Acoustic Emission Measurements to Understand Transition Straining Processes and Seismicity Triggering by Power Impacts

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Abstract

We recorded Acoustic Emission (AE) of loaded specimens of terrestrial materials in order to understand the principles of earthquake triggering by externally applied physical fields. We carried out long duration rheological tests, while making high frequency measurements of strain and AE. Experiments have been performed on pristine rock samples subjected to creep tests under uniaxial compression.

Our experiments revealed the response of AE activity to power applied externally (application of electromagnetic field and vibrations). We tested a number of samples made of different materials. Two generalized modes of responses to electromagnetic impacts (EI) were identified. In addition, the structure of AE signals were studied, which are emitted during inelastic straining of granitic specimens, loaded under uniaxial compressive stress and additional EI. Spectral analysis of AE signals shows the presence of some peculiar kinds of spectra, and some dominant frequencies can be identified.

We analyzed the temporal dependence of AE activation for the major spikes on the AE activity plot, in order to study the transition processes, in terms of critical parameters of rock deformation processes (according to hypothesis of a simple power-law increase, within the cumulative Benioff strain). Spontaneous fluctuations and responses were considered, to impacts of different physical fields (vibrations, electric pulses). It was shown that an avalanche-like mode of AE has a distinctive AE activity curve, which can be approximated by a power-law.

Keywords: Acoustic emission (AE), electromagnetic (e.m.) field, electromagnetic impact (EI), rock, response, vibrations, triggering.

Introduction and experimental set-up

Close to the end of the 20th century, the progress of science and technology pointed out new possible ways of approaching the problem of how to reduce the hazard of strong earthquakes. One unexpected way might be to create some physical fields, which can influence the structures within the terrestrial crust, thus inducing a tectonic unloading of overstress and reducing the seismic hazard. Initially, the effects, which permit a control of the deformation processes in seismic zones, was manifested in terms of induced seismicity, resulting from underground nuclear explosions, or from fluid industrial waste injection into boreholes located in seismic areas. Another way resulted from variation of water level in large water reservoirs, or from mining operations etc. It was shown that application of high voltage to the Earth can increase the number of small earthquakes that occur in a given time, thus presenting the possibility of redistributing the seismicity and decreasing the number of major events.

Some operative active procedures, for triggering manmade relaxation of tectonic stress in the Earth's crust, appear the most acceptable from the geoenvironmental viewpoint. One method deals with electromagnetic (e.m.) action using pulses of electric currents. Some pioneering results were obtained in Russia and Kyrgyzstan (UIPE, OIVTRAN) [1] while investigating the effects of high power e.m. pulses produced by magnetohydrodynamic (MHD) generators. The focus was the seismic activity in the regions of the Bishkek and Garm test fields. A very important result was that such manmade actions always triggered seismic events of lesser magnitude (M<5). Such actions appear therefore useful for civil and scientific purposes.

The present paper is devoted to the simulation of a phenomenon of triggering weak seismicity by actions of impulsive physical e.m. fields (so-called power-impacts). Acoustic and electromagnetic energy release is a well known effect during the process of formation of structural defects and the fracture of terrestrial materials [2, 3, 4, 5]. It appears therefore reasonable to assume that an effect ought to be observed from EI on the processes of defect accumulation in loaded rock specimen (such as microcracking and so on). The manifestation of such inverse energy conversion is that the AE and the rate of rocks straining are influenced by the externally applied electromagnetic impacts (EI). The target of our investigation is the study of the response to electric power action on specimens of terrestrial materials. The investigation of the AE pattern based on waveform analysis appears significant and it helps to reveal the physical origin of the emission pulse.

In addition, the results of structural studies can provide some essential information on the kinetics of fault formation process within a loaded solid. In this way, for instance, the emergence of a second spectral maximum of acoustic signal, with a frequency lower than for the main maximum, implies the microcracking transition from a stage of diffusive accumulation of defects to a clustering stage of defect growth [6]. Our experience showed that the combined analysis of statistic and structural AE data allows obtaining comparably more reliable results and achieving a more straightforward interpretation.

