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Blow-up Modes in Fracture of Rock Samples and Earth's Crust Elements

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Abstract—It is well known that the final stage of macroscopic fracture develops as a catastrophe in a superfast blow-up mode. However, the specific features of this stage are well studied only on large scales of earthquakes. Of particular interest for fracture prediction are both the stage of superfast catastrophic fracture and the mechanical behavior of the medium in the state of self-organized criticality prior to transition of fracture to the blow-up mode in order to reveal precursors of fracture transition to the catastrophic stage. This paper studies experimentally and theoretically the mechanical behavior of the medium prior to the catastrophic stage and transition to the blow-up mode. Rock samples (marble and artificial marble) were tested in three-point bending and uniaxial compression tests. The lateral surface velocities of loaded samples were recorded using a laser Doppler vibrometer. The recording frequency in measurements was 48 kHz, and the determination accuracy of the velocity amplitude was 0.1 μm/s. The estimated duration of the blow-up fracture stage is 10–20 ms. The mechanical behavior of samples in the experimental conditions, including the catastrophic fracture stage, is simulated numerically. The damage accumulation model parameters are determined from a comparison with the experimental data. Certain features of the mechanical response prior to catastrophic fracture are revealed which can be interpreted as fracture precursors.

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1. INTRODUCTION. IS IT POSSIBLE TO PREDICT CATASTROPHIC FRACTURE?

The problem of catastrophic fracture of various objects—material samples in laboratory experiments, loaded structural elements, Earth's crust elements, including rock masses with mine openings—is a global challenge. Evaluation of the load life of various objects and reliable prediction of deformation stages, including catastrophic fracture, is one of the urgent problems of the physics and mechanics of fracture. Earth sciences study tectonic movements, attendant seismic processes, and major earthquakes in the context of the physics and mechanics of fracture.

Though first models of catastrophic fracture of Earth's crust elements were based on the most general and clear concepts of fracture mechanics (elastic energy accumulation, the limiting state, elastic recovery, etc.), in the subsequent investigation the geomedium is taken as a complex multiscale block system. Numerous complex models were developed to account for the geomedium specificity: significant heterogeneity, damage accumulation and healing, gas saturation features, presence of fluids, scale effect, etc. However, no model, even being complex, is able to account for a variety of geomedium structures. For this reason, each model focuses on the aspects thought to be the most significant (dilatancy-diffusion model, avalanche-like unstable fracture model, block sliding models and their variations, consolidation model, etc.). That is why the available models are insufficiently general.

This situation casts a reasonable doubt upon the possibility of predicting the place and time of catastrophic fracture using approaches of fracture physics and mechanics. One can say about the crisis of ideas in catastrophic fracture prediction. However, the already developed and tested models give a sufficiently complete and correct representation of deformation processes in the Earth's crust, the physical nature of earthquakes, and more generally, possible causes of catastrophic fracture of any solid and medium. The problem of fracture prediction and life evaluation, for example, of metallic structural elements, is no less urgent than the problem of earthquake prediction. It is still at the stage of great uncertainty despite thoroughly studied physical mechanisms and special features of fracture of metal specimens of different compositions. We need a fairly simple general approach to the fracture problem that disregards numerous specific details and focuses on general laws of the object evolution. This approach is possible in the context of the theory of nonlinear dynamic systems [1, 2].

