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Self-Excitation of the Earthquakes

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Abstract

Numerous correlations between magnetic and seismic events unambiguously indicate that the magnetic control of the earthquakes is a fundamental phenomenon. It proceeds from the remarkable physics of magneto-plasticity of solids, which implies acceleration of dislocations by microwaves. The motion of dislocations provides release of dangerous elastic energy of the earthquake focus and transforms elastic energy into the safe energy of plastic deformation. Magneto-plasticity seems to be the most important mechanism of the magnetic control because the piezoelectric effect as a suggested mechanism of magnetic control should be excluded (Chelidze *et al.*). Magnetic control certifies earthquake focus as a receiver of microwaves; on the other side, numerous observations exhibit emission of microwaves generated by earthquake focus, so that it can be considered as a permanent generator of microwaves. The idea of this paper is to offer a mechanism of self-excitation of the focus: self-triggering is suggested to be induced by microwaves generated by earthquake focus itself. The more intensive is the crack formation, the higher is the density of microwaves, which accelerate dislocations and intensify crack formation: it is a feedback breeding, avalanche-like process. Both functions of earthquake focus, to be simultaneously generator and receiver of microwaves, are integrated into the same space and time. It excludes such limitation of the magnetic control as the penetrability of the rocks for microwaves.

Keywords

Earthquake, Dislocation, Microwaves, Magneto-Plasticity

1. Introduction

The supply of elastic energy in the earthquake focus is determined by competition of the two processes: accumulation of the energy, which is inevitable, and relaxation of the energy, which can be influenced by external actions. In particular, the focus is known to be controlled by magnetic interactions. Magnetic control of the earthquakes does not imply the possibility to prevent or suppress earthquake; it is a means to elucidate physics of the phenomenon, to deliberately reveal, select and bring to light the most reliable precursors, indicators of the earthquake preparation as a means of its forecasting [1] [2] [3]. Nevertheless, there are many observations convincing that the magnetic control is not a myth and it even prevents some earthquakes [4].

Magnetic control of the earthquakes is based on the remarkable phenomenon, the magneto-plasticity of solids; it implies the impact of magnetic and electromagnetic fields on the early steps (and phases) of the earthquake preparation and occurs at the level of atoms or ions and dislocations; the latter are the precursors of cracks, which ultimately result to the earthquake. The correlation between seismicity and microwaves is now well substantiated and proved by direct and reliable observations. The crossing point, where seismicity meets microwaves, is the dislocation. Namely these structural defects are responsible for the accumulation of elastic energy, when dislocations are trapped by traces of impurities, by other dislocations or various structural faults; in solid state physics it is known as a dislocation strengthening. Elastic energy, accumulated in focus, is supported mainly by these immobilized dislocations. On the other hand, namely these captured, sleeping dislocations are the receivers of microwaves; the latter liberate dislocations, stimulate their motion and release dangerous elastic energy transforming it into the safe energy of plastic deformation.

There are two facets in the correlations between seismicity and microwaves: the influence of microwaves on the seismicity (we will identify it as the magneto-seismic effect) and generation of microwaves by the earthquake focus (we will call it as the seismic-magnetic effect). In the former case the focus is a receiver of microwaves, in the latter case the focus is the emitter of microwaves. The purpose of this paper is to unite both as a feasible reason for the earthquake self-excitation, self-triggering.

2. Magneto-Seismicity

Magneto-seismicity is not a myth. There are many observations, which reliably exhibit correlations between magnetic perturbations and seismic response. These correlations are found both in natural magnetic perturbations (magnetic storms, solar activity) and artificial, hand-made exposure of the earthquake focuses to electromagnetic irradiation by discharges of magneto-hydrodynamic generators. Some magneto-seismic effects were summarized earlier [4]; here their more extended collection will be presented.

