# MHD EFFECTS ON MICRO- LEVEL AND MODELING OF PHYSICAL FIELDS INFLUENCE OVER LOADED ROCKS

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**Abstract.** Given work represents the results of laboratory modeling of effect of power electromagnetic impacts (EI) over stress-strained structures in specimens of terrestrial materials. 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. Our experiments revealed the response of AE activity to power applied externally (application of electromagnetic field and vibrations). A number of specimens made of different heterogeneous materials (semi-brittle rocks, ceramics, sand-cement mixture) were tested. We analyzed the temporal dependence of AE activation for the major spikes on the AE activity plot, in order to study the transition straining processes. Possible ways of results explanation as well as interrelation with full-scale observations of elecrotriggering have been discussed.

УДК 550.348; 550.37 МГД- ЭФФЕКТЫ НА МИКРОУРОВНЕ И МОДЕЛИРОВАНИЕ ВЛИЯНИЯ ФИЗИЧЕСКИХ ПОЛЕЙ НА НАГРУЖЕННЫЕ ГОРНЫЕ ПОРОДЫ

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**Аннотация.**В данной работе представлены результаты лабораторного моделирования энерговлздействий электромагнитных импульсов на напряженно-деформиованные структуры в образцах геоматериалов. Чтобы понять природу триггерного влияния внешних физических полей на землетрясения регистрироваласт акустичкская эмиссия (АЭ) нагруженных образцов геоматериалов. Проведены длительные реологические испытания с широкополосными(высокочастотными) измерениями деформации и АЭ. Эксперименты выявили отклики АЭ на внешние энерговоздействия (наложение электромагнитного поля или вибраций). Исследованы образцы из различных гетерогенных материалов (полухрупкие горные породы, керамика, песчано- цементные смеси и т.п.) С целью исследования переходных деформационных процессов проанализирована временная зависимость нарастания АЭ для наиболее значимых всплесков на графиках активности АЭ. Обсуждаются возможные подходы к объяснению результатов и взаимосвязь с натурными наблюдениями электротриггерных эффектов.

## Introduction

The noticeable progress in controlling overstress relaxation in specimens of loaded terrestrial materials can be achieved with the use of laboratory modeling that allows realization of a wide range of load conditions, model characteristics, methods and parameters of experiment. Note that in physical experiments, we regard the acoustic emission (AE) as a model of real seismicity that is statistically self-similar in a wide range of scales. It is well known that AE is a good indicator of inelastic straining processes and microfracture. The activity of AE appears to be very sensitive to all changes in strain rate of tested specimen. So, acoustic emission measurements can put some light on the physics of seismic process, in particular on such specific aspect as possibility of unloading of tectonic localized overstress due to external factors

We carried out long duration rheological tests with the help of 100-tons spring press UDI (designed by A.N. Stavrogin, VNIMI, S-Petersburb), while making wideband measurements of strain and AE. Experiments have been performed on pristine rock samples and on artificial heterogeneous materials subjected to creep tests under uniaxial or biaxial compression. During modeling experiments we focused measurement system to record the AE of specimens of terrestrial materials loaded by uni- or biaxial compression and additionally undergoing by electromagnetic impacts excited externally. The general task of each experimental session was to reveal increments or decrements of AE activity correlating to electromagnetic impacts or other physical fields power on (so-called AE responses power actions). Our previous experiments [Bogomolov, Manjikov, Sychev 2001], [Bogomolov, Il'ichev, Zakupin, 2004] revealed AE activation as a response to power applied externally (application of electromagnetic field and vibrations). Developing investigations of rock samples AE electromagnetic stimulation, a new set of experiments under axial loading using the spring rheological press with the strength up to 100 tons was carried out. The aim was to study AE in rocks specimens influenced by electrical pulses with parameters never been used before. Besides, we have implied the superposition of several components of electromagnetic fields (crossed electric and magnetic fields, in particular) as well as combined electro- and vibration actions to simulate power impacts over geological medium in strained-stressed state.

Treating the obtained results and comparing them with newest concept of electric charges release while microfracturing [Freund, 2000], [Zuev, 1990] we recognized, in a certain sense, the presence of bridge between phenomenon of MHD conversion of energy at geophysical MHD generators and at activated zones inside rock specimens producing AE responses to power impacts. This idea appeals to just discovered circumstance that insulating terrestrial materials become semiconductors with a number of atom and vacancy charge carriers while microcracking. Free charges may form plasma-like medium near crack tip, so they are to contribute to high sensitivity of AE response to electromagnetic pulses applied externally [Bogomolov, Alad'ev, Zakupin, 2004]. The plausible hypothesis is that the transfer of plasma-like steam inside cracks cavity may be caused by crossed electric and magnetic fields and this MHD inversion may be one of mechanisms of power impacts effect over microcracking rate (developing as change in AE activity).

