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Research the dynamical characteristics of slow deformation waves as a rock massif response to explosions during its outworking

Hachay O.[a]*, Khachay O.[b],Shipeev O.[c]

[a]*Institute of geophysicsUB RAS,Amundsen str.100,Ekaterinburg,620016, Russia*
[b]*Ural Federal University,Mira str.19, Ekaterinburg 620002, Russian Federation*
[c]*Tashtagol mine,Kemerov region,Tashtagol,Lenina 21 Ekaterinburg 652990, Russian Federation*

Abstract The use of additional parameter-velocity of slow deformation wave propagation allowed us with use method of phase diagrams identify their hierarchic structure, which allow us to use that information for modeling and interpretation the propagation seismic and deformation waves in hierarchic structures. It is researched with use of that suggested processing method the thin structure of the chaotic area for two responses of the massif on a high energetic explosion in the northern and southern parts of it. The results are significant for understanding the high energetic rock shock and evaluation a criterion for massif stability estimation.

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Keywords: massif response, slow deformation waves, seismic mine catalogue, analyze of observed data, phase diagrams, massif stability

1. Introduction

As a result of generalization of the long time natural geomechanical and geophysical measurements data on the mines of polymetallic rocks it was established a nonlinear rocks reaction on heavy dynamical influence and also

Corresponding author:Hachay O. Tel.: +79122276074; fax: +73432678872.
E-mail address: olgakhachay@yandex.ru

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distribution waves of pendulum type, which are created by geoblocks of different hierarchic rank [1]. Their velocities differ from the velocities of seismic waves by their lower values [2, 3]. The research of the rock shock massif state of the Tashtagol mine with the approaches of the theory of dynamical systems [2, 3] had been provided to reveal the criterions of changes the dissipative regimes for real rock massive, which are heavy technogenic influenced .For realization of that research it had been used the data of seismic catalogue of the Tashtagol mine during two years: from June 2006 up to June 2008. It had been used the space-time coordinates of all dynamical responses of the massif, which occur during that period inside the mining field, and also of explosions, which had been arranged for massif mining and of values of the fixed by the seismic station energy. [8]. The phase portraits of the massif state from the northern and southern areas are constructed in the coordinates *E(Ev)(t)* and *d(E(Ev)(t))/dt*, *t*-time expressed in the parts of 24 hours, *Ev*-released by the massif seismic energy in joules. Here we had analyzed the morphology of phase trajectories of the seismic response on explosion action during different subsequent time intervals of the southern mines area. In the papers, for instance, [8, 9] for the first time it had been analyzed the seismological detailed mines information from the point of view of synergetic and theory of open dynamical systems. Using the quality analysis of phase trajectories [5] it had been shown the repeating regularities that represent the transitions of the massif state from the chaotic state to the ordered state and reverse. It had been formulated a new physical statement of the problem for modeling the state of the rock massive, which are under heavy action. If in other statements of the general theory of open dynamical systems [10, 11] the problem of the system transition from the ordered state to the chaotic state had been researched in our case for our system the chaotic state of the given level (parameter) is from one side a stable state for our system. From the other side that parameter is a control parameter for the system transition to the state with another parameter that is for the system catastrophic. After realization of that catastrophe the system creates again the chaotic area with the parameter value near to the initial. In the paper [12] the further research of the detailed seismic catalogue was devoted to space-time oscillatory peculiarities of synergetic features of the rock shock massif by its outworking using explosion methods.

2. Method of processing

Using the ideas, considered in the papers [1–3], and posed questions by the analysis of seismological monitoring data we decided to add the analyzed base by data of space coordinates of explosions, include them into the processing method if seismological monitoring data and it by new parameters. Let us consider each point of explosion as a source of seismic and deformation waves. Using the kinematic approach of seismic information processing we shall each point of massif response use as space-time point of the first arrival of the deformation wave for calculation of its velocity. Let us introduce two groups of velocity gradations: the first group –from 1000 m/hour up to 500 m/hour, from 500 m/hour up to 100 m/hour, from 100 m/hour up to 50, from 50 m/hour up to 10 m/hour, from 10 m/hour up to 1 m/hour, from 1 m/hour up to 0. 01 m/hour; second group – from 1000 m/sec up to 500 m/sec, from 500 m/sec up to 100 m/sec, from 100 m/sec up to 50 m/sec, from 50 m/sec up to 10 m/sec, from 10 m/sec up to 1 m/sec, from 1 m/sec up to 0. 01 m/sec. All responses together with their space-time characteristics, velocities and energies we have to distribute according to these gradations and calculate the average values of the released energetic characteristics and correspondently the average velocities of the deformation waves train from the explosion to another one.