The response of the seismicity on the magnetic storms in seismically active region of Kazakhstan and Kyrgyzstan was studied by Sobolev *et al.* [5]. The number of earthquakes occurring after storms was shown to increase in some areas and decrease in other ones. The correlations of the two events, magnetic storm and earthquake, based on the observation of these two events during 1973-2010 years, were analyzed by Guglielmi *et al.* [6]. The number of strong earthquakes with $M \geq 5$ was shown to decrease after the storm by more than 30%, *i.e.* the earthquake focuses partially lose their elastic energy; this 30% decreasing means that the magnetic storm prevents each third large magnitude earthquake. Moreover, the distribution of the earthquake frequencies was revealed to be markedly shifted to the lower magnitudes, *i.e.* earthquakes $M \geq 5$ are happened rarer after magnetic storm than before; it is statistically reliable conclusion that the magnetic storm suppresses powerful earthquakes.

The relation between the earthquakes and geomagnetic phenomena was established recently [7] [8]; the authors separated periods of geomagnetic activity into very quiet and extremely disturbed, and then correlated them with seismic activity. Analyzing the NEIC earthquake catalog of the US Geological Survey over a 20-year period, from 1980 to 1999, it was shown that the planetary earthquake activity under quiet geomagnetic conditions is noticeably higher than the activity under disturbed conditions. In particular, the probability of the powerful earthquake with magnitude $M \geq 8$ was shown to be twice higher in magnetically quiet days than that in the magnetically active days [8]. This impressive result is in accordance with idea that geomagnetic activity stimulates release of elastic energy and unambiguously convinces the reliability of the magnetic control of seismicity.

The recently published observations of Chinese-Japanese joint team of authors [9] reliably demonstrate that the geomagnetic storms decrease the number of large (with $M > 7.0$) earthquakes; indeed, by using superposed epoch analysis they have shown that the probabilities of global earthquakes were clearly higher before geomagnetic storms than after them.

The stimulation of energy low focuses was illustrated by Guglielmi *et al.* [10]; by using the widespread indices, the Wolf numbers W, to characterize solar activity the authors have found the certain relationship between earthquakes and solar activity. The global daily magnitudes M_g, calculated over the 20-year period from 1980 to 1999, were correlated with daily W numbers; the pairs $M_g – W$ are shown in **Figure 1**. From the 7300 pairs there were identified two subsets forming the lower and upper sextiles S_n: the lower sextile corresponds to small M_g, the upper one to large M_g. It clearly demonstrates the effect of the Sun on the earthquake activity: solar activity stimulates seismic activity triggering earthquake focuses.

Figure 2 demonstrates the number of the earthquakes as a function of the interplanetary magnetic field. Indices +– and –+ denotes the days when the field changes the sign; this inversion of sign is known to be accompanied by strong magnetic perturbations. The indices ++ and –– denote the days when the sign is permanent. Evidently, the frequency of earthquakes in magnetically disturbed days is by 20% higher than in magnetically quiet days. These examples exhibit magnetic stimulation of the safe earthquakes.

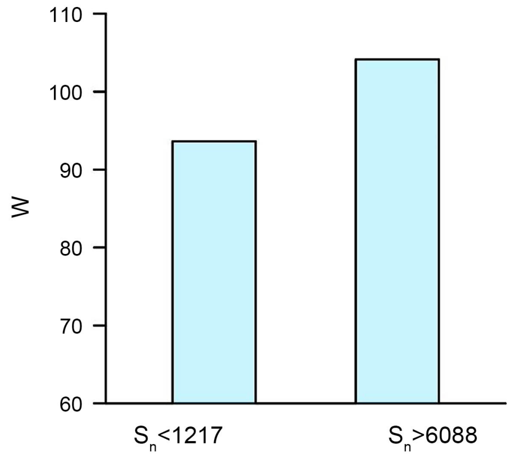

Figure 1. The average daily Wolf numbers *W* with weak and strong seismic activity (left and right columns respectively).

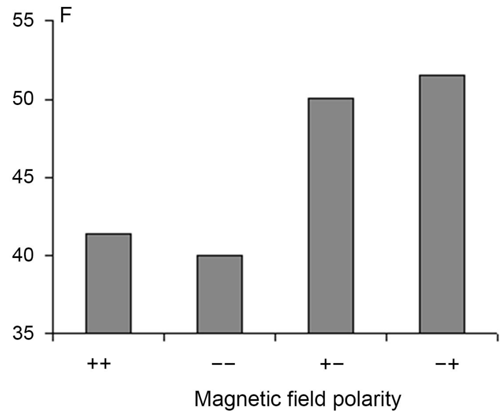

Figure 2. The frequency *F* of the earthquakes (in days^{-1}) in North California as a function of the interplanetary magnetic field polarity. The figure is composed of the data from catalogue of Northern California Earthquake Data Center (NCEDC) by Zotov and Guglielmi.

