Iveta Cholevová*, Josef Mazáč*, Lukáš Janák*

THE ANALYSIS OF RECORDS OF GAS-AIR MIXTURE AMOUNT AND METHANE CONCENTRATION IN DEPENDENCE ON BAROMETER PRESSURE

1. INTRODUCTION

The history of coal mining in the region of Ostrava was more than 200 years long. The termination of coal mining was initiated in 1991, when a period of coal mining decrement and deep coal mines abolition started under authority of a decree of the government. After stopping the coal mining activity and after the technical abolition of coal mines, the process of firedamps´ release into worked-out areas, which often communicate with the surface, is still going on. This happens mainly in areas where coal beds occur close to the surface. Methane is thus released from closed coal mines. This gas is dangerous mainly because of its explosiveness in mixture with air. Methane comes within so called greenhouse gases and so has a negative impact on global warming of Earth. In course of working of coal mines in Ostrava, the underground methane was lead off by ventilation and later by degassing. The firedamps' release intensity from worked-out areas is influenced by many factors, most significantly by barometer pressure changes. In 1995, the realization of degassing wells was initiated. Its goal was to prevent the area from uncontrolled gas release. Searching and of old major workings and its equipment by exhaust gas raises started to be carried out as well.

An integral part of the created degassing system is an implementation of regular measurements in individual localities. Within the framework of monitoring, methane concentrations, gas-air mixture amount and barometer pressure rates are measured among others. A part of these measurements was utilized for implementation of an analysis, the goal of which was to gain as much information as possible about relations within the measurements.

* VŠB – Technical University of Ostrava, Ostrava-Poruba, Czech Republic

2. DATA ORIGIN AND EXPLOITATION GOALS

Analyzed data originate from the monitoring unit of the degassing well used for leading off damps from the underground, which is situated in Slezská Ostrava. Damps contain namely dangerous methane, which is a result of the coalification process. Its release is a natural process, which embodies a high rate of randomness. Contemporary findings in this area show that the outflow of firedamps into the atmosphere is virtually and above all related to barometer pressure's development. In case of lower rates of barometer pressure, firedamps are released from the underground to the surface and it comes to their intermixture with the atmosphere. In case of higher barometer pressure rates, by contrast, the atmosphere is pushed back to the underground. Acquisition of knowledge is aimed right at this phenomenon's research.

3. THE STRUCTURE OF GAINED DATA

The significance of attributes:
– Date – Date of the measurement. The measurement was realized from August 8, 2004, 7 AM to February 10, 2005, 6 AM every day in one hour intervals. The total amount of gained data was 4415.
– Maximum_CH4 – Real attribute with the significance of the maximum volume rate CH4 in mixture in course of one hour of the measurement (%).
– Average_CH4 – Real attribute with the significance of an average volume rate CH4 in mixture in course of one hour of the measurement (%).
– CPM_UP – Real attribute, the rates of which represent the amount of gas flowing to the atmosphere (m^3/h).
– CPM_DOWN – Real attribute, the rates of which represent the amount of gas returning to the underground (m^3/h).
– Pressure – Real attribute with the significance of barometer pressure at the time of the measurement (hPa).

4. TRANSFORMATION AND DERIVATION OF DATA

In terms of the following data preprocessing, we realized derivation of new attributes CPM_DOWN-CPM_UP and line slope_PRESSURE. Their significance and motivation after the derivation will be stated below. Further the categorization of a number of attributes was carried out because of application of some methods to the analyzed data. It was not necessary to realize neither standardization nor normalization.

5. DERIVED ATTRIBUTES AND THEIR SIGNIFICANCE

– CPM_DOWN-CPM_UP – The difference of rates of attributes CPM_DOWN and CPM_UP. This operation can be carried out, because at the moment when one of the attributes has a nonzero rate, the other one certainly takes zero rate. The derived attrib-

ute thus records the air mixture flowage through the borehole - positive rates indicate flowing in the direction of the underground, whereas negative rates in the direction of the atmosphere. Instead of working with two attributes, we need only one now, which simplifies the following analysis.

– CPM_DOWN-CPM_UP_CAT1 – Categorization of attribute CPM_DOWN-CPM_UP according to these intervals (Tab. 1).