AE results to be a good indicator of inelastic straining processes and microfracture. During our experiments, we focused our system on the records of AE of several loaded specimens of terrestrial materials. Some AE features turned out to be crucial parameters for revealing correlations between the rate of pre-failure straining processes, and the externally applied power impact. The modeling of inverse processes involves creep test of rock specimens, and of specimens of artificial heterogeneous materials, loaded by uniaxial compression. The experiments were performed by the spring rheological set UDI with a maximum compressive load of 100 tons (designed by A.N. Stavrogin, VNIMI, S-Petersburg). Fig.1 shows the experimental set up.

We tested a number of samples, made of granodiorite, quartzite, granite, halite, and zirconium oxide ceramic. In addition, some concrete specimens were tested, prepared according to Stavrogin's prescriptions [7] and having size 100x120x250 mm^3. Additional electric power impacts were generated by external sources during a deformation session, while keeping a constant compression load.

During our experiments, the following sources of additional power-action were used: square-wave generator G5-54 giving a square-wave signal, with amplitude close to 50 V, duration of order of 5-50 μs, frequency 1-3 kHz; 10 kV generator of sparks (with no waveform control). The capacitor discharges that supplied electric pulses had parameters: time of voltage ramp about 1 μs and peak voltage of order of 1 kV. A generator of triangular pulses GI-1 (300 V voltage amplitude) and the sinusoidal generators G3-112, G3-33 also were used for simulating power-impacts. The vibration effects were simulated during our experiments on the UDI machine. We arranged vibration sessions, by fastening a small size vibrator (buzzer) to the lateral surface of the specimen being tested. Sinusoidal AC signals of the G3-112 or G3-33 were supplied to the input of a vibropack (i.e. a small-size buzzer, or speaker unit) for exciting vibrations of a given frequency. During the vibration session, we controlled the constancy of amplitude and frequency of the electric signals supplied to the vibropack. AE and electromagnetic emission signals were recorded in a wide frequency band, 80 kHz-5 MHz. Such experimental setting permits an effective signal waveform control. The measuring system operates in a waiting mode, triggered by AE events.

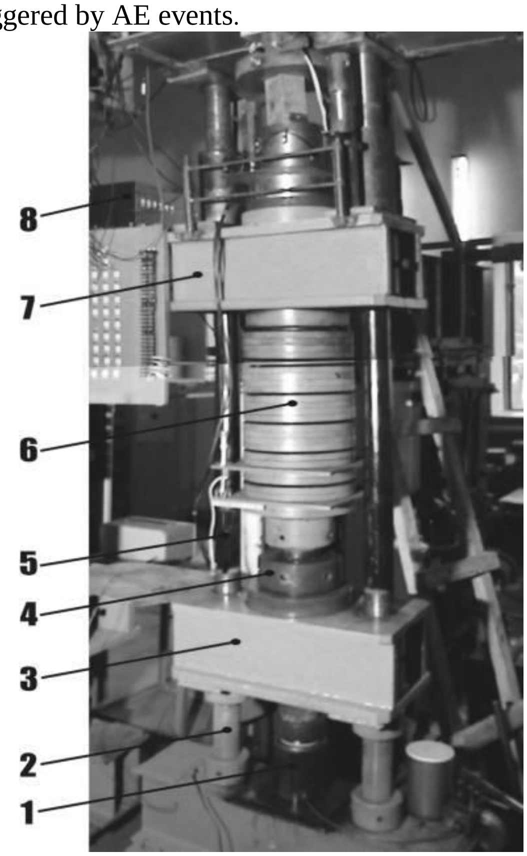

Fig.1.General view of the rheological experimental setting UDI (1- hydraulic jack, 2,5- supporting rods, 3- lower cross-arm, 4- clamping-nut, 6-springs, 7-higher cross-arm, 8- block of amplifiers)

The specimen is located on a lower plate with built-in AE sensors, integrated with cable amplifiers. A system of five lower sensors provided the location of the AE sources. When the rate of longitudinal waves in the material is determined, and its lateral size is not less then 60 mm, a 5-channel system permits a determination of the coordinates of the AE sources with high precision (several millimetres).

From the top, the specimen is confined by an upper plate, while the alignment with the lower plate is accomplished by using a spherical joint.

In most cases, single noise-immune sensors are used for recording low AE signals. Such sensors were applied to the sides of specimen. The signal from the one of the side sensors (SE2000, DECI company), after suitable amplification and filtration, triggered the operation of the recording equipment – ADC (CAMAC standard). The other sensor (SH350), which was attached to the specimen surface, allowed for investigating shear acoustic waves.

