. The slope surface is dissected by erosion. Besides, the additional vibration load arises because of sand quarrying on the area of terrace with the use of heavy machines. The inundation of the slope foot both by reservoir water and the surface waters from the quarrying pit entails the decrease of the bearing power of soil, and formation of landslide steps. The glide surface is presented by intensely weathered argillites of the Verkholensk Member of Cambrian. Another inherited geological process peculiar to this territory but not exposed at the surface is karst. The occurrence of karst is revealed below the 10 m-thick rock mass of Quaternary. According to the data of symmetrical electric

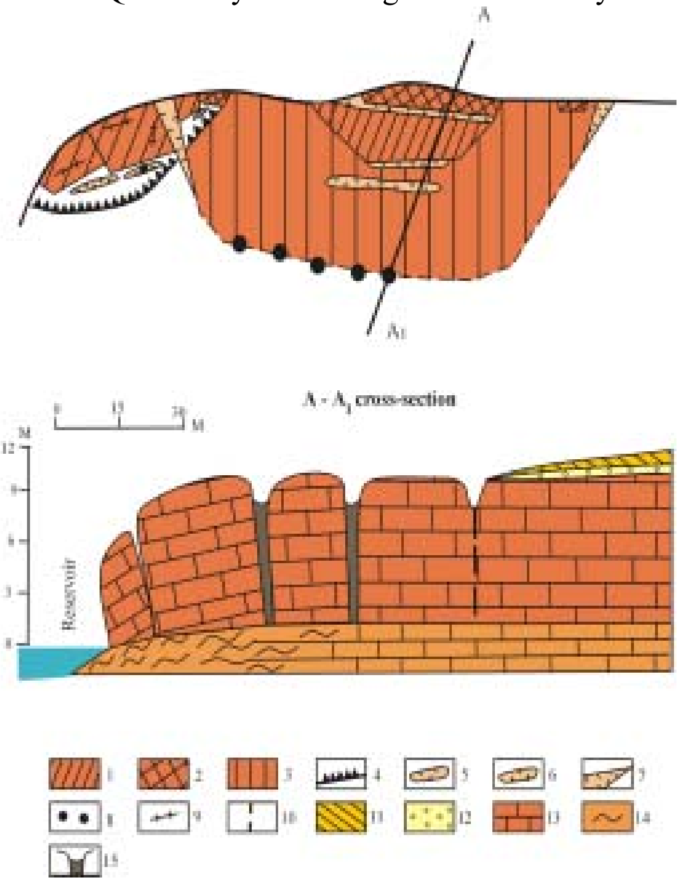

Fig. 2. Schematic plan and geological cross-section of the landslide slope in the cape area of Chaloty bay.

1– sliding block-steps of various height; 2 – small frontal blocks deviated towards the reservoir (detachment type); 3 – implied formation of a new block; 4 – devolvement walls; 5 – trenches with turf-covered boards; 6 – trenches with turf-uncovered boards; 7 – erosion forms developing along fracture zones; 8 – karst-suffosion-landslide holes; 9 – fractures on block-steps; 10 – implied borderline of formation of a new landslide step; 11 – diluvial sandy loam; 12 – sandy-pebble alluvium; 13 – Cambrian carbonaceous rocks; 14 – leaching residuals (clays, dolomitic meal); 15 – debris-filled sliding trenches

profile (SEP), the occurrence of mantled paleokarst is typical of the area; the karst depression has been disclosed by a 63 m-deep drill-hole. Other drill-holes delineated the cryptic karst forms, all of them being filled with water-abundant loose material of high conductivity.

Solid models of the Bykovsky tract have been made (plan of 2001-2002) using the standard software programs (Fig. 3). The analysis and comparison of the results of repeated surveys in the form of situational geodynamic models provide the evidence of the changes in the territory, defining the amount of actual changes with maximum accuracy. Each year the beach scarp piedmont retreats for about 10 meters. In the cases of no retreat, the outcrop of bedrocks is stated, with the formation of notches due to the intense leaching of karsting rocks and additional abrasion, as well as the infiltration of fresh water into the rock mass of the shore. The foot of the circle of sliding was washed out with the ablation of the step and failure of the second landslide step. A new circle originated, in which a scour started to develop. The interaction of different processes induced the development of abrasion-landslide, erosion-landslide, erosion-abrasion and abrasion-karst types of shore slopes. In the area near the settlement Bykovo the outcrops of intensely eroded dolomite bedrocks occur; these are in the zone of variable water abundance, being subject to the wave action only during the high water level stand. Here the NW- and SW-striking wave-cut caves of 1.5 to 4 m depth and 0.7 to 1.5 m height have been formed.

It can be expected, that due to the almost 40-year exploitation of a man-made reservoir the soil-subsidence or formation of anthropogenic karst holes in the rock mass of the Angara Member (dolomite with gypsum intercalations) can occur. Besides, the time of the existence of a reservoir (backwater zone) is sufficient (according to data of V.M. Filippov) for the origination of modern caverns (of up to 1 m diameter) in gypsified rock mass. The time required for origination of such caverns is 12 to 40 years in gypsum mass, 35700 to 52600 years in dolomite and 14900 to 18900 years in limestones (Filippov, 1988).

