

Geological factors of gassing of the east inclined longwall # 3 of m_3 bed at O.F. Zasiadko mine

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Abstract. The paper deals with the fact that gassing of the East inclined longwall (EIL) # 3 of the m_3 bed at the «O.F. Zasiadko mine» are caused by a combination of mining-geological conditions. The main geological factor is the presence of a synclinal fold, characterized by increased fracturing. The map construction of local structures, the use of gravity data and seismological observations allow to effectively isolate gas-saturated zones and, therefore, correct degassing projects and parameters of ways to prepare workings.

1 Introduction

Mining-geological conditions of mines operation become more complicated every year. The average depth of coal mining in Donbas reached 800 m, and the maximum 1400 m. Almost 90 % of the mines are classified as overcategorical one upon gas. One third of the mines develop beds dangerous on gas-dynamic events. Therefore, the working and the development of modern methods of continuous operational monitoring and assessment of the gas-dynamic state of the massif to ensure the effectiveness of the stoping and development workings are of particular relevance. The development of such methods is based on the knowledge of the main factors affecting the occurrence of gas-dynamic events. The purpose of the paper is to determine the main geological factors that influenced on the gassing of Eastern inclined longwall # 3 of the m_3 bed located at the «O.F. Zasiadko mine» field.

2 Methods

To achieve this purpose, the complex research was conducted. This complex includes the study and generalization of actual geological material, the results of research by geophysical methods: gravity prospecting and seismological monitoring carried out on the

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«O.F. Zasiadko mine» field. We used an analytical method for selecting the positive local structures (the trend-analysis of the surface of coal beds and sandstones). It is explained in complete detail in paper [1].

3 Results and discussion

Abnormal gasification of East inclined longwall # 3 (EIL # 3) of the m_3 bed occurred at 5.25 a.m., March 4, 2015 at a depth of 1300 m. The longwall was mined to the rise by a long pillar (2100 m). The length of the longwall is 315 m. By the time of the accident, the longwall advance to the rise was ~ 800 m.

The «O.F. Zasiadko mine» field is located in the central part of the Donetsk-Makiivskiy district of Donbas. In the geological structure of the mine field, deposits of middle and upper carbon are involved. The bedding of suits is concordant, without breaks, sometimes there are intraformational erosions. The lithological complex of medium carbonic rocks is represented by interchanging the layers of sandstones, aleurolites and argillites of varying thickness, containing thin beds of limestones and coals [2].

In regional tectonic level, the mine field is located within the tectonic block bounded by large structures of various types. In the south, the block is bounded by the sublatitudinal Mushketivskiy fault, in the west and east by the Vetkivska and Chaykinska flexures respectively, in the north by the Kalmius-Toretska kettle hole. Coal beds are disturbed by medium and low amplitude folded and ruptured dislocations, channel erosions, endogenous fracture. Thrusts prevail among the faulting. The branching, location and configuration of thrusts reflect the impact of shear forces that occurred at different stages of the structure formation at the section [1].

Analysis of gas sampling materials showed that over most of the area the natural gas content of coal beds is characterized as moderate, turning into high one. In the interval of the studied depths of 270–1400 m, the natural methane content of the beds increases from 8–10 to 20–25 m³/t daf. The relative methane yield of the mine, according to the categorical measurements from 1981 to 2005, ranges from 29.7 to 1257.8 m³/t day output. It was established that coal gases include: methane (CH₄), nitrogen (N₂), carbon dioxide (CO₂), hydrogen (H₂), helium (He), and an insignificant content of heavy hydrocarbon gases. The methane content ranges from 74.6 to 98.7 %. The low content of helium and heavy hydrocarbons in the composition of the gas indicates the absence of mantle gas inflows.