Additional electric power-impacts were applied during our experimental sessions. We had to wait for some time of sample exposure, after load increase and before carrying out measurements, in order to avoid the bias of the unsteady processes, caused by the non-uniformity of load ramping up and by the edge effects (surface microchipping etc.) Permanent AE recording started when the manifestations of transition processes (low frequency fluctuations) became of the same order as the natural noise.

Depending on the particular task of any given experiment, one can choose a suitable number of measuring channels to be activated during a single measuring session. For instance, we used 6 or more AE measuring channels for locating the microcracks, which are the AE sources. The multichannel location system operates both with signals from 5 sensors, mounted on the lower plate, and from the sensors fixed on the lateral surface of the specimen. Alternatively, one should use the minimal number of channels for reaching the maximum processing speed, as this involves a reduction of the size of the output files to be stored in the computer.

Experimental results

The results from the main part of our investigation are shown in Fig. 3-10. As a rule, the AE response from loaded specimens of terrestrial material involves an increase of AE activity. Sometimes (though rarely) such growth is followed by a temporal drop of the AE activity after the power-impact. In any case, the integral effect is an increase of AE events.

The growth occurs with some delay after the starting instant of an applied action. Then, the AE activity damps off to its former background, or (in some cases) even below the average level. Fig. 3 shows the triggering effect of the electric pulses produced by the G5-54 generator on the AE of quartzite specimen. The AE activity curve of Fig.3 can be explained in terms of a stick-slip earthquake nucleation model.

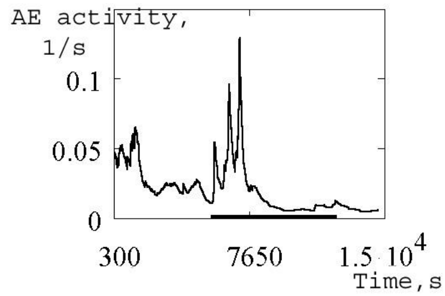

Fig.3. AE activity of quartzite specimen *vs.* time. Electric actions took place during the time interval 5700-12400 s, as shown by the bar; the parameters of the periodic pulses produced by the G5-54 generator were 2kHz, 5mks, 60V.

A part of the curve displays a great energy release after the trigger by the external source of the e.m. pulses; after some time the trend shows a quick drop of AE activity (analogue to the stress drop) down to a level comparatively lower than the level before the power action. It should be noted that the quartzite specimen has some internal cracks with consolidated edges (peculiar locking structure). One can assume that the localization of strain at some of the old cracks results in the shift of crack faces, like the behavior of contacting blocks in the well-known stick-slip model for earthquakes.

The case of a long delay of AE activation by electric impacts is shown in Fig.4 as a temporal plot of AE activity of a granodiorite specimen. The response to the effect of some pulses, supplied by the square wave generator G5-54, was recorded 1000 seconds after the trigger. Fig.4 shows that the AE activity is increased by a factor 20, compared with its background level, while it later rapidly drops to its initial level.

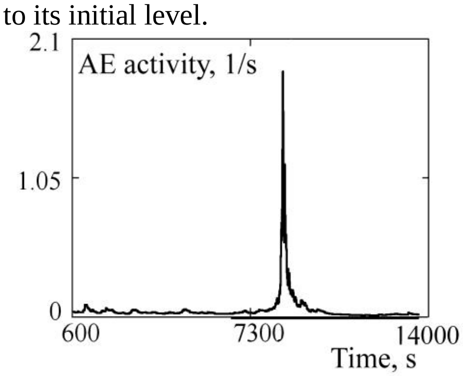

Fig.4. AE activity of a granodiorite specimen *vs*. time. Electric actions were applied during the time interval 7125-13620 s; the parameters of periodic pulses produced by the G5-54 generator were 2.5kHz, 20mks, 50V.