Preparing and conducting experiments related to the effect of weak seismicity triggering by actions of impulsive physical fields (so-called power impacts, EI) we took into account present state of this problem and results obtained at the largest (i.e. natural geophysical) scale of length. Initially the effects allowing to control deformation processes in seismogenerating zones manifested itself as induced seismicity, which results from underground nuclear explosions [Tarasov, Tarasova, 1995], or from fluid industrial waste injection to borehole located in seismic area [Healy, Rubey, Griggs, 1968], or from variation of water level in large water storage, or from mining operations, as reviewed in [Nikolaev N.I.,1977], etc. Thereafter it was revealed that dynamical actions might redistribute the seismicity in following manner. They are to decrease the number of major events due to growth of energy released by week earthquakes. Presently, some approaches to realize this very promising scenario are in progress. The research of Japanese scientists who studied interrelation between microseismicity distribution and water injection near Nojima Fault may be considered as one of them [Tadokoro, Nishigami, Ando, 2001 ]. The second approach based on well known effect of vibration triggering involves using of powerful vibrators [Nikolaev A.V., 1987], [Alexeev, Glinsky, Drjahlov, 1996]. The third (newest) way is electromagnetic actions by electric current flashing. Because of electrokinetic effects and capillary water in terrestrial crust the last idea is to proceed from assumptions relevant to the first way. Pioneer results on the effect of power electromagnetic pulses produced by magnetohydrodynamic (MHD) generators to test tee seismic activity in regions of Bishkek and Garm testing fields were obtained in Russia and Kyrgyzstan (Shmidt Institute of Earth Physics of RAS, United Institute for High Temperatures of RAS, Scientific Station of RAS) [Tarasov, Tarasova, Avagimov, 2001]. It is very important that such external impacts always triggered the seismic events of minor magnitude ($M<5$). The correspondence of our results (to be described below) with that of reviewed works reads promising from viewpoint of that the concept of controlled tectonic overstress relaxation is working.

**Experimental set-up**

The work on modeling above electromagnetic influence involves the creep test of specimens of rocks and of artificial heterogeneous materials overburden by uniaxial or biaxial compression. The experiments were performed on spring rheological installation UDI with maximum compressive load of 100 tons (designed by A.N. Stavrogin, VNIMI, S-Petersburg). The Fig.1a shows the experimental set up.

Some specimens of semibrittle or pseudo-plastic materials were examined with the help of minor, 20 tons spring rheological machine (fig 1 b). The spring compliance of minor press is 10 times more than that of UDI. This allows, in contrast to UDI, that the change in main load is quite negligible in spite of certain shortening of a creeping specimen under compressive load and correspondent elongation of loading spring. We tested a number of intact samples manufactured from granodiorite, quartzite, granite and halite. Some concrete specimens which were prepared by routine of [Stavrogin, Protosenya, 1979] and have the sizes exceeding that of rocks were tested as well. Water- saturated specimens of zirconium dioxide ceramics were examined also to distinguish the role of current conductive fluids in sensitivity of terrestrial materials straining rate to electric impacts.

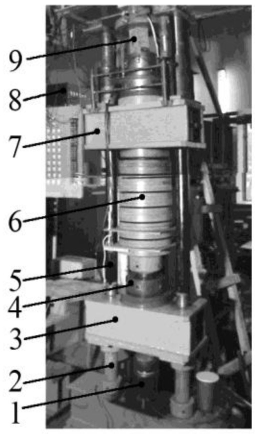



Fig. 1a. General view of rheological installation UDI
1- hydraulic jack
2,5- supporting rods,
3-lower cross-arm
4- clamping-nut,
6-springs
7-higher cross-arm,
8- block of amplifiers
9- specimen
Dimensions of concrete specimen are 100x120x250 mm3

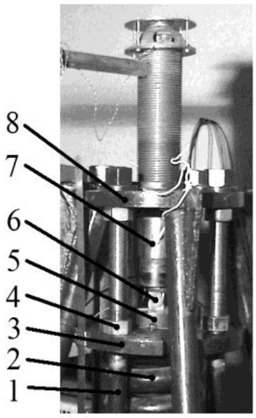



Fig.1b. Small rheol. installation.
8-Higher plate
7-Higher cross-arm
6-Specimen
5-Lower cross-arm
4-Check-nuts
3-Baseplate
2-Spring
1-Columns

Specimen located on the lower pivot with built-in AE sensors, which constructively integrated with cable amplifiers. System of five lower sensors provided for AE sources location. From the top specimen is limiting by higher pivot while it's alignment is performing with using the spherical joint integrated with lower pivot. In most cases for low AE signals recording the single noise-immune sensors are used. These sensors applied to the side surface of specimen. Signal from the one of the side sensors (SE2000, DECI company) after amplification and filtration performed the operating of trigger of recording equipment – ADC (CAMAC standard). AE signals were recorded on wide frequency region 80 kHZ-5 MHz. This allows signals waveform control. The measuring system operates in a waiting mode: recording starts every time when the signal magnitude exceeds threshold.

