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PRESENT PROBLEMS CAUSED BY THE RELEASE OF MINE GAS INTO THE AIR AND MEASURES TO DECREASE THE AMOUNT RELEASED

Summary. In the article, negative impacts of methane released (gas released by mining activities from the coal matter or surrounding rocks) into the air and problems associated with global warming connected with the principle of so-called greenhouse effect are presented. Manners of releasing gases from closed mines, including characteristics of the most important factors influencing the escape of mine gases to the surface are provided. With active coal mines, methods of possible methane releasing from seams or surrounding rocks are described.

In the next part of article, the evaluation of data acquired from the gas drainage of chosen area of a face of the company, Ostrava-Karvinå Mines (henceforth referred to as OKD), Paskov Mine, Staříč plant, classed as with the 2nd degree of coal and gas outburst hazard is processed. Basic parameters of seams and the area of face evaluated, the method of gas drainage and volumes of gas drained during the operation of this face are given. In the article, the area of face evaluated is documented by a figure of the mining-geological situation of face, including the layout of gas drainage boreholes.

AKTUALNE PROBLEMY SPOWODOWANE EMISJĄ GAZÓW KOPALNIANYCH DO ATMOSFERY ORAZ POMIARY DOTYCZĄCE JEJ ZMNIEJSZENIA

Streszczenie. W artykule przedstawiono negatywny wpływ emisji metanu (gazu uwalnianego poprzez działalność górniczą z materii węglowej lub otaczających skał) do atmosfery oraz problemy związane z globalnym ociepleniem, ze szczególnym naciskiem na efekt cieplarniany. Zostały także omówione sprawy emisji gazu z zamkniętych kopalń, łącznie z charakterystyką najważniejszych czynników wpływających na proces wypływu gazów ku powierzchni. Opisane zostały także metody odmetanowania złóż lub sąsiadujących skał w czynnych kopalniach.

W drugiej części artykułu omówiono obróbkę danych uzyskanych z odmetanowania wybranego rejonu ściany wchodzącego w skład Kopalń Ostravsko – Karwińskich (zwanych później OKD), kopalni Paskov, zakładu Staric sklasyfikowanych w drugim stopniu zagrożenia wybuchem pyłu węglowego i gazu. Przedstawione zostały podstawowe parametry złoża i ściany, a także sposób odmetanowania wraz z objętością uzyskanego w ten sposób gazu. W artykule rejon ściany jest przedstawiony na rysunku górniczo – geologicznym wraz z naniesionymi otworami odmetanowania górotworu.

1. Introduction

The growth of human population and the not yet limited economic growth of especially countries with highly-developed economies result in disturbing the equilibrium of many systems. The civilization affects, by its expansiveness and aggressiveness, the air, climate, soil, water, cycles of substances, other living organisms, and even itself. On the surface of our planet, a point not affected by human activity can be found only with difficulty. Even at the depths of oceans, in the outer space around the planet and also in inaccessible polar areas can be found traces of extraneous substances that would never get to these places without human acting. As problems drawing human attention most at present [1], the following items are regarded:

- global warming (global climate change);
- weakening the ozone layer in the stratosphere;
- acid atmospheric deposition (acid precipitation)
- a threat to biological biodiversity.

2. Global Warming

The problem connected with global warming is associated with the principle of so-called greenhouse effect that acts as the protection of our planet surface against drastic changes in the day-to-night temperature range. To the Earth, the Sun emits as a body of the temperature of 6 000 K radiation, whose maximum wavelength is about 500-600 nm. About 25% of solar radiation reflects, before penetrating to the Earth's surface, from the atmosphere and escapes to the universe again. Another about 25% is absorbed by aerosols and gases in the atmosphere. Of 50% of radiation impinging the surface, about 5% is reflected from clouds, the water level and snow cover. Less than half the radiation energy thus strikes the Earth's surface, is absorbed by the surface and warms it. The surface of the planet is, however, warmed to a substantially lower temperature than is that of the Sun, and thus emits the radiation of greater wavelength. Then, it emits infrared radiation; however, this is absorbed by some gases in the atmosphere for some time. Part of this radiation escapes into the universe, which cools the planet, but part is emitted back to the surface and warms it. The greenhouse effect can be expressed as a difference between the Earth's surface temperature measured by satellites from the cosmic space and the average temperature at the planet surface.