Remarkable result were obtained on ceramic specimens of zirconium oxide (Fig. 5-8). Fig.5 shows the temporal dependence of AE activity. The plot represents the results obtained during an experimental session with an external source which supplies a power-impact in addition to the main compressive load (the loading is equal to 1 t, or 12,5% of the breaking load). The square wave generator G5-54 was used as source. Fig. 6 gives the AE activity dependence during the session with no additional impacts (the load was equal to 3 tons) and it should be compared with the case of fig. 5. Fig. 6 shows that the AE activity of a specimen tested by the usual straining conditions (without external EI) tends to decrease, and it attains a quasistationary level (so-called background) by some time interval, typically lasting 2000-3000 sec. The value of such steady level is very low for the loading conditions of the AE activity plots that are of concern in fig. 5 and 6. In addition, the spontaneous fluctuation amplitudes are quite small (fig. 6). Fig. 5 shows the damping of AE activity from its usual trend (decreasing slightly, or saturating) that takes place in some short-term delay (100 s) after the start of the external action. In fact, the considerable growth of AE activity above its typical trend is the response to the effect of power impacts for the materials that we investigated.

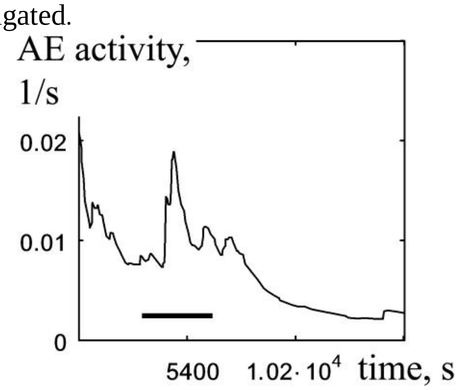

Fig.5. AE activity of a water saturated ceramic specimen *vs.* time. Electric actions were applied during the time interval 3400-6500 s; the parameters of the periodic pulses produced by the G5-54 generator were 20kHz, 5mks, 60V (12.5% of the fracture load).

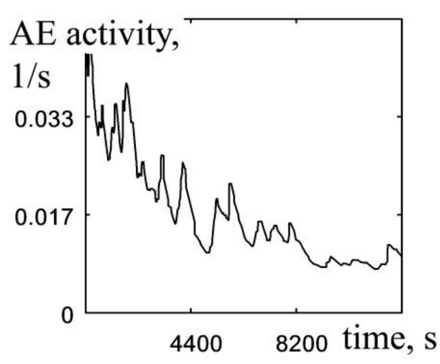

Fig.6. Comparative curve. AE activity of the same specimen *vs.* time (session with no electric actions, 37% of the fracture load).

Two phases of response can be distinguished in the case history of fig. 5. The first phase involves an abrupt growth of AE activity and its subsequent damping (its duration is close to 1000s). The second phase denotes a smooth evolution, or some stabilization on a level that clearly exceeds the background (the duration is determined by the time of the external EIs stop, i.e. close to 2000 s in the present case history). The second phase of the response is followed by a rapid drop of the AE activity, when the source of the power-impact is turned off. It is worth stressing, when comparing fig. 5 and 6, that the AE activity background depends on the main load. Generally, the larger the load of the main compression, the larger average AE activity. This is caused by the growth of the microcracking rate with the increasing stress. Correspondingly, the mathematical expectation of the time lag between AE events shortens (this concerns AE's accompanying new crack nucleation, while the existing crack stretch shortens).

Fig. 7 shows an example when the inductive spark generator (much like a car spark-ignition system) was applied in order to allow for some instant high-voltage impacts aiming at enhancing the electric current through the tested specimen. It should be noted that the result was obtained when the specimen was under a load of 68% of its breaking load. Three series of pulsed impacts were applied during the session. The number of spark discharges during every series is 3, 13, and 20, shots respectively, the interval between shots always being 10 seconds.

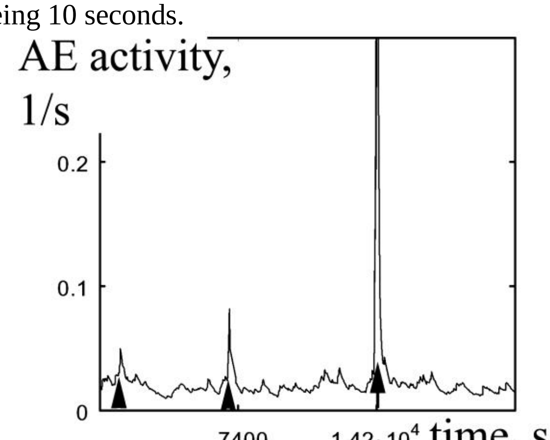

Fig.7. AE activity of a water saturated ceramic specimen *vs.* time. Arrows denote the instants of pulse actions by the spark generator (up to 10кV). 3 , 13, and 20, discharges were accordingly applied, respectively. Measurements at 68% of the specimen fracture load.

