Assessment of the Impact Hazard of the Array Taking Into Account the Geological Features of the Structure of Electric Profiles

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Abstract. The current geodynamic situation at the Tashtagol iron ore Deposit is considered. The impact hazard of the array was determined using electrometric coefficients obtained taking into account the geological structure of the array. An assessment of the correspondence of the obtained coefficients to actually registered geodynamic phenomena was made.

1 Introduction

The experience of mining all ore deposits in Western Siberia shows that with increasing depth of mining operations, there is an increase in the intensity and frequency of manifestations of mountain pressure in a dynamic form. The most representative in terms of manifestations of dynamic phenomena is Tashtagolskoe field.

A total of 595 events with an energy of more than 100 J were recorded at the Tashtagolsky mine during the period from February 2018 to August 2019 within the horizon (-350), with more than 70% of them occurring below the horizon (-300). Their distribution by month and energy class is shown in table 1. At the same time, during the period under review, there is an increase in cases of mountain pressure manifestations in the workings, and there is an increase in energy and the approach of the foci of events to the workings.

Table 1. Distribution of geodynamic events by month and energy class within the horizon (-350) for the period from 01.02.18 to 30.08.19.

Date	Energy class of a geodynamic event						Violation of fastening of mine workings	Total
	2	3	4	5	6	7		
February 2018	27	4	1	-	-	-	-	32
March 2018	6	-	-	-	-	-	-	6
April 2018	8	2	-	-	-	-	-	10
May 2018	4	3	1	-	-	-	-	8
June 2018	9	6	2	1	-	-	-	18

July 2018	11	5	2	-	1	-	-	19
August 2018	9	1	2	-	-	-	-	12
September 2018	13	4	1	-	-	-	-	18
October 2018	12	-	-	-	-	-	-	12
November 2018	18	1	-	-	-	-	-	19
December 2018	4	5	-	-	-	-	-	9
January 2019	11	-	4	1	-	-	-	16
February 2019	30	12	-	2	1	-	+	45
March 2019	29	11	2	1	-	-	+	43
April 2019	25	9	1	-	-	-	-	35
May 2019	69	12	4	-	3	-	+	88
June 2019	47	8	1	-	2	-	+	58
July 2019	75	12	3	-	-	1	+	91
August 2019	37	13	3	1	-	2	+	56
Subtotal	444	108	27	6	7	3	6	595

At the same time, during the period under review, there is an increase in cases of mountain pressure manifestations in the workings (table 2), and there is an increase in energy and the approach of the foci of events to the workings.

Table 2. The manifestation of rock pressure.

Geodynamic events	Date	Energy, J	Energy class	Manifestation of the rock pressure
1	28.02.2018	1442374	6.2	Violation of fastening of mine workings
2	06.02.2019	5516.046	3.6	
3	26.03.2019	365907.4	5.6	
4	17.05.2019	35910.68	4.6	
5	16.06.2019	14762.41	4.2	
6	30.06.2019	2190742	6.3	
7	21.07.2019	70076416	7.8	
8	16.08.2019	41717324	7.6	

Currently, at the mines, in particular, at tashtagolskoye, for the regional forecast of the degree of impact hazard of the array, it is carried out mainly by methods of Electrometry and microseismics. The foreign experience of recent years is mainly limited to the coal deposits of China and Poland [1-10] and is based on the study of similar individual issues, while focusing on the technology of mining and the mechanism of formation of a mining shock, rather than its forecast. The impact hazard of the array during electrometric measurements at the

first stage is determined by the value of the electrometric coefficient $K_{\rho}^* = \rho_{cp} / \rho_n$, where ρ_{cp} - the average value of the CUES for the entire measuring profile or for each structural block, ρ_n - the average value of CUES in the absence of geodynamic phenomena. When the coefficient is set $K_{\rho}^* < 1$ in controlled workings, special measures are taken to identify impact-prone areas of the array.