It should be noted in conclusion, that karst processes in the shore area of the Bratsk reservoir are of the inherited nature and develop primarily in old caverns. Notable activation of karst is associated with technogenic factors. In all cases discussed here, the reservoir is considered to be an important contributor to the change of the shore area massif.

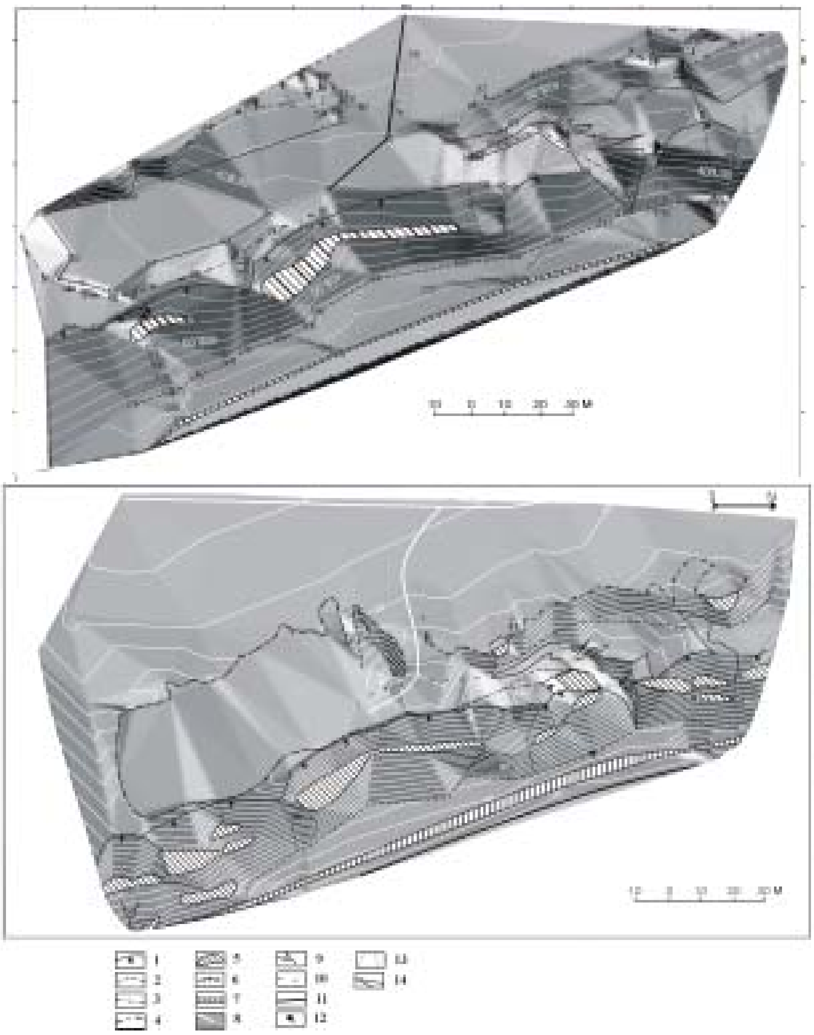

Fig. 3. Volumetric cartographic models of the key segment (2001 – 2002)
1 - brow of devolvement of a landslide cirque; 2 - foot of a landslide slope; 3 - bottom of an erosion form; 4 – quarry; 5 - landslide step; 6 – fracture; 7 - abrasion scarp; 8 - ground road; 9 - landslide-flow; 10 – wash; 11-water line of the reservoir; 12 - spring outlet; 13 - crest between landslides; 14 - brow of an erosion form

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Part II-4 Geogenic and anthropogenic conditions of carbonate rock dissolving within phreatic zone of the Cracow Jurassic karstic area (southern Poland)

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Abstract
The paper presents results of hydrochemical investigations carried on in the nineties within the karstic region of Cracow Upland. The problem of acid rain observed in the vicinity of Ojców area as well as slow vertical migration of sulfate pollution front within vadose zone are presented. Hydrochemical effects of carbonate dissolving within phreatic zone at the regional scale were traced. Sr, SiO_2 and HCO_3 ions were favoured as the tracers useful for dissolving process observation. The correlation between carbonate dissolving and the urban-industrial agglomeration of Cracow proximity was identified.
Key words: fissure-karstic water, carbonate rock solution, transformation of water chemistry

0 Introduction

The Cracow-Czestochowa Upland (CCU) is the most extensive and uniform karst region in Poland. It is a belt of Upper Jurassic limestone extending from Cracow in the southeast to Czestochowa in the northwest on the northeast slope of the Silesian – Cracow Monocline (Fig. 1). The CCU covers an area of 1470 km^2 and forms an Upland 100 km long and 10 to 30 km wide. Residual hills of Paleogene age separated by infilled karst depressions are the most characteristic features of the Cracow – Czestochowa Upland. More than eight hundred small caves are known in this area, but only two of them reach 1 km of aggregate passage length (Glazek et al., 1992).