2. LOADED MEDIUM AS A MULTISCALE NONLINEAR DYNAMIC SYSTEM

The loaded geomedium is now universally known as a multiscale hierarchically organized block system. Any solids, rock samples in this case, are also typical nonlinear dynamic systems. The fact that an extended geomedium cannot be reduced to small samples is also apparent. A great problem is the evaluation of strength characteristics of extended Earth's crust elements and their elastic moduli. Nevertheless, characteristic stages of the stress-strain state evolution and macroscopic fracture of small samples and Earth's crust elements have common features and phenomenological description resulting from the methodology of nonlinear dynamic systems. In our opinion, it is more correct to speak not about the hierarchy and scales of blocks, but about the scale hierarchy of cracks and/or faults as extended bodies—surfaces of small thickness relative to their linear dimensions (the larger the linear dimensions, the greater the thickness of the fault [3]). In this case, both the small sample and geomedium are natural fractals in the sense that fractal systems of cracks as smaller layers separating consolidated structural elements of different scale formed in them during a long mechanical evolution, which can be considered as blocks if necessary. In loading, such medium experiences inelastic deformation due to, among other things, relative displacements and rotations of structural elements.

Whenever the macroscopic scale of the object (rock sample or structural element of the Earth's crust), the stress-strain state evolution will be qualitatively similar, and the related damage accumulation processes will have a common phenomenology due to scale invariance and self-similarity of fracture. This is evidenced by the Gutenberg–Richter occurrence law of seismic events. The essence of this law is that the fracture process is self-similar on all scales, for this reason, it is impossible to distinguish any scale in a fractured medium. The Gutenberg–Richter law holds also for small samples under fracture [4].

Another important feature of the evolution of loaded solids is the presence of a slow quasistationary stage of accumulation of small-scale damages, which have low amplitude and are very weakly pronounced. Stress fluctuations near such microscopic damages are extremely small, and so does the radius of their long-range action. When the concentration of such microdamages is relatively low, they hardly interact. At a critical level of concentration (the Zhurkov criterion of fracture), the cracks begin to interact; the loaded medium passes to a state of self-organized criticality when all damage processes are correlated due to the information exchange of stress microwaves generated by emerging cracks. Their coalescence and the fracture transition to the macroscopic level occur in the ultrafast catastrophic mode. To study this mode is one of our main tasks.

Another task is to test the damage accumulation model based on general considerations of the theory of nonlinear dynamic systems, according to which the damage accumulation rate in a loaded medium $\mathrm{d}N/\mathrm{d}t$ is a power-law function of the accumulated damages N:

$$\frac{\mathrm{d}N}{\mathrm{d}t} = a(\sigma, \lambda)N^{\alpha}, \quad a(\sigma, \lambda) = \frac{(\sigma - \sigma_0)^2}{[\sigma^*(\lambda + 1)]^2 T^*}. \qquad (1)$$

Here σ is the actual local stresses, the parameter $a = a(\sigma, \lambda)$ depends on the stress and Lode–Nadai coefficient λ defining the stress state form [5], σ_0 determines the minimum stresses for damage accumulation, σ^* is the model parameter that defines the damage accumulation rate and has the stress dimension, and T^* is the model parameter that in fact represents the computational time compression in respect of the real time. It has a time dimension and is chosen so that stress waves generated by local changes of the stress-strain state under slightly varied loading conditions can make 1–3 passes to provide the information exchange between deformable structural elements. It is because of this information exchange that self-organization and the state of self-organized criticality are possible in the medium. In so doing, the medium demonstrate a coordinated cooperative response to loading and its evolution passes to the ultrafast catastrophic mode. It is clear that such an information exchange accompanies any real process since deformation velocities in the medium are usually many orders of magnitude lower than speeds of disturbances that propa-