3. Results and discussions

From the analysis (figure 1.) we can conclude that the values of average through the whole period of observation velocities of the deformation waves, propagated in the southern and northern parts of rock massif of the mine only slightly differ from each other, and for the four gradations practically coincide. By that the energy amount, which is carried by the waves of the four gradations of the first group differs also only slightly. But for waves with velocities from gradations 10 m/hour-1 m/hour, and 1 m/hour-0.01 m/hour the average released energy amount during the period of observation in the northern part of the mine is more on the order of 2 of the correspondent value of the southern part. Regarding the deformation waves of the second group in the northern part of the mine, only three gradations are realized during the whole period of observation, in the southern part of the mine - four. The amount of the released energy by waves of that group is approximately equal (figure 1).

The morphology of the phase diagrams with taking into account the velocities of deformation waves propagation, remains the same as it was shown in the paper [6], but the centers of the chaotic quasistable state for these two gradations are shifted along the horizontal axis relative to each other (figure 2). That can testify the influence of the hierarchic massif structure that extends waves with average velocities of different gradations.

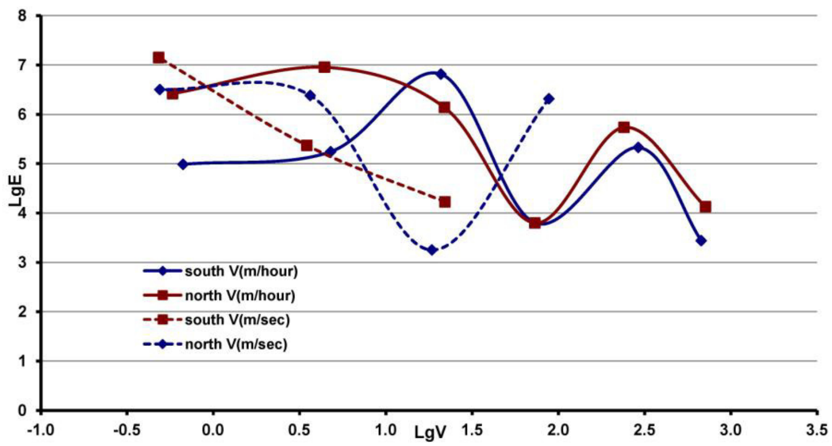

Figure 1. Distribution of the summarized released energy E by dynamical events, propagated with different average velocities *Vav* during the period of observation 24. 07. 2011 – 07. 07. 2012.

Legend: South-southern part of the mine, North-northern part of the mine.

