Future of Mining Techniques in Deep Ore Mines without Catastrophic Risks

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Abstract : *Self-organization is not a universal property of matter, it exists under certain internal and external conditions and this is not associated with a special class of substances. The study of the morphology and dynamics of migration of anomalous zones associated with increased stresses is of particular importance in the development of deep deposits, complicated by dynamic phenomena in the form of rock impacts. An important tool for this study is geophysical survey and monitoring. To describe the geological environment in the form of an array of rocks with its natural and technogenic heterogeneity, one should use its more adequate description, which is a discrete model of the medium in the form of a heterogeneous block medium with embedded heterogeneities of a lower rank than the block size. We have carried out an analysis of the morphology of the structural features of disintegration zones before a strong dynamic phenomenon. The introduction of the proposed integrated passive and active geophysical monitoring into the mining system, aimed at studying the transient processes of the redistribution of stress-strain and phase states, can help to prevent catastrophic dynamic manifestations during the development of deep-located deposits. Active geophysical monitoring methods should be tuned to a hierarchical heterogeneous model.*

Keywords — *anomalous stress zones, morphology and dynamics dangerous zones, including geophysical monitoring in the mining system, analyze of* preventing *catastrophic events.*

I. INTRODUCTION

The most important result of geomechanical and geodynamic studies of the past century was the discovery of a close relationship between global geodynamic and local geomechanical processes caused by mining operations, especially in tectonically active zones. No less important result of the research was the conclusion about the fundamental role of the block-hierarchical structure of rocks and massifs for explaining the existence of a wide range of nonlinear geomechanical effects and the emergence of complex self-organizing geosystems. Hierarchical structure is typical for many systems, especially for the Earth's lithosphere, where more than 30 hierarchical levels from tectonic plates with a length of thousands of kilometres to individual mineral grains of millimetre size were identified by geophysical studies [1]. Thus, the earth's crust is not a continuous medium, but a discrete block system and, like any synergetic discrete ensemble, has hierarchical and self-similarity properties [2].

In recent decades, a new science has been born - the physics of noneqiulibrium processes associated with concepts such as irreversibility, self-organization, and dissipative structures [3]. Irreversibility is known to lead to many new phenomena, such as the formation of vortices, vibration chemical reactions, or laser radiation. Irreversibility plays an essential constructive role. It is impossible to imagine life in a world devoid of the interconnections created by irreversible processes. The prototype of the universal law of nature is Newton's law, which can be summarized as follows: acceleration is proportional to force. This law has two fundamental features. It is deterministic: since the initial conditions are known, we can predict the motion. And it is reversible in time: there is no difference between predicting the future and restoring the past; the movement to the future state and the reverse movement from the current state to the initial one are equivalent. Newton's law is the basis of classical mechanics, the science of the motion of matter, of trajectories. Since the beginning of the 20th century, the boundaries of physics have expanded significantly. Now we have quantum mechanics and the theory of relativity. But, as we will see from what follow, the main characteristics of Newton's law — determinism and reversibility in time — have been preserved. Is it possible to modify the very concept of physical laws so as to include irreversibility, events, and the arrow of time in our fundamental description of nature? The adoption of such a program entails a thorough revision of our formulation of the laws of nature, and it became possible thanks to the remarkable successes associated with the ideas of instability and chaos [3, 4]. Returning to the results obtained for unstable mountain massive, we can note that monitoring studies should be conducted in an active mode, i.e. there must be an excitation source (seismic or other nature), and a response is recorded from it for a not very long time, then the effect must be repeated and phase diagrams of the state of the rock mass can be built for this process.