Table 1

CPM_DOWN-CPM_UP	CPM_DOWN-CPM_UP_CAT1	Significance
(–, –20>	0	significant increase
<– 20, –5>	1	increase
<–5, 5>	2	quiescent state
<5, 20>	3	decrease
< 20, –>	4	significant decrease

– CPM_DOWN-CPM_UP_CAT2 – Categorization of attribute CPM_DOWN-CPM_UP according to these intervals (Tab. 2).

Table 2

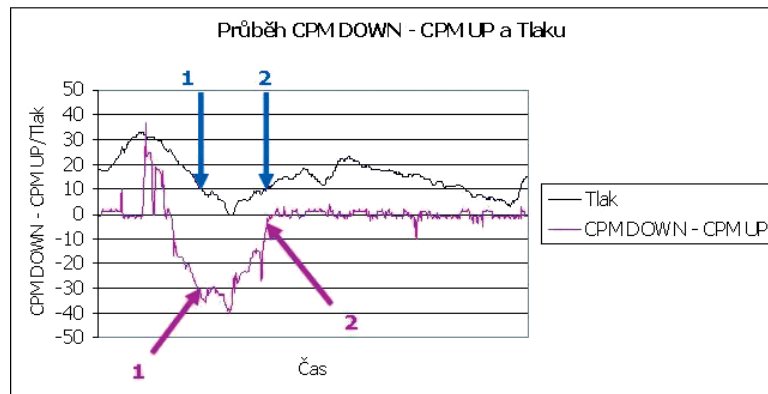| CPM_DOWN-CPM_UP	CPM_DOWN-CPM_UP_CAT2
(–, –5>	0
<–5, 5>	1
<5, –>	2

This double categorization of attribute CPM_DOWN-CPM_UP was carried out, because we were unable to estimate an optimal division into categories in advance.

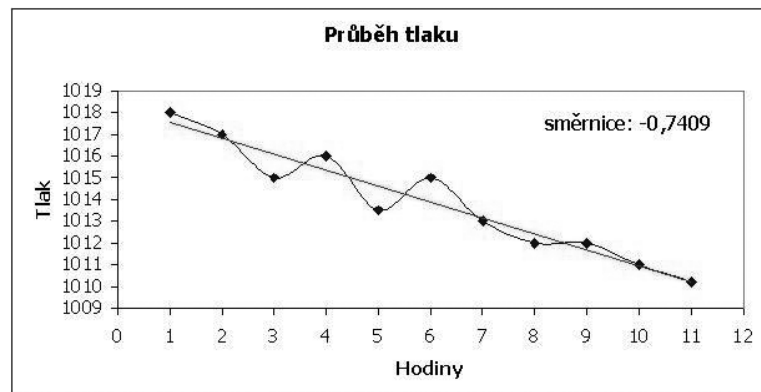– PRESSURE_CAT – Categorization of attribute PRESSURE according to these intervals (Tab. 3).

Table 3

Presure	Presure_CAT
<–, 999>	0
<1000, 1005>	1
<1005, 1010>	2
<1010, 1015>	3
<1015, 1020>	4
<1020, 1025>	5
<1025, 1030>	6
<1030, –>	7

– Line slope_PRESSURE – Real attribute, derived from attribute PRESSURE. This attribute was supposed to take into account, that the movement of firedamps is not only dependent on barometer pressure rate, but also on its time flow. In the Figure 1 we can see that in case of identical barometer pressure rates (blue indicators Nos.1,2), the rates of CPM_DOWN-CPM_UP (pink indicators Nos.1,2) differ significantly.

Fig. 1. CPM_DOWN-CPM_UP and Pressure development
(průběh = underground gas returning rate [m^3/h], tlak = pressure, čas = time)

Therefore we can suppose that the gases' movement through the degassing well is not only influenced by barometer pressure rate, but also by its development – i. e. whether it decreases or increases and how intensively. That is why we created a derived attribute line slope_PRESSURE. Its rate for each measurement record (the point in the graph "Pressure development") is calculated as a line slope of a regression line [2], which we inset through the mentioned point and through ten previous ones. Figure 2 documents the calculation of attribute line slope_PRESSURE for the 11th hour.

Fig. 2. Line slope calculation demonstration
(průběh tlaku = pressure measurment, směrnice = line slope, tlak = pressure, hodiny = hours)

According to the attribute's rate it is possible to state barometer pressure development:
- Line slope_PRESSURE > 0 …. the pressure at the given moment increases.
- Line slope_PRESSURE < 0 …. the pressure at the given moment decreases.
- Line slope_PRESSURE = 0 …. .balanced state.
- Line slope_PRESSURE| …….. decrease/increase intensity.
- Line slope_PRESSURE_CAT – Categorization of attribute line slope_PRESSURE according to these intervals (Tab. 4).

