Analysis of Geodynamical Conditions of Region of Burning Coal Dumps Location

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Abstract. Spontaneous combustion of coal dumps and their impact on the environment of mining regions remain important environmental problem, in spite of the measures that are being taken. The paper presents the hypothesis, which states that the location of coal dumps at the boundaries of geodynamically active crust blocks promotes the appearance of conditions for their combustion. At present geodynamically active crust faults that affect the operating conditions of engineering facilities are observed not only in the areas of tectonic activity, but also on platforms. According to the concept of geodynamical zoning, geodynamically dangerous zones for engineering structures can be not only large, well-developed crust faults, but also just formed fractures that appear as boundaries of geodynamically impacting and hierarchically ordered crust blocks. The purpose of the study is to estimate the linkage of burning dumps to boundaries of geodynamically active crust blocks (geodynamically dangerous zones) for subsequent development of recommendations for reducing environmental hazard.

The analysis of 27 coal dumps location was made for one of the Eastern Donbass regions (Russia). Nine of sixteen burning dumps are located in geodynamically dangerous zones, which, taking into account relatively small area occupied by all geodynamically dangerous zones, results that there is a concentration (pcs/km²) of burning dumps, which is 14 times higher than the baseline value. While the probability of accidental obtaining of such a result is extremely low, this can be considered as the evidence of the linkage of burning dumps to geodynamically dangerous zones. Taking into account the stressed state of the rock massif in this region, all geodynamically dangerous zones can be divided into compression and tension zones. The statistic is limited, but nevertheless in tension zones the concentration of burning dumps is 2 times higher than in compression zones. Available results of thermal monitoring of burning dumps in this region also show that linearly extended firing sources oriented along geodynamically dangerous zones are observed. The obtained results show that geodynamical conditions of mining region, in which coal dumps are located, is important factor that impacts the creation of conditions for their spontaneous combustion and subsequent impact on the environment. Then this factor should be controlled by choosing the place for dumps location. It is proposed to carry out these works for the entire mining region of the Eastern Donbass, where there are more than 200 coal dumps.

1. Introduction

At present geodynamically active crust fractures, which affect operating conditions of engineering facilities, are being discovered not only in tectonically active areas, but on the platforms as well [1-4].
According to geodynamical zoning concept, not only large, well-marked crust faults may be hazardous for engineering facilities, but also forming faults, which appear as the boundaries of geodynamically interacting and hierarchically ordered crust blocks [5]. Locating of engineering facilities on the boundaries of crust blocks results in increased accident rate in mines, pipelines, engineering services and etc. [5-8].

In many mining regions of the world the problem of spontaneous firing of coal waste dumps, where coal mining waste is stored, is of high priority despite the measures taken [9-13]. The main reason of spontaneous firing is exothermic reaction of coal matter oxidation, which appears due to air intake into the dump body. So, preventive measures against spontaneous firing are aimed to isolation of bottom and slopes of the dump in order to prevent atmospheric air intake and treatment of the dump body with antipyrogenes. But when locating the dump on the boundary of geodynamically active crust blocks more favourable conditions for air intake into the dump body may appear due to modern ongoing geodynamical processes. This hypothesis, according to which the location of coal dumps on the boundary of geodynamically active crust blocks promotes the appearance of conditions for their firing, is the concept of performed research.

As far as we know, no research was performed on linkage of burning dumps with the boundaries of geodynamically active crust blocks. At the same time, the problem of spontaneous firing of dumps and selection of their location is of high priority not only from technical-and-economic viewpoint, but from environmental viewpoint as well. In this connection, the task to estimate linkage of burning dumps with the boundaries of geodynamically active crust blocks is considered in this paper through the example of one of the Eastern Donbass regions.

2. Research methods
In late 1980’s in one of Donbass regions complex scientific research was performed to study geodynamic processes and stress condition of the rock massif within two mine fields [14], which included the works on detection of block structure of the region. In this paper we partially used the schemes of block structure of crust and also the data about stress condition of the region, which was obtained earlier. Width of the area of blocks boundaries influence (Нgoz) may be evaluated as 10N, where N – wings displacement amplitude [5]. For the considered region width of the area of influence Hgoz in calculations is taken equal to 200 m. It means that, if any part of the dump is within the area of blocks boundaries influence, then it is assumed that the dump is located on the blocks boundary.