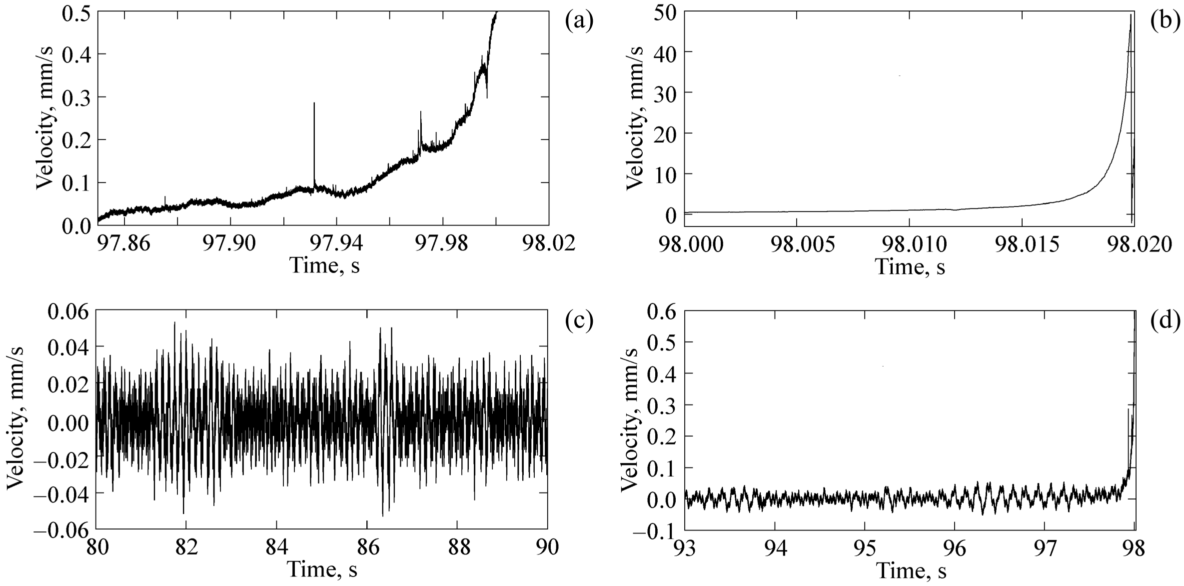

Fig. 1. Time dependence of the free surface velocity of the sample in compression at different deformation stages.

gate with speed of sound. The parameter $\alpha = 2$ or is close to 2, which leads to a hyperbolic law of damage accumulation with increasing time. Power laws of this type are a fundamental property of evolution of many dynamic systems [2, 6].

Expression (1) is conveniently expressed in terms of the function of the damage measure $0 \le D = N/N^* \le 1$ (at $D \to 1$ the medium is fractured, where N^* is a certain critical number of damages when $D = 1$). Following (1), we derive the function of the damage measure in the form:

$$D = \int_0^{t^*} \frac{(\sigma - \sigma_0)^2 D^{\alpha} \mathrm{d}t}{[\sigma^*(\lambda+1)]^2 (N^*)^{1-\alpha} T^*}. \tag{2}$$

This simple model includes two phenomenological parameters with the simple sense: σ_0 is the threshold stress, above which damages start to accumulate, at $\sigma < \sigma_0$ $D = 0$; $(\sigma^*)^2 (N^*)^{1-\alpha} = C$ is the experimental phenomenological parameter. It defines damage accumulation rate in the medium. The upper limit of the integral t^* defines the local life of the medium depending on the actual local stresses. The multiplier $(\lambda + 1)$ regulates the damage accumulation rate in the medium depending on the stress-strain state form $(-1 \le \lambda \le 1)$. In a shear region λ is close to zero, in shear-compression zones $0 < \lambda \le 1$, and in shear-tension zones $-1 < \lambda < 0$. Thus, the damage accumulation rate in zones where tension-shear prevails are much higher than in zones where compression-shear prevails (in tension zones $\lambda \to -1$, and the multiplier $(\lambda + 1) \to 0$) [5].

The current resistance to plastic flow (current strength) in local volumes of the medium degrades as damages accumulate in them and is corrected by the formula:

$$Y_{\text{cur}} = Y_0(1 - D). \tag{3}$$

3. EXPERIMENTS AND NUMERICAL SIMULATION OF FRACTURE OF ROCK SAMPLES

Experiments on loading of small samples (marble and artificial marble) are performed on a universal DVT GP D NN testing machine (Devotrans Inc.). Samples are tested in compression and three-point bending tests. In compression, the samples measure 15 × 15 × 15 mm. In three-point bending, their size is 15 × 15 × 50 mm with the 4 cm gauge area.