Table 4

Line slope_Pressure	Line slope_Pressure cat	Significance
(–, –1.0>	0	intensive decrease
<–1.0, –0.3>	1	decrease
<–0.3, 0.3>	2	balanced state
<0.3, 1.0>	3	increase
< 1.0, –>	4	intensive decrease

– Categorization and attributes' derivation overview (Tab. 5).

Table 5

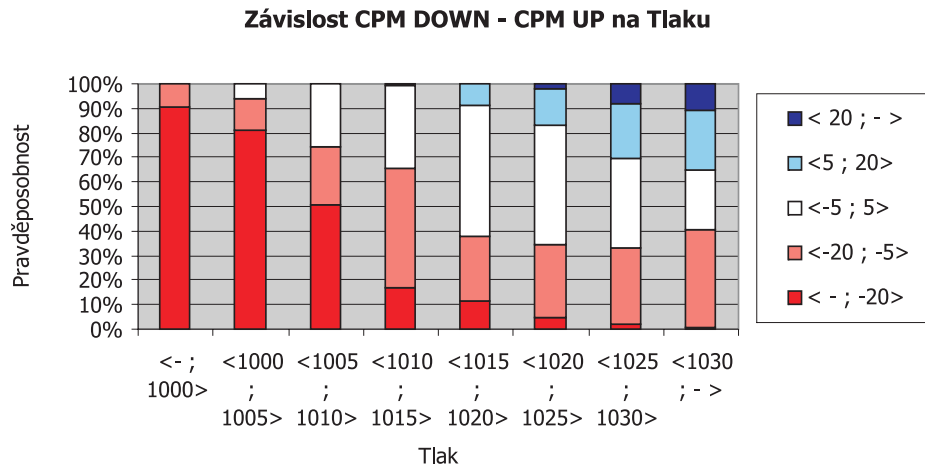| Original attribute(s)	Derived attribute	Operation
PRESSURE	PRESSURE_CAT	categorization
PRESSURE	line slope_pressure	derivation by calculation
line slope_pressure	line slope_pressure_Cat	categorization
CPM_DOWN-CPM_UP	CPM_DOWN-CPM_UP	derivation by calculation
CPM_DOWN-CPM_UP	CPM_DOWN-CPM_UP_CAT1	categorization
CPM_DOWN-CPM_UP	CPM_DOWN-CPM_UP_CAT2	categorization

6. FINAL STRUCTURE OF DATA (Tab. 6)

Table 6

Attribute	Attribute type
Maximum_CH4	real
Average_CH4	real
PRESSURE	real
PRESSURE_CAT	categorical
LINE SLOPE_PRESSURE	real
LINE SLOPE_PRESSURE_CAT	categorical
CPM_DOWN-CPM_UP	real
CPM_DOWN-CPM_UP_CAT1	categorical
CPM_DOWN-CPM_UP_CAT2	categorical

7. KNOWLEDGE GAINING

As already has been mentioned, the whole process of knowledge gaining will be focused on the research of barometer pressure's influence on firedamps' deportment.

Závislost CPM DOWN - CPM UP na Tlaku

Fig. 3. Dependence of CPM_DOWN-CPM_UP on Pressure rate
(pravděpodobnost = probability, tlak = pressure)

With regard to supposed existence of causal relation between attributes PRESSURE and line slope_PRESSURE and attribute CPM_DOWN-CPM_UP, and with help of associations searching method GUHA, we realized the following three analyses (Fig. 3).
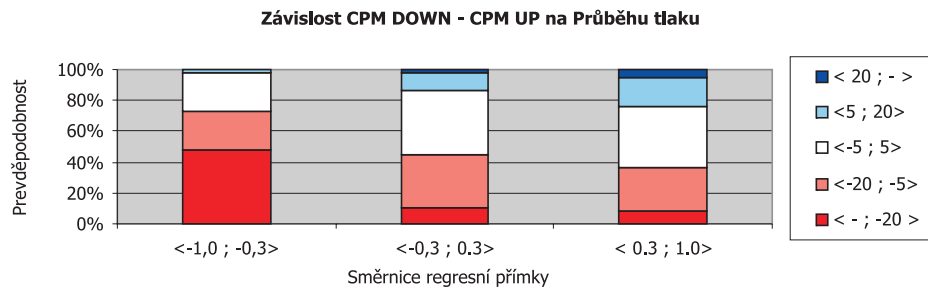
1) PRESSURE and CPM_DOWN-CPM_UP relation.