Additional electric power impacts produced by external sources took place during a deformation session with constant level of compressive load. It took place in some time of sample exposure just after load increment but before measuring session to avoid the bias of unsteady processes caused by non-uniformity of load ramping up and edge effects (surface microchipping etc.) Permanent registration of AE started when the manifestations of transition processes (low frequency fluctuations) became of order of natural noise.

During experiments the following sources of additional power action were used: square-wave generator G5-54 giving square-wave signals, which amplitude was close to 50 V and duration was of order of 5-50 $\mu$s; the frequency was being 1-3 kHz; 10 kV generator of sparks (without waveform control); capacitor discharges supplying electric pulses with parameters: the time of voltage ramping was about 1 $\mu$s and the peak voltage was of order of 1 kV. A generator of triangle pulses GI-1 (300V being the voltage amplitude) and sinusoidal generators G3-112, G3-33 were used to simulate power impacts as well. The waveform of powerful electric pulses applied for Earth soundings at Bishkek geodynamic test site if taken into account for above selection of generators: simulating natural-scale EI the most measuring sessions involved action of square-wave pulses supplied by G5-54 generator. Other sources were used to reveal the significance of such factors as voltage amplitude, rate of pulse rise, and pulses repetition rate for AE activation considered. Also we performed AE measurements during trial session with crossed electric and magnetic fields impacts. A magnetic coil supplied by AC sinusoidal current was the source of additional magnetic field with near 0,004 T maximal amplitude of inductance. The coil was placed near lateral surface of a rectangular specimen so that the induced magnetic field be approximately orthogonal to electric field, produced by electrodes fasten to other (transversal) facets. Alternative magnetic field was used to avoid negative bias of ferromagnetic elements of press. Frequencies of electric and magnetic fields were the same for the sake of synchronization. So, dynamical force and perturbed velocity of charged particles fluctuated with that frequency.

Our investigation of acoustic responses to EI was planed to involve a comparison with the effect of vibration stimulation of AE activity described previouly [Bogomolov, Manzhikov, Sychev, 2001], [Alad'ev, Zakupin, Bogomolov, 2003], [Sobolev, Ponomarev, Kol'tsov, 1995]. To reproduce vibration effects for the same samples that were affected by additional EIs during experiments on UDI machine we arrange vibration sessions by fastening small size vibrator (buzzer) to the lateral surface of the tested specimen. Sinusoidal AC signals of generator G3-112 or G3-33 were supplied to the input of vibropack (small size buzzer or speaker unit) to excite vibrations of given frequency. During vibration session we controlled the constancy of amplitude and frequency of electric signals supplying vibropack.

**Results**

We used the temporal plots of AE activity in order to estimate the dynamics of cracks growth, in particular under effect of EI. We performed the moving window averaging of AE events accumulation rate to calculate the AE activity. Experimental data has been checked for false events presence. Criteria of such verification were spectral parameters of AE.

Obtained indicative results of our investigation the have been represented on Fig.2-7. As a rule the responses of AE from loaded terrestrial materials represent a growth of AE activity. Sometimes (rarely) such growth follows by the temporal drop of AE activity after power impact; the integral effect being increment of AE events. The growth occurs with some delay after the instant of action beginning. Then AE-activity reduces to background or (in some cases) still below the average level. Fig.2a demonstrates the triggering effect of electric pulses produced by G5-54 generator on acoustic emission of quarzite specimen. One can see from fig.2 that the response to EM pulse can be distinguished easily even in case of low level of AE activity. AE activity curve showed by Fig.2a one can explain in terms of stick-slip eathquake nucleation model. We have a part of curve with a great energy release after triggering action of external source of electromagnetic pulses and after some time we have a part with quick drop of AE activity (analogue to stress drop) to level lower in comparison with level before power action. It should be noted, that the quarzite specimen has interior cracks with consolidated edges (peculiar locking structure). One can assume that the localization of strain at some of the old crack results in the shift of crack faces like behavior of contacting blocks in well-known stick-slip model of earthquake.