II. INFORMATIVE SIGNS OF HIGH-ENERGY DYNAMIC PHENOMENA PREPARATION ACCORDING TO MINE SEISMOLOGICAL MONITORING.

To create a dynamic model adequate to the processes of preparing high-energy manifestations in mountain areas that are under a strong technogenic impact, it was necessary to use monitoring data in a natural occurrence. For this, an analysis was made of the data from the detailed seismic catalogue of the Tashtagol underground mine for two years of observations from January 2006 to January 2008. The data used are the spatial-temporal coordinates of all dynamic phenomena — array responses that occurred during this period inside the mine field and explosions performed to mine the array, as well as the values of the energy of explosions and array responses recorded by the seismic station [5]. The entire mine field was divided into two halves: the workings of the north-western section, the areas of the Western and Novo-Kapitalnaya shafts and the holes from 0 to 13 were designated by us as the northern section. Excavations from 14 to 31, the southern ventilation and field drifts, the shaft of the reaching 106 J and even 109 J [5,6]. Obviously, there are two interdependent processes: the Southern mine, the excavations of the southeastern section are designated as the southern section. All response events from horizons with marks of 140 m, - 210 m, - 280 m, - 350 m (maximum depth 800 m) were analyzed. The effects in the form of explosions were carried out in the southern, south-eastern, north-western and northern areas. The seismological catalogue was also divided into two parts: northern and southern, according to events: responses and explosions that occurred in the northern and southern parts of the mine field. Phase portraits of the state of arrays of the northern and southern sections are constructed in the coordinates E0(t) and d(E0(t))/ dt, t-time, expressed in fractions of a day, E0-seismic energy allocated by the array in Joules. In [6] we had analysed the morphology of the phase trajectories of the seismic response to explosive actions at various consecutive time intervals of the southern section of the mine. During this period, according to the data on technological and mass explosions produced, most of the energy was pumped into the southern part of the mine. In addition, at the end of 2007, it was in the southern section that one of the strongest mountain strikes in the entire history of the mine's operation took place. As a result of the analysis, the characteristic morphology of phase trajectories of the response of an array located locally in time in a stable state is identified. On the phase plane there is a local region in the form of a coil of interlaced trajectories and small emissions from this coil, not exceeding 105 J in energy. At some time intervals, this outlier exceeds 105 J, process of energy accumulation, which is reflected in the region by attracting phase trajectories, and the process of resonant discharge of accumulated energy. It is interesting to note that after this reset, the system returns again to the state of region attracting phase trajectories. This is confirmed by a detailed analysis of the phase trajectories of the seismic response of the massif before and after the strongest rock impact. However, the process of changing the state of the array is strongly influenced by the process of a fairly regular external impact in the form of explosions of various powers. During the time between explosions, the array does not have time to isolate the energy, that it received, which leads to a lag response lag and the nonlinearity of its manifestation, which makes it difficult to predict the time of a highly energetic destructive event [7].Based on the ideas presented in [8], the analysed database was supplemented by the spatial coordinates of the explosions. On this basis, a new algorithm was developed for processing the seismological information of a detailed mine catalogue taking into account the kinematic and dynamic characteristics of deformation waves propagating at different velocities in a rock massif under intense external influence in the form of mass or technological explosions [9]. It was found that waves, propagating with velocities from 10/ h to 1 m / h are the predominant carrier of energy in the array and contributing to its release. Events occurring in an array with these velocities and having a release energy of less than 104 joules contribute to the creep restructuring of hierarchical inclusions of block parts of the array, which leads to the organization of a new section of dynamic instability. Events occurring in the massif with these velocities and having release energy greater than 105 joules can be used as precursors and which are recommended to be taken into account when adjusting the explosions in one or another part of the massif. The complete absence of these events indicates an increase in the stress state in the mine array as a whole.

A. Algorithm for processing seismological information to determine informative features of the preparation of high-energy dynamic phenomena

In the present work, quantitative estimates of the delay parameter of the high-energy response of the array to a number of technogenic impacts were undertaken, during which the absence of the response of the array accounted for a significant part of the time. Push (Sh.36) with an energy of 8.14E + 08 j. occurred on 11/25/2007 with coordinates x = 11928m, y = 11627m, z = -264m (+ (- 450m)). It is designated, like all the other studied responses that occurred in the southern part of the mine with the letters Sh. and number 36. The explosions are indicated in the form (i), where the i-is a number of the explosion for the period 2006-2008. We obtained additional estimates of the distances from the explosion point to the response point of the array. The coordinates of the explosions and responses of the massif were taken from the seismic mine catalogue of the Tashtagol mine.