The graph in the Figure 3 shows the dependence of CPM_DOWN-CPM_UP rates only on attribute PRESSURE. In each interval of attribute PRESSURE, the column shows the setup of pertinence's probability into intervals of attribute CPM_DOWN--CPM_UP.

Generally, we can say that with increasing barometer pressure rates, also the probability increases that attribute CPM_DOWN-CPM_UP acquires positive rates and vice versa, which corresponds with the expectation. From the point view of security, we are naturally interested especially in intervals of attribute CPM_DOWN-CPM_UP < –; –20 > and <–20 ; –5>, when it comes to a significant exit of firedamps with CH4 content to the surface.

2) Line slope_PRESSURE and CPM_DOWN-CPM_UP relation.

The following graph in the Figure 4 shows the dependence of CPM_DOWN--CPM_UP rates only on attribute line slope_PRESSURE. In each interval of attribute line slope_PRESSURE, the column shows the setup of pertinence's probability into intervals of attribute CPM_DOWN-CPM_UP.

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Závislost CPM DOWN - CPM UP na Průběhu tlaku

Fig. 4. Dependence of CPM_DOWN-CPM_UP on Pressure development
(pravděpodobnost = probability, průběh tlaku = pressure development,
směrnice regresiní přímky = regression line's line slope)

From the graph we can find out that with increasing rates of the regression line's line slope, also the probability increases that attribute CPM_DOWN-CPM_UP acquires positive rates and vice versa. From the practical point of view it means that in case of increasing barometer pressure, the probability increases that the gas will be pressed down to the underground.

3) Attributes PRESSURE and line slope_PRESSURE and attribute CPM_DOWN--CPM_UP relation.

When researching dependencies, we concentrated on searching of connection between barometer pressure and line slope expressing decreasing or increasing movement and the amount of firedamps getting out of the underground to the surface. Realized calculations have confirmed that in case of low barometer pressure, which was prefigured by its sudden decrease, the probability of firedamps' release into the atmosphere increases significantly. With increasing barometer pressure this probability decreases.

8. ANALYSIS OF THE REMAINING ATTRIBUTES

From other, so far not analyzed attributes, especially Average_CH4 attribute appears as interesting – real attribute with the significance of an average volume rate CH_4 in mixture in course of one hour of the measurement. To be able to describe its dynamics, it is necessary to characterize phenomena related to damps' movement.

Simply explained: If barometer pressure is relatively high, the atmosphere is pressed into the underground and it "accumulates" in the surrounding of the degassing well's bottom (blue area in Fig. 5a) and it simultaneously expands to the surrounding rocks.

At the beginning of barometer pressure decrease, it comes to an escape of damps to the surface. However, because an air with low CH_4 content is accumulated at the degassing well's bottom (blue area in Fig. 5b), low rates of its content are measured by the monitoring unit. However, CH_4 content rates increase gradually and at the moment, when only an underground atmosphere is found at the degassing well's bottom (area in Fig. 5c), a gaseous mixture with relatively high and constant CH_4 content passes through the degassing well.
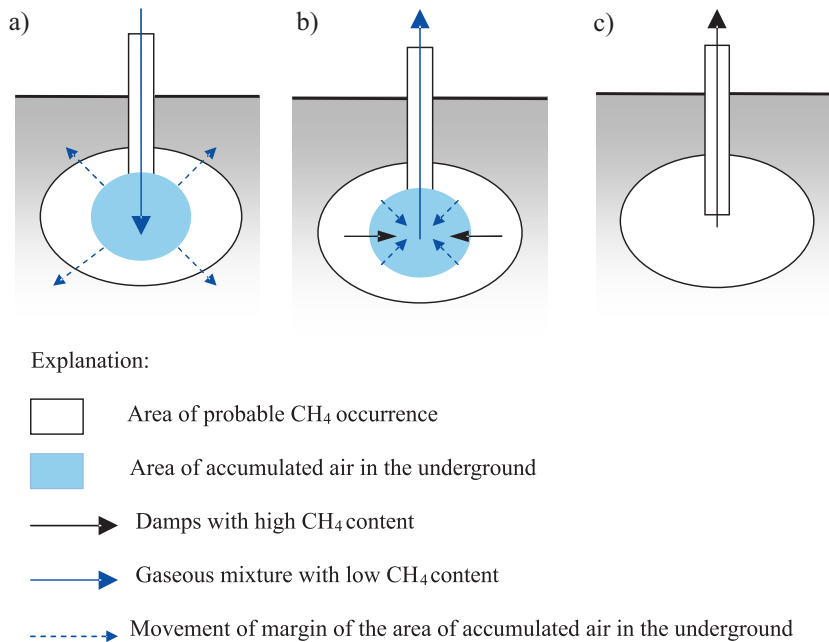
a)   b)   c)