The responses to power-impacts have similar spike shapes, but the response amplitudes are different. All three responses to EI are characterized by some abrupt leading edge and some lesser duration. The largest response was observed in the third discharge, the peak activity exceeds more than 15 times the averaged background (one event per 50 sec) . The difference in amplitudes can be caused by a different number within the shot-series. The fact that the majority of events in the third spike (response to the 20 shots series of discharges) was originated after the 10^{th} shot, appears to be in favour of such hypothesis. Alternatively, such fact could be a manifestation of an aftereffect (during the third EI series the residual structural changes occurred while the first and second impact series were still playing some role in the forced activation). The results obtained are likely to imply some considerable role, in the aforementioned effect, of polarization (electric charge accumulation and/or separation). This should justify the fast responses to major pulsed-impacts, as well as the delayed responses to the quasistationary action of some weak periodic pulses.

The results of the previous studies show that the effects of EI over various rocks are more evident when the load is in the range of 80-90% of the fracture load for every given specimen. It was noted that at such loads the state of the material is close to a critical point (instability). Locked AE sources (multiple microcracks) originate, and develop, close to such state. The larger the load, the greater the number of AE sources. Therefore, it appears clear why all materials in such state denote an enhanced perceptibility to the external action. By this, even some weak external perturbation can trigger a system bifurcation towards some new steady state, with an increased level of AE activity. We carried out special experimental sessions testing specimens with loads close to, or within an 80-90% range (compared to fracture), in order to determine the threshold when the state of the tested rock becomes unstable. Besides, the interest to such sessions is related to the results of some recent investigation [8]. They stressed [8] that, at such loads, rocks should result to be very sensitive to the superposition of some modeling power-impacts from some sources. Owing to such inference, we carried out an experiment with a combined power-impact session. At first, some weak vibrations were produced by a buzzer, electrically biased by a G3-112 sinusoidal generator. Then, after some time following the start of the vibroaction, the specimen was additionally stressed by some electric pulses by the GI-1 generator (pulses of triangular waveform with 150 V amplitude and duration close to 15 msc). The measurements were performed when the load was approximately 75% of fracture. Fig. 8 shows the recorded AE activity. The growth of the AE activity results from the combined effect. Slow growth of averaged AE activity (the background trend) is observed after turning on the source of the electric pulses.

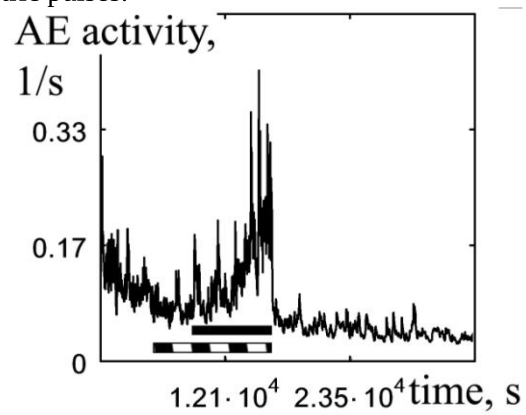

Fig.8. The same plot as in fig 7. Solid band denotes the period of electric action by the GI-1 generator (f=25 kHz, u=350 V). The dotted band shows the period of electric action by the G3-112 generator (f=2.2 kHz). The measurements were performed at 75% of fracture load.

Such trend can be filtered from the background of some considerable spontaneous fluctuations (the larger the load of the uniaxial compression, the greater the fluctuations and the amplitude of their bursts) The rate of the AE activity rise increases drastically after 3000 s from the beginning of activation. Both sources were switched off when the AE activity increased by 30 times compared to its starting background, and shifted to some new steady (i.e. non–diminishing) level. At the time instant of the double switching off, the AE activity abruptly dropped to a level even below its former background before activation. Such results of the investigation of such combined effect over some loaded specimens of terrestrial materials, emphasize the wide range of possible optimization of the external power-impact sources. Subsequent research of various optimization aspects will promote some unprecedented approach to the control of straining processes within loaded media, based in particular on the analysis of the AE responses.

