

New Methods for Monitoring Trigger Effects in The Earth's Crust Using Modern Physical Theories

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Introduction

In recent decades, a new science has been born-the physics of nonequilibrium processes, associated with such concepts as irreversibility, self-organization and dissipative structures [1]. Irreversibility plays a significant constructive role; it is impossible to imagine life in a world devoid of interconnections created by irreversible processes. The prototype of the universal law of nature is Newton's law, which can be briefly formulated as follows: acceleration is proportional to force. This law has two fundamental features. It is deterministic: once the initial conditions are known, we can predict motion. And it is reversible in time: there is no difference between predicting the future and restoring the past; movement to the future state and backward movement from the current state to the initial state are equivalent. Newton's law underlies 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. We now have quantum mechanics and the theory of relativity. But, as we will see from what follows, 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 in our fundamental time? 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 [1,2]. Returning to the results obtained for unstable mountain massive, we can note that monitoring studies must be carried out in an active mode, i.e. there must be a source of excitation (seismic or other nature), and a response is recorded from it for a short time, then the action must be repeated and for this process it is possible to construct phase diagrams of the state of the rock mass, indicating the degree of its instability for a finite time interval.

Informative Signs of Preparation of High-Energy Dynamic Phenomena According to The Data of Mine Seismological Monitoring

To create a dynamic model, adequate to the processes of preparation of high-energy manifestations in mountain ranges under strong anthropogenic impact, it was necessary to use monitoring data in natural bedding. For this, the analysis of the data of the detailed seismic catalog of the Tashtagol underground mine for two years was carried out. The space-time coordinates of all dynamic phenomena were used as data - the responses of the array that occurred during this period inside the mine field, and the explosions produced to develop the array, as well as the values of the energy of the explosions and responses of the array fixed by the seismic station [3]. The entire mine field was divided into two halves: workings of the north-western section, areas of the Zapadnoye and Novo-Kapitalnaya shafts and workings from 0 to 13 are designated by us as the northern section. Workings from 14 to 31, southern ventilation and field drifts, the South mine shaft, workings of the southeastern section are designated as the southern section. All events-responses from horizons with marks-140m,-210m,-280 m,-350m (maximum depth 800m). Impacts in the form of explosions were carried out in the southern, southeastern, northwestern and northern areas. The seismological catalog 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 the massifs in the northern and southern sections are plotted in the coordinates $E_0(t)$ and $d(E_0(t))/dt$, t is the time expressed in fractions of days, E_0 is the seismic energy released by the array in J.

In [4], the morphology of the phase trajectories of the seismic response to explosive effects at various successive time intervals of the southern section of the mine was analyzed. During this period, according to data on technological and massive explosions, most of the energy was pumped into the southern section of the mine. In addition, at the end of 2007, it was in the southern section that one of the strongest rock bumps occurred in the entire history of the mine operation. As a result of the analysis, the characteristic morphology of the phase trajectories of the response of the array, which is locally in time in a stable state, has been identified. On the phase plane, there is a local region in the form of a coil of intertwined trajectories and small ejections from this coil, not exceeding 105 J in energy. At some time intervals, this ejection exceeds 105 J, reaching 106 J and even 109 J [4,5]. Obviously, there are two interdependent processes. The process of energy accumulation, which is reflected in the area, that attracts phase trajectories, and the process of resonant discharge of the accumulated energy. It is interesting to note that after this reset, the system returns again to the same 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 shock. However, the process of changing the state of the rock massif is strongly influenced by the process of a fairly regular external influence in the form of explosions of various powers.

During the time between explosions, the array does not have time to release the energy it receives, which leads to a response delay and nonlinearity of its manifestation, which makes it difficult to predict the time of a highly energetic destructive event [3]. Based on the ideas outlined in [6], the analyzed database was supplemented with data on the spatial coordinates of explosions. On this basis, a new algorithm for processing seismological information of a detailed mine catalog was developed taking into account the kinematic and dynamic characteristics of deformation waves propagating at different speeds in a rock mass under intense external influence in the form of massive or technological explosions [7]. It was found that waves propagating at velocities from 10 to 1 m/h are the predominant carrier of energy in the array and contribute to its release. Events occurring in the array with these velocities and having the release energy 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 array with these velocities and having release energy greater than 105 joules can be used as precursors, that are recommended to be taken into account, when correcting the explosions in a particular part of the array. The complete absence of these events indicates an increase in the stress state in the mine massif as a whole.

Review of Catastrophe Theory Methods for Studying the Loss of Stability of Nonlinear Dynamic Systems

The first information about the theory of catastrophes appeared in the press around 1972, where it was testified that this theory provides a universal method for studying all jump-like transitions, discontinuities, and sudden qualitative changes [8]. Following VI Arnold [9], the sources of the catastrophe theory are the theory of singularities of smooth Whitney mappings and the theory of bifurcations of dynamical systems of Poincare and Andronov. The concept of "bifurcation" means bifurcation and is used to denote qualitative rearrangements of various objects when the parameters on which they depend are changed, and bifurcation occurs due to the trigger effect. Disasters are called abrupt changes that occur in the form of a sudden response of the system to a smooth change in external conditions. As a rule, the degree of catastrophe is associated with the values of the recorded jumps, so if the response of the environment is less than a certain value, then the catastrophe is a creep process and it is usually not destructive. If the response of the environment is greater than a certain value, then the greater it is, the more this process belongs to destructive disasters. The evolutionary process, reflecting the response of the system to the applied action, is mathematically described by a vector field in the phase space [10]. The point in the phase space defines the state of the system, and the vector applied at this point indicates the rate of change of the state. The points at which the vector vanishes are called equilibrium positions. Over time, oscillations can be established in the system, while the equilibrium state becomes unstable.