The hydrographic conditions of the CCU are typical to karst area, such as scarcity of surface water, disappearing and reappearing of surface stream and abundant groundwater. Upper Jurassic limestone complex forms a huge fissure – karst – porous aquifer (A. Różkowski et al., 1996). Cracow Upland is the southern part of CCU. It consists of Olkusz Upland, Krzeszowice trough and Tenczynek horst. The paper presents results of investigation on dissolving of carbonate reservoir rocks by karstic waters conditioned by geogenic and anthropogenic factors on the regional scale. There are also presented regularities of linear distribution of sulfate, chloride and alkalies concentration in these waters.

1 The geological setting

The CCU is formed by a monoclinal belt of Upper Jurassic limestone gently dipping to the northeast. It consists of a thick Upper Jurassic carbonate sequence partly covered by Upper Cretaceous and Cenozoic deposits and underlain by the Middle Jurassic "ore-bearing clays". Typical for this area is block tectonic. Three general types of calcareous rocks may be differentiated in the Jurassic carbonate sequence (Dżułyński 1952, Różycki 1953):

1. Thin-layered marly limestone and marl in the bottom part of the sequence. These rocks are of low permeability and slightly karstified along surface or discontinuities.
2. Layered micritic limestone of the intermediate permeability and karstifiability.
3. Biothermal limestone and massive (rocky) and chalky limestone. These rocks are pure limestone, over 95% $CaCO_3$. They are permeable and strongly karstified. Within these rocks occur large caves and caverns. Karst forms are filled partly or completely with Cenozoic deposits.

The Upper Jurassic carbonate complex was affected by karstification during two periods, namely: 1/ the Early Cretaceous and 2/ Cenozoic (Glazek, 1989).

2 Hydrogeological setting of Cracow Upland

The Upper Jurassic aquifer built of rocky and platy limestones of the Cracow Upland comprises the area of Jurassic outcrops under Quaternary overburden and, in its eastern part, also Cretaceous overburden which show different permeability (Różkowski A. et al., 1997). The Lower Oxford marls form underlying isolating series. Hydraulic connection of water from Upper Jurassic and Quaternary sediments and, in its eastern part, also Upper Cretaceous deposits, exists in vertical profile. Values of permeability coefficient determined on a base of test pumping are in the range from 7.78×10^{-4} m/d to 280.8 m/d. Hydraulic conductivity is highly differentiated as well (1.5×10^{-1} m^2/d to 6687 m^2/d). Storativity of rock massif in the regional scale is 9.9% (Pacholewski, 1984). System of karstic fractures, fissures, bedding plans, and caverns plays a basic rule in water transmissivity through limestones.

The Upper Jurassic aquifer corresponds to a model of shallow karst-fissured basin with free and partly confined water level because of its general conditions of water transmissivity, recharge and discharge. Regional outflow takes place in the NE and E directions under Cretaceous basin of the Miechów trough. The Upper Jurassic aquifer

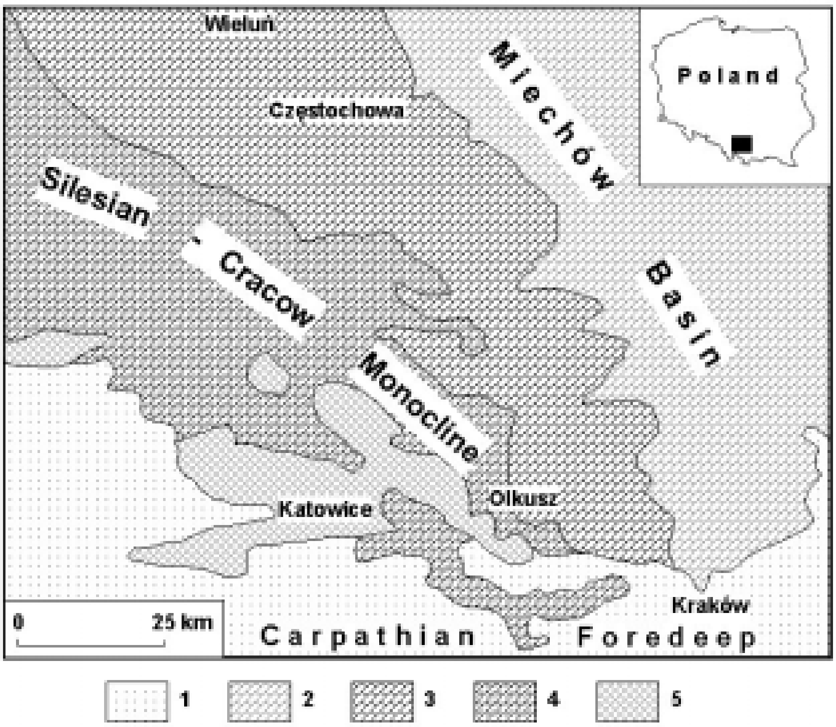

Fig. 1. Position of study area against the background of Alpine structural complex (after A. Kotas, 1985)

Explanations: 1 – Miocene of Carpathian Foredeep; Mesozoic cover of Paleozoic platform:2 – Cretaceous, 3 – Jurassic, 4 – Triassic, 5 – Upper Paleozoic of the Paleozoic platform

is drained mainly by local and intermediate flow systems created by deeply cut valleys of rivers and streams. An average drainage modulus i. e. acquired by modelling studies is 5.5 $dm^3/s \cdot km^2$ (475 $m^3/d \cdot km^2$) (J. Różkowski et al., 2001). This aquifer shows a high yield (safe yield 117,000 m^3/d) and belongs to the Major Groundwater Basins of Poland (Kleczkowski, ed., 1990). In fact, it is the only aquifer of economical importance in the studied area. At the same time, the uncovered character of the aquifer, hydraulic connection with Quaternary horizon and its hydraulic structure favours the intensive infiltration and migration of anthropogenic pollution from the surface. The studied karstic environment is vulnerable to pollution centres and large-size range pollution of agricultural origin as well as to atmospheric pollution connected with proximity of Cracow and Upper Silesia urban-industrial agglomerations.