In order to confirm the accuracy of our measurements, we reproduced the results of our previous works [6,9] concerning the triggering effect of some weak low frequency vibration. Fig. 9 shows the temporal plot of the AE activity of a granite specimen during a vibration session. The plot envisages a distinctive response to vibrations. Experiments with vibrations were arranged by using the speaker as the vibration source and the G3-33 generator like electric supply. Fig. 9 shows that the duration of the delay of the response is of the order of 1000 s. The AE activity growths by a factor of 4 compared to its initial background. A drop of the AE activity occurs after turning off the vibration source. However, a short duration of AE activity occurs during the first 500 seconds after switching off the vibration source. Then, the AE activity slowly damps off to a level lower than its value before applying vibrations.

In addition to granitic specimens, the AE responses of gabbro specimens were investigated. Fig. 10 shows an AE response similar to the case of granitic specimens. Test were made under vibration. The delay results close to 1000 s. Aftereffects (the part of the plot corresponding to repeated AE increase and very slow decrease of AE activity) are observed also in the present experiment. Its duration somewhat exceeds the delay before activation. Both fig. 9 and 10 show the activation delay and the aftereffect by the action of physical fields. The comparison shows a similarity of the AE responses to vibrations (fig.9) and to electromagnetic impacts (fig.10).

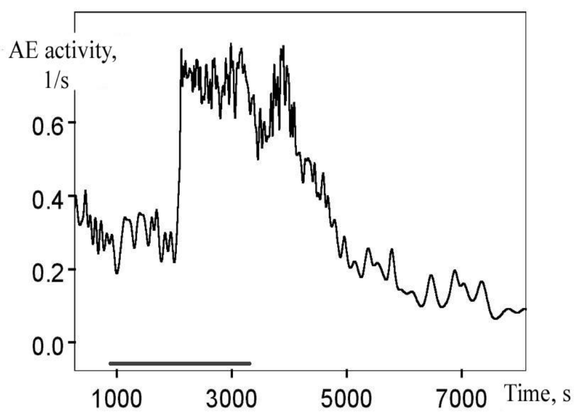

Fig.9. AE activity of granitic specimen vs. time. The band indicates the period of electric action by the G3-33 generator (1kHz, 2V). The measurements were carried out at 95% of fracture load.

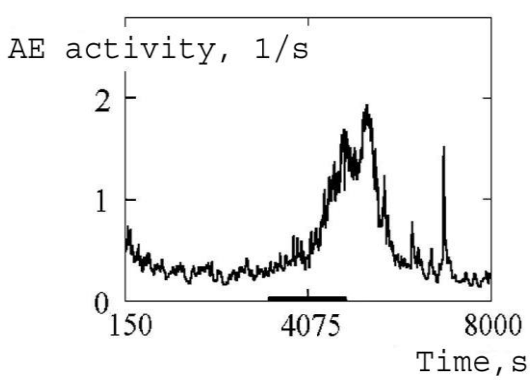

Fig.10. AE activity of gabbro specimen *vs*. time. The band indicates the period of electric action by the G5-54 generator (2kHz, 30mks, 60V). The measurements wre carried out at 85% of fracture load.

Some spontaneous activation is observed, accompanying the triggering responses in fig.10. Such activation was observed on different materials. During the experiments, with no additional EI, the mathematical expectation of spikes, estimated by testing control specimens, was of the order of 4000-6000 sec. Its particular value depends on the load level and on the time delay after the last load increment. Taking into account the frequency of occurrence of the spontaneous spikes and the number of EI sessions, a small part of the AE activity fluctuations can be related to spontaneous activations, which coincide with the time lag of the externally applied actions. In this way, fig.4 shows an example of the AE activity response to EI during an experimental session in which no large spikes above background occurred before the electromagnetic impact.

In a number of cases it was not difficult to distinguish the AE response from a spontaneous spike. This can be easily seen in fig. 7 and 10. The plots show the difference between the AE activity parameters (such as amplitude and duration) of spontaneous and forced spikes. In particular, in fig.7 the amplitude of the spontaneous spikes is considerably less than the response AE. One can distinguish in fig.10 spontaneous fluctuations by their minor duration and amplitude, compared to the same parameters of the forced activation.