On the «O.F. Zasiadko mine» field gas-dynamic events of all types were observed. There were two sudden outbursts of coal and gas at the mine: over the l_4 bed with intensity of 100 tons and over the m_3 bed with an intensity of 75 tons of coal and 2500 m³ of gas. Outbursts in the case of concussion blasting are 42. One of them is confined to the coal bed m_3 , the rest to field workings along the sandstones m_1Sm_3 , $l_7^1Sl_8$, L_7Sl_7 , l_4SL_5 , L_5Sl_5 , L_1Sl_1 , k_8Sk_9 . The intensity of sandstone outbursts ranges from 30 up to 650 m³ of the rock, and gas from 100 to 11700 m³. 128 blows emissions were fixed at the mine with methane concentration up to 82 % and lasting from several hours to five months. The nature of emissions is from calm to very frequent breakthroughs of water and gas. About 90 % of blows are confined to cracks, zones of low-amplitude disturbances, wings of folds. Lithologically, most of them are confined to cracks in the sandstones occurring in the roof and floor of all coal beds worked, especially in the Sofiiivskiy, Semenivskiy and Vetkivskiy thrusts, in the zone of influence of the Vetkivska flexure.

Within the area, the most gas-saturated are the beds: $N_1SN_1^3$, $M_9Sm_8^1$, M_4SM_5 ($m_4^1Sm_5^1$), $m_1SM_1^2$, $L_7S_1^7$, from which gas emissions with bursts and gushing of water and gas occurred. Free gas collectors are represented by zones of fractured and tectonically disturbed rocks.

The main factors determining the change in methane content within the estimated area

are: depth, stratigraphic position and degree of coalification of the estimated coal beds, the presence of numerous coal interbeds and thick (up to 50-72 m), fractured sandstones with zones of breaks in the floor and roof, as well as the tectonic structure of the field.

When analyzing the accident that occurred on 04.03.2015 in EIL # 3 of the m_3 bed, the volumes of emission methane released into the mine workings of the coal bed m_3 were calculated during the stoping – from consumed coal, from overworked and underworked rocks and coal beds [3].

The total predicted amount of methane emission released into the mine workings of EIL # 3 of the m_3 bed from underworked and overworked spaces is $\sim 30 \text{ m}^3/\text{m}^3$, and from the coal bed under development $m_3 \sim 24 \text{ m}^3/\text{t}$. In all, $\sim 54 \text{ m}^3/\text{t}$ of methane emission has to release into the mine workings. The actual relative methane yield of the EIL # 3 is $52 \text{ m}^3/\text{t}$. Ventilation and degassing carried out in the working was calculated on this volume of methane. Consequently, the gasification of the workings of EIL # 3, which occurred almost instantaneously (measurements 5–10 minutes before the explosion, showed approximately acceptable concentrations of methane), was the result of a large amount of methane breakthrough from the enclosing rocks. The inflow of methane occurred from the highly-permeable zone.

When investigating the causes of the gas-dynamic phenomenon, it was observed firstly ingress of acetone into the longwall. The explanation of this phenomenon requires further detailed studies.

Taking into account connection of gas-dynamic events to dislocations, the structural-geological position of the section where the accident occurred was considered. According to the method [1], a map of local second-order structures of the coal bed m_3 has been constructed (Fig. 1).