3 Chemistry of waters infiltrating into carbonate massif

Chemistry of rainwaters and waters infiltrating through vadose zone (caves) studied locally in Ojców National Park on turn of the century is presented by M. Leśniok et al. (2002) and Motyka et al. (2002). During the nineties there were acid rains observed in this area connected with emission of sulfate dioxide from industrial area of Upper Silesia and Cracow deposited in rainout process. At the same time reduction of alkalescent dust emission to atmosphere was observed. Acid rains with pH about 4.5 are characterized by electrical conductivity (C_M) of range 3.5 mS/m, increased concentration of sulfate ion (average 4~6 mg/dm^3) and low concentration of calcium ion (usually less than 2.0mg/dm^3). Approximate concentration of subordinately occurring in rainwater SiO_2 as well as Sr and Ba ions connected mainly with activity of energetics (Pacyna, 1980) and were respectively: 0.17 and 0.002, 0.005 (mg/dm^3).

Process of acid rain water buffering in deeper soil layers and in carbonate rock environment causes change of water pH in caves into slightly alkaline (average value about 8.0). In these waters considerably increase: C_M (average is about 60 mS/m), concentration of major elements (average values in mg/dm^3: SO_4 155, Ca 134) and subordinate ones (average values in mg/dm^3: SiO_2 9.75, Sr 0.091, Ba 0.027). Change of chemical type of water to HCO_3-SO_4-Ca or SO_4-HCO_3-Ca is conditioned by slow migration of sulfate pollution front within vadose zone. Sulfates originate from rainwater and from buffering of acid rains by carbonate rocks.

4 Dissolving of carbonate rocks in phreatic zone on regional scale

In the area of Cracow Upland differentiated dynamics of carbonate rock dissolving has been observed. Rate of this process is conditioned upon geological structure, aggressiveness of infiltrating waters and human impact. Within phreatic zone aggressive waters with saturation index to calcite (SI_c) from –0.8 to +0.45 are dominant. Karstic waters are more aggressive during autumn-winter period while during spring and summer time they can oscillate close to saturation limit. Aggressiveness of these waters may be modified periodically by significant share of calcium and magnesium salts from anthropogenic processes in subterraneous karstic zone and in soil which are not connected with the effect of rock dissolving (Różkowski, 2002). Within Cracow Upland, a part of Silesia-Cracow monocline, predominate Upper Jurassic limestone outcrops. The regional inclination towards NE results within Nida syncline with a presence of an overburden of marly and marly-calcerous sediments of Upper Cretaceous. In the southern part of Cracow Upland block tectonic prevails. In tectonic troughs thick complex of Tertiary clayey sediments occurs in overburden. Area of Cracow Upland is of agricultural character. It passively receives an aerial pollution from Upper Silesia and Cracow agglomerations.

In Upper Jurassic aquifer waters alkali earth metals strontium and barium as bicarbonate and silicon as hydrated silica commonly occur as a result of carbonate leaching. Average contents of these elements in limestone are: Sr 400~850 ppm, Ba 90 ppm, SiO_2 3.4 per cent by weight (Polański, 1988). In Upper Jurassic deposits exploited in Cracow Upland area average content of SiO_2 is from 0.77% (Rząska II) to 8.59% (Wolbrom-Zarzecze); usually it does not exceed 2.5%. Sr concentration in soil of Cracow Upland western part ranges from 20 to about 150 ppm and Ba concentration is in range 5~50 ppm, while in bottom sediments of water courses concentrations vary respectively: Sr 10~80 ppm, Ba 25~100 ppm (Lis, Pasieczna, 1995). Ionic radius of Sr is bigger than of Ca that is why Sr comes easier in aragonite than in calcite structure. During diagenesis process with porous water participation less stable in the environment aragonite transforms into poor with magnesium calcite what can release considerable part of Sr and leads to its concentration (Reeder J., ed. 1987). Carbonate rocks are poor with barium what results from considerable difference of ionic radii of Ca and Ba. It makes difficult barium to enter into structure of calcium carbonate. More significant barium concentration is connected with increased participation of clayey admixture and barite occurrence (Polański, 1988), however in Silesia-Cracow monocline area barite accompanies mainly Paleozoic sediments and Triassic Zn and Pb ore deposits (Harańczyk, Szostek, 1970).

Average concentration of selected hydrogeochemical elements within rock leaching zone in groundwater of moderate climate are as follows: SiO_2 14.3, Sr 0.245, Ba 0.17 (mg/dm^3) while the most frequent values are: Sr 0.005~0.050, Ba 0.002~0.010 (mg/dm^3) (Macioszczyk, 1987). In Poland in natural usable water average amount of Sr is 0.1 and Ba – 0.15 (mg/dm^3) (Kabata-Pendias, Pendias, 1999). Strontium as a mobile element accompanies calcium during its migration with water while barium, as poorly mobile element is quantitatively subordinate to strontium. Insignificant solubility of minerals containing silica influences its occurrence in water in subordinate amount.