The hourly distribution of earthquakes in the Caribbean area was revealed to exhibit significant correlation with the distribution of high-frequency geomagnetic variations; the latter were recorded by the GOES13 satellite and by SJG ground magnetic station [11]. The hourly distribution of seismicity has a bay-shape form with a significant increase in the number of earthquakes at night, from 11 PM to 5 AM. This result agrees well with observation [12] that after bursts of electromagnetic radiation, induced by solar plasma, there was statistically significant decrease in the number of earthquakes (**Figure 3**).

The variations of solar activity were also shown by Duma *et al.* [13] to be in correlation with the earthquake activity. Hagen *et al.* [14] have noticed that the period 2003-2010 of extended solar minimum was mostly seismically active in the region of South Atlantic anomaly. However, the authors [15] have found that the solar-terrestrial triggering of earthquakes is insignificant; nevertheless they could not reject the solar-terrestrial triggering itself.

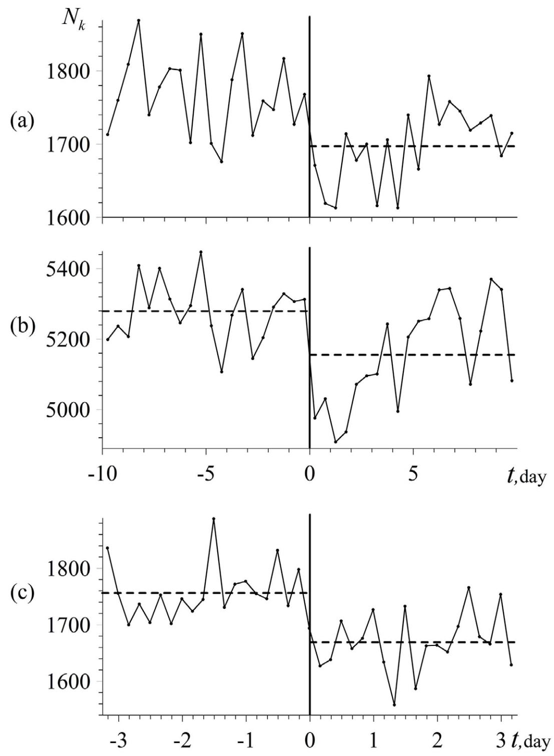

Figure 3. The time variation of the number of the earthquakes with magnitude $M > 4.4$ (a), of the total number of earthquakes (b), and of the total number of earthquakes with high time resolution (c) before ($t \leq 0$) and after ($t > 0$) splashes of solar irradiation.

Urata *et al.* [16] have found that the surges of solar winds, characterized by K_p index, a logarithmic measure of the magnetic field deviation, strongly correlate with the onset of earthquake. This correlation depends on the magnitude of earthquakes: the strong earthquakes of the M8 class are more closely associated with K_p surges than M6 class ones. It is emphasized that the geomagnetic disturbances are the important factors which are synchronized with earthquakes. The strong correlation between solar activity and large earthquakes was analyzed by Marchitelli *et al.* [17]; it was found that the proton density, induced by solar wind near the magnetosphere, strongly correlates with the occurrence of large earthquakes ($M > 5.6$) with a time shift of one day. The authors emphasize that this result opens new perspectives in seismological interpretations, as well as in earthquake forecast.

The relation of the coronal hole driven high speed solar wind streams with seismicity was statistically examined [18]; it was shown that the Sun is a significant agent provoking earthquakes. In particular, it was revealed a surprising result, that the output of the global seismic ($M \geq 6$) energy shows a periodic variation of ~27 days, which is the mean rotational period of the Sun.

