INFLUENCE OF THE WEAK MECHANICAL DISTURBANCES ON THE FRACTURE NUCLEATION BEHAVIOR ACCORDING AE-MEASUREMENT.

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Two stages model of fracture process in heterogeneous materials is developed in A.F. Ioffe Physico-Technical Institute. The first stage that occupies the major period of time in the entire process is associated with the noncorrelated nucleation of microcracks. The second final stage is governed by formation and development of the fracture nucleation source. The fracture nucleation source behavior is under analysis during small-scale load-unload series.

The kinetic concept of the strength of solids [1-3] and large experimental data set about cracks appearance and developing [3-4] lets to obtain the two-stage model of the transition from micro- to macrofracture of heterogeneous materials that is invariant to the scale of a loaded body [5]. The applied stress F is distributed in a complicated way over the structural elements (i) of size (1_i). The weakest structural elements will fracture and form microcracks whose sizes are comparable to those of structural elements. Accumulation of these independent events going relatively slow and calmly and do not sufficiently change any material characteristics.

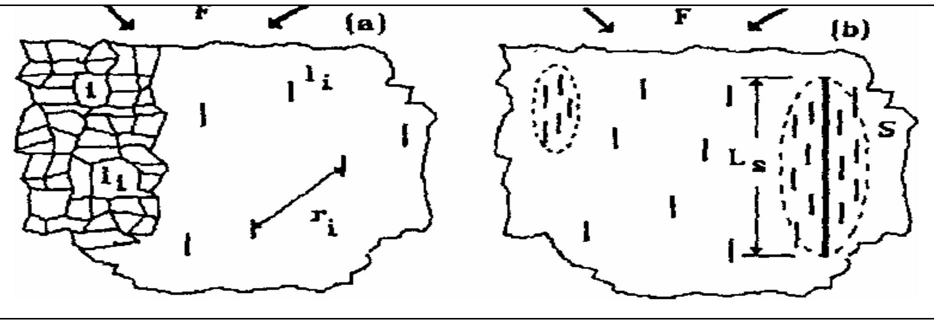

Fig. 1. Two stages during accumulation (a) and development of cracks (b).

This stable stage is shown on Fig. 1a. What will occur with an increase of the concentration of such stable microcracks nucleus. When its concentration exceeds a level, defined by equation (1) for cluster parameter K, a qualitatively new behavior of these cracks may be expected.

$$K = \frac{r_i}{l_i} \approx 3 \quad (1)$$

where $r_i \approx C^{-1/3}$ is distance between nearest microcracks, C is its concentration.

In those areas, where exceeds the critical concentration level, begins the interaction process of microcracks and appears a nucleus of future breakdown. Under constant conditions, microcracks on this stage merge into lager ones very rapidly (Fig. 1b). So forms enlarged crack L_s, joins sometimes several clusters and grows up next heterogeneous size level or breaks the sample if this size compatible with sample dimension. The equation (2) connect total lifetime of sample τ with duration of the first diffusion stage t_1 and the second critical stage t_s.

$$\tau = t_1 + t_s \qquad t_1 >> t_s \qquad \tau >> t_s \quad (2)$$

According this equation, it would be very important to forecast the moment of the critical stage beginning as the closest breakdown precursor [6].

The process of cracks accumulation can be justified as time events flux, every event has spatial and time coordinates and represents one definite microcrack's rupture. The energy, radiated during this process by elastic waves, detects by acoustic emission sensors, so event flux can be accompanied be acoustic emission (AE) impulse set. Energy parameters of AE impulse E carry information about size of crack. Also it is possible to calculate source coordinates and determine place and moment of nucleation appearance using concentration criteria. And besides, statistical analysis of AE impulses on time let us to estimate the moment of critical stage beginning using distribution characteristics of time interval Δt between two chronologically nearest AE events (Fig. 2).

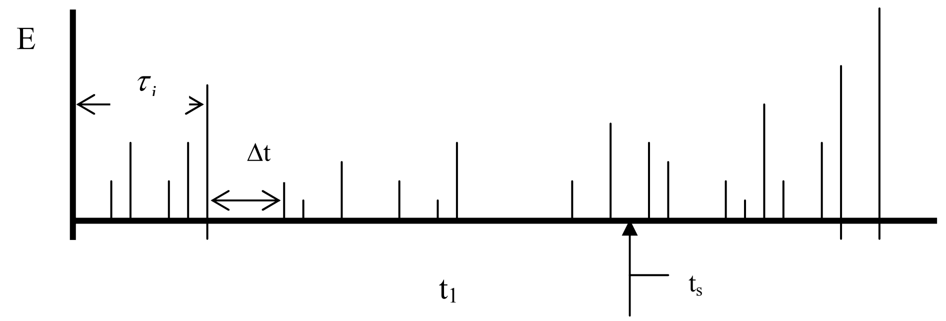

Fig. 2. Flux of rupture acts in time.