In order to analyze linkage of burning dumps with the boundaries of crust blocks current data base was updated in accordance with actual condition of the dumps in this region and also mathematical statistics methods were used.

When analysing geodynamical conditions of the dumps location areas, approaches being developed in tectonophysics were also used, according to which for space-fixed fracture areas type of deformation on the boundaries of the blocks may be determined (compression-tension-shear) [15-17 at al.].

3. Results
3.1 Analysis of linkage of burning dumps with the boundaries of crust blocks
Data about actual condition of coal dumps is presented in table 1. Twenty-seven dumps are located in the region being researched. Firing happened at 16 of these dumps, and 6 of them at this continue to burn currently. Nine of 16 dumps where firing happened are located on the boundaries of crust blocks, table 1, figure 1.
Table 1. Actual condition of coal dumps in the region of Shakhty, Eastern Donbass

| No. | Condition    | Total | Located on the blocks boundaries |
|-----|--------------|-------|----------------------------------|
| 1   | Burning      | 11    | 6                                |
| 2   | Extinguished | 5     | 3                                |
| 3   | Not burning  | 11    | 2                                |
|    | TOTAL:       | 27    | 11                               |

Figure 1. Scheme of dumps location where spontaneous firing happened in the region of Shakhty, Rostov region

Let’s estimate and compare specific density (concentration) of burning dumps location outside and on the boundaries of geodynamically active blocks (pcs/km²).

Area of the region being researched:

\[ S_0 = 228 \text{ km}^2 \]  

Total length of the blocks boundaries in the region being researched:

\[ L_{goz} = 45 \text{ km} \]  

Area occupied by the areas of blocks boundaries influence:

\[ S_{goz} = L_{goz} \times H_{goz} = 45 \times 0.2 = 9 \text{ km}^2 \]

Then specific density of burning dumps location within the territory being researched \( \rho_1 \) will be equal to:
\[ \rho_1 = \frac{N_1}{S_0} = \frac{16}{228} = 0.07 \text{ pcs/km}^2 \]  \hspace{1cm} (4)

where \( N_1 \) – total amount of burning dumps (table 1).

Specific density of burning dumps location on the blocks boundaries \( \rho_2 \) will be equal to:

\[ \rho_2 = \frac{N_2}{S_{goz}} = \frac{9}{9} = 1 \text{ psc/km}^2 \]  \hspace{1cm} (5)

where \( N_2 \) – amount of burning dumps located on the blocks boundaries.

We may determine that \( \rho_1/\rho_2 = 14 \), i.e. concentration of dumps where spontaneous firing happened on the boundaries of crust blocks is 14 times bigger than their average concentration in this territory. It may be considered as evidence of linkage of dumps where firing happened with the boundaries of crust blocks.

### 3.2 Analysis of tectonophysical conditions in the areas of burning coal dumps location

Regional stress field in the region shows subhorizontal direction of maximum compression \( \sigma_{\text{max}} \), which effects in sectors of 90-180° (NW and SE of the sector). Study of local stress field in the region of Donetsk shows that axis of maximum compression \( \sigma_{\text{max}} \) is horizontally oriented in NW direction (135°), axis of minimum compression \( \sigma_{\text{min}} \) is horizontally oriented in NE direction and axis of intermediate stresses \( \sigma_2 \) is vertical. Paper [18] contains the results of stress measurement in Donetsk mines by the means of hydraulic fracturing. The authors conclude that maximum compression in the region is horizontally oriented and exceeds vertical component by 2.4 – 3.5 times.

Thus, we may assume that in the region of coal dumps location being researched shear stress field acts where maximum compression is SE-NW oriented. In this stress field on vertically oriented boundaries of blocks 4-4 and 2-2 of north-west direction according to the scheme presented in figure 1 tension conditions arise, and on the boundaries of blocks 1-1 and 3-3 of north-east direction compression conditions arise. On the boundaries of blocks exposed to tensile deformation according to proposed hypothesis more favourable conditions may arise for deformation of the dumps bases and air intake to stored coal material.

Distribution of burning dumps on the boundaries of blocks with different tectonophysical conditions is presented in table 2.