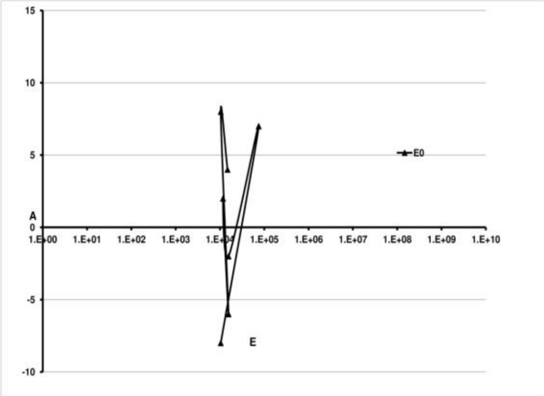

Fig.1a.

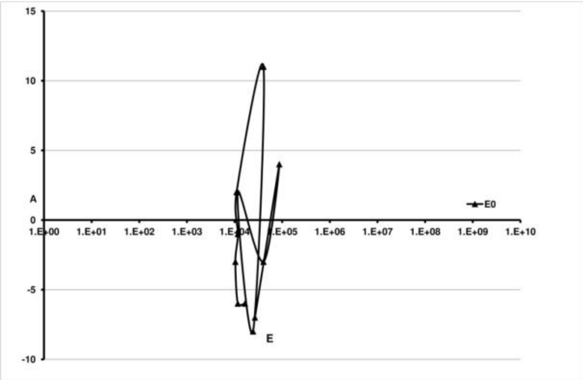

Fig.1b.

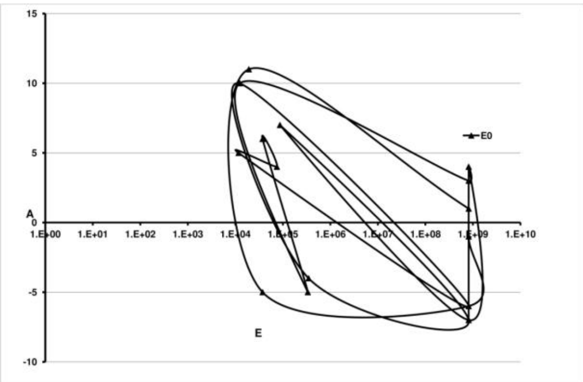

Fig.1c.

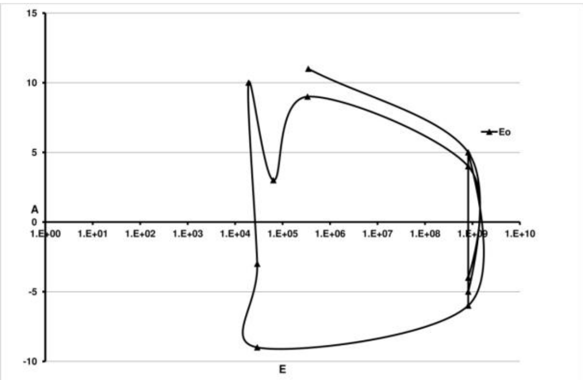

Fig.1d.

Figure 1. (a-d). Phase diagrams of the dynamic state of the array of the southern part of the mine array for the period 2006-2008. a) r = 0-50m; b) r = 50-100m; c) r = 100-150m; d) r = 150-200m. Designations: vertical axis: A = aLgf, a = sign, horizontal axis: E = E0- response energy.

As follows from the analysis of the data in Fig. 1 (a-d), the response of the Sh.36 array in the form of a high-energy response appears only starting from the distances between the impact point and the response from 100m to 200m. At the same time, the reaction time of the array to the effect exerted in the form of an explosion is tens or even hundreds of days. Therefore, despite the fact that the explosion of Sh.36 from the explosion (78) occurred almost instantly, it was preceded by a long process of preparing a resonant energy release, which must be accompanied by electromagnetic monitoring of the occurrence and accumulation of disintegration zones in the volume of the array: dx = 100 -180m, dy = 33-180m, z = (-210 - (- 300)) + (- 450) m.

The developed new algorithm for processing the seismological information of the detailed mine catalog allows extracting additional important information for predicting hazardous phenomena in ore mines and for developing the theory of dynamic phenomena in natural geological and geophysical environments.