In general, two types of response to e.m. power-action can be recognized. The first type corresponds to observations of some short-term increment of the AE activity (Fig. 7). In such case, the activation front appears quite sharp. Usually, such responses were recorded when the sample is loaded by some compressive stress of moderate value. Upon taking into account the rate of the response rise and its subsequent drop, one can assume that the response arises inside some domain with subcritical stressed-strained conditions, and this entails avalanche formation of defects. In most cases, such type of response of rocks specimens is reduced during the repeated electric impacts at the same stress: we recorded minor or marginal manifestations or we observed no such repeated response at all (opposite to water saturated ceramic specimens, such as in fig.7).

The second type of response can be characterized by some steady increment of AE activity (fig. 9, 10). The enhanced AE level remains quasistationary during some long time after the electric impact. Then (in the case of no repeated impacts) it returns smoothly to its initial value. Sometimes, the AE activity decreases to a level below its initial background. Thus, the aftereffect is observed for responses of the second type. In the case that repeated EIs are applied to the steady phase of response to primary EI, the transition to the new state with still higher AE activity appears possible. As a rule, the second type responses were revealed at large values of the main compressive load, close to the breaking loads.

Upon taking into consideration the well-known Kaiser effect, one can try to explain the suppression of the AE response during repeated electric impact (first type responses). Usually, the Kaiser effect is formulated in terms of some stress decrease and subsequent increase: the AE growth after the stress decrease requires a stress increase by some value exceeding the decrease [10]. It is usually assumed that some microcracking is controlled by the stress increment. Actually, the rate of crack growth depends on a number of parameters [11], and the specific surface energy is very important. Such parameter of the crack surface state is sensitive to electric effects, in addition to fluid or vapour adsorption. A change of the value of the surface energy accelerates or reduces the subcritical crack evolution (the length is much less than the Griffith one). Such changes are followed by changes of the observed AE activity, which look quite similar to the Kaiser effect. The origin of such formal similarity is as follows. The load increment, as well as every external impact, result into some energy input, which is sufficient for triggering the evolution and/or propagation of some limited amount of structural defects. A spike of the AE activity due to some external action (electric impact, in particular) can be treated as a manifestation of a rapid growth of the available microcracks triggered by EI. Thus, the repeated EI application, over some given stress-strain state of a specimen, gave no result (no trigger), due to the absence of any defect, which were preexisting for propagation, though waiting to be triggered. A new population of microcracks is to be expected to arise after a load increment is applied to change the specimen state. Then, the AE responses to the trigger by electric impacts should occur again.

The comparative analysis of the AE activity responses by specimens of various rocks demonstrates the presence of generalized features that respond to the EI influence. Possible physical mechanisms that can explain such EI effect are discussed in next section.

Discussion

We found by our experiments that the effect of the e.m. field on strained structures has different modes, depending on its source, on the specimen material, on the value of the main load, and on the duration of the specimen exposure to such load. The superposition of all such factors predetermines the kind of AE response to an electric impact, particularly the variations of specific parameters of the response. Upon discussing the role of the e.m. effects in straining and breaking some terrestrial materials that are relevant for earthquake nucleation, the electromagnetic triggering of some inelastic strain rate can be interpreted on the one hand in terms of some unified relationships between mechanical (straining, fracture) and e.m. phenomena within loaded solids. On the other hand, an increasing attention was given by geophysicists and seismologists for such interrelation, namely for the generation of electromagnetic emission (EME) signals at different stages of fracture. It could be assessed that the faulting of terrestrial materials are followed by EME [2-4,12], which presumably ought to be treated like fracture precursors [13,14]. EME from loaded rocks were recorded in laboratory studies simultaneously with AE [2,5,12]. EME are caused by the conversion of some elastic into electromagnetic energy during microcracking, or other fast processes, on the micro- and meso-structural levels. Actually, the effect, of the EIs externally excited, on strain rate and particularly on AE, represents the possible inverse process of the energy conversion (compared to EME). The dimensional scaling of such effects of direct and inverse conversion, in order to understand the possible trigger of weak seismicity, can be speculated upon as follows.

A distinctive property of the stressed-strained state of terrestrial materials is its self-similarity on different scale lengths (from laboratory sizes of some cm, up to the natural seismological scale). There are a number of works [15,16] (for instance) confirming the similarity of near-critical dynamics from large scale of earthquakes down to the microscopic scale of the rheological structures of specimens. Among them the works implying AE measurements [17,18] have revealed that the statistical parameters of time series of the observed AE events (AE activity, amplitude and duration of AE) reflect the self-organized criticality of the fracture processes. This implies the self-similarity of the emission effects at various length scales, the multi-scale similarity being valid for EME and AE during the rock specimen fracture.