Extensive experiments with magneto-hydrodynamic generators for many years [19] [20] [21] [22] have also detected correlation between magnetic and seismic events. For example, by measuring the number of the earthquakes for 30 days before pulses of magneto-hydrodynamic generator (m) and for 30 days after pulses (n) it was shown that $m/n > 1$ (about 1.15 - 1.45) for the large-magnitude earthquakes, but this ratio $m/n < 1$ (about 0.8 - 0.9) for the low-magnitude earthquakes. At first glance, these effects seem to be enigmatic and contradictory but these two effects are not independent, they may be coexisting: firstly, the suppression of the large-magnitude earthquakes means simultaneously its transformation into the small-amplitude earthquakes, and, secondly, the pulses may induce weak earthquakes as it is discussed below. Such synchronism suggests that the magnetic perturbations stimulate release of elastic energy of the earthquake focus by liberation of trapped dislocations [23] [24].

The temporal structure of seismicity of the North Tien Shan (Central Asia) under influence of strong electromagnetic discharges is shown in **Figure 4**: the pulses induce earthquakes; the effect attenuates in time in agreement with magneto-plasticity physics [20].

3. Inconsistencies in Magneto-Seismic Effects

No doubts that the magneto-seismic effects are firmly substantiated; the inconsistencies are revealed only in the sign of the effects—is it positive or negative, do magnetic perturbations induce earthquakes or suppress them. Indeed, the number of earthquakes occurring after magnetic storms was shown to increase in some areas and decrease in other ones [5]; other examples of such inconsistencies are given in the previous Section.

The origin of these apparent inconsistencies proceeds from the fact that magneto-seismic effects are sensitive to the energy class of the earthquake [16]. They depend on the energy status of the earthquake focus: how it is close to or far from the threshold of rheological explosion, how it is overflowing with energy and trapped dislocations which hold this energy. For this reason magnetic control is a double-faced phenomenon: it may devastate focus suppressing earthquakes, but it may provoke them. The possible scenario of the magnetic control is hardly predictable: electromagnetic pulses may activate earthquake focus, if it extremely loaded with energy, but they may devastate and keep it more distant from the threshold of rheological explosion. They may stimulate the "ripening" of the low-energy focus and induce low-magnitude safe earthquakes. These events are the function of the energy state of the focus; it is worthy to keep in mind that magneto-seismic effects summarized in previous Section were attributed to the earthquakes of different energy classes. It is an occasion to emphasize once more, how the precursors are important to characterize energy status of the focus.

4. Magnetically Induced Sliding and Deformation of Crust

Figure 5 clearly demonstrates that the tectonic deformation ε drastically increases after irradiation of the earthquake focus by magneto-hydrodynamic generator; these experiments were carried out in Central Asia regions Garm and

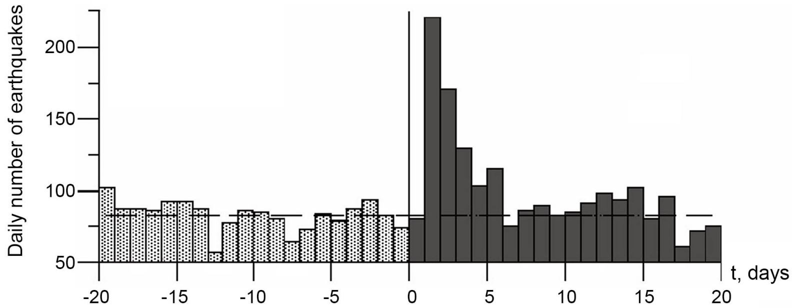

Figure 4. The daily number of the earthquakes before and after of high energy electromagnetic pulses; the moment of pulses refers to $t = 0$.

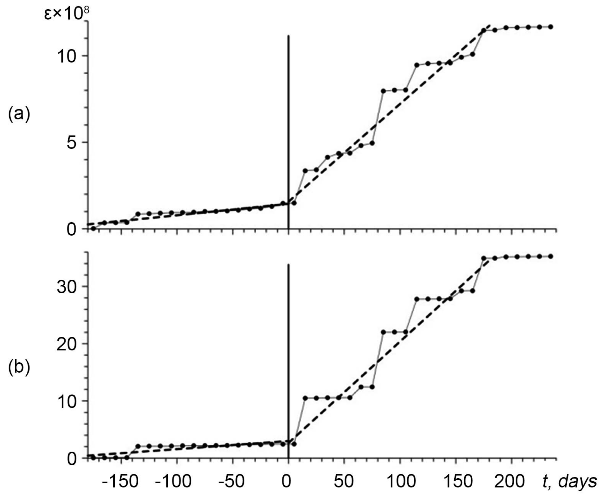

Figure 5. Total tectonic deformations ε (a) and deformations of the upper layer (b) before irradiation by electromagnetic pulses from magneto-hydrodynamic generators ($t < 0$) and after it ($t > 0$). The instant of pulses corresponds to $t = 0$.