The gases that have capabilities to absorb infrared thermal radiation are called greenhouse gases. To them, especially water steam, carbon dioxide, ozone, nitrogen monoxide and methane contributing to the greenhouse effect by about 0.8 K belong. Because the gases occur in the Earth's atmosphere independently of human activities, the greenhouse effect should be taken as natural phenomenon.

However, during some human activities, a larger amount of greenhouse gases than natural is released. As an example, rotting processes in municipal waste landfills contributing to the production of methane, or the emissions of mine gases rich in carbon dioxide and methane due to mining activity can be given. The emissions of mine gases rich in methane (CH_4), or in a mixture with carbon dioxide (CO_2) on the surface are a significant factor manifesting itself in the Ostrava and Karviná parts of the Ostrava-Karviná Coalfield (henceforth referred to as OKC) after finished mining activity and mine closure. In these areas, this is a permanent phenomenon, which follows from the geological structure of deposit, the thickness and properties of cover. It may show itself in points (in the surroundings of old mine workings open to the surface, or through insufficiently treated closed old mine workings especially in the periods of sharp drop in barometric pressure) and in areas [2], i.e. the escape of gases from excavations of seams in points of gas-permeable overburden or via tectonic zones.

3. Factors Influencing the Escape of Mine Gases to the Surface in Closed Mines

The escape of mine gases, especially methane, to the surface is influenced by many **natural, atmospheric** and **mining-technical factors.**

To the group of natural factors we assign the rank (degree of coalification) of seam, the pressure of gases, the thickness of seam, the depth of burial and the gas-permeability of surrounding rocks, the temperature difference, surrounding seams, tectonic structures and the overburden. Members of the group of atmospheric factors are barometric pressure and rainfall, and among the mining-technical factors the effects of mining and mine closure can be ranked (finished ventilations, reduced gas drainage, the flooding of mines and the method of mine working closure).

The Degree of Coalification (Rank)

The rank of coal is expressed by the content of volatile matters in the coal matter. With the growing rank, the content of volatile matters decreases and, on the contrary, the content of carbon C increases, and usually the amount of methane also arises. Coal seams in OKC show a high rank and a considerable coal gas capacity. Methane will be released from the coal substance even after finishing mining activity.

The Pressure of Mine Gases

What is decisive of movement of mine gases below ground and their escape to the surface is a pressure difference between the point of gas occurrence below ground and the point on the surface. In a case of escape of mine gases to the surface, a difference between the pressure of mine gases and the barometric pressure is crucial. After stopping ventilation, the overpressure ranging from 10 to 300 Pa will be created.

The Thickness of Seam

Methane as the most hazardous constituent of mine gases occurs in the coal seam and in the surrounding rocks. Into the surrounding rocks, methane migrates depending upon their natural gas permeability and disturbance of rock mass due to mining activities. Generally, it holds true that the higher is the seam thickness, the greater amount of methane is contained in this seam, or is released from this seam. With the increasing thickness of mined seam, effects of loosening the overlying and underlying layers and unmined coal seams grow. Thus the gas permeability of surrounding rock mass will increase and from unmined surrounding seams methane will be released.

The Depth of Burial and the Gas Permeability of Surrounding Rocks

With the growing geodetic and the stratigraphical depth of burial of coal seam, the rank of coal usually increases. The depth of burial has a considerable effect on methane escape to the surface. If in the given point, any natural or artificial paths for methane escape to the surface do not occur (tectonic structures, mine workings open to the surface, etc.), then the thickness of Carboniferous formation increases with the depth of burial in the given point, and thus also its resistance to the escape of methane to the surface.