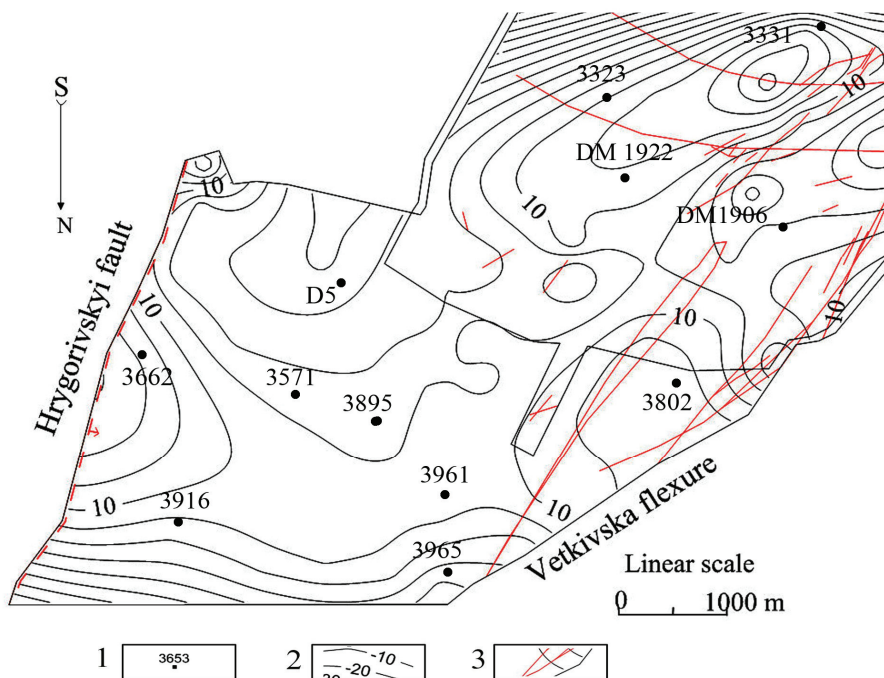


Fig. 1. Map of the second-order local structures of the coal bed m_3 at the «O.F. Zasiadko mine» field: 1 – exploration wells; 2 – isolines of local structures; 3 – faultings.

EIL # 3 is located in the bottom eastern part of the syncline. Its axis passes about 1.5 km eastwards of the Vetkivska flexure.

Signs of increased gas-dynamic activity in the zone of the synclinal fold appeared even in the process of geologic exploration activities. Gas-dynamic activity was noted in the well # 3792, located in the zone of influence of the synclinal fold. In this well, from a depth of 730 m from the sandy stratum $N_1^3SN_1^5$, there was a sudden burst of a gas-water fountain, which functioned for about 15 days. After that, a calmer gas emission from the $m_4^1Sm_5^1$ sandstone was noted. In the process of underworking the well by the 14th and 15th western longwalls directly near it (150 meters westwards) in the 14th western belt entry on August 26, 1998, there was coal and gas outburst. With the deepening of mining operations also in the zone of small-amplitude disturbance ($H - 0.6 - 1.7$ m) of the same syncline at 550 m upon the fall from well # 3792 in the 16th western belt entry, on February 23, 2001, a second sudden coal and gas outburst occurred.

Mining operations at the bottom of the syncline revealed small-amplitude disturbances ($H - 0.5-1.75$ m). Increased fracturing of the coal-bearing massif is confirmed by gravitational and seismological data.

The Dnipropetrovsk geophysical expedition carried out a high-precision gravimeter observations S 1:5000 on the mine field and constructed a residual Δg_{res} map with an isoanomalous section of 0.05 mGal. This map was used to identify and track decompression zones.

According to the gravity data, the coal-bearing stratum is heterogeneous and consists of bands of interchanging anomalies — positive (zones of compacted rocks — contour 0.1) and negative (zones of rocks loosening — contour minus 0.25). The width of the bands is ~ 700–800 m. Their strike coincides with the direction of rocks fracturing.

Synclinal and anticline folds are reflected in the gravitational field, respectively, by the minimum and maximum values of the gravitational anomalies. EIL # 3 is located in the zone of local gravitational minimum, i.e. confined to the section of increased fracturing ("decompression") in the sedimentary cover.

To determine the distribution of fracturing in the mountain massif in the process of mining, the results of seismological observations carried out at the «O.F. Zasiadko mine» field were used, applying the Polish seismic system "ARAMIS"[4]. This system records the seismic events resulting from cracking, fixes the magnitude of their energy and determines the coordinates of the origin. Based on the results of observations, a database was compiled, which was used to study the seismic regime of the mine, selection of fracture zones and the dynamics of their development.

The state of the massif was monitored during the working of the m_3 bed on the 18th eastern longwall, East inclined longwall (EIL) and 18 western one. The sensors are placed in the plane of the m_3 bed in such a way as to monitor the rock mass in the zones of stoping and development workings. This arrangement made it possible to cover with representative observations a mine field with a total area of about 10 km².