On Fig. 3 localization map of AE sources into sample body during different stage of microcracks developing [4] is shown. The first diffusion stage on Fig. 3a determines by approximately equal distribution of AE sources into sample volume, but on Fig. 3b we can show significant concentration peak pointing onto future nucleation position.

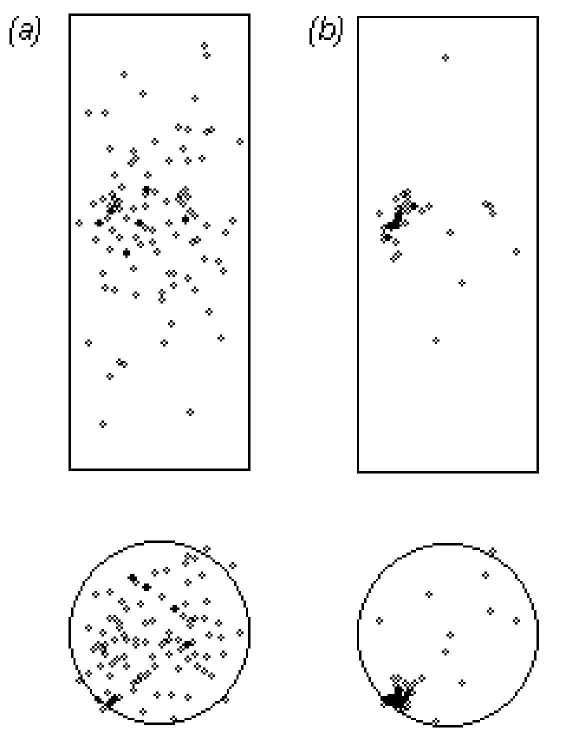

Fig. 3. Localization map for diffusion (a) and nucleation (b) stages.

Both method for nucleation stage detection, mentioned above, are in use now to determine time and spot of critical changes beginning, but both of them have several limitations. As usual there is a problem to supply safe location and enough number of AE events in various conditions. So the measurement should be held into monitoring manner from the beginning of the loading process toward to full destruction. But sometimes, carrying acoustic test of the large extensive construction, we have not such possibility. As usual, in this case the construction is examined by significant increased level of load, that can lead to its early aging. One of the main goal of this work is to present the method for distinguishing the initial stable stage from critical one.

Series of experiments under rock materials were held to study fracture nucleation behavior. During mechanical loading process the sample status was controlled by fast rate 10-channel AE system A-Line32D. On-line AE flux analysis and sources localization let to determine the critical stage beginning with enough accuracy. Examining the specimen by various loading values and forms we can compare it response on initial and fracture nucleation stages of destruction process. On Fig. 4 the granite rectangular prism 140x70x70 mm size specimen loading diagram shown. Totally three constant level expositions were completed under different load levels. Every time except constant loading a specimen was examined by small-scale (not more than 10% from static value) notched cycling loading. Here the AE activity response time dependence shown. It is easy to notice, that during the first (earliest) cycling series AE activity value rapidly decreased down until natural acoustic noise value while cycling peak number increased. On the second exposition level we can observe qualitatively the same situation. Based on AE location map and energy parameters time behavior we concluded that on these two expositions the specimen situated on the diffusion study of microcracks accumulation. But further load increasing lead to process transit to the critical fracture stage. On this moment the load increasing was stopped and specimen began examined by the same cycling influence as during earlier series. And the AE activity response hardly changed. Later we analyzed AE activity behavior separately during loading increasing and decreasing in every cycling peaks for all three series to obtain correlation between AE parameters and loading trend.