Remarkable result has been obtained on a ceramic specimens (Fig.3). The fig. 3a shows an example of the session when the inductive spark generator (like to car spark ignition system) was applied to allow momentary high voltage impacts aiming to enhance the electric current though tested specimen. It should be noted that the result has been obtained when the specimen was under load of value of 68% of break load value. Three series of pulsed impact take place during the session, the number of spark discharges in each series is 3,13 and 20 shots correspondingly, the interval between shots is always equal to 10 seconds. One can see on the presented plot that the responses to power impacts are of similar spike shape but the responses differ by amplitudes. All three responses to PI are characterized by have abrupt leading edge and minor duration. The response to third series of discharges is the largest, the picked value of activity is more than 15 times exceeds the averaged background (an event per 50 seconds). The difference in amplitudes may be caused by different number of shots in series. The fact that the majority of events in third spike of activity (response to 20 shots series of discharges) originate after $10^{th}$ shot speaks in a favour of this hypothesis. Alternatively this may be a manifestation of aftereffect (during the third series of EI the residual structural changes occurred while first and second series of impacts are to play certain role in forced activation). The results obtained are likely to signify the considerable role of polarization (electric charge accumulation and/or separation) in the above effect. This is to explain fast responses to major pulsed impacts as well as delayed responses to quasystationary action of weak periodic pulses.

The results of previous studies demonstrated that the effects of electromagnetic impacts over various rocks are the most explicit when the load is in the range of 80-90% from fracture load for given specimen. It was noted that the state of material is close to critical point (instability) at such loads. Locked sources (multiple microcracks) of AE originate and develop at this state, the more load the more number of source -sites It is clear that the materials is this state are of enhanced perceptibility to external action, so even weak external perturbation may cause the system bifurcation to new steady state with increased level of AE activity. We have carried out special experimental session testing the specimens by load close or within 80-90% range (compared to fracture) in order to determine threshold when the state of tested rock becomes unstable. Besides, the interest to such session is related to results of resent work [Bogomolov, Il'ichev, Zakupin, 2004]. It has been remarked in tais work that the rocks at these loads should be very sensitive to superposition of modeling power impacts from some sources. Motivated by this we have performed experiment with combined power impact session. At first weak vibrations produced by buzzer electrically biased by G3-112 sinusoidal generator influence the specimen during a session. Then, in some time after start of vibroaction the specimen has been additionally supplied end effected by electric pulses of GI-1 generator (pulses of triangular waveform with 150 V amplitude and near 15 mcs duration). Measurements were performed when the value of load was approximately 75% of fracture. Fig. 3b demonstrates the plot of AE activity variations recorded on this experiment. The growth of AE activity is marked to result from the combined effect. Slow growth of averaged AE activity (the trend) takes place after turn on of electric pulses source.

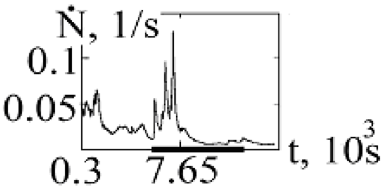



Fig.2. AE activity of quartzite specimen vs. time. Dark band notes the interval of electric action by G5-54 generator (pulses frequency, length and amplitude were correspondingly 2kHz, 5mks, 60V)

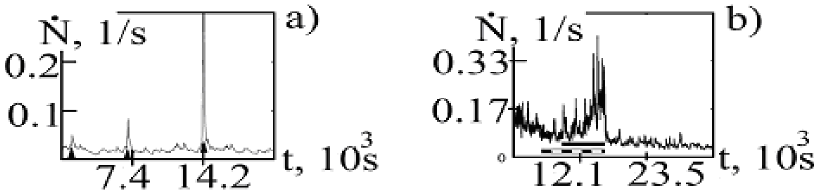



Fig.3. AE activity of water saturated ceramic specimen vs. time:
a) during the session with sparks generator (voltage up to 10кV, impact times are noted by arrows, 3, 13 and 20 discharges were being supplied.
b) during the session with combined actions. Solid band shows the period of electric action of GI-1 generator,f=25кHz, V=350V). Dotted band - the period of vibroaction ( G3-112 generator, is powered on to supply buzzer by f=2,2кHz AC voltage).

Such a trend may be filtered from background of considerable spontaneous fluctuations (the more load of uniaxial compression, the more fluctuations and the more amplitude of their bursts) The rate of activity rise increases drastically after 3000 s from the beginning of activation. Both sources were powered off when the activity of AE growths by 30 times in comparison with the initial background and comes to the new steady (non –diminishing) level. At the dual power off moment AE activity drops abruptly up to level even below than the background before activation. Represented results of investigation of combined effect over loaded specimens of terrestrial materials underline the wide possibility of optimization of external power impacts sources. Subsequent research of various optimization aspects will promote to approach the control of straining processes in loaded media based in particular on the analysis of AE responses.