The Surroundings of Seam

The coal gas capacity of Carboniferous rock mass is also influenced by the amount of methane released from the surrounding seams; the amount depends on the number and thickness of these seams, the pressure of methane in the seams and further on the distance between the seam concerned and the influencing seam. The process of influencing the surrounding rock mass takes place even after finishing mining operation, because the caved-in area is gradually totally consolidated and the effective height of caving, fissure growing and sagging of overlying layers increases.

Tectonic Structures

From the point of view of mine gas escape to the surface, tectonic structures represent very important natural paths of communication between primary sources of methane below ground and the surface. The tectonic structures offer lower resistance to the migration of mine gases than the undisturbed rock mass.

Overburden

The escape of mine gases to the surface depends, to a great extent, on the thickness of overburden (Tertiary), its gas permeability and level of disturbance due to natural processes and mining activity. In several cases, the overburden is totally missing in OKC. The Carboniferous rock mass outcrops and so-called "Carboniferous windows" are produced. The properties of overburden were taken as major criterion for the delimitation of areas endangered by the escape of mine gas to the surface. [3]

Barometric Pressure

One of the most important factors influencing the escape of gases to the surface is barometric pressure. As follows from the evaluation, the escape of mine gases to the surface occurs above all at a sharp drop in barometric pressure; a pressure change of 20 hPa/24 hours being regarded as sharp pressure drop.

Rainfall

This parameter influences the gas permeability of natural and artificial communications.

Effects of Mining

The gas permeability of undisturbed Carboniferous rock mass is rather small. It is the effects of mining activity (especially mining operations) on the overlying rock mass that are decisive of the escape of mine gases to the surface. Attention must be paid especially to points above the edges of worked-out spaces, where not only mere subsidence occurs, but also horizontal and vertical deformation with the subsequent tectonic disturbance may take place.

Mine Closure

According to legislation, any active mine must have an independent ventilation system. The mine must have forced and continuous ventilation. This type of mine ventilation creates permanent underpressure in mine spaces and draws off diluted mine gases to the surface. What has the crucial effect on the intensity and extent of mine gas escaping to the surface is stopping ventilation in the closed mine. In mine spaces significant changes occur immediately. The composition of mine atmosphere changes into the atmosphere of old mine workings, the pressure and temperature of mine gases increase, which are factors supporting the escape of gases to the surface.

To active mines, gas drainage had to be introduced in many cases to deal with the increased gas capacity of coal seams and their surroundings. Mining legislation requires the continuous operation of gas drainage system. Thus the escape of gases from mine workings to the surface is prevented, and the discussed gases can be industrially utilised either directly in the mining plant, or by supplying to the distribution network and selling to customers. Moreover, the economic benefit from selling this gas is not negligible either. The operation of exhaustion stations of closed mines acts up to commercial demand, and when demand for the exhausted gas is not ensured, the station is stopped.

Another mining-technical factor influencing the escape of gases to the surface is the flooding of underground spaces of closed mines. By flooding the underground mine spaces, the volume of spaces is diminished, in non-flooded underground mine spaces the pressure of mine gases increases and the mine gases are forced up to the surface.

4. Releasing the Methane from Active Coal Mines into the Air

In the case of active mines, methane escaping from coal seams or immediate roof and floor is diluted with fresh air and released into the atmosphere, and participates in the greenhouse effect, or is drawn from the mine on purpose and is used industrially (gas drainage). By gas drainage, gases are drawn from the seams by gas drainage boreholes into the gas drainage pipes that are connected to the gas drainage station located on the surface of underground mine. The methane is exhausted by means of underpressure to the surface, where it can be industrially used by the mining company itself or can be supplied to the distribution network for other users [4].

Gas drainage reduces the negative impact of released methane on the atmosphere and is an important aspect of economics of mining company and is also a measure that favourably influences the mining operations in areas endangered by coal and gas outbursts [5,6,7].