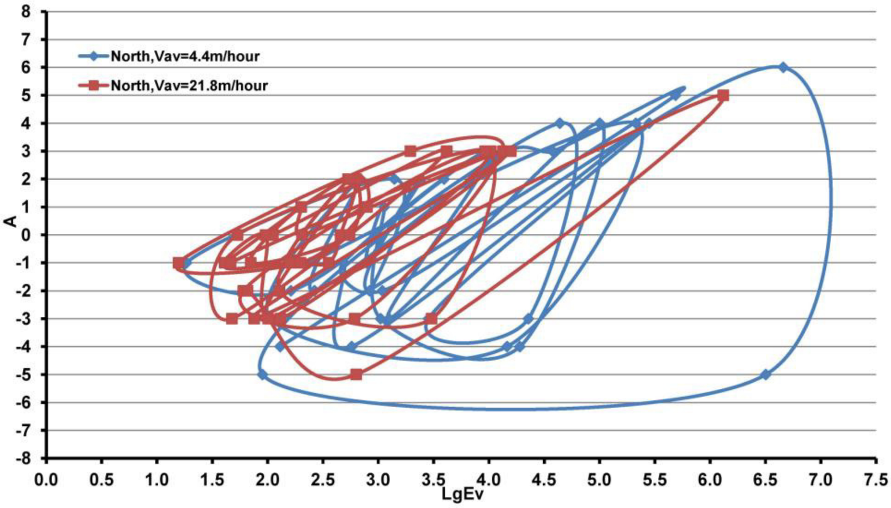

Figure.2. Hierarchic structure of phase diagrams of the northern part of the mining field during the period of observation 24. 07. 2011 – 07. 07. 2012 for two gradations of the velocity values of the deformation waves propagation. *E*-released energy in joules by the massif during the explosions, A=$aLgf$, $f = \left|\partial E / \partial t\right|$, a=$sign\ \partial E$, the other designations are the same as for the figure 1.

For the southern part of the mining field the morphology of the phase diagrams corresponds to the morphology for the northern part, but the shift the chaotic quasistable state in the phase diagrams (figure 3) is absent. That can testify the influence of the heterogeneous but not hierarchic structure of the massif that created the deformation waves with average velocities of two different gradations. That result of course is linked with given period of the massif state observation. It is very interesting to search the stability in time the structure of the phase diagrams.

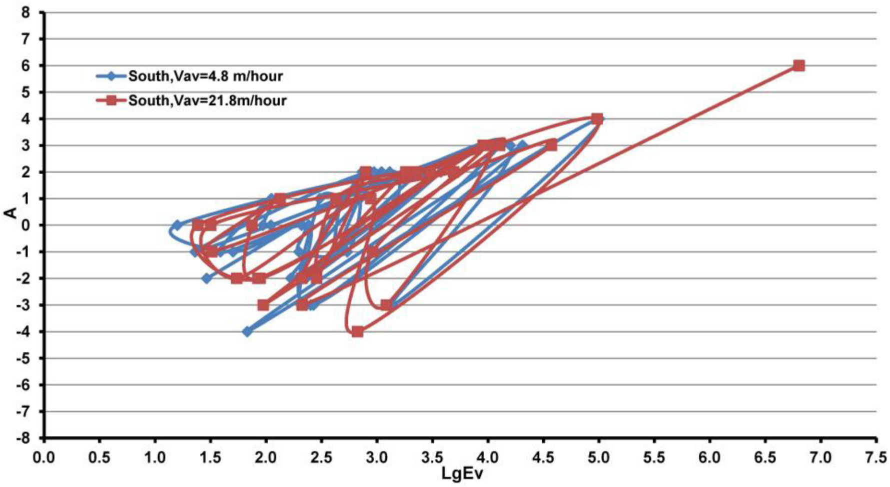

Figure 3. Hierarchic structure of phase diagrams of the southern part of the mining field during the period of observation 24. 07. 2011 – 07. 07. 2012 for two gradations of the velocity values of the deformation waves

propagation. *E*-released energy in joules by the massif during the explosions, A=$aLgf$, $f = \left|\partial E / \partial t\right|$, a=$sign\ \partial E$, the other designations are the same as for the figure 2.