All tests are performed at a constant load up to macroscopic fracture of the sample. This provides a determination of the sample life depending on the applied load. Surface velocity of the loaded sample is recorded using a Polytec laser Doppler vibrometer (OFV-505 laser sensor head, OFV-5000 controller with the VD-09 decoder). Doppler vibrometry measures displacement velocity parallel to the laser beam direction. Since the laser is directed perpendicular to the lateral surface of the sample, experimental values correspond to the normal component of the lateral surface velocity. The data are recorded in 20.83 μs increments, the velocity determination accuracy is 0.1 μm/s, and the laser spot at the measuring point is about 50 μm in diameter.

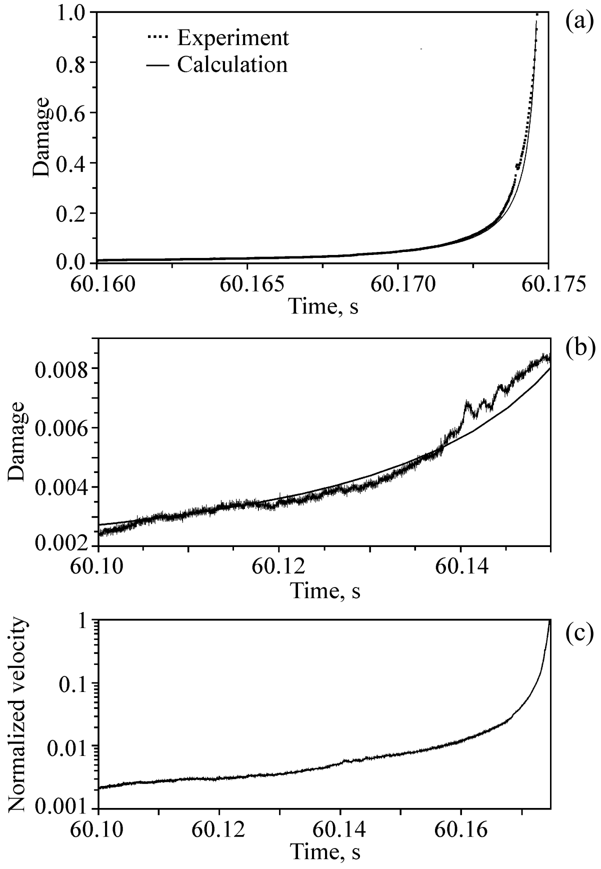

Fig. 2. Catastrophic stage of the stress-strain state evolution reflected in lateral surface velocities (experiment) and damage (calculation) (a); record of the lateral surface velocity of the sample in comparison with the theoretical evolution curve of the damage measure D in enlarged scale prior to a macrocatastrophe (b); transition of fracture to the blow-up mode (c).

Figure 1 shows a typical time dependence of the free surface velocity in the transition from the quasistationary stage of damage accumulation to catastrophic macroscopic fracture of marble samples in compression experiments.

In fact, consideration can be given only to the last 100 ms of the displacement velocity when it exceeds the noise by 2–3 times (Fig. 1a). This stage corresponds to the state of self-organized criticality and the blow-up mode. The development of fracture as a macrocastrophe can be conventionally attributed to the last 20 ms prior to failure starting from the time instant ≈98 s (Fig. 1b). Throughout the quasistationary stage (from 0 to 97.9 s) external noise is comparable in amplitude with the useful signal, and therefore this stage is not analyzed (Figs. 1c and 1d).

To verify the damage accumulation model (1) and (2) as well as to study features and duration of the catastrophic fracture stage distinguished by the damage accumulation rate, surface velocities are assumed to be totally dependent on the damage growth within the loaded sample. In so doing, model (1) and (2) will also describe changes in surface velocities of the sample. This assumption is based on the fact that any significant fracture in the sample volume generates stress waves that, on arrival at the surface, affect its displacement. This is analogous to recording the Earth's surface movements by seismographs for the analysis of the seismic process. For this reason, the surface velocities are normalized to unity in terms of the maximum velocity achieved at macroscopic catastrophic fracture. In this case, the time dependences of the damage measure D and displacement velocity should be close, and they actually are.

