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Earthquake under Control: Is It Feasible?

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Abstract

The ultimate and noble goal of seismology as a science is to find reliable means to predict the place, time and magnitude of expected earthquake. There are significant achievements on the way to this goal: there is a fairly clear understanding chemical physics and mechanics of the earthquake, there are reliable indicators and precursors of the approaching seismic events. However, this understanding remains to be purely intellectual achievement; it looks like highly desirable but hardly attainable purpose. Earthquake prediction is unattainable like absolute zero temperature: you may approach it, but never reach. As an alternation there is reliable evidence that microwave induced release of energy, accumulated in the earthquake focus, may be implemented by hand-made means (such as magneto-hydrodynamic generators). Magnetic control of the earthquake focus by microwave exposure is a unique means to decrease magnitude of the earthquake and transform catastrophic event in the less dangerous one. However, positive experience of reducing the magnitude of earthquake is rather limited and hardly may be implemented in practice; evidently, earthquake control is unfeasible project.

Keywords

Earthquakes, Dislocations, Microwaves, Forecasting, Prediction

1. Introduction

As it was pointed out by Goda *et al.* [1] “mega quakes pose major threats to modern society, generating casualties and fatalities, disrupting socioeconomic activities, and causing enormous economic loss across the world” (this statement ignores the human-induced wars, which are even more terrible). Uyeda in his famous paper [2] (its preliminary version was published on March 10, 2011, a day before the 11 March super-giant Tohoku earthquake) has noted that the

"Japan's national project for earthquake prediction has been conducted since 1965 without success" (it is worth noting that this statement is universal and concerns world seismology). On his opinion the main reason of no success is the failure to capture precursors. However, even if the precursors are certainly and successfully detected, it is impossible to prevent earthquake as an inevitable seismic event, frequently catastrophic, its magnitude may be controlled by decreasing energy, accumulated in the earthquake focus. The aim of this paper is to integrate numerous observations, which unequivocally certify that the only reliable means to artificially influence on the energy state of the earthquake focus are microwaves. This statement is based on the remarkable phenomenon, known in solid state physics as the magneto-plasticity, *i.e.* the dependence of the mechanical properties of *diamagnetic* solids on the *magnetic* fields.

The long history of seismology, since Rudolf Wolf (1816-1893), is full of intriguing observations, irrefutably exhibiting the relation between magnetic and seismic events. Extensive and highly convincing studies of magneto-seismicity, *i.e.* the relationship between microwaves and seismicity, have been carried out by Hayakawa [3]-[8] and many other authors [9] [10] [11] [12] [13]. These observations certify two facets of magneto-seismicity: they identify earthquake focus firstly, as a microwave generator, as an emitter and, secondly, as a microwave receiver. The purpose of this paper is to accentuate and illustrate these facets.

2. Earthquake Focus as a Generator of Micro- and Radio-Waves

The earthquake focus is a giant lithospheric mechano-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. It is a key paradigm irrefutably formulated by Sornette [14]: "it is not possible to get a reasonable description of an EQ if one forgets about the chemical processes occurring at the smallest scale". The preparation of an EQ and its triggering proceeds on the atomic level and, therefore, in order to control EQ it is reasonable to rely on the atomic scale.

The energy in the EQ focus is created by anisotropic deformation induced by tectonic motion and stress; it is accumulated and stored mostly in the dislocations trapped by impurities in crystal lattice, by neighboring dislocations or crystal interfaces. This energy is finally transformed in cracks; their opening can generate electric discharges between the edges 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 [15]; it means that the earthquake focus is indeed electromagnetic emitter.

The well-known phenomenon of rheological explosion, which occurs under shear deformation of strongly compressed solids and which seems to imitate earthquake, was shown to generate radio-frequency radiation in the range of 60 - 100 MHz [16]. The direct observation of electromagnetic emission, induced by micro fracturing, was performed by Molchanov *et al.* [17]. It is worthy to remind that the cracks created by destruction of crystals, besides of electromagnetic emission, generate also luminescence (tribo-luminescence) as well as X- and γ-rays and even neutrons [18]. Possibly, the generation of these cracks induces infrasound and micro-trembling of ground, which is the reason of anomalous animal behavior and which is considered to be one of the forecasting factors of approaching earthquake.

3. Electromagnetic Signals as the Earthquake Precursors

Numerous observations unambiguously demonstrate that the earthquake focus is an emitter of electromagnetic radiation, which spans a broad spectral range from kHz to MHz. The microwave pulses emitted by focus are suggested to consider as an indication of the "ripening" earthquake focus, as a precursor of the coming and expectative catastrophe, as a means to forecast EQ [19] [20]. Low-frequency electromagnetic signals observed before strong earthquakes were described by Rokityansky *et al.* [21] [22], in particular, before the 2011 Tohoku earthquake.