2 Theoretical part of the question

However, the iron ore deposits of the Mountain Shoria are represented by a large number of vertical or steeply falling contacts between rocks that compose the array around the mine workings, and the electric profile lines laid along their sides intersect a set of fairly well-defined vertical (steeply falling) rock layers. When an electric current flows or electromagnetic waves propagate through a layered medium, reflection and refraction phenomena are observed at the contacts of the layers, which affects the distribution of the CUES along the measuring profile. Thus, this array should be represented as an alternation of vertical homogeneous isotropic layers of rocks [11-13]. If the electrical resistance of the i - th layer is equal to

$$R_i = \rho_{ki} / h_i, \quad (1)$$

then the entire layered array should be represented as a parallel connection n resistors with resistance R_i each layer. Then the total (equivalent) resistance of the array R_{equ} will be equal to:

$$\frac{1}{R_{equ}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n} = \sum_{i=1}^n \frac{1}{R_i} \quad (2)$$

Subject to (1) formula (2) will take the form:

$$\rho_{k(equ)} = \frac{\sum_{i=1}^n h_i}{\frac{h_1}{\rho_{k1}} + \frac{h_2}{\rho_{k2}} + \dots + \frac{h_i}{\rho_{kn}}} \quad (3)$$

A similar approach to accounting for the number of layers and replacing their set with one equivalent is used in the theory of grounding devices, especially when designing grounding and lightning protection systems.

3 Results and discussion

Using the formula (3), the electrometric measurements were recalculated for all controlled workings (Cargo and Empty crosscut, South-Eastern field drift) on the horizon (-350). Table 3 shows the results of this recalculation and a comparison of the obtained electrometric coefficients based on the arithmetic mean of the CUES K_{ρ}^* and taking into account the geological structure of the array K_{ρ}^{**} .

Table 3. Results of recalculation and comparison of electrometric coefficients Tashtagolsky mine for the period from 01.02.18 to 30.08.19.

Date of measurement	South-East field drift		Cargo crosscut		Empty crosscut	
	K_{ρ}^{**}	K_{ρ}^{*}	K_{ρ}^{**}	K_{ρ}^{*}	K_{ρ}^{**}	K_{ρ}^{*}
14.02.2018	0.51	1.48	0.41	0.69	1.04	1.31
13.03.2018	0.37	1.07	0.25	0.43	0.91	1.10
07.05.2018	0.62	1.13	0.39	0.77	0.61	1.04
05.06.2018	0.30	1.00	0.22	0.43	0.36	0.66
02.07.2018	1.68	2.19	1.70	2.11	0.90	1.48
30.07.2018	2.40	3.08	0.44	0.53	1.52	2.36
07.08.2018	0.82	1.46	0.99	1.34	0.38	1.06
14.09.2018	0.66	1.07	0.71	1.08	0.31	0.77
04.10.2018	1.76	2.27	0.85	1.30	0.34	0.83
23.11.2018	1.09	2.01	1.28	1.63	0.42	1.12
04.12.2018	2.87	3.04	1.95	2.13	0.84	1.31
10.01.2019	0.53	1.15	0.45	0.90	0.31	0.98
07.02.2019	1.07	1.66	0.63	1.24	0.23	0.81
05.03.2019	0.85	1.33	0.40	0.43	0.43	0.67
02.04.2019	0.75	1.25	0.42	0.94	0.27	0.98
27.05.2019	0.37	0.88	0.33	0.89	0.69	1.13
10.06.2019	0.27	0.72	0.56	1.21	0.49	1.07
02.07.2019	0.60	0.98	0.75	1.24	0.60	1.01
23.08.2019	0.40	0.80	0.27	0.63	0.40	0.71

Electrometric values of the coefficients K_{ρ}^{**} on average, by 40%, and in some cases by 70% reduced, compared to K_{ρ}^{*} . The quantitative distribution of the obtained qualitative characteristics of the impact hazard of the array is presented in table 4.

Table 4. Quantitative distribution of qualitative characteristics of rockburst hazard in the array Tashtagol Deposit for the period from 01.02.18 on 30.08.19 year.

Data processing methods	K_{ρ}^* – electrometric coefficient determined according to the current instructions			K_{ρ}^{**} – electrometric coefficient determined with consideration of the geological structure of the electric profile		
Quality indicators possible manifestations of geodynamic phenomena	There is no possibility of geodynamic phenomena occurring in the rock mass	Local stress concentration is carried out in the rock mass	Possible geodynamic phenomena of class 3 and 5	There is no possibility of geodynamic phenomena occurring in the rock mass	Local stress concentration is carried out in the rock mass	Possible geodynamic phenomena of class 3 and 5
Quantity	35	19	3	9	20	28

Electrometric coefficient K_{ρ}^{**} four times less often pointed to the absence of the possibility of geodynamic phenomena and nine times more often - on the possibility of occurrence of geodynamic phenomena above the third class. Figure 1 shows more clearly the comparison of average values of electrometric coefficients K_{ρ}^{**} for the horizon (-350). The graph clearly shows three periods characterized by a reduced (from October to December 2018) and increased geodynamic activity of the array (from February to September 2018 and from January to August 2019). In this case only the average values of the electrometric coefficients K_{ρ}^{**} in most cases they demonstrate compliance with registered geodynamic phenomena.