Explanation:

☐   Area of probable CH_4 occurrence

▨   Area of accumulated air in the underground

⟶   Damps with high CH_4 content

⟶   Gaseous mixture with low CH_4 content

- - - ▸   Movement of margin of the area of accumulated air in the underground

Fig. 5

The time, in which this CH_4 content increase lasts, depends on the previous pressure development. If the period, when the atmosphere is pressed down to the underground, is relatively short, a small amount of atmosphere accumulates in the underground and at the moment of pressure decrease it comes to a very fast CH_4 content increase.

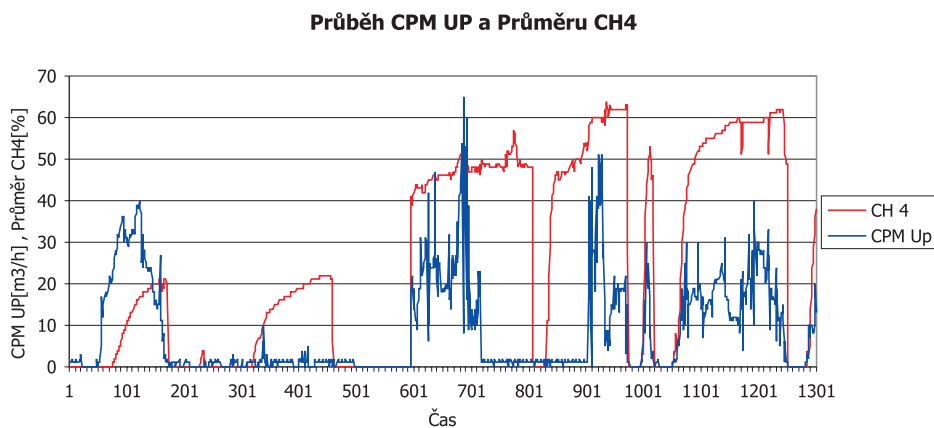The following graph (Fig. 6) documents the above-mentioned observation.

Průběh CPM UP a Průměru CH4

Fig. 6. CPM UP and CH_4 average development
(průměr CH_4 = CH_4 average, průběh CPM_UP = CPM_UP development, čas = time)

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In the graph we can see that at the moment of firedamps' exit to the surface (blue curve), an average CH_4 content in gaseous mixtre increases (red curve). We can also see that the increase rate and the maximum attained rate are dependent on the previous development.

9.   CONCLUSION

The construed pursuit concentrated mainly on studying the movement of gas-air mixture in the degassing well in dependence on barometer pressure development. Firedamps' release into the atmosphere is a natural process though, which embodies a high rate of randomness, but in use it was confirmed that it is influenced by barometer pressure's time flow. In case of its lower rates, firedamps are released from the underground to the surface. In case of higher pressure rates, by contrast, the atmosphere is pushed back to the underground. We tried to specify and express exactly the description of this relation by methods of acquisition of knowledge from data.

By GUHA method's [1] application to analyzed data, a hypothesis about the existence of causal relation between barometer pressure development and gases' movement in the degassing well got confirmed. The found rules made it possible to predict with a certain accuracy and on the basis of PRESSURE and line slope_PRESSURE attributes' rates, what CPM_DOWN-CPM_UP attribute's rate will be – Figures 3 and 4.

Average_CH4 attribute was not included into the analysis. For its analysis by methods of acquisition of knowledge from data, at first, it was necessary to derive several new attributes (taking previous CPM_UP development etc. into account). Anyway, the application of these methods would perhaps be difficult and apparently unsuitable for this type of data.

REFERENCES

[1]   Hájek P., Havránek T., Chytil, M.: *GUHA Method*. Prague, Academia 1982
[2]   Šarmanová J.: *Theory of Data Processing*. Ostrava, Lecture Notes 1997