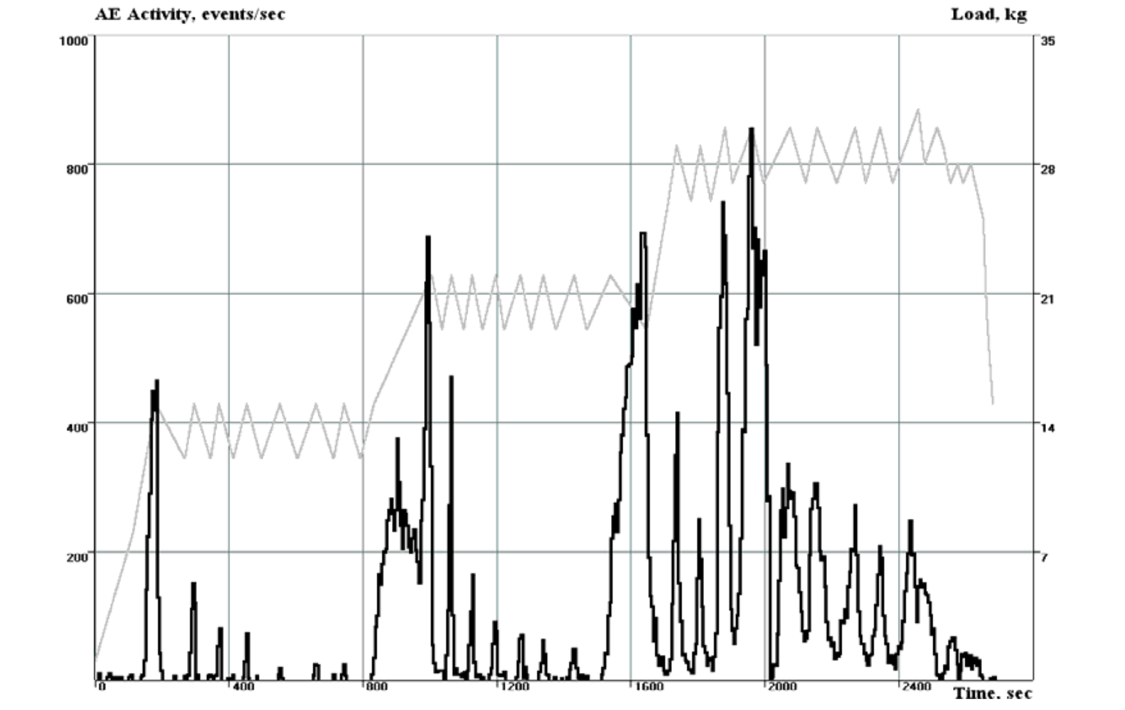

Fig. 4. Loading time diagram and AE activity time dependance.

On Fig. 5 the averaged AE activity, being normalized on loading peak duration and maximum AE activity response value, shown for the 1st and 3rd series (curve 1 and 2 correspondingly).