Bishkek [20] [25] [26]. The upper curve characterizes the total pool of the earthquakes in the Garm region; the low curve refers to the earthquakes occurring in the upper layer (on the depth 5 km and less). The values on the y-axes are normalized on the volumes of these regions, so that absolute magnitudes of ε are not important; what is indeed important that they unambiguously certify significant deformation of crust, induced by electromagnetic irradiation, in perfect agreement with magneto-plasticity as a means of magnetic control.

The rates of deformation are also increased by 10 - 20 times; thus in Garm the rate of deformation before irradiation was 2.42 (in generally accepted conventional units), while under irradiation the deformation rate was almost 20 times higher. These observations demonstrate slow plastic deformation of the earthquake focus, induced by electromagnetic pulses.

The tectonic deformations induced by electromagnetic discharges were also detected by Chelidze *et al.* [27]; moreover, by using an elegant experimental technique of sliding a sample of rock (granite, basalt, labradorite) placed on the supporting sample, which is inclined at the slope, close to, but less than the critical angle, they modeled natural mechanics of the earthquake. These beautiful experiments have unambiguously proved that electromagnetic pulses modify intermolecular and inter-surface forces, responsible for adhesion and friction, and induce sliding. Electromagnetic initiation of slip is in a perfect accordance with the magneto-plasticity, which implies the motion of dislocations to the interfaces modifying intermolecular forces, changing the friction and stimulating sliding. Extremely important conclusion, derived from these experiments, is that the piezoelectric effect as a suggested principal mechanism of electromagnetically induced slip should be excluded.

Magnetically induced slipping was demonstrated also by Novikov *et al.* [28]; by using almost the same technique they have shown that the sharp slip of a movable sample on the supporting block occurs as the triggering the artificial, laboratory "earthquake" hand-made by electromagnetic pulses.

The correlation between the strong natural magnetic storms and the seismic noise, accompanying these storms and characterized by pulses of displacements with amplitude of ~2 μm and duration of a few minutes [29], is in a perfect agreement with magneto-hydrodynamic results mentioned above. The amplitudes of the pulses are approximately identical at the stations located both in seismically active and quiet regions. The properties of the pulses do not depend on the weather conditions. The pulses are detected in the records from all seismic stations located on the continents. It is hypothesized that the sharp changes in the electromagnetic field during a storm serve as a trigger for the release of energy accumulated in the Earth; the latter seems to induce displacement of rocks as a result of the motion of dislocations.

5. Magneto-Physics of the Earthquakes

Now we will consider why and how captured dislocation functions as a microwaves receiver. The property of microwaves to move dislocations results from the remarkable phenomenon known as the magneto-plasticity. It implies the dependence of the mechanical properties of diamagnetic solids on the magnetic fields. It is worthy to remind that the magneto-plasticity proceeds from the electron transfer between trapped dislocation and trapping ion [4] [24]; it generates spin pair because each partner carries unpaired electron. The pair is in the singlet spin state S because electron transfer does not change spin; magnetic field produces conversion of the spin pair from singlet spin state S into the triplet state T with the rate ΔgβH, where ΔgβH is the difference of Zeeman frequencies of unpaired electrons on the partners of spin pair, g_1 and g_2 are their g-factors. It is remarkable that in both S and T states of the spin pair Coulomb interaction is switched off, Coulomb trap disappears; the trapping ion does not hold dislocation, it is now free and starts movement.

The Earth magnetic field splits triplet state into the three substates T_0, T_+, and T_- which differ by spin projections (0, +1, and −1 respectively). This Zeeman splitting exhibits the most important property of spin pair to serve as a receiver of the microwaves; the latter stimulate conversion of T_0 into T_+ and T_- and populate these states of spin pair. In contrast to the reversible S–T_0 spin conversion the transformation of T_+ and T_- states into S state is strictly spin forbidden, so that the dislocation cannot return into the initial trapped state; now it is free and moves, *i.e.* microwaves accelerate dislocations and increase the path of their runs, providing release of elastic energy. This is a key point where magnetic control of the earthquake is accomplished, where transformation of elastic energy into the energy of plastic deformation occurs.