**Table 2.** Specific density of location of dumps where firing happened on the boundaries of crust blocks

| Location of the blocks boundaries in modern stress field | Amount of dumps where firing happened | Total length of blocks boundaries, km | Specific density of dumps where firing happened on the blocks boundaries, pcs/km² |
|--------------------------------------------------------|--------------------------------------|--------------------------------------|----------------------------------------------------------------------------------|
| Boundaries located in tension sectors                  | 5                                    | 17                                   | 0.29                                                                              |
| Boundaries located in compression sectors               | 4                                    | 28                                   | 0.14                                                                              |
4. Discussion of the results
4.1 Estimation of reliability of conclusion on linkage of burning dumps with the boundaries of
geadynamically active blocks
Let’s estimate the probability of the fact that 9 of 16 burning dumps are on the boundaries of the
blocks accidentally.

Let’s suppose that burning coal dumps are distributed in accidental order. Then geometric
probability of the fact that the dump is within the area of block boundaries influence \( P_{gd} \) will be equal
to:

\[
P_{gd} = \frac{S_{goz}}{S_0} = \frac{9}{228} = 4\%
\]  

Let’s determine the probability of the fact that not less than \( x=9 \) of \( n=16 \) burning dumps will be on
the boundaries of the blocks accidentally using the formula from [19]:

\[
B(x; n; P_{gd}) = \sum_{i=0}^{x-1} b(i; n; P_{gd}) = 1 - \sum_{i=x}^{n} b(i; n; P_{gd})
\]  

In this case \( x - 1 = 9 - 1 = 8 \)

As values \( P_{gd} \) and \((1/n)\) are of the same magnitude and \( P_{gd} < 0.1 \), let’s use the formula:

\[
B(x; n; P_{gd}) \approx 1 - \Psi(x; n; P_{gd}),
\]

where \( \Psi(x; n; P_{gd}) = \Psi(x; \mu) \) - Poisson distribution.

For the considered case \( \mu = n \times P_{gd} = 16 \times 0.04 = 0.64 \). Values of function \( \Psi \) data [19] are
presented in table 3.

**Table 3. Values of function \( \Psi \)**

| x  | 0   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| \( \Psi \) | 1   | 0.7275 | 0.3732 | 0.1429 | 0.0431 | 0.0107 | 0.0022 | 0.0004 | 0.0001 |

Let’s plot a curve of function \( \Psi = f(x; \mu) \) per data from table 3, figure 2.
It is seen from the curve that probability of the fact that 9 of 16 burning dumps will accidentally be on the boundaries of the blocks is negligibly small, which formally proves the conclusion on linkage of burning dumps with blocks boundaries.

4.2. Tectonophysical conditions in areas of burning dumps location

Nine burning dumps, which are on the boundaries of crust blocks, are almost equally distributed between the boundaries of north-east and north-west extensions, but total length of the boundaries of north-west direction (tension boundaries) is less due to which concentration of dumps on these boundaries (pcs/km2) is approximately 2 times higher, table 2. Although here we have limited statistical sample, never the less such distribution of burning dumps may be attributable to the fact that on the boundaries of crust blocks with tensile conditions more favourable conditions arise for fracture of insulating course of dump and air intake into its body through cracks due to traction force.

Also linkage of burning coal dumps with the boundaries of crust blocks is indirectly proved by linear shapes of seats of fire detected during monitoring of dumps [20]. For example, on the dump at Nesvetayevsksya mine, which was piled in tiers, seats of fire are stretched in a chain in north-west direction, which corresponds with extension of the boundary of geodynamically active blocks.

5. Conclusions

Analysis of results of geodynamical zoning, stress condition of the region, locations of burning coal dumps and shapes of seats of fire in the region of Shakhty, Eastern Donbass allows supposing that one of the factors affecting the conditions of spontaneous combustion of dumps is modern geodynamical processes. The following research results argue for this supposition:

- Specific density of location (concentration) of burning coal dumps and coal dumps where firing happened on the boundaries of crust blocks (pcs/km²) is 14 times higher than background value of this parameter.
- Specific density of location (concentration) of burning coal dumps and coal dumps where firing happened on the boundaries of geodynamically active blocks with tension conditions is higher than on the boundaries with compression conditions.
- Seats of fire on several dumps located on the boundaries of geodynamically active blocks have linear shape oriented in accordance with extension of blocks boundaries.

Further, it is planned to extend this research on other regions of Eastern Donbass and involve more extensive statistical material into the analysis.

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