III. IMPLEMENTATION OF SAFE OPERATION OF ORE ARRAYS AT GREAT DEPTHS.

It is shown that the process of mining the massif, which is a dynamic process, can be controlled by following the recommendations given by the theory of disasters [10]. In this process, the control parameters are the energy values during explosions and the location of these explosions relative to the studied or mined area of the array. The kinematic and dynamic parameters of the deformation waves, as well as the structural features of the array, through which these waves pass, act as internal parameters. The use of analysis methods for short-term and medium-term forecasting of the state of a rock mass only when using control parameters is not enough if there is a sharp heterogeneity of it. However, the joint use of qualitative recommendations of the theory of disasters and spatial-temporal data on changes in the internal parameters of the array will prevent disasters during mining of mine arrays. To implement these recommendations, continuous seismological monitoring in the mine should be used, as it is organized, for example, in the Tashtagol mine and active induction electromagnetic monitoring, which should be carried out according to the results of seismological monitoring to identify quiet zones, especially in the area of mining. As an example, we conducted an analysis of seismological active monitoring of the mountain range, based on the scheme of application of the theory of disasters. The main purpose of this monitoring is to determine the precritical state of the massif, which is being mined by explosive actions. It is determined by the value of the response energy, not exceeding 104 joules. If this value exceeds this value within 105-107 joules, then the state of the array is considered critical. With response energies of 108–109 or more, the state of the array is considered supercritical or catastrophic. On November 25, 2007, in the mine of Tashtagol, 27 orth, at a depth of 714 m, a rock shock with an energy of 8.14 · 108 joules occurred. We will try to trace the preparation of this event from the point of view of the loss of stability of the array and the connection of this effect with the energy impact of the explosions and their position. The volume under investigation is determined by the following geometry: along the OX axis: excavations 25-31 (≈240 m), along the OY axis: (determined by the length of the unit vectors between the field and ventilation drifts on average ≈240 m), along the OZ axis: (horizons -140, -425, (≈590-875m)).Let us analyze the morphology of the time process of energy Ek (j.) Responses of the array to explosive action in time from June 4, 2006 to November 25, 2007 According to these data, the process of preparing a dynamic phenomenon (rock impact Ek ~ 109 J) in 27 orth is clearly visible. What is characteristic: from April 4 to September 17, a lull with Ek <103 J was observed in the region of ort 26. At that time, technological and mass explosions were carried out at 18 ort, as well as technological explosions in the southeast and at 26 ort . Since September 24, 2006 up to December 24, the reaction to an explosion within the test volume has a different morphology, the oscillatory process alternates with a irregular emission, after which the system returns to the oscillatory process, thereby relieving excess of internal stresses. Further, mining continued at 27 ort, however, despite this, a calm zone was established Ek <103 J, the explosions from September 30 to November 10, which occurred mainly at 27 ort, did not bring the studied region of the array to the stage of the oscillation process of energy transfer. During the repeated explosion in block 27 on November 25, 2007, a complex dynamic catastrophic process occurred. There are three foreshocks, one aftershock, four precritical and one supercritical of energy surge. These results confirm the conclusion that it is necessary to have detailed information about the hierarchical structure of the block being worked out and its structural change. If in the 26th ort it was possible to avoid a strong rock shock, in the 27-th ort, using the same mining technology, this was not possible. As a result of the analysis, the following conclusions can be drawn. Once again we are convinced that the process of mining the rock mass is a dynamic process. Disaster theory offers recommendations for managing this process. For this, it is necessary to determine the control also the internal parameters of the dynamic system, which is the massif under explosive action. As follows from the data of the seismological mine catalogue for this process, the control parameters are the energy values during explosions and the location of these explosions relative to the studied or mined area of the array. The kinematic and dynamic parameters of the deformation waves [11, 12], as well as the structural features of the array, through which these waves pass [13], act as internal parameters. The use of analysis methods for short-term and medium-term forecasting of the state of the rock mass only using control parameters is not enough, because there is a sharp heterogeneity of them. It is necessary to include in the monitoring system an analysis of changes of the internal parameters of the array for using qualitative recommendations of the theory of disasters to control the process of mining the mine array.

IV. ACOUSTIC MONITORING OF ZONES OF ABNORMAL STRESSES, DETERMINATION OF THEIR POSITIONS, SURFACES, ASSESSMENT OF CATASTROPHIC RISK.