For a sample in compression, the experimental time dependence of the normal displacement velocity at a point of one of the surfaces parallel to the compression axis is shown in Fig. 2 in comparison with the theoretical curve for the damage measure D calculated from (1) and (2) at $\alpha = 1.875$.

The model parameter C is chosen so that the calculated damage curve coincides with the experimental dependence for the free surface velocity normalized to unity at the fracture moment. The life t^* is experimentally found. The most interesting is the last stage prior to failure. As plotted in the figure, the lateral surface velocity at the catastrophic stage of fracture very rapidly increases by three orders of magnitude.

In all experiments, the catastrophic stage of fracture of brittle samples does not exceed 15–20 ms. The frac-

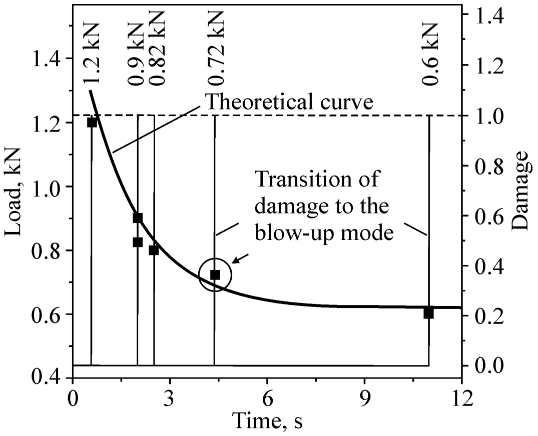

Fig. 3. Comparison of the experimental data (points) with the calculation results on three-point bending loading of artificial marble samples (curves). Thin lines are the calculated dependences of the sample life (damage) at the given loads (indicated at the top), the thick curve is the calculated theoretical dependence of the life on the applied load.

ture transition to the blow-up mode in logarithmic coordinates is shown in Fig. 2c. In so doing, the definition of the catastrophic stage remains very arbitrary because the noise at the quasistationary stage is comparable with the useful signal and low-frequency oscillations of the surface are also highly pronounced (Fig. 1c). If a point when the oscillation amplitude is twice the noise ($t \approx 97.96$ s) is taken as the transition to a catastrophe, the catastrophic stage will have the duration of 60 ms. At the quasistationary stage, microdamages lead to very small velocities (about 0.0005–0.0010 in normalized units), which are absorbed by the noise with the amplitude below 10^{-3}. Another reason why displacement values are still improper at the quasistationary accumulation stage is related to a rather low recorded frequency, being equal to 48 kH, provided by the VibSoft software features. Obviously, microdamages generate higher frequencies. All the presented measurement results are significantly higher than the noise threshold.

The theoretical curve and experimental data are in almost ideal agreement at $\alpha = 1.875$, somewhat below 2, which is typical for such power-law dependences that determine the evolution of real dynamic systems.

Kocharyan et al. [7, 8] and Ostapchuk [9] performed the experimental investigation of interblock sliding over a specially organized layer of granular filler to study such sliding mode as dynamic failure. Its duration distinguished by a catastrophic drop in shear force during the interlayer fracture ranges from 40 to 80 ms [9], which is very close to our values.

If we estimate the catastrophic stage duration at 20 ms, a longer catastrophic stage of unhardening of the interblock layer in the experiments reported in [7–9] is evidently governed by its greater viscosity as well as by its constrained deformation caused by a heavy block and normal loading applied to it, though in the present experiments the lateral surfaces of small brittle samples remain free. It was earlier shown [10] that constraint deformation can accelerate the blow-up stage by several times and even by orders of magnitude, thus dramatically changing the temporal scenario of the medium fracture.