In contrast to experimentation with such loose material as zirconium dioxide ceramics we also studied experimentally the reaction of dense but water-saturated granodiorite specimens to short high voltage discharges applied externally (Fig. 4).

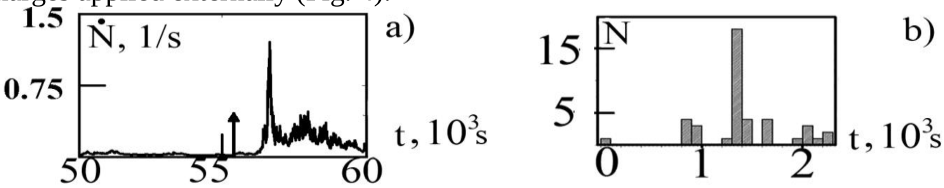



Fig.4. Examples of growth of AE after high-voltage stimulation: water saturated granodiorite specimen, arrow is a moment of set of 10 electrical discharges, with near 1 kV voltage spike each; b)dry granodiorite specimen, capacitor discharges were in temporal intervals: 850-950 s, 1250- 1350 s, 1650-1700 s.

The reaction to a series of 10 pulses with amplitude of about 600 V was observed with the delay of ~ 1000 seconds and displayed the sharp increase in AE activity (by a factor of tens). After 3000 s the AE activity decreases almost to the initial level. One can see from AE activity plot that the main difference between response of granodiorite specimen to EI and the same response of ceramic specimen is a length of delay. AE response of granodiorite occurred with long-duration lag, meanwhile Response of ceramic specimen to EM discharge was in 10-50 s after electric discharge. When acoustic activity of a rock sample is very low (for instance, few tens counts were recorded rather than flow of AE events) the effect of electric stimulation of AE may be revealed in terms of temporal distribution of events (see Fig 4b). One can see that AE signals were recorded mostly during periods when high voltage discharges took place every 10 seconds. In this case the delay of response was equal to ceramic specimen one (fig.3a).

It should be noted that the rheological test on spring machine involves unavoidably the most unfavorable condition to observe the effect of electromagnetic triggering. This is related to relaxation of metastable state (which is very sensitive to triggering impacts) without energy influx like that at a press with given constant rate of compression growth. Fig.5a shows the degradation of AE activation when repeated power impact occurs. This peculiar feature of AE responses to electromagnetic pulses is related to above relaxation. Motivated in part by the principle that even small stress or strain increments can contribute metastable state we arranged vibration sessions on our loading machine by fastening a small size vibrator (buzzer) to the lateral surface of the specimen being tested. Sinusoidal AC signals of the G3-112 generator were supplied to the input of a vibropack for exciting vibrations of a given frequency and constant amplitude. By this way we tried to simulate dynamic component of load (always being present under constant rate straining). Although such simulation is too rough, combination effect of dynamic loads (weak vibrations) and electromagnetic pulses is worth analyzing. Fig.5b demonstrates the distinct reaction of acoustic emission of a concrete sample to combined action of electric pulses and vibrations. At first power impact test (2000-8000 s) we initially turned on the source of electric pulses and then the vibropack. Vice versa order of power on corresponds to the second test period (12000-20000 s). In both cases the response of AE activity to combined vibroelectric action exceeds the superposition of typical acoustic responses (for given material and given conditions) to separate action of electric pulses and vibrations. The increment of AE activity in the second case is less that that in the first. This may be correspondent with general responses degradation tendency mentioned above.

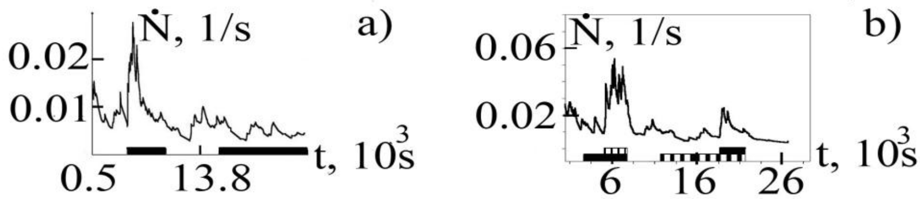



Fig.5. AE activity of intact concrete sample with pyrofyllite inclusion vs time: a) stimulation by square waveform unipolar periodic electric pulses, band denotes the time of action; b) combined electrovibroaction: solid band shows the period of action by unipolar electric pulses (50 V amplitude), dotted band denotes vibration action period.