The formation of structures during irreversible processes is associated with a qualitative jump upon reaching threshold (critical) parameters. Self-organization is a supercritical phenomenon when the parameters of the system exceed their critical values. When a system deviates strongly from an equilibrium state, its variables satisfy non-linear equations. Nonlinearity is an important and general feature of processes that occur far from equilibrium. Moreover, the supercritical return of entropy is possible only if there is an unusual, special internal structure of the system [14]. This means that self-organization is not a universal property of matter, it exists under certain internal and external conditions and this is not associated with a special class of substances. So, there are two classes of irreversible processes: 1. destruction of the structure near the equilibrium position, this is a universal property of systems under arbitrary conditions; 2. the appearance of structures far from the equilibrium position under the conditions that the system is open and has nonlinear internal dynamics, and its external parameters have supercritical values. I. Prigogine called them dissipative structures [15]. The study of the morphology and dynamics of migration of these zones is of particular importance in the development of deep deposits, complicated by dynamic phenomena in the form of mountain impacts. An important tool for this study is geophysical exploration. One of the fundamental mining problems, which are traditionally referred to as the problems of geomechanics, is the development of theoretical and experimental methods for studying the structure and condition of rock masses in order to predict and prevent catastrophic phenomena during mining. This problem is compounded by the fact that the rock mass is under direct or indirect technogenic impact, which leads to significant unsteadiness of both the structure and the state of the mass [16]. When conducting mining operations in highly stressed rock massifs, man-made seismicity is manifested, the forecasting and prevention issues of which receive a lot of attention in all countries with a developed mining industry. An important role here belongs to the short-term forecast; the methodology for selecting criteria for it is still a problem, both in mining and in seismology [17]. In the framework of the IGD SB RAS School, important results have been achieved in studying the state of the rock massif in the framework of nonlinear geomechanics [18] using geophysical methods with the resolving ability to detect the nucleation and decay of self-organizing structures [19].

B. Theory, research methods.

In [19], studies were conducted aimed at developing criteria for the spatial-temporal complex active and passive seismic and electromagnetic monitoring to prevent destructive dynamic phenomena based on six-year seismological monitoring data carried out by the mountain impact service at the Tashtagol underground mine and the experience gained from using the IGF Ural Branch of the Russian Academy of Sciences developed systems of induction electromagnetic space-time monitoring on arrays of various composition before and after the mass explosions.
We have analyzed the morphology of the structural features of disintegration zones before a strong dynamic phenomenon. During the next cycle of electromagnetic observations at the Tashtagol mine in August 2007 On August 9, there was a mountain impact with an energy of log E = 6.9 in the pillar, located in the alignment of Ort 3 at a level of 16 m below the soil of horizon -280.
Three days before a mountain strike, in the orts of 3.4 in the geoelectric sections of the soil, sub vertical discrete structures are found into which disintegration zones are combined. These structures appeared in a resonance mode at different frequencies and only at one frequency for each ort. We discovered the same phenomenon earlier in one day at the mine Estyuninsky and SUBR, mine 15 [20]. The appearance of these structures of sub vertical morphology is a precursor of a strong dynamic phenomenon; however, to determine the location and magnitude of an event, it is necessary to have information about the state of the ort arrays and membership in the corresponding ranks about the stability of the array, as was done in [21].

At present, theoretical results on modeling the electromagnetic and seismic fields in a layered medium with hierarchical inclusions are in demand. Simulation algorithms were constructed in the electromagnetic case for 3D heterogeneity, in the seismic case for 2D heterogeneity [22,23]. It is shown that with an increase in the degree of hierarchy of the medium, the degree of spatial non-linearity of the distribution of the components of the seismic and electromagnetic fields increases, which corresponds to the detailed monitoring experiments in shock-hazardous mines of the Tashtagolsky mine and the SUBR. The constructed theory demonstrated how complicated the process of joining methods using an electromagnetic and seismic field is to study the response of a medium with a hierarchical structure. This problem is inextricably linked with the formulation and solution of the inverse problem for the propagation of electromagnetic and seismic fields in such complex environments. In [24, 25], the problem of constructing an algorithm for solving the inverse problem using the equation of the theoretical inverse problem for the 2D Helmholtz equation was considered. Explicit equations of the theoretical inverse problem are written out for the cases of electromagnetic field scattering (E and H polarization) and linearly polarized elastic wave scattering in a layered conducting and elastic medium with a hierarchical conducting or elastic inclusion, which are the basis for determining the contours of misaligned inclusions of the l-th rank of the hierarchical structure. Obviously, when solving the inverse problem, monitoring systems configured to study the hierarchical structure of the environment should be used as the initial monitoring data. On the other hand, the more complex the medium, the each wave field brings its own information about its internal structure, therefore, the interpretation of the seismic and electromagnetic fields must be carried out separately, without mixing these databases.