On the phase plane, steady-state oscillations are depicted by a closed curve called the limit cycle. In [9], the study of the evolution of a dynamical system is associated with a change in time of internal and control parameters. In this regard, after loss of stability of equilibrium, two types of steady-state regimes can be observed. One of them is an oscillatory periodic mode. This type of loss of stability is called soft loss of stability, since the established oscillatory regime at low super criticality differs little from the equilibrium state. The second type is associated with the following features: before the steady state loses stability, the region of attraction of this mode becomes very small, and random perturbations throw the system out of this region before the region of attraction completely disappears. This type of loss of stability is called hard loss of stability, while the system leaves the stationary mode in a jump and switches to another mode of motion. This mode can be another steady stationary mode, or steady oscillations, or a more complex motion. The established modes of motion are called attractors. Those of them that are different from equilibrium states and strictly periodic oscillations are called strange attractors and are associated with the problem of turbulence [11].

As a result of the analysis, the following conclusions can be drawn. The mining process is a dynamic process that can be controlled by following the recommendations given by disaster

theory. In this process, the values of the energy during explosions and the location of these explosions relative to the studied or mined area of the massif appear as control parameters. The internal parameters are the kinematic and dynamic parameters of deformation waves [12-15], as well as the structural features of the array through which these waves pass [16,17]. The use of analysis methods for short-term and medium-term forecasts of the state of a rock mass only when using control parameters is not enough in the presence of its sharp heterogeneity. However, the joint use of high-quality recommendations of the theory of disasters and spatial-temporal data on changes in the internal parameters of the array will prevent disasters during the development of mine arrays.

Conclusion

In the case of studying the state of mountain ranges, it is necessary to organize active seismic and deformation monitoring similar to that organized inside unstable mountain ranges. An active influence can excite a source of an electromagnetic or laser type. The basic principle: monitoring should be active and regularly repeated, then the processing algorithm described above can be used bypassing the time paradox. The area of possible catastrophic destruction can be identified by the area of calmness of the array response, despite the effect of the source in this area.

References

1. Prigogine I, Stengers I (2009) Time, chaos, quantum: Towards the solution of the paradox of time. Book House LIBROKOM, Russia, pp. 232.
2. Hawking S (1990) A brief history of time: From the big bang to black holes, Moscow, Russia.
3. Khachay OA, Khachay AY (2012) Study of the stress-strain state of hierarchical media. The third tectonophysical conference at the IPE RAS, Moscow, pp. 114-117.
4. Khachay OA (2013) Study and control of the state of mountain ranges from the standpoint of the theory of open dynamic systems. Mining Informational and Analytical Bulletin 7: 145-151.
5. Khachay OA, Khachay AY, Khachay OY (2012) Dynamical model for evolution of rock massive state as a response on a changing of stress-deformed state. In: Quadfeul SA (Ed.), Fractal analysis and Chaos in Geosciences, (Chapter 5), UK, pp. 174.
6. Oparin VN, Vostrikov VN, Tapsiev AP (2006) About one kinematic criterion for predicting the limiting state of rock massifs based on mine seismological data. FTSPRI 6: 3-10.
7. Khachay OA, Khachay OY (2014) Algorithm for constructing a scenario for the preparation of rock bumps in rock masses under the influence of explosions according to the seismic catalog. Mining Informational and Analytical Bulletin 4: 239-246.
8. Andronov AA, Vitt AA, Khaykin SE (1981) Oscillation theory. In: (2nd edn), Nauka, Moscow, pp. 918.
9. Arnold VI (1990) Arnold VI (1990) Catastrophe theory. In: (3rd edn), Science physical-mat Lit, Moscow, USA, p. 128.
10. Naimark YI (1978) Dynamic systems and controlled processes, Nauka, Russia, pp. 336.
11. Klimontovich YL (2007) Turbulent motion and structure of chaos. (2nd edn), Kom Kniga, Moscow, pp. 328.
12. Khachay OA, Khachay OY (2005) A method for assessing and classifying the stability of a rock mass from the standpoint of the theory of open dynamic systems based on geophysical monitoring data. Mining informational and analytical bulletin 6: 131-141.
13. Khachay OA, Khachay OY, Klimko VK (2013) Dynamic characteristics of slow waves of deformation as a response of the massif to explosive effects. Mining informational and analytical bulletin 5: 208-214.
14. Khachay OA, Khachay OY, Shipeev OV (2013) Investigation of the hierarchical structure of the dynamic characteristics of slow deformation waves-response to explosive effects. Mining Informational and Analytical Bulletin 5: 215-222.
15. Khachay OA, Khachay OY, Klimko VK, Shipeev OV (2015) Informative signs of the preparation of high-energy dynamic phenomena according to the data of mine seismological monitoring. Mining Informational and Analytical Bulletin 4: 155-162.
16. Khachay OA, Khachay OY, Khachay AY (2015) New methods of geoinformatics for monitoring wave fields in hierarchical environments. Geoinformatika 3: 45-51.
17. Khachay OA, Khachay OY, Khachay AY (2016) New methods of geoinformatics for the integration of seismic and gravitational fields in hierarchical environments. Geoinformatika 3: 25-29.

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