Process of Upper Jurassic rock dissolving on regional scale is marked by increase of dissolved elements in water according to direction of regional flow (E, NE) but in the southern part of the Upper Jurassic aquifer – from tectonic horsts towards tectonic troughs. This general tendency can be modified by intermediate and local flows connected with rivers and their tributaries as well as by human impact what is reflected in chemical composition of streams and shallow wells water in rural areas. Variability of C_M, concentration of Ca and Mg (as T_H), HCO_3 and subordinate elements: SiO_2, Sr and Ba in water of phreatic zone is presented in figures 2 and 3 and in the table 1.

J. D. Hem (1989) estimating quantitative effect of carbonate minerals dissolving assesses that almost one half of bicarbonates occurring in groundwater is derived from rock carbonate dissolving and the second one is from CO_2 penetrating from air and from soil layers into water.

Within the Upper Jurassic aquifer low concentration of elements derived mainly from limestone dissolving occur on its western boundary, however with increasing tendency in the area of Zn and Pb ore mining activity in Olkusz region. In watershed area of Olkusz plateau where the highest effective infiltration is observed (>200 mm per year) dynamics of carbonate rock leaching is moderate. Significant effect of karstic dissolving is observed in the eastern part of the Upper Jurassic aquifer and in the Dłubnia river valley where hydraulic connection with Upper Cretaceous aquifer through hydrogeological "windows" and of the lateral type (overflow of dammed water) (Burzewski, 1969) exist. Considerably higher dynamics of carbonate rock dissolving in comparison with Olkusz plateau is observed towards south in the area of Tenczynek horst close to urban-industrial agglomeration of Cracow and farther in southern direction from culmination of groundwater table (260~300 m above sea level) to tectonic troughs of Cholerzyn-Półwieś and Rybna.

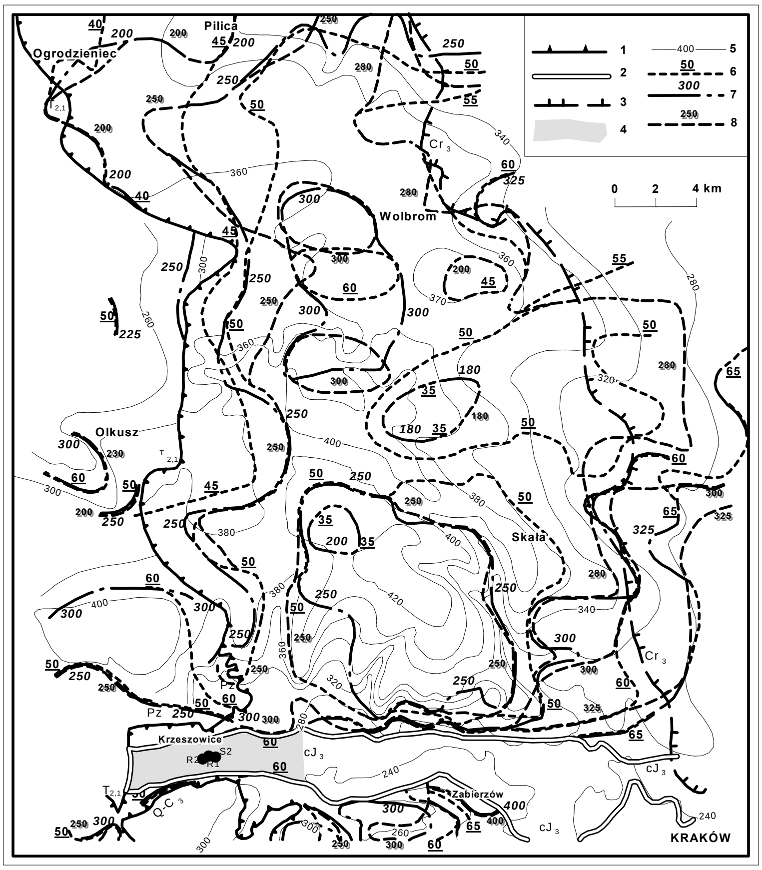

Fig. 2. Variability of carbonate rock elements dissolved in karstic water within Olkusz Upland and Wolbrom Gateway area

Explanations: boundary of the aquifer: 1 – Upper Jurassic unconfined, 2 – Upper Jurassic isolated, 3 – Upper Cretaceous; 4 – lack of usable horizon; 5 – groundwater watertable; contours of: 6 – C_M (mS/m), 7 - T_H (mg $CaCO_3/dm^3$), 8 – HCO_3 concentration (mg/dm^3)

Table 1. Range of concentration of elements originating from limestone dissolving in the southern part of CCU

Element	C_M	T_H	SiO_2	Sr	Ba
Area	ms/m	mg$CaCO_3/dm^3$	mg/dm^3	μg/dm^3	μg/dm^3
1	31~43	135~260	4~9	28~63	9~22
2	36~65	200~310	4~8	40~143	9~30(55)
3	31~50	165~250	6~10	37~65	9~21
4	48~70	240~360	10~25	160~400	24~90
5	48~>65	260~365	10~18	70~170	30~>90

Study area: 1 – western boundary of the Upper Jurassic aquifer (to the north from Wolbrom Gateway), 2 – Olkusz-Krzeszowice trough, 3 – watershed area of Olkusz plateau, 4 – eastern boundary of the Upper Jurassic aquifer, 5 – Tenczynek horst.