In the next part of this contribution, the method of gas drainage in a chosen face of the Paskov Mine is described.

5. Dealing with the Gas Drainage of Face No. 050 530 in OKD, Paskov Mine, Staříč Plant

The mining company OKD, a.s. concerning with the underground mining of hard coking coal pays great attention to problems of utilisation of Carboniferous gas that is used as equivalent of natural gas from the point of view of energy as well as ecology.

At present, the drainage of gas from the gas-bearing rocks in mined faces is introduced for the reason of safety in the sense of reducing the emissions of Carboniferous gas into mine workings and, on the other hand, for the benefit of effective use of methane as energy source.

The observed face No. 050 530 in the Staříč Mine is, from the point of view of problems of outbursts, classed as with the 2nd degree of coal and gas outburst hazard.

With reference to the fact that the above-mentioned face in the Staříč Mine is classified, from the point of view of gas conditions and methane emissions, as a face with a higher CH_4 gas capacity, this increased gas capacity must be dealt with by means of gas drainage.

The face is situated in the 1st mining field – Sviadnov, the mining claim of Staříč Mine. It is developed by the initial short connecting gate No. 050 3530/1, the intake airway No. 050 5136 and the upcast airways Nos. 050 5134/1 and 050 5134. The face length along the strike is about 900 metres.

The project of gas removal by gas drainage was based on a necessity of reducing methane emissions into mine airs to a permissible limit according to safety regulations and the Decree of Czech Mining Authority No. 22/1989 Coll., and thus also of ensuring the safety of mining operations.

For the given face, the gas capacity was estimated, according to the gas drainage project, at 28 000 m^3 of $CH_4.day^{-1}$ at the daily production of 1000 t of coal with the 55% effectiveness of gas drainage.

The thickness of mined seam was 0.9 m on the average; in the point of seam splitting the thickness was even 1.4 m.

The gas drainage of the face was designed by opposite boreholes into the roof of the face; the boreholes being drilled from the upcast airway No. 050 5134 in triples or pairs at the spacing of 25 m.

Parameters of drilled gas drainage boreholes into the left side of road No. 0505134/1 from the road length interval from 375 m to 300 m are as follows: the directions of boreholes are 30^0, 40^0 and 50^0, the inclines of boreholes are $+14^0$, $+12^0$ and $+10^0$ and the total depth of boreholes is 100 m. At the length of 275 m, the gas drainage boreholes were drilled to the left side at the directions of 20^0, 30^0 and 40^0, and the inclines were $+14^0$, $+12^0$ and $+10^0$, with the total borehole depth of 100 m. From the road length of 250 m to that of 100 m, the gas drainage boreholes concerned were drilled in pairs from one location at the directions of 30^0 and 40^0 to the left side with the borehole inclines of $+14^0$, $+12^0$ and the final depth of 100 m.

The gas drainage boreholes to the left side of road No. 0505134 in the length period from 350 m to 25 m were designed with the directions of 30^0, 40^0 to the left side and the borehole inclines of $+14^0$, $+12^0$ and the final depth of 100 m.

With the designed boreholes, the determined length of surface casing was 9 m. Drilling works had to be performed minimally 80 m in advance of the face front. In the gas drainage project, a reconstruction of gas drainage pipe line to so-called lost gas pipe line was designed.

The boreholes had to be connected to the gas pipe line by rubber hoses Js 50 dimensioned to fit for the pressure of gas mixture. Altogether, 6 400 m of gas drainage boreholes in 29 locations were designed.

Mining works were done from January 2004. Gas drainage began to be performed gradually; the first gas removal by means of gas drainage boreholes was started in March 2004 with the gas drainage of face at the rate of 2 819 m^3 of $CH_4.day^{-1}$; gas drainage efficiency being 49.2%. The mining operations were finished in December 2005. The mining-geological situation of the face in the mining claim and the layout of gas drainage boreholes are shown in Fig. No. 1.