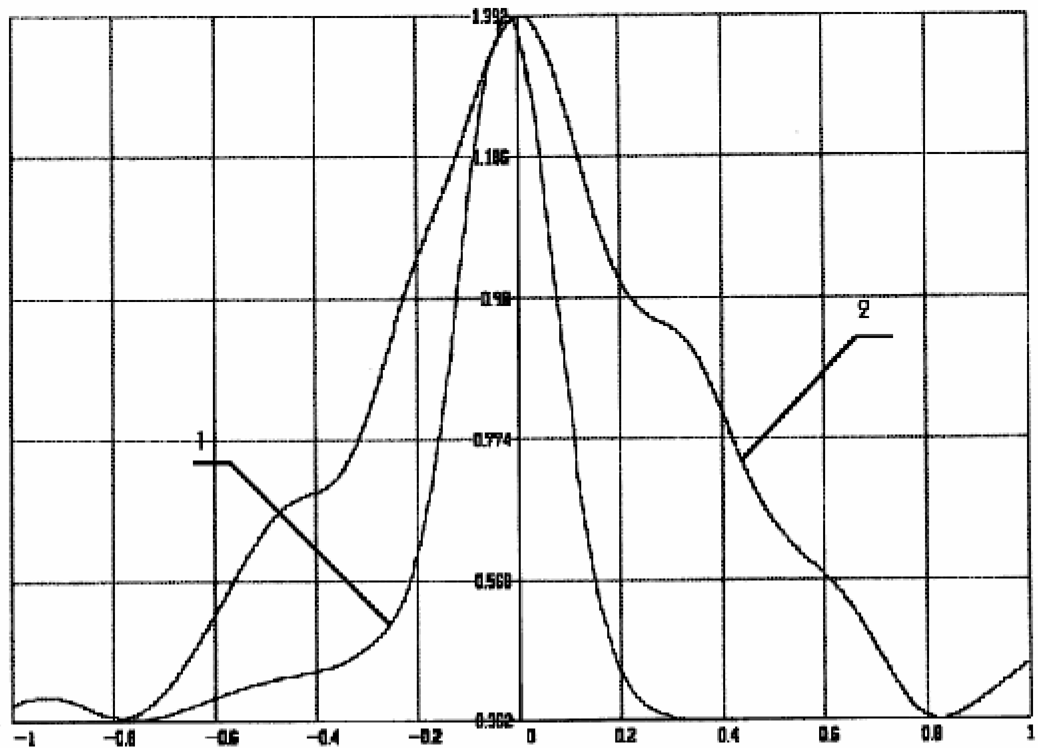

Fig. 5. Normalized AE activity peaks for diffusion (curve 1) and fracture nucleation (curve 2) destruction stages.

Negative axis direction correspond to increasing load, positive – decreasing load. AE activity of the 1st series (curve 1) is concentrated mainly into narrow time interval near loading peak maximum, and besides, there is significant response asymmetry because sharp AE decreasing during unloading. Total activity during loading exceeds ones during unloading 2 times. The critical stage (curve 2) describes by much wider response time distribution, and it has no significant asymmetry.

The same features we observed on another AE parameters behavior. On Fig. 6 relation γ of AE impulse energy and duration during unloading period to the same parameters during loading period for all three cycling series. On X-axis static load value presented. The first two points from the left side correspond to the initial diffusion stage. After that, significant growth of γ-parameter observes detecting fracture nucleation study start.

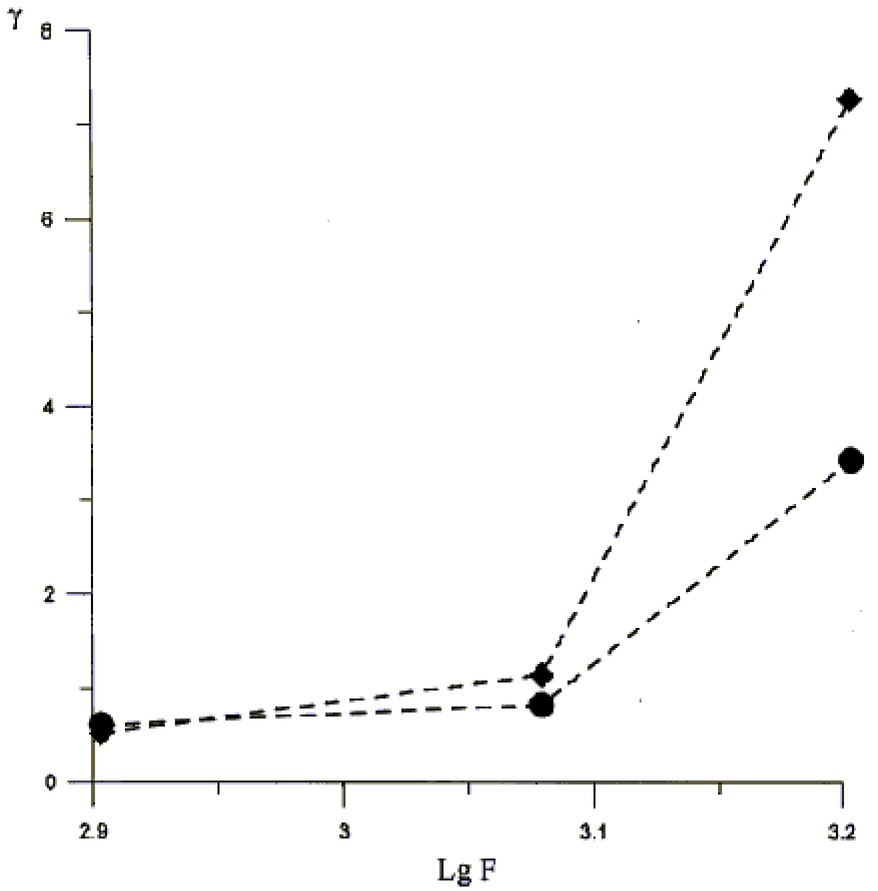

Fig. 6 Dependence of γ on loading value for AE impulses duration (•) and energy(♦).

So, as a conclusion we propose following thesis:

1. The fracture nucleation appearance hardly influences on specimen AE response to weak loading variations.

2. The AE response analysis on weak cycling variations of loading could help us to determine the current destruction stage: diffusion or critical. Also, we do not need valuable loading increasing under static one to do this determination.