The most intense e.m. phenomena, which are undoubtedly related to the straining process in the Earth crust, are a prominent effect observed for some hours before strong earthquakes, and sometimes such effects can be observed even visually. For a long time, such an effect is well-known in the seismic region of Central Asia. Recently, this phenomenon has attracted new attention, for explaining the model proposed in [19], and some other publications. It is curious, and important, that the fundamentals for the proposed explanation of strange lights that precede a shock, is close and it even partially overlaps with the basic principles of the kinetics of the defects within solids (point carriers, dislocations, microcracks), which are relevant for triggering the effect of the power-impacts. The consideration given here below appear to support such inference. The idea of [19] is that the immense pressures generated before an earthquake can generate electric currents in some igneous rocks, which normally act like insulators. Shortly, they behave like "p-type" semiconductors, meaning that they contain mobile positive charges, which can conduct some electrical charge. The crystals within volcanic rocks contain some paired oxygen atoms, called peroxy groups, which can snap under stress. Freund speculates that once a peroxy group is snapped, a negative oxygen ion will remain trapped in the lattice of the rock, while a positive charge – or hole – will be free to flow outwards.

The available models of charge transfer within the Earth's crust stresses the possible mechanism of interaction, of free carriers of electric charge, with an e.m. field externally applied to the loaded geologic media, or to a tested specimen. **The density of released positive charges should oscillate, due to e.m. field pulses**. The oscillation of charge carriers will be delivered to the main frame of the loaded body (i.e. to the crystal lattice in the simplest case). The triggering effect of the vibrations, even a very weak effect, is well-known. The aforementioned interaction of the e.m. field with charges generated according to [19] is therefore a <u>candidate for the explanation of the electromagnetic trigger.</u> Actually, at the conditions of our modeling experiment, this effect can excite vibrations of amplitude of 10^{-8} - 10^{-7} of the main stress value. Meanwhile, the vibrations (of lower frequency but of amplitude close to 10^{-6}) can increase the AE activity (see for example fig. 9 or that from [9]). It should be emphasized that other mechanical actions caused by e.m. pulse, such as the attraction of the electrodes, the ponderomotive force acting on steel plates in contact with the specimen etc.) are negligible, compared to other estimated factors. The similarity of the relaxation effects of the rocks, after load increment and after voltage supply, were considered in [20]. Our present results show that the electric polarization occurs in both cases, and that the polarization is finally related to the inelastic strain, because the tested materials have no piezoelectric properties.

In addition, the cloud of positive charges might influence the dislocation processes. Our previous work [6] appealed to a model of moving dislocations that produce a plastic strain of the solid, or at least of some domains inside the loaded medium. When the dislocations move across a domain that contains charged defects (i.e. positive holes in our case), they become charged and contribute some electric charge transfer (this can result essential in low conductivity semiconductors). Charging or discharging dislocations can occur, depending on the density of the point defects. The mobility of the dislocations at some given stress and temperature is controlled by point charge carriers, which surround and screen the charged dislocations (this is the so-called effect of Cottrell cloud). Dislocation slip, which determines the plasticity at microlevel, controls the relaxation rate of the overstress, which is localized at some sites. The probability of microcracking is maximum at such sites of stress concentration, described as sources of emission signals. The larger the rate of stress relaxation, the smaller the AE intensity caused by microcracking, and vice versa. In this way, one can distinguish two mechanisms, at least, of the way by which e.m. pulses can influence the inelastic component of rock strain, which is followed by some observable AE change. Future investigations are likely to give some quantitative estimates of the AE effectiveness in the study of the trigger by electromagnetic impacts, in addition to the aforementioned qualitative consideration.

The first results obtained during our investigations showed that our chosen approach for modeling the relationships between mechanical and e.m. effects on phenomena occurring in the geologic environment is reasonable, and additional work in this direction appears very promising.

The present research is partially carried out by the grant YGI-2316-BI-02 of the American Fund of Civil Researches and Development for the New Independent States (NIS) of the former Soviet Union.

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