An overview of gas conditions during mining operations and results of gas drainage of the face No. 050530 can be found in the table given below. It is evident from the overview that in the period of mining from 2004 to 2005, the real production of the face amounted to 356 t per day on the average instead of designed 1 000 t.

In the period evaluated, the exhalation of methane amounted on the average to 6 732 m^3 of $CH_4.day^1$, the rate of real gas drainage was 3 140 m^3 of $CH_4.day^{-1}$ instead of designed 15 400 m^3 of $CH_4.day^1$. In the period of mining, the efficiency of gas drainage was 31.8%. The average total coal gas capacity per day of the face mined was 9 871 m^3 of $CH_4.day^{-1}$ in the course of observed 2 years' period of mining operations. The gas drainage of face achieved the best results in May and June 2004, when 6 916 m^3 of CH_4.day^{-1} in May 2004 and 6 200 m^3 of CH_4.day^{-1} in June were removed by gas drainage at the average production of 736 t.day^{-1} in May and 730 t.day^{-1} in June. In the other periods, 2 100 to 3 800 m^3 of CH_4.day^{-1} was removed.

Table 1

Evaluation of parameters of the face – Opening and Development Plan (ODP) and the reality FACE No. 050 530

PORUB 050 530	Objemový průtok		konc. CH_4	Těžba		Exhalace celková		Exhalace relativní		Degazace		Účinnost degazace		Plynodaj. celková		Plynodaj. relativní	
	OPD	skuteč.		OPD	skuteč	OPD	skuteč.	OPD	skuteč.	OPD	skuteč.	OPD	skuteč.	OPD	skuteč.	OPD	skut.
(rok\měs)	(m^3/min)	(m^3/min)	(%)	(t/d)	(t/d)	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)	(%)	(%)	(m^3/d)	(m^3/d)	(m^3/d/t)	(m^3/d/t)
2004 / 1	990	1230	0,3	1000	225	12600	5314	12,60	23,62	15400	0	55	0	28000	5314	28,00	23,62
2	990	1050	0,3	1000	402	12600	4536	12,60	11,28	15400	0	55	0	28000	4536	28,00	11,28
3	990	1150	0,3	1000	560	12600	4968	12,60	8,87	15400	2819	55	36,20	28000	7787	28,00	13,91
4	990	1200	0,3	1000	708	12600	5184	12,60	7,32	15400	4838	55	48,27	28000	10022	28,00	14,16
5	990	1250	0,6	1000	736	12600	10800	12,60	14,67	15400	6916	55	39,04	28000	17716	28,00	24,07
6	1020	1260	0,8	1000	730	12600	14515	12,60	19,88	15400	6200	55	29,93	28000	20715	28,00	28,38
7	1020	1220	0,6	1000	516	12600	10541	12,60	20,43	15400	3312	55	23,91	28000	13853	28,00	26,85
8	1020	1050	0,5	1000	0	12600	7560	12,60	0	15400	1200	55	13,70	28000	8760	28,00	0,00
9	1020	950	0,4	1000	0	12600	5472	12,60	0	15400	830	55	13,17	28000	6302	28,00	0,00
10	1020	980	0,4	1000	226	12600	5645	12,60	24,98	15400	2118	55	27,28	28000	7763	28,00	34,35
11	1020	990	0,6	1000	272	12600	8554	12,60	31,45	15400	2904	55	25,34	28000	11458	28,00	42,13
12	1020	1010	0,7	1000	364	12600	10181	12,60	27,97	15400	4790	55	32,00	28000	14971	28,00	41,13
2005 / 1	1020	1030	0,6	1000	279	12600	8899	12,60	31,90	15400	3215	55	26,54	28000	12114	28,00	43,42
2	1020	1010	0,4	1000	247	12600	5818	12,60	23,55	15400	1262	55	17,82	28000	7080	28,00	28,66
3	1020	1050	0,3	1000	268	12600	4536	12,60	16,93	15400	1779	55	28,17	28000	6315	28,00	23,56
4	1020	1010	0,3	1000	339	12600	4363	12,60	12,87	15400	3043	55	41,09	28000	7406	28,00	21,85
5	1020	990	0,4	1000	296	12600	5702	12,60	19,26	15400	2909	55	33,78	28000	8611	28,00	29,09
6	1020	990	0,4	1000	369	12600	5702	12,60	15,45	15400	2713	55	32,24	28000	8415	28,00	22,80
7	1020	1050	0,3	1000	362	12600	4536	12,60	12,53	15400	3752	55	45,27	28000	8288	28,00	22,90
8	1020	1050	0,3	1000	439	12600	4536	12,60	10,33	15400	4378	55	49,11	28000	8914	28,00	20,31
9	1020	1020	0,5	1000	366	12600	7344	12,60	20,07	15400	3820	55	34,22	28000	11164	28,00	30,50
10	1020	1000	0,4	1000	201	12600	5760	12,60	28,66	15400	5363	55	48,22	28000	11123	28,00	55,34
11	1020	930	0,4	1000	293	12600	5357	12,60	18,28	15400	2850	55	34,73	28000	8207	28,00	28,01
12	1020	800	0,5	1000	332	12600	5760	12,60	17,35	15400	4307	55	42,78	28000	10067	28,00	30,32