Biaxial loading by constant stress, in contrast to uniaxial compression, allows recording distinct reaction (namely the response to electric stimulation) of a specimen even under creep test. Experiments were held on the same 100 tons spring press with the help of spring attach for lateral compression, the maximum lateral load being 30 tons. Results are shown on Fig.6; the plots of AE activity indicate that action by periodic pulses of moderate voltage (a) as well as high voltage capacitor discharges (b) can stimulate AE growth. In both cases the activation occurs in same delay after start of electric action; the length of delay being near 1000 s in the case (a) but in the case (b) it being less than 100 s. Fig.6 demonstrates that electric stimulation was powered on when the mean level of AE activity drops after recent stepwise increment of main load at the beginning of measuring session. Quasi-monotonic plot decrease is interrupted due to a response to electric pulses action.

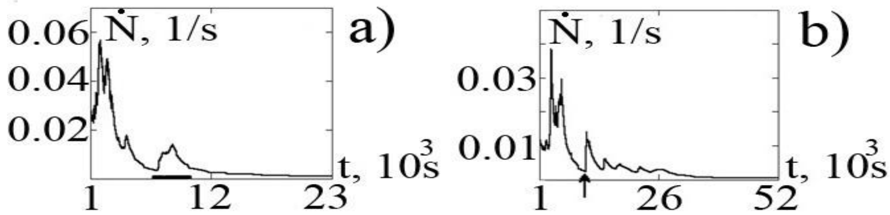
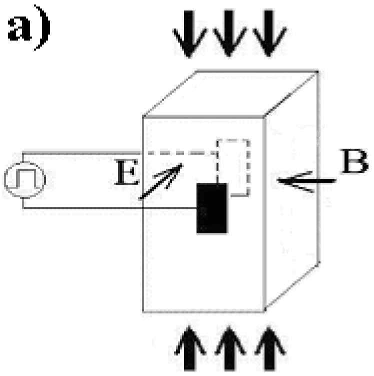



Fig.6 Examples of growth of AE of intact concrete samples loaded by biaxial compression and electric pulses. The lateral stress is about 20 % of main stress: a) action of the same periodic pulses as in the case of Fig 6a, b) action by solitary high voltage pulse of capacitor source.

It was found previously [Kuksenko, Mahmudov, Ponomarev, 1997] that the increment of uniaxial compressive load results in electric polarization of overburden specimen. The effect took place in spite of that the specimen material had no piezoelectric properties. The polarization appears to relax slowly at constant load condition. A polarization of heterogeneous material (rocks) implies the presence of electric induction, and hence domains, dipoles and, sometimes, even charge carriers inside specimen. Undoubtedly, for water saturated samples double electric layers contribute the changes in polarization. It is important for further explanation of nature of AE activation by electric pulses that electromagnetic (E.M.) fields applied externally can counteract with elements of forming metastable electrical structure. Particularly, momentum stress may be created by a vector product of external electric field and polarization vector. It is well- known that microcracking is more sensitive to momentum stress than to simple increment of a stress component, the latter being negligible on the background of main load. The example of Fig.6 (electric action during continued creepage) is well correspondent with such hypothesis. We paid attention to the other aspect of interaction between external E.M. field and charge carriers participating in polarization process. When free charges are temporarily generated in some domain inside poorly conducting media (the mechanisms will be discussed below in the next section) this zone becomes supersensitive to the action of crossed electric and magnetic fields. This is related to the effect of mgnetohydrodynamic pumping, which is inverse effect in respect to well known MHD conversion. It is unidirectional drift of positive and negative charges in plasmas that is the simplest manifestation crossed E.M. fields effect.

To confirm or disprove above assumption involving “virtual” free charges we performed AE measurement during trial session with crossed electric and magnetic fields impacts. Fig.7 shows the abrupt growth of AE during action of crossed E.M. fields. Note that some activation took place after start of electric component source. But AE growth became much steeper when magnetic coil producing magnetic field of intensity amplitude of about 0,004 T was powered on. As shown on Fig.7 the effect of crossed E.M. fields over AE activity of loaded rocks has been revealed. This is essential supplementary knowledge to well-known effect of electric triggering of rocks straining rate and fracturing. Since crossed E.M. fields can influence even quasineutral medium with free charge carriers (like semiconductors plasmas) the effect is of interest from viewpoint of verification of the hypothesis of interrelation between microcracking, mechanically induced polarization and AE sensitivity to power impacts.