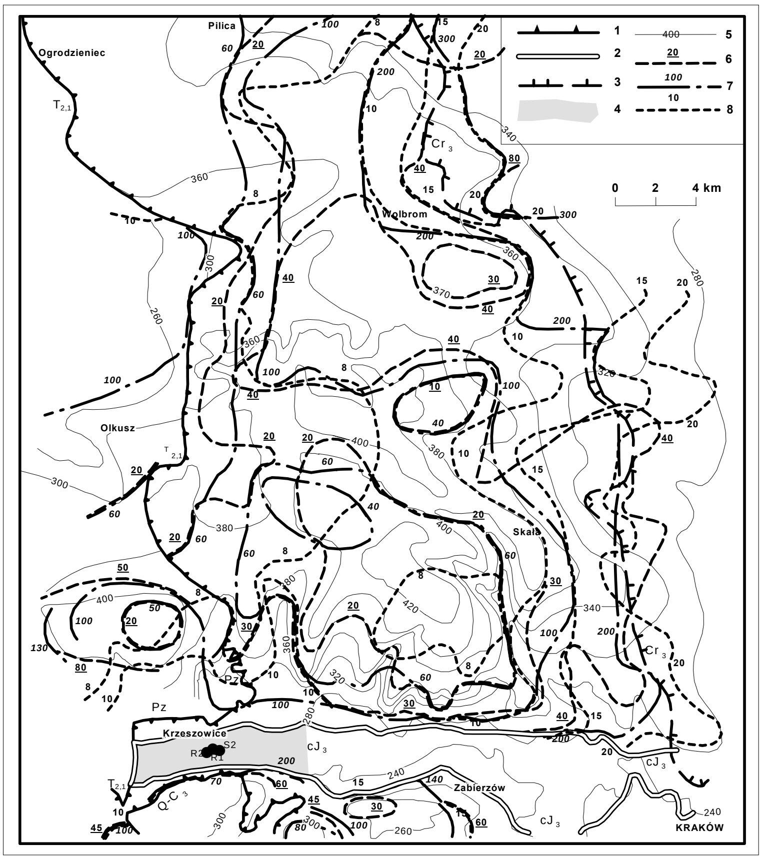

Fig. 3. Variability of carbonate rock elements dissolved in karstic water within Olkusz Upland and Wolbrom Gateway area

Explanations: boundary of aquifer: 1 – Upper Jurassic unconfined, 2 – Upper Jurassic isolated, 3 – Upper Cretaceous; 4 – lack of usable horizon; 5 – groundwater watertable; contours of concentration in water of: 6 - Ba (μg/dm^3), 7 – Sr (μg/dm^3), 8 – SiO_2 (mg/dm^3)

Maximal concentration of dissolved components has been found in area of Krzeszowice trough where usable water of J_3 horizon occurs. Its T_H is 370~450 mg/dm^3, SiO_2 concentration exceeds 13 mg/dm^3 and Sr and Ba concentrations are within limits: 0.4~1.8 and 0.12~0.15 mg/dm^3. In Krzeszowice mineral water isolated from active circulation zone is exploited. It is of chloride type from joint Cr_1-J_3 horizon (S-2 well) and of sulfate one occurring in Tortonian strata with gypsum (R-1 and R-2 wells). Chloride water is characterised by total mineralization about 3.0 g/dm^3 and concentration of SiO_2 22~26, Sr about 2.50, Ba to 0.15 mg/dm^3. Sulfate water of infiltration origin, probably from climatic optimal season (R-1) and Atlantic (R-2) is characterised by similar mineralization (2.39~2.68 g/dm^3) and significantly higher concentration (in mg/dm^3) of: SiO_2 (47~56), Sr (10.2~13.8) and minute one of Ba (<0.01~0.02) (Wagner, 2000). These data reflect geological structure and water circulation conditions.

In quantitatively degraded waters exploited by dug wells and drained by springs within rural areas there is observed a group of waters with unnaturally high concentration of carbonate rock dissolving indices which are: C_M 130 mS/m, T_H 580 mg $CaCO_3/dm^3$, SiO_2 30, Sr 0.77 and Ba 0.11 mg/dm^3.

Distribution of sulfate, chloride and alkalies in karstic water is also influenced by regional rules but it is stronger modified by human impact (local anomalies occur) (Fig. 4, 5). There is observed an increase of mentioned elements from elevated parts of Jurassic plateau according to water flow directions and also (mainly in case of sulfate) towards S and E where thickness of isolating overburden sediments is higher. Along the western boundary of the Upper Jurassic basin, similarly to the main components of limestone, predominate lower concentrations of above-mentioned elements with the increase tendency towards the central part.