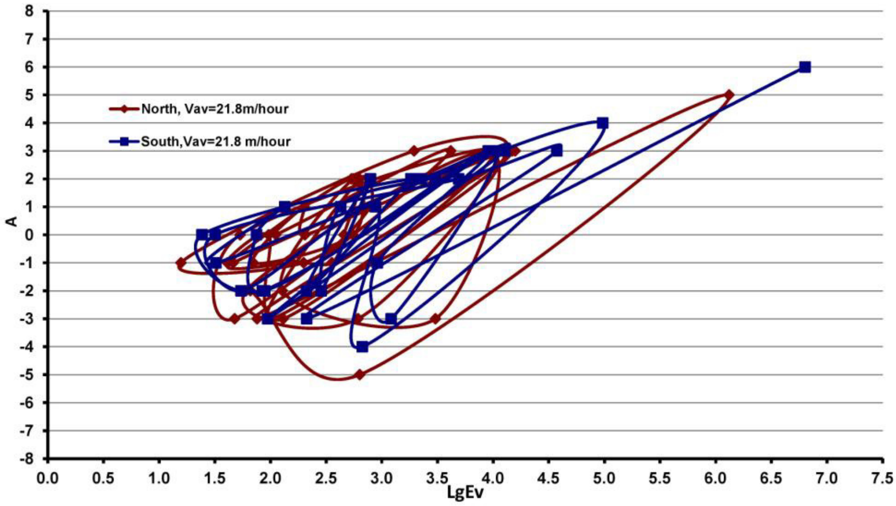

Figure 4. The structure of the phase diagrams for the southern and northern parts of the mines field during the period of observation24. 07. 2011 – 07. 07. 2012 for one and the same average velocity gradation of deformation wave propagation: from 50 m/hour up to 10 m/hour. *E*-released energy in joules by the massif during the explosions, A=$aLgf$, $f = \left|\partial E / \partial t\right|$, a=$sign\ \partial E$, the other designations are the same as for the figure 3.

The result of comparison of phase diagrams structures of the southern and northern parts of the mines field (figure 4) testifies the absence of the chaotic area shift. There are subsequent with energy increasing jumping and return into the quasi stable chaotic area for the northern part, for the southern part we can see only one high energetic outburst. It is interesting to note that the values of the average velocities of the deformation waves for the northern and southern parts are equal.

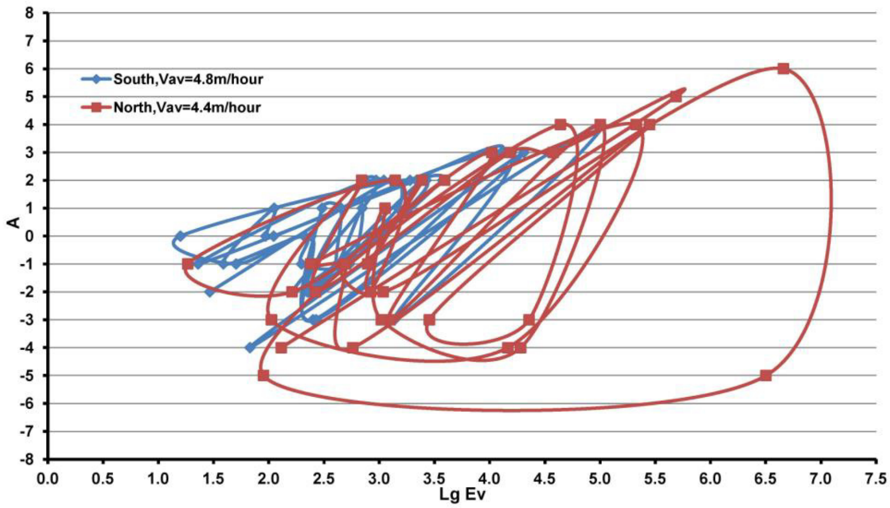

Figure 5. The structure of the phase diagrams for the southern and northern parts of the mines field during the period of observation24. 07. 2011 – 07. 07. 2012 for one and the same average velocity gradation of deformation wave propagation: from 10 m/hour up to 1 m/hour. *E*-released energy in joules by the massif during the explosions, A=*aLgf*, $f = \left|\partial E / \partial t\right|$, *a=sign* ∂E, the other designations are the same as for the figure 4.

The result of comparison of phase diagrams structures of the southern and northern parts of the mines field (figure5) for other group of average velocities testifies that the chaotic area shift exists. It is a very significant fact in processing of the seismological catalogue data. At first the different groups of deformation waves are different sensitive to the types of massif structure. And therefore we can classify the massif structure on simple heterogeneous and with hierarchic structure. If the local structure is more complicated we can expect the more nonlinear response that can lead to a catastrophic event.

4. Conclusions

Using the additional parameter-velocity of propagation slow deformation waves allowed with use of the method of phase diagrams to identify the hierarchic structure of the massif. That information can be used for modeling and interpretation propagation of seismic and electromagnetic waves in the hierarchic structures [13]. The results are significant for understanding the high energetic rock shock and evaluation a criterion for massif stability estimation.

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