C. Simulation of diffraction of sound by two-dimensional abnormally stressed heterogeneity of a hierarchical type, located in an N-layer elastic medium

In [26], an algorithm is described for modeling sound diffraction by a two-dimensional elastic hierarchical inclusion located in the J-th layer of an N-layer medium. $G_{sp,j} = \left(M, M^0\right)$ is the function of the source of the seismic field, the boundary-value problem for which was formulated in [26]; $k_{1ji}^2 = \omega^2\left(\sigma_{ji} / \lambda_{ji}\right)$- wave number for a longitudinal wave, in the given expression, the index ji means that the properties of the medium are inside the heterogeneity, ja is outside the heterogeneity, λ is the Lame constant; σ is the density of the medium; ω is the circular frequency; $\vec{u} = grad\varphi$ - displacement vector; φ^0 is the potential of a normal seismic field in a layered medium in the absence of heterogeneity: $\varphi_{ji}^0 = \varphi_{ja}^0$ .We assume that the density of the hierarchical inclusion for all ranks of l and the enclosing layer are the same, and the elastic parameters of the hierarchical inclusion for all ranks differ from the elastic parameters of the enclosing medium, then the system of equations can be written in the form:

$$\frac{(k_{1jil}^2 - k_{1j}^2)}{2\pi} \iint_{SCl} \phi_l(M) G_{Sp,j}(M, M^0) d\tau_M + \phi_{l-1}^0(M^0) =$$
$$= \phi_l(M^0), M^0 \in S_{Cl},$$
$$\frac{\sigma_{jil}(k_{1jil}^2 - k_{1j}^2)}{\sigma(M^0) 2\pi} \iint_{SCl} \phi_l(M) G_{Sp,j}(M, M^0) d\tau_M + \phi_{l-1}^0(M^0) =$$
$$= \phi_l(M^0), M^0 \notin S_{Cl}.$$
(1)

D. Modeling diffraction of an elastic shear wave on an abnormally stressed heterogeneity of a hierarchical type located in an N-layer elastic medium

Similarly to (1), the same process is written out for modeling the propagation of an elastic transverse wave in an N-layer medium with a two-dimensional hierarchical structure of an arbitrary section morphology using the integral relations written in [27].

$$\frac{(k_{2jil}^2 - k_{2j}^2)}{2\pi} \iint_{SCl} u_{xl}(M) G_{Ss,j}(M, M^0) d\tau_M + \frac{\mu_{ja}}{\mu_{jil}} u_{x(l-1)}^0(M^0) +$$
$$+ \frac{(\mu_{ja} - \mu_{jil})}{\mu_{jil} 2\pi} \oint_{Cl} u_{xl}(M) \frac{\partial G_{Ss,j}}{\partial n} dc = u_{xl}(M^0), M^0 \in S_{Cl},$$
$$\frac{\mu_{jil}(k_{2jil}^2 - k_{2j}^2)}{\mu(M^0) 2\pi} \iint_{SCl} u_{xl}(M) G_{Ss,j}(M, M^0) d\tau_M + u_{x(l-1)}^0(M^0) +$$
$$+ \frac{(\mu_{ja} - \mu_{jil})}{\mu(M^0) 2\pi} \oint_{Cl} u_{xl}(M) \frac{\partial G_{Ss,j}}{\partial n} dc = u_{xl}(M^0), M^0 \in S_{Cl}. \quad (2)$$