V porubu 31.12.2005 ukončeno dobývání

Porub – face Účinnost degazace – gas drainage efficiency

Plynod. celková – total coal gas capacity Plynod. celková – total coal gas capacity

Plynodaj. relativní – relative coal gas capacity Plynodaj. relativní – relative coal gas capacity

Objemový průtok – volume discharge

OPD – OD

Konc. – conc.

Skuteč. –real

Těžba – production

Exhalace celková – total exhalation

Exhalace relativní – relative exhalation

Degazace – gas drainage

6. Conclusion

In the period observed, the exhalation of methane amounted, on the average, to 6 732 $m^{3\cdot}$ of $CH_4.day^1$, the real gas drainage 3 140 m^3 of $CH_4.day^{-1}$ instead of designed 15 400 m^3 of $CH_4.day^1$. In the period of mining, the efficiency of gas drainage was 31.8%. The average total coal gas capacity per day of the face mined was 9 871 m^3 of $CH_4.day^{-1}$ in the course of observed 2 years' period of mining operations. The gas drainage of face achieved the best results in May and June 2004, when 6 916 m^3 of $CH_4.day^{-1}$ in May 2004 and 6 200 m^3 of $CH_4.day^{-1}$ in June were removed by gas drainage at the average production of 736 $t.day^{-1}$ in May and 730 $t.day^{-1}$ in June. In the other periods, 2 100 to 3 800 m^3 of $CH_4.day^{-1}$ was removed by gas draining. Although owing to smaller volumes of coal worked out from the given seam the designed values of gas drainage were not acquired, the volume of drained gas contributed to the improvement of the situation from the ecological point of view.