In three-point bending experiments, the life of brittle marble samples is studied for small times, about several tens of seconds, depending on the applied load. The experimental results are shown in Fig. 3 in comparison with the 2D and 3D calculations of fracture of rock samples.

These three-point bending calculations [11] thoroughly reproduce the experimental conditions. Since $C = (\sigma^*)^2 (N^*)^{1-\alpha}$ is the only adjustable parameter in the model, it is selected by one experimental point (it is circled in Fig. 3). The other experimental points are in very good agreement with the theoretical curve obtained in numerical calculations. Each experimental point in Fig. 3 is averaged over 4–6 experiments. Also shown is the damage measure D as a function of time, including the transition to the blow-up mode, for the given loads. As in all experiments the catastrophic stage of macroscopic fracture lasts no more than 20 ms, which is more than three orders of magnitude less than the quasistationary stage of microdamage accumulation, the macrofracture process in Fig. 3 looks like a blow, similarly to dynamic failure in block sliding [7].

As can be seen from the comparison of the theoretical and experimental data (Figs. 1–3), a simple model of damage accumulation based on the fracture description in terms of the evolution theory of nonlinear dynamic systems gives very good agreement with the experimental findings.

4. BLOW-UP MODES IN GEOMEDIA. PARADOXES OF HIGH AND LOW VELOCITIES

The study of current vertical and horizontal movements of the Earth's surface revealed the presence of anomalies in geodynamic processes typical for both aseismic and seismically active areas. It was found that geodynamic anomalies are not an exception to the rules. They are fairly common and contradict the concept of inherited movement of past epochs. Until the last decades of the 20th century, it was believed that the current movements of flat plates in aseismic areas are characterized by low velocities of the Earth's crust elements about 5–10 mm/year, while seismically active regions have significantly higher velocities of 50 mm/year or more, which complies with the concept of posthumous movement.

Detailed studies of special features of vertical and horizontal movements of the Earth's surface in both aseismic and seismically active areas, which were performed in the 1970–90s and are generalized by Kuzmin [12–14], reveal paradoxical deviations of deformations in fault zones from inherited behavior. Aseismic areas have many different-scale local zones of anomalous vertical and horizontal movements of the Earth's surface, which fall on faults. These movements have high amplitudes (50–70 mm/year), short periods (0.1–1.0 year), are localized in space (0.1–1.0 km), and demonstrate a pulsating and alternating pattern. Being extremely high (5×10^{-5}–10^{-4} mm/year), the average annual deformation velocity are identified as superintensive velocities [12, 14]. Kuzmin refers to such anomalous deformation behavior of geomedia as a high-velocity paradox. The revealed significant spatiotemporal heterogeneity of deformation in the Earth's crust requires that conventional approaches to the study of deformation and fracture mechanisms of the Earth's crust elements be revised.

Such activation of deformation processes, which has a pulsating character, makes it possible to consider faults and adjacent regions as autowave systems that generate a deformation response of the medium in the form of slow deformation autowaves [15–17]. Such deformation excitations interpreted as autowaves can propagate both along faults (intrafault waves) and from one fault to another (interfault waves) [16, 18]. Estimated velocities of interfault autowaves range 20–30 km/year and more; those of intrafault autowaves, 4–10 km/year [16]. It should be noted that we observe a great variety of slow deformation disturbances with a very wide range of velocities [18]. The word "observe" is a misnomer here as parameters of slow deformation waves are estimated from indirect data, mainly from observations of migration of deformation and seismic activity as well as by variations in geophysical fields. There is every reason to believe that slow deformation autowaves make a significant contribution both to the formation of fracture foci and can act as earthquake triggers by activating faults [16, 18, 19].