3. It is possible to stimulate fracture nucleation developing by weak cycling.

4. Taking into account an invariant method of the two-stages model to the scale factor, we can try to apply above mentioned ideas to study of earthquake nucleation sources. For example, the group of Chinese scientists held an analysis of several powerful earthquakes nucleation sources behavior taking into account weak gravitational influence caused by Moon orbital movement [5]. Relation γ of several forecasting parameters between unloading and loading periods were analyzed in detail. The result is shown on Fig. 7. Stable behavior of γ parameter during seismically calm period sharply changes shortly before critical events, that why it can be used for earthquake forecasting goals.

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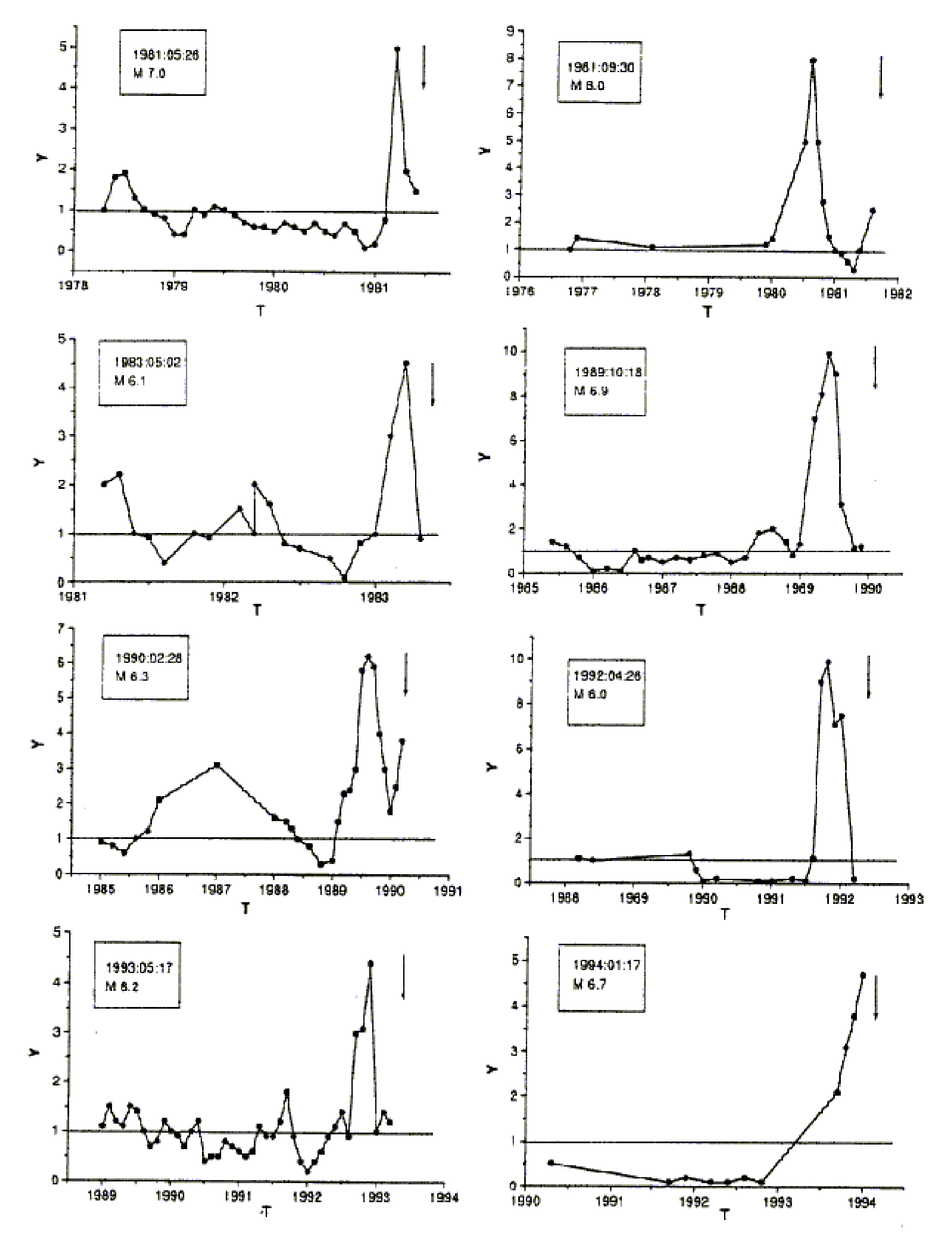

Fig. 7. Parameter γ time variation during several powerful earthquakes period from 1980 until 1994 year.