In comparison with above data, an average concentrations of major elements in groundwater of rock leaching zone in moderate climate are as follows (mg/dm^3): Ca 37.3, Mg 10.5, Na 23.8, K 3.0, HCO_3 212, Cl 10.9, SO_4 14.7 (Macioszczyk, 1987).

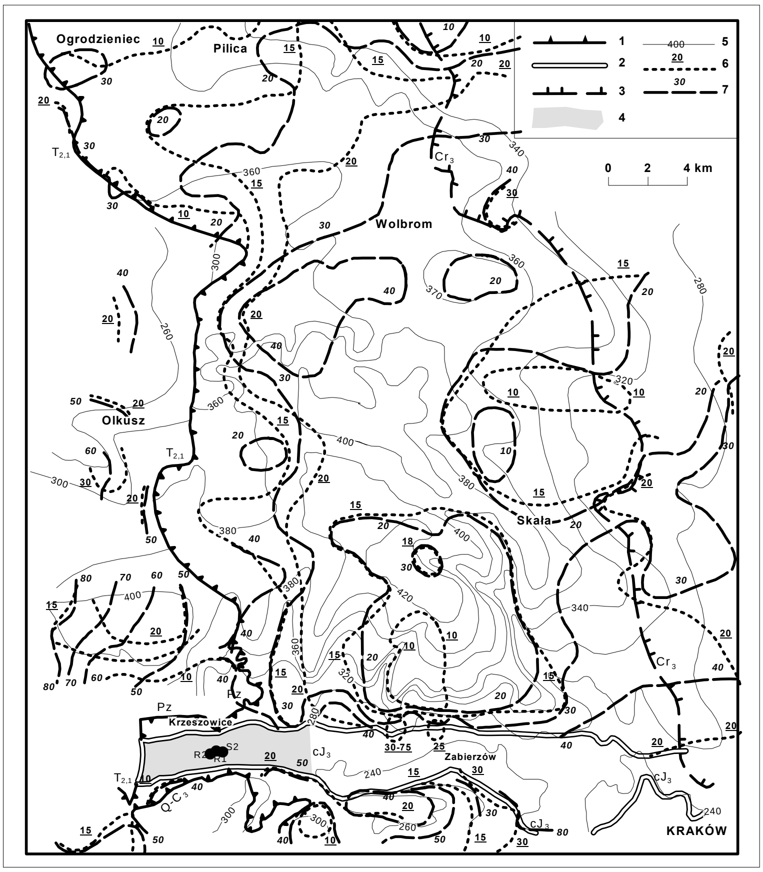

Fig. 4. Variability of sulfate and chloride concentrations in the Upper Jurassic aquifer within Olkusz Upland and Wolbrom Gateway area

Explanations: boundary of aquifer: 1 – Upper Jurassic unconfined, 2 – Upper Jurassic isolated, 3 – Upper Cretaceous; 4 – lack of usable horizon; 5 – groundwater watertable; contours of concentration in water of: 6 – chlorides (mg/dm^3), 7 – sulfates (mg/dm^3)

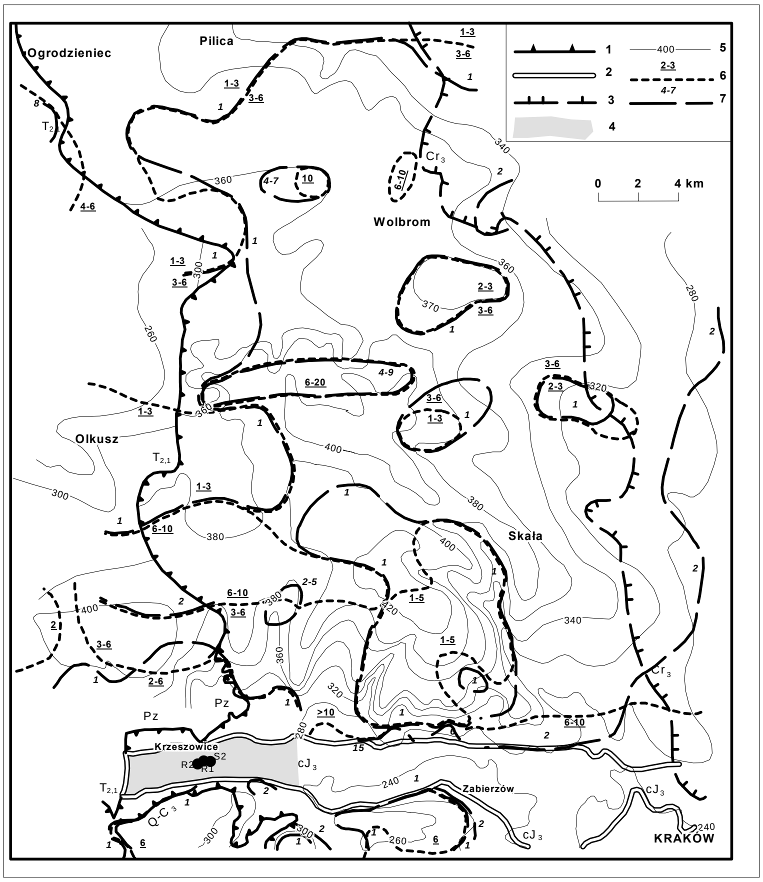

Fig. 5. Variability of alkalies concentrations in the Upper Jurassic aquifer within Olkusz Upland and Wolbrom Gateway area
Explanations: boundary of aquifer: 1 – Upper Jurassic unconfined, 2 – Upper Jurassic isolated, 3 – Upper Cretaceous; 4 – lack of usable horizon;
5 – groundwater watertable; contours of concentration in water of:
6 – sodium (mg/dm^3), 7 – potassium (mg/dm^3)

5 Conclusions

■ Within Cracow Upland karstic area as a result of carbonate rock leaching there is observed an increase of soluble components in water according to the direction of regional flow towards NE and E, however in the southern part – in meridional direction from horsts to tectonic troughs.