It is the most important that by taking into account both Zeeman and dipolar inter-electron interactions in spin pairs the transitions T_0–T_+ and T_0–T_- fall in the low frequency region from Hz to kHz [4]. It covers almost continuous band in the range of kHz frequencies; due to their penetrability in rocks these low frequency waves are efficient in the stimulating trapped dislocations. Namely these frequencies seem to be responsible for the magnetic stimulation of dislocations and magnetic control of the earthquakes.

6. Earthquake Focus as a Microwave Generator (Emitter)

The earthquake focus is a giant lithospheric mechanically stimulated chemical reactor, in which preparation of the earthquake starts on the atomic level: dissociation of chemical bonds, both covalent and ionic, generation of dislocations, their motion and coalescence in microscopic cracks accompanied by shear micro-displacements. The opening of crack generates electric discharges between the walls of crack, like between the plates of capacitor. The growing crack was shown by direct measurements to transfer charges from 10^{-7} to 10^{-5} Cu per crack, and the moving crack generates electromagnetic field of power of 10^{-20} - 10^{-17} W [23]. The rheological explosion, which occurs under shear deformation of strongly compressed solids, imitates earthquake; it was shown to generate radio-frequency radiation in the range of 60 - 100 MHz [30]. It is worthy to remind that the cracks created by destruction of crystals, besides of microwaves, generate also luminescence (tribo-luminescence) as well as X- and γ-rays and sometimes even neutrons [31]. By analyzing isolated large-amplitude magnetic pulses, so called Big Magnetic Pulses BMP, and seismic events, accompanying BMP, it was revealed [32] that the number of earthquakes after BMP increases by statistically reliable 6%; these microwave pulses emitted by earthquake focus were suggested to consider as a precursor of the coming and expectative catastrophe [32] [33].

Many observations unambiguously demonstrate that the earthquake focus is an emitter of electromagnetic radiation, which span a broad spectral range from kHz to MHz [1] [2] [3] [34]-[42]. The emission is considered as a highly important and reliable means to elucidate the state of the focus and sometimes even to foresee the coming catastrophe. However, it can also perform another function as shown in the next Section.

7. Self-Excitation of the Earthquake: How It Occurs?

Why the energy, accumulated in the focus, does not store there eternally or, at least, does not slowly dissipate, why it is emitted by earthquake almost instantly like explosion? Certainly, there is a factor, which induces self-excitation of the focus; there is a trigger which switches on explosive emission of the accumulated energy. It is highly probable that the triggering is accomplished by microwaves. Generated by cracks they accelerate the motion of dislocations; the latter coalescence in cracks. The more intensive is the crack formation, the higher is the intensity of microwaves, which stimulate dislocations and intensify crack formation: it is a breeding process maintaining feedback. Shortly: microwaves move dislocations and stimulate their coalescence into the cracks; the latter emit microwaves moving dislocations. It is like an avalanche, like a race of cracks with dislocations urged by microwaves. Finally, this race results to the self-excitation of the earthquake.

8. Conclusion

Microwave pumping is a solid proof of the magneto-plasticity as a means to affect earthquake focus; namely these microwaves are responsible for the magneto-seismic effects detected by natural observations and stimulated artificially. Microwaves transform elastic energy of diamagnetic solids into the energy of plastic deformation by controlling mobility of dislocations via magnetic interactions in the electron spin pairs on the trapped dislocations, in which Coulomb interaction is switched off. It is conceivable to use magnetic control of dislocations in the earthquake focus to avoid catastrophic earthquakes, transforming them into the weak, small-magnitude ones; it is practically illustrated by influence of discharges of magneto-hydrodynamic generators on the earthquakes. Magnetic control is shown to be double-faced phenomenon: it may devastate high-energy focus, but it may stimulate, provoke low-magnitude earthquakes, inducing their self-excitation. It is worthy also to note that the magneto-seismic effects are a means to elucidate, to deeper understand intriguing physics of the earthquakes.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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