The summarizing collection of electromagnetic fields generated by earthquakes was presented by Johnston [23]; similarly, the records of electromagnetic emission from the powerful Asian earthquakes are summarized by Li *et al.* [24]. The precursory signature effects of the Kobe earthquakes were revealed by Hayakawa *et al.* [25] [26] [27] [28]; similar signature effects of the Guam and Izu earthquakes were detected and described [29] [30] Anomalous radio propagation before and after the 2011 Tohoku earthquake demonstrated strong iono-spheric disturbances triggered by the earthquake appearing in the oblique ionogram; they show very clear signature of the wave-shape-trace. An oblique ionogram was observed at 04:45 UTC on 11 March 2011 one hour before the 2011 Tohoku earthquake. This slopy-shape-trace is considered as the pre-seismic iono-spheric precursor [31]. Electromagnetic effects induced by seismic events are discussed by Sorokin and Hayakawa [14].

All these observations unambiguously evidence that the electromagnetic emission accompanying mechanical evolution of the EQ focus is the forecasting factor. Moreover, it is predicted to be the most reliable and universal means to foresee EQ [32]. The authors assert that the electromagnetic radiation frequency analysis gives the possibility to simultaneously determine all necessary three characteristic parameters (magnitude, epicenter, time of occurring) for incoming earthquake prediction with great precision.

4. Magnetically Controlled Seismicity

The functioning of the earthquake focus as an electromagnetic generator and emitter provides a means to forecast earthquake; now we will discuss even more important function of the earthquake focus to be the receiver. It certifies the relation between electromagnetic action and seismic response, *i.e.* magnetically controlled seismicity. Magneto-seismicity is not a myth. There are many observations, which reliably exhibit correlations between magnetic perturbations (magnetic storms, solar activity and other magnetic perturbations) and seismic response.

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.* [33]. The number of strong earthquakes with M ≥ 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 ≥ 5 are happened rarer after magnetic storm than before; it is statistically reliable conclusion that the magnetic storm suppresses powerful earthquakes. **Figure 1** shows how the frequency of the large earthquakes (M ≥ 5) decreases after magnetic storms.

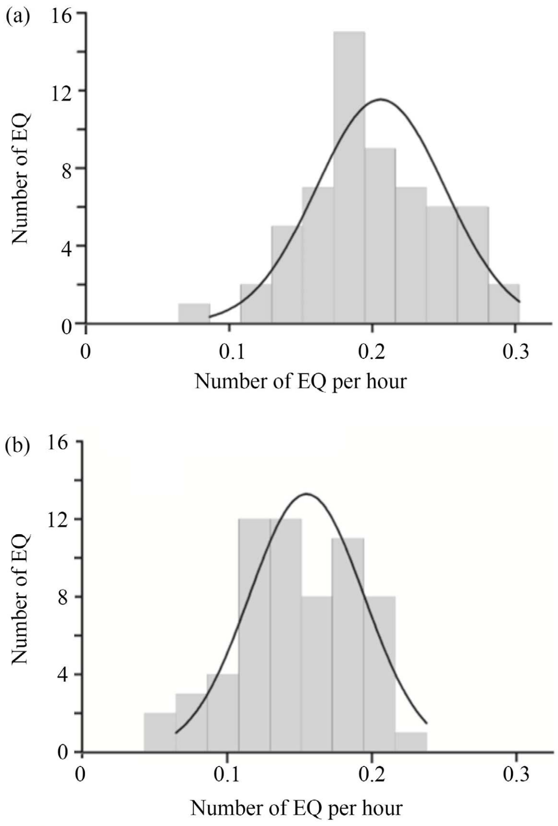


Figure 1. The distribution of the frequency earthquake appearance (number of the earthquakes in 60 min interval) before magnetic storm (a) and after it (b). Smooth curves approximate normal distribution; it is evident that the distribution of frequencies is markedly shifted to the lower magnitudes [33].

The relation between the earthquakes and geomagnetic phenomena was confirmed recently [34] [35]; the authors separated periods of geomagnetic activity into very quiet and extremely disturbed, and then correlated them with seismic activity. By 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 activity of earthquakes under quiet geomagnetic conditions is noticeably higher than the activity under disturbed conditions. In particular, the probability of the powerful earthquakes with magnitude $M \geq 8$ was shown to be twice higher in magnetically quiet days than that in the magnetically active days. 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.

By analyzing isolated large-amplitude magnetic pulses, so called Big Magnetic Pulses BMP, and seismic events, accompanying BMP, it was revealed that the number of earthquakes after BMP increases by statistically reliable 6%; the duration of this seismic after-effect is about 1 - 2 hours [20]. The recently published observations of Chinese-Japanese joint team of authors [36] 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 response of the seismicity on the magnetic storms in seismically active region of Kazakhstan and Kyrgyzstan was studied by Sobolev *et al.* [37]. The number of earthquakes occurring after storms was shown to increase in some areas and decrease in other ones. The correlation was found 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 [38]. 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.

The stimulation of energy low focuses was illustrated by Guglielmi *et al.* [39]; 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 2**. 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.