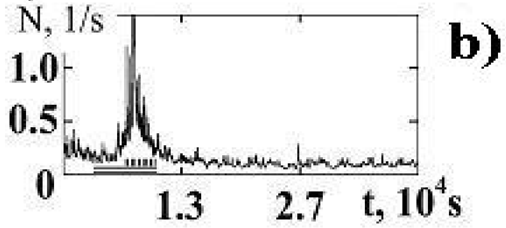




Fig.7 Experiment with loaded specimen of Westerley granite in crossed E.M. field: a) the geometry: directions of main compression (vertical), of electric field strength E, and of magnetic inductance B are orthogonal; b) temporal plot of AE activity during the session with crossed E.M. fields power on (the frequency of both f= 4 kHz).

So, obtained experimental results demonstrated that the chosen approach to modeling relationships between mechanical and electromagnetic effects or phenomema in geologic media is reasonable, further work in this direction is very promising.

**Discussion**

The comparative analysis of AE activity responses of specimens of various rocks demonstrates the presence of generalized features of EI influence. Let’s try to discuss possible physical mechanisms to provide the effect of EI. It has been found while experimental studies that the effect of electromagnetic field on strained structures has different modes depending on the source of electromagnetic field, the specimen material, the value of main load, and the time of specimen exposure under this load. The superposition of these factors predestines the kind of response to electric impact, particularly the variations of responses specific parameters.

Discussing the place of electromagnetic effects in straining and rupture of terrestrial materials in relevance to earthquake nucleation one can treat the electromagnetic triggering of inelastic strain rate as a one side of unified relationships between mechanical (straining, fracture) and electromagnetic phenomena in loaded solids.

The distinctive property of stressed-strained state of terrestrial materials is its self- similarity for different scale length (from large scale of earthquakes down to the microscopic scale of the specimens rheological structures) and the similarity of dynamics of such state near critical point. Some works implying AE measurements [Diodati P., Marchesoni F., and Piazza,1991], [Canneli M., Cantelli R., Cordero, 1993] have revealed that the statistical parameters of AE events flow (AE activity, amplitude and duration of AE) reflect the self-organized criticality of the fracture processes. This means the self- similarity of emission effects at various scales of length, the multi-scale similarity being valid for electromagnetic and acoustic emissions during rocks specimens fracture.

The greatest electromagnetic phenomena undoubtedly related to straining process in earth crust is the shining during or some hours before strong earthquake which sometimes was observable even visually. This fact was well-known Central Asia seismic region long ago. Recently this phenomenon has attracted new attention due to explaining model proposed in [Freund, 2000] and some other publications. It is curious and important that the fundamental of proposed explanation of strange lights preceded shock is close and even overlaps partially with the basic principles of Kinetics of defects in solids (point carriers, dislocations microcracks) which are relevant to triggering effect of power impacts. The consideration below may speak in a favor of this. The idea of Freund F. is that the immense pressures generated prior to an earthquake cause igneous rocks, which normally act as insulators, to briefly behave like “p-type” semiconductors, meaning that they contain mobile positive charges that can conduct electrical charge. Crystals in volcanic rocks contain 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.

Given model of charge transfer in earth crust notes the possible mechanism of interaction of free carriers of electric charge with electromagnetic field applied externally to the loaded geologic media or to tested specimen. The density of released positive charges is to oscillate due to pulses of electromagnetic field. A funny coincidence is that above mechanism is quite similar to well-known effect excitation of ionic sound in plasmas! Oscillation of charge carriers will be delivered to the main frame of loaded body (the crystal lattice in the simplest case). In a general case this effect (similarly to electrostriction) is described by ponderomotive force exerted to non-conducting body without piezoelectrical properties. Such a force is proportional to squared electric field strength [Landau, Livshitz, 1982]. But in the case of crossed E.M. fields drift perturbations and secondary oscillations (to be delivered to main frame) are to be proportional to absolute value of electric strength. Phenomenologically, this looks like seeming anomalous piezoelectric effect. Even small magnetic field may be important for processes involving positive holes. Actually, the larmor radius for the holes in even weak magnetif fields (say from 0,0001 to 0,005 T) may be rather small, because their effective mass is less than that of lattice ions. We estimated that larmor radius was of order of a millimeter at the condition of our experiment. This parameter may be less than one centimeter for rocks massifs in Earth magnetic field. Curved trajectory of holes may be essential for stability of major cracks with open cavities which width exceeding larmor.