In seismically active areas, the revealed geodynamic anomalies are formulated as a low-velocity paradox [13, 14]. It reflects the following situation: according to long-baseline GPS data the annual average deformation velocity of the Earth's surface is 10^{-8}–10^{-9} per year or less, and according to high-precision short-baseline geodetic and deformographic observations they are measured at 10^{-6}–10^{-7} per year and more. Paradoxes of high and low velocities as well as the phenomenon of deformation activity migration in the form of deformation autowaves can be explained neither in the context of inherited movements nor by conventional mechanics of elastoplastic flow, but they naturally fit into the paradigm of evolution of the geomedium as a typical nonlinear dynamic system.

The representation of the geomedium as a multiscale block system has long been an unquestionable fact. The debate is only about rules of a block scale increase, i.e. by how many times the subsequent block scale differs from the previous one. In our opinioun, it is more correct to speak not about blocks but about linear scales of geomedium structures, in particular, about scales of the crack and fault systems that obey the principle of universal fractality of solids and media [20]. According to this principle, the minimum scale is the lattice parameter of the loaded material, and each subsequent scale is the sum of the two previous ones. The principle is valid for both very small samples and extended geological bodies. So far, there has been no contradicting parameter found. This point of view allows us to consider rock samples and geomedia as natural fractals, for which the crack and fault systems are fractal structures. These structures are particular geological bodies dividing the object into a statistically ordered system of structural elements, from the smallest elements comparable with interatomic distances to the largest ones comparable with the tectonic plate size.

A deformation response of such multiscale hierarchically organized natural fractal to loading will be substantially heterogeneous in space and time. Because of the nonlinearity of the medium as a typical nonlinear dynamic system, all deformation processes will be also nonlinear (inherited movement of past epoch is out of the question). This nonlinearity leads to localization of spatial distribution of parameters and then to temporal localization of the processes. The presence of negative and positive feedbacks and their competition increase the spatiotemporal heterogeneity of deformation. Negative feedback stabilizes the deformation process. The presence of localized inelastic deformations and/or damage leads to stress relaxation in these regions which slows down deformation, thus contributing to healing of damaged regions. Positive feedback accelerates the fracture process in the autocatalytic mode: localized damages decrease strength characteristics, which enhances localization processes. These deformation processes develop throughout the hierarchy of scales, which leads to the formation of fractal structures of cracks and/or faults as extended weakened regions. Spatial localization is replaced by temporal localization of deformation, which develops in the superfast mode as a catastrophe in the corresponding local zone. This general pattern of deformation evolution explains the paradoxes of high and low velocities.

These fundamental properties (nonlinearity—spatial localization of the parameter distribution—temporal localization) determine the two-stage evolution of any nonlinear dynamic systems, i.e. a relatively slow quasistationary stage of accumulation of changes, in this case, damages on microscales, and ultrafast mode of the fracture transition to the macroscale, which usually develops as a catastrophe. For this reason, the aseismic area where average deformation velocities are low will have different-scale local zones with short-term high deformation velocities fitting the ultrafast stage of the stress-strain state evolution in the geomedium as a typical dynamic system. At the slow quasistationary stage of the stress-strain state evolution, the damaged medium is healed. This scenario is of a quasiperiodic character. Because of the scale invariance of deformation processes, including fracture, they are self-similar throughout the scale hierarchy. Such a pulsating pattern of deformation generates local instabilities exciting the active loaded medium and generating deformation autowaves in it. Apparently, local zones of anomalously high vertical and horizontal movements in aseismic regions account for the dynamics of a variety of different-scale deformation processes localized in space (0.1–1.0 km) and time (0.1–1.0 year). Such local deformation instabilities ensure a global stability of the aseismic area. This process is similar to the phenomenon of jerky flow of metal specimens when the whole spectrum of dynamic failures (local small-amplitude disturbances with high velocities) occurs against the background of the stable trend of macroscopically slow deformation. This is a fundamental property of evolution of any nonlinear dynamic system that is in the state of self-organized criticality when the global stability of the dynamic system is sustained by the development of multiple local instabilities.