$G_{ss,j} = (M, M^0)$ - the source function of the seismic field of the problem under consideration, it coincides with the Green function written in [27] for the corresponding problem; $k_{2jil}^2 = \omega^2 (\sigma_{jil} / \mu_{jil})$, $\mu_{jil} \neq \mu_{ja}$ is the wave number for the transverse wave; $\sigma_{jil} = \sigma_{ja}, \mu$, is the Lame constant; u_{xl} is the component of the displacement vector; l = 1 ... L is the number of the hierarchical level; u_{xl}^0 is the component of the displacement vector of the seismic field in a layered medium in the absence of heterogeneity of the previous rank if l = 2 ... L, $u_{xl}^0 = u_{x(l-1)}$, if l = 1, $u_{xl}^0 = u_x^0$, which coincides with the corresponding expression for the normal field in [27]. It should be noted that the structure of equations (2) coincides with the general case when the hierarchical heterogeneity has not only elastic parameters different from the parameters of the containing medium, but density parameters at all ranks differ from the density parameters of the containing layer. The difference between this problem lies only in the values of the wave number. Thus, the response of the medium associated with the longitudinal wave is more sensitive to the region of elastic heterogeneities in the array. This should be taken into account when assessing the status of a complexly organized geological environment. In the paper[25], the problem of constructing an algorithm for solving the inverse problem using the equation of the theoretical inverse problem for the 2-D Helmholtz equation was considered. An explicit equation of the theoretical inverse problem is obtained for the cases of scattering of a linearly polarized elastic wave in a layered elastic medium with a hierarchical elastic inclusion, the density of which for all ranks is equal to the density of the containing layer. An iterative algorithm for determining the contours of misaligned inclusions of the k-th rank in a hierarchical structure is constructed with the sequential use of the solution of the direct problem of calculating the elastic field of the k-1 rank. With an increase in the degree of hierarchical structure of the medium, the degree of spatial non-linearity of the distribution of the components of the seismic field increases, which implies the exclusion of linearization methods for creating interpretation methods. This problem is inextricably linked with the solution of the inverse problem for the propagation of the seismic field in such complex environments using explicit equations of the theoretical inverse problem. For the first time, an equation was written for determining the surface of an abnormally stressed inclusion in a hierarchical layered-block medium according to acoustic monitoring data. In practice, using this algorithm, according to acoustic monitoring data, we can localize the region of a possible source of a rock shock or an impending earthquake and estimate the degree of abnormal elastic stresses.

V. DISCUSSION AND CONCLUSION

When constructing an anomalously stressed geomechanical model without taking into account the anomalous effect of density heterogeneities within the inclusion, analysis of the anomalous acoustic effect using data on the propagation of a shear wave shows that it is also more sensitive to the form of inclusion, compared with the acoustic effect on the propagation of a longitudinal wave. However, it follows from these expressions that the influence of the density parameters in the host medium in the seismic model cannot be neglected, and when interpreted, they affect the values of the desired anomalous elastic parameters that cause the anomalous stress state. If these values are used in the construction of the geomechanical model, then these values of the elastic parameters will not reflect the stress state of the analyzed medium. It is shown that with an increase in the degree of hierarchy of the medium, the degree of spatial non-linearity of the distribution of the components of the seismic and electromagnetic fields increases, which corresponds to the detailed monitoring experiments in shock-hazardous mines of the Tashtagolsky mine and the SUBR. The constructed theory demonstrated how complicated is the process of complexion methods using electromagnetic and seismic field. It is to study the response of a medium with a hierarchical structure. This problem is linked with the formulation and solution of the inverse problem for the propagation of electromagnetic and seismic fields in such complex environments. In the paper [25], the problem of constructing an algorithm for solving the inverse problem using the equation of the theoretical inverse problem for the 2D Helmholtz equation was considered. Using the theory of solving the inverse problem, one can trace the migration of zones of abnormal stresses, their increase or decrease due to cyclic explosive influences during mining of the array, and also assess the possible risk of high-energy dynamic phenomena in the array. The most important conclusion consists on that fact: the monitoring system must be tuned to search the rock massif as a hierarchical structure. The catastrophic events are linked with the dynamics of the hierarchical inclusions state. For today we have sufficient knowledge to use these systems with mathematical software of predicting catastrophic events.

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