Recorded seismic events for the period 2009-2013, projected onto the plane, are shown in Figure 2. On average, 300-400 events were recorded at the mine during the month. For the period 2009-2013 15356 phenomena were recorded. The magnitude of the relative energy of origins ranged from 10^1 to 10^5 conventional units [4].

The location of the centers of seismic events has a certain order in space and in time. A generalized analysis of the mining and seismicity cycles revealed their close relationship. When assessing the impact of mining on seismic activity, it was found that up to 70 % of all events occur within the developed areas of a mine field, and in areas adjacent to mining operations up to 200 m – 20 % of events. The remaining 10 % refers to various dynamic processes occurring in the massif.

EIL and EIL # 3 were developed upon the rise. To the left of them is an unspoiled massif, complicated by tectonic disturbances. EIL and EIL # 3 are characterized by high values of the origins relative energy (104–105 conventional units) of recorded events. The

peculiarity of the EIL mining is the fact that the fixed origins of seismic events are distributed over a large area, far beyond the perimeter of the longwall (Fig. 2). It is quite conceivable that the high activity of fracturing is due to the fact that the section is in a shear zone, which according to the data is currently active. According to seismic observations, multiple fracturing occurred in the middle part of the longwall. Fracturing was confirmed when observing the longwall by a P-1 strength testing. The recorded strength reductions coincide with the areas of increased fracturing, which is consistent with the data obtained by the seismic method.

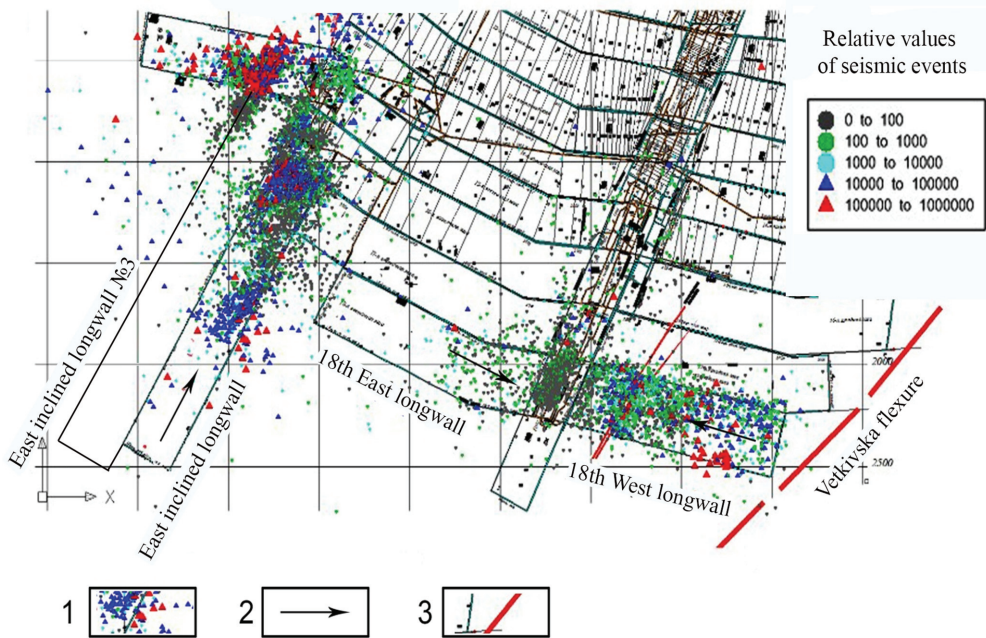


Fig. 2. Seismic events of varying intensity recorded during mining of the m_3 bed for the period 2009-2013: 1 – projections onto the plane of epicenters of seismic events; 2 – the direction of mining longwall; 3 – tectonic disturbances.

Seismological data obtained at the section of the accident and fixed the fracturing revealed a zone of weakened fractured rocks extending 300 m south-east of the D-5 well and 170 m north-west of the D-5 (all in the line of the Eastern inclined longwall # 3).

Seismological studies have shown that the recorded seismic events in the massif form zones with the same orientation as the gravimetric anomalies, and are confined to negative gravitational anomalies, that is, to the zones of weakened rocks.