Fig. 1. Electrometric coefficients (K_{ρ}^* and K_{ρ}^{**}) and geodynamic phenomena for the period from 01.02.2018 to 30.08.2019.

This is also evidenced by data on average values K_{ρ}^{**} for the horizon (-350) for recorded geodynamic phenomena shown in table 5.

Table 5. Correspondence of registered geodynamic phenomena to electrometric coefficients K_{ρ}^{**}

% p. p.	Date of measurement	K_{ρ}^{**}	The presence of geo- dynamic phenomena is higher third class	Correspondence of geodynamic phenomena to electrometric coeffi- cients
1	February 2018	0.7	yes	Confirms
2	March 2018	0.6	no	Not confirmed
3	April 2018	0.5	yes	Confirms
4	May 2018	0.4	yes	Confirms
5	June 2018	0.3	yes	Confirms
6	July 2018	1.4	yes	Not confirmed
7	August 2018	0.7	yes	Confirms
8	September 2018	0.6	yes	Confirms
9	October 2018	1.0	yes	Not confirmed
10	November 2018	0.9	no	Confirms
11	December 2018	1.9	no	Confirms
12	January 2019	0.4	yes	Confirms
13	February 2019	0.6	yes	Confirms
14	March 2019	0.6	yes	Confirms
15	April 2019	0.5	no	Not confirmed
16	May 2019	0.5	yes	Confirms
17	June 2019	0.4	yes	Confirms
18	July 2019	0.7	yes	Confirms
19	August 2019	0.4	yes	Confirms

Table 5 shows that out of 19 measurements, the discrepancy between the electrometric coefficient K_{ρ}^{**} and the registered geodynamic phenomena was found in four cases.

4 Conclusion

Thus, processing of measurement results taking into account the geological structure of electrophiles significantly approximates the electrometric forecast to the real assessment of the seismic events that occurred. The forecast efficiency increases to 80%.

References

1. Q. Qihu, Scholl of engineering bulletin, **3**, 109-117 (2014)
2. C. Wang, *Evolution, Monitoring and Predicting Models of Rockburst: Precursor Information for Rock Failure* (Springer, New York, 2018)
3. L. Dou, Z. Mu, Zh. Li, A. Cao, S. Gong, International Journal of Coal Science & Technology, **1**, 278-288 (2014)
4. R. Patyńska1, A. Mirek, Z. Burtan, E. Pilecka, E3S Web Conf., **36**, 1-8 (2018)
5. F. Xia-Ting, *Rockburst: Mechanisms, Monitoring, Warning, and Mitigation* (Butterworth-Heinemann, Berlin, 2018)

6. Z. Li, X. He, L. Dou, G. Wang, *Geosciences Journal*, **22**, 623-639 (2018)
7. Wei Shen, Lin-ming Dou, H. He, G. Zhu, *Arabian Journal of Geosciences*, **10**, Article number: 196 (2017)
8. A. Cao, L. Dou, Ch.Wang, X. Yao, J. Dong, Y. Gu, *Rock Mechanics and Rock Engineering*, **49**, 4407-4422 (2016)
9. C. Lu, L. Dou, N. Zhang, J. Xue, G. Liu, *Natural Hazards*, **73** (2014)
10. J. He , L. Dou , A. Cao , S. Gong, J. Lü, *Journal of Central South University*, **19**, 1086-1091 (2012)
11. D. Szurgacz, J. Brodny, *Sustainability*, **11(9)**, 2570 (2019) DOI: doi.org/10.3390/su11092570
12. D. Szurgacz, J. Brodny, *Energies*, **12(20)**, 3945 (2019) DOI: doi.org/10.3390/en12203945
13. D. Szurgacz, J. Brodny, *Energies*, **13(2)**, 405 (2020) DOI: <https://doi.org/10.3390/en13020405>