The same explanation holds for the low-velocity paradox when low and medium velocities of horizontal deformations are observed in the seismically active area under severe compression, which is in conflict with high velocities of unidirectional monotonous motions of lithospheric plates [14] and the concept of current inherited movement of past geological epochs. In this case, similarly to the previous one, comparatively slow movements are accompanied by rapid catastrophic displacements in fault zones when the fracture process develops as a large-scale catastrophe in the blow-up mode.

5. CONCLUSIONS

The life experiments for small samples of marble and artificial marble depending on the applied load reveals two stages of damage and fracture accumulation: long quasistationary and superfast catastrophic stages. The latter occupies no more than 10^{-3} of the total life t^*. Distinguished conditionally by the deviation from a slow almost linear accumulation of microdamages at the quasistationary stage, the catastrophic stage as a blow-up mode lasts for 100–70 ms. The duration of a sharp increase of the surface velocity when its amplitude exceeds that at the quasistationary stage by orders of magnitude is within 10–20 ms. The lateral surface velocity amplitudes at the quasistationary stage are small and are indistinguishable from noise, which is explained by the insufficient sensitivity of the equipment.

A determination of the time of fracture transition to the catastrophic phase is the main task in studying the formation mechanisms of fracture foci and laws of the stress-strain state evolution during deformation. This will solve the problems of predicting the onset of the catastrophic stage of fracture. Reliable separation of the stages of the stress-strain state evolution upon fracture is provided by special features of acoustic emission generated by multiple acts of microscopic fracture. Changes in statistical acoustic emission parameters can be precursors of the fracture transition to the catastrophic stage [21].

Given very short blow-up stages, the knowledge of the time of transition to it will provide at best from several minutes to tens of minutes. It is necessary to identify a preliminary stage of preparation of the catastrophic fracture source when the geomedium as a dynamic system is in the state of self-organized criticality. In so doing, its response to loading becomes cooperative self-consistent and can be identified by features of high-frequency seismic noise, which was evidenced elsewhere [21, 22]. Since external noise and insufficient frequency characteristic of the equipment gives no way of discovering disturbance features at the quasistationary stage of fracture, we say that the catastrophic stage is conditionally distinguished by formal signs of accelerated growth of the sample surface velocity.

A simple damage accumulation model based on a power-law dependence of accumulated damages on their number describes very well the average trend in the sample surface velocities as well as the catastrophic stage of fracture for short lives of loaded samples depending on the applied load. Model calculations of fracture and the calculated life are in very good agreement with experiments. These 2D and 3D calculations completely reproduce the experimental conditions for three-point bending loading of samples. As a damage accumulation model, we take the discussed model with power law damage accumulation.

Thus, the study of deformation and fracture of a solid as a typical nonlinear dynamic system evolving in the force field opens up new prospects for prediction of catastrophic fracture. The found local anomalies of vertical and horizontal movements of the Earth's surface typical for both aseismic and seismically active areas, known as high- and low-velocity paradoxes, are completely explained within the evolutionary concept of all deformation processes in a loaded solid. According to this concept, deformation and fracture processes at all scale levels develop by the scheme fitting the fundamental laws of evolution of nonlinear dynamic systems: deformation and/or damage localization in space, a slow quasistationary phase of accumulation of small-scale changes in the system, transition of the loaded medium to the state of self-organized criticality, deformation localization in time, and fracture in the superfast catastrophic mode. Thus, all deformation processes in aseismic and seismically active areas develop by this scheme, being contradictory to the conventional pattern of inherited movement of past epochs. They differ only in the scale of deformation catastrophes. Such deformation activation on different-scale faults generates deformation excitations in the medium as well as in the faults themselves, which propagate in the form of slow deformation waves of different intensities.

The mentioned scenario of deformation and fracture processes of small samples and geomedia is in complete agreement with the observations and corresponds to the general laws of evolution of nonlinear dynamic systems.

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