Increased fracturing of the section is confirmed by geological documentation of mine workings. So, on the EIL # 3 sketch from February 19, 2015, from the air passage upwards 2 zones of fracturing (brecciation) of the roof in the m_3 bed are marked – the first is at a distance of 50 m with a thickness of 10 m, and the second is at a distance of 85 m with a thickness of 30 m (at the moment the accident it was already mined-out space). When sketching a conveyor pass, cracks and erosions were also recorded (point (PC): 116+5.3 m; 117 + 1.2 m; 135 + 6.2 m; 146 + 4.5 m - 145 + 8 m). Coal in the zones of tectonic disturbance is dull, its tendency to spontaneous combustion is higher. These zones coincide with the expected place of methane breakthrough and its ignition.

Owing to the relatively high thickness of the m_3 working bed (up to 1.65 m), the calculated zone of influence of its mine workings strikes upwards from 206 m (for coal beds) to 118 m (for sandstones). In this interval, 2 thick gas-bearing sandstones are located

in the roof of the m_3 bed - $m_4^0SM_4^1$ in 42 meters higher and $m_4^4Sm_5$ 100 meters higher. Both of them are in the drainage zone of EIL # 3, but the gas recovery factors are different ($k_{deg} = 0.54$ and 0.15 , respectively). In the presence of fracturing zones, the degassing coefficient of sandstones rises sharply, as does the volumes of methane emission from them.

During the development of the EIL and EIL # 3 of the m_3 bed, located to the westward (and further from the bend of strata zone), even if these decompression zones were opened, they did not get development. So when EIL development there was a downpour and an increased fracturing. In the influence zone of this longwall (in the arch) in decompression zones, fractured accumulations of methane were formed. These inflows of methane to the mine workings were regulated by a ventilation and degassing system. Therefore, these workings were not classified as dangerous due to gas shows.

EIL # 3, located above (and closer to the bend of strata in the m_3 bed), where the accident occurred, was already worked out in the disturbed massif, where the decompression of the rocks is greater. In case of massif disturbance – caving of the hung roof at a distance of 40 m, this zone began to “work”, fractures opened and methane migrated into the mine workings from the additional underworked and overworked strata. At the same time, the decompression zone connected the mined-out space of the underlying eastern inclined longwall with EIL # 3, where gasification occurred.

Most likely, the smoldering coal in the mined-out space during the breakthrough and “blowing” with methane caught fire and outbursted. Methane explosions occurred where the concentration was explosive 5–16 %, and methane ignited and burned at higher concentrations. Considering the predicted place of ignition in the mined-out space, it can be assumed that the flame “ran” along the developed longwell space up and down to the conveyor and air passages and along them to areas where the methane concentration was less than 16 %, where the outbursts occurred. The breakthrough of methane occurred there in the mined-out space of the EIL # 3, which caused the inflow of methane from highly permeable cavities in the zone of disturbed rocks in a catastrophically short time, in large volumes and under high pressure.

Conclusions

Specific geological-structural conditions of the EIL # 3 of the m_3 bed at the «O.F. Zasiadko mine» led to the formation of a gas-saturated zone, which is in hydrodynamic equilibrium with the massif. This zone is characterized by increased fracturing. After working the EIL # 3, the gas-saturated zone turned out to be in a disturbed and weakened mined-out space. The disturbance and weakness of the mined-out space was due to the working below longwall and the caving of a large area of the hung roof. Under the influence of depression cracks opened, “dumb” in the unloaded massif, which led to the breakthrough of methane and instantaneous gasification of the workings, and, consequently, to the accident.

Thus, gassing of the EIL # 3 of the m_3 bed at the «O.F. Zasiadko mine» caused by a combination of mining-geological conditions. The main geological factor is the presence of a synclinal fold, characterized by increased fracturing. Mapping of local structures and the use of seismological observations make it possible to effectively identify gas-saturated zones and correct degassing projects and parameters of ways to prepare workings.

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