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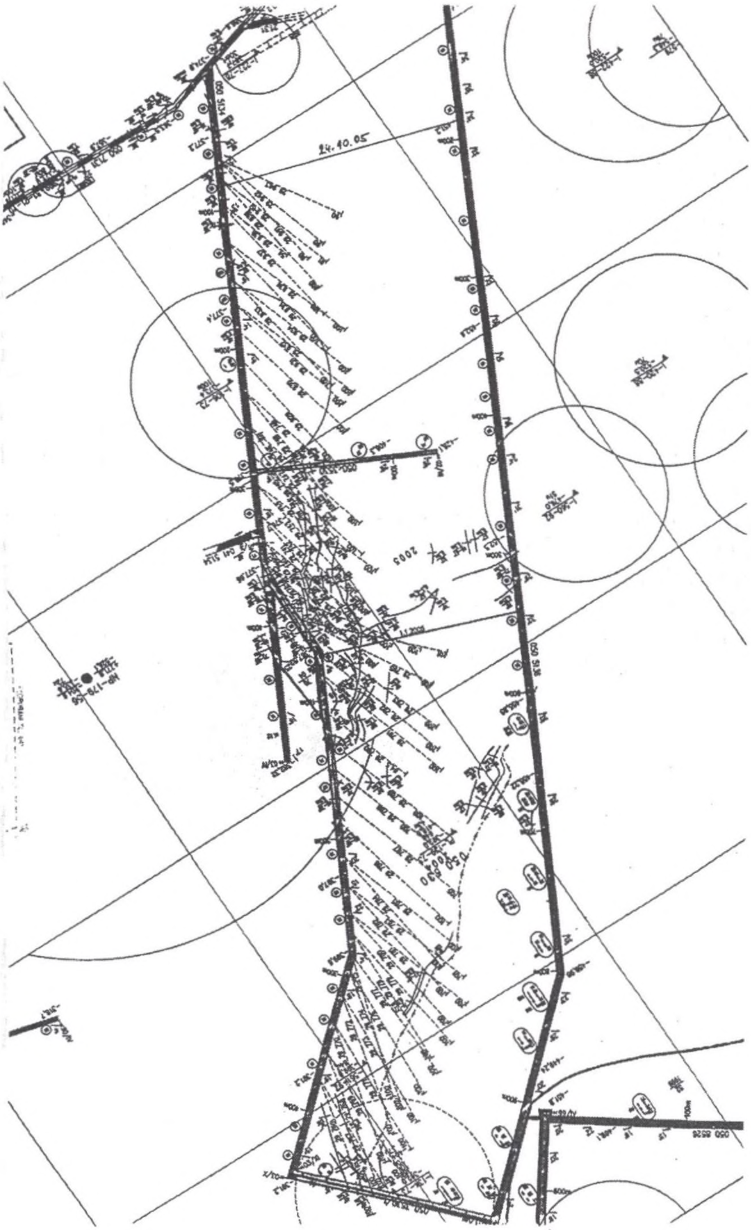

Fig. 1. The mining-geological situation of face No. 050 530 in the mining claim and the layout of drilled gas drainage boreholes

Rys. 1. Sytuacja geologiczno – górnicza ściany nr 050530 w rejonie górniczym wraz z naniesionymi otworami odmetanowania

REFERENCES

1. Dirner,V. a kol.: Ochrana životního prostředí. Ministerstvo ŽP Praha a VŠB-TUO, 1997, ISBN 80-7078-490-3.
2. Martinec P., Mikulík O., a kol.: Program podpory cíleného výzkumu a vývoje AV ČR, reg.č.: S3086005: „Vliv útlumu hlubinného hornictví na děje v litosféře a životní prostředí" – cíle a výsledky řešení (2000-2004). Documenta Geonica 2005, Akademie věd České republiky Ústav geonomy Ostrava, ISBN, 80-86407-09-8.
3. Beránek C.: Komplexní systém prevence před důlními plyny a opuštěnými díly v podzemí OKR. Disertační práce doktorského studia, Ostrava 2002.
4. Hudeček V., Moroz O.: Problems of outbursts of coal and gases in the Paskov mine, Staříč plant.Vseukrainskij naukobo-techničnij žurnal girničogo profilju Visti Doneckogo institutu 1´2005, ISBN 966-7745-30-9, s. 121-127.
5. Hudeček V.: Closure of Vertical Mine Workings by Using Waste Materials from Mining Activity. ČasopisTransactions of the Universities of Košice,2 2005, ISSN 1335-2334, p. 7-11.
6. Urban P., Hudeček V.: The experience of management of research into and prevention against outbursts of coal and gas in Donbas and the Czech republic. Zeszyty Naukowe Politechniki Śląskiej, seria Górnictwo z.270, 2005, s. 343-352.
7. Hudeček V.,Urban P.: Solving problems associated with the outbursts of coal and gases in the Paskov mine.TUR 2005, IV international conference mining techniques 2005, str.83-87, Krakow-Polsko, ISBN 83-915742-7-X.

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