■ The most intensive process of carbonate rock dissolving is observed in karstic waters within areas located close to urban-industrial agglomerations (for example within Tenczynek horst in vicinity of Cracow). But maximal concentrations of studied elements occur in the part of basin isolated from the surface and under condition of local human impact.

■ There was found that in distribution of sulfate, chloride and alkalies the regional rules are valid, however modified by human impact. Increase of the concentrations takes place from watersheds in agreement with water flow direction and also (mainly sulfate concentration) on S and E, where higher thickness of isolating overburden sediments is observed.

■ Within studied carbonate rock environment zonal variability of mainly Sr, SiO_2 and HCO_3 concentration seems to be a useful index of the dissolving process, conditioned by length of groundwater circulation. Increased values of C_M and T_H are more scattered as a result of human impact influence modifying water chemistry.

■ In connection with observed rules in distribution of hydrogeochemical elements in karstic waters the methodology of natural hydrogeochemical background determination should be modified. Change from statistic approaching to dynamic one taking into account recharge conditions and length of water flow is advisable.

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Summary

The paper presents results of hydrochemical investigations carried on in the nineties within the karstic region of Cracow Upland, mainly of rural character, which is under anthropopressure from agglomeration of Cracow and Upper Silesia. Progressing acidification of rainfall correlated with decrease of mineralization and calcium ion concentration was stated. Within vadose zone of carbonate rock massif there is observed a change of water pH in buffering process to slightly alkaline, dynamic increase of major elements concentration as a result of carbonate rock leaching, slow vertical migration of sulfate pollution front. Within phreatic zone there is observed an increase of Ca, Mg, SiO_2, Sr and Ba ion concentration in water along regional flow direction (E, NE) whereas in the southern part of the Upper Jurassic aquifer – from tectonic horsts toward tectonic troughs. The most intensive process of carbonate dissolving is observed within karstic water of Tenczynek Horst located in the neighborhood of the urban-industrial agglomeration of Cracow. Maximal concentrations of determined elements are observed in a part of the aquifer isolated from the surface as well as under the influence of local anthropopressure. Increase of SO_4, Cl and alkalies concentrations of diversified genesis in the phreatic zone water is observed generally from watershed areas in accordance with the water flow paths, as

well as (mostly sulfates) in the direction of increasing depth of isolating cover. In the environment of Cracow Jurassic carbonates zonal variability of Sr, SiO_2 and HCO_3 concentrations is an useful indicator of the dissolving connected with the time of groundwater circulation. Increased TDS and total hardness values result as well from local anthropopressure influence modifying water chemistry.

Part II-5 Impacts of Kizel coal mining on environment(Abstract)

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Kizel Coal Basin is 200 km north of Perm, western Ural. More than 50 elements are usually occurred in coal seams, and 12 of them enjoy a concentration 10~1000 times higher than the general background. The coal measures of Kizel Basin are of Lower Carboniferous with carbonate rocks. The depth of karstification is 1000~1100m. The water discharge from the coal mine could be 2500 m^3/per hour when karstified strata is encountered, and series of environmental problems followed. Moreover, there are a lot of sulfide and sulfate minerals, such as pyrite, gypsum in the coal measures, which made the geochemical features of the coal mine water complicated, e.g, there are acidic water(pH=2~3), or water with high TDS(35mg/l). Although the Kizel Coal mine has been stopped operation, the acidic and hard water is still self-flowing, and damaging the karst ecosystem of the region.

Part II-6 New observation on karst caves in southeast Baikal region(Abstract)

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The study of underground world around Baikal Lake could be traced back to the 80s of 19 century. Now about 50 caves have been investigated with a total length of 5000m. The depth of the deepest cave is 150m. Most of the caves are developed in the carbonate rocks, especially the Paleozoic limestone with a content of CaO up to 55%.

The Haitae Cave, 300 km SE of Chita City, is characterized by permanent cave ice, in the form of ice stalagmite, and ice flower. It is about 10~120cm thick near the cave wall, but could be 3.5~4m in the central part of the cave, with a total volume of 13,300~15,300 m^3(67×57×3.5~4m). Microclimate monitoring of the cave were carried out. The results are listed below.

Date and time	Air temperature(℃)		Air moistore(%)	
	surface	in cave	surface	in cave
Jan 21, 1990(3pm)	-32	-1	72	96
April 8, 1990(3pm)	+4.2	-0.7	46	94
May 8, 1990(3pm)	+10.2	+0.2	33	98

The wind velocity in the entrance of the cave is 1.7~2.0m/sec(April, 1990)