Resuming we remark that the action of electromagnetic pulses results in microvibration excited inside tested specimen. Since the triggering effect of vibrations, even very weak, is well - known above interaction of electromagnetic field with released charges [Freund, 2000] is a candidate for explanation of electromagnetic triggering. Actually at the conditions of our modeling experiment this may excite vibrations of amplitude of $10^{-8}$ - $10^{-7}$ of main stress value, meanwhile the vibrations of lower frequency but of amplitude close to $10^{-6}$ can increase the AE activity [Bogomolov, Manzhikov, Sychev, 2001] It should be noted that other mechanical actions caused by electromagnetic pulse such as attraction of electrodes, ponderomotive force acting on steel pivots contacting with specimen etc. are negligible compared to enough estimate. The similarity of rocks relaxation effects after increment of load and after voltage supply were considered in [Kuksenko, Mahmudov, Ponomarev, 1997]. Results of these works demonstrated the electric polarization takes place that in both cases, the polarization being finally related to inelastic straining as the materials tested have no piezoelectric properties.

Besides above the cloud of positive charges is to influence the dislocation processes. Our previous work [Trapeznikov, Bogomolov, Manzhikov, 1997] appealed to a model of moving dislocations realizing plastic strains of solid or at least of some domains inside loaded material. When the dislocations move across a domain containing charged defects (positive holes in our case) they become charged and contribute electric charge transfer (this may be essential in low conductivity semiconductors). Charging or discharging dislocations may occur depending on the density of point defects. The movability of dislocations at given stress and temperature is controlled by point charge carriers surrounding and screening charged dislocations (so called effect of Cottrell cloud). Dislocation slippage realizing the plasticity at microlevel are to control the relaxation rate of overstress localized at some sites. The probability of microcracking is the maximal at such sites of stress concentration, described as sources of emission signals. The more rate of stress relaxation the less intensity of AE caused by microcracking and vice versa. So, one can distinguish at least two mechanisms of that how electromagnetic pulses could influence over inelastic component of rocks straining which is followed by observable change in AE. The subsequent research is likely to give some quantitative estimates of effectiveness of AE triggering by electromagnetic impacts in addition to above qualitative consideration.

As remarked above AE activity may be considered as microscopic model of seismic activity in real terrestrial crust. Various spikes of local seismicity of some days length were repeatedly recorded by KNET seismic network ar the territory of North Tien Shan. We considered the correlation between changes in weak seismicity at the territory of Bishkek test site and dates when electromagnetic soundings on the base of powerful electric sourses were performed in special mode, with enhanced electric charge transfer [Sycheva, Avagimov, Bogomolov, 2003]. It may be curious that the waveform of unipolar electric pulses in a such mode is similar to typical waveform of pulses which had been produced by geophysical MHD generators. Meanwhile, everyday electromagnetic soundings which allow to control apparent electric resistivity of crust involve bipolar pulses. Special unipolar electric soundings are taken place approximately once in 35 days from January 2000 at Bishkek test site. Every additional probe session involves supply of 200 unipolar pulses with duration of 5 or 10 seconds. Both: energy influx and electrochemical transfer turns out to be larger by times than in case when MHD-generators were applied. While study of linear scaling of AEs electrotriggering we succeeded in finding correlation of weak seismicity change in the region of Bishkek test site and noted electromagnetic impacts with the help of statistical data manipulation based on method of observational periods superposition. The routine is described by [Sycheva, Avagimov, Bogomolov, 2003] in details, and the main result is shown on the fig. 8.

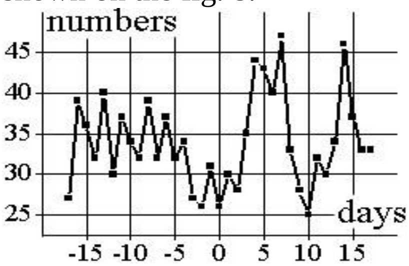



Fig 8. Distribution of daily numbers of seismic events recorded by KNET seismic network**.** The cumulative plot is composed by 35 temporal intervals, each of 35 days length. Days of EI correspond to zero at cumulative plot. Dotted line shows the level of dispersion, defined during the first 17 days (before EI).

One can see on Fig.4 that the result of 35 days periods superposition is that the plot of daily earthquakes number has different forms in the first one half of cumulative window (before EIs) and in the second that (after EIs). Activation occurs on 4-7 day after EI. The existence of lag is similar to AE increments observations in laboratory experiments. It's worth emphasizing that the homogenezation of seismicity temporal distribution based on the periods superposition is adequate, because various irregular factors such as remote earthquakes, explosions, lunar-solar tides, ionospheric disturbances etc. also can trigger seismicity alterations (beside electromagnetic sounding pulses under above consideration). In general, the distinguished effect of EI during special soundings looks similar to results of laboratory modeling (Fig2-7)!

Resuming, one can remark that the effects of electromagnetic triggering is to be universal for wide class of terrestrial materials under subcritical loads and for various scales of length. The ambiguous geophysical MHD experiment of the seventies and eighties may be recognized as a precursor of modern application of electromagnetic power soundings to problem of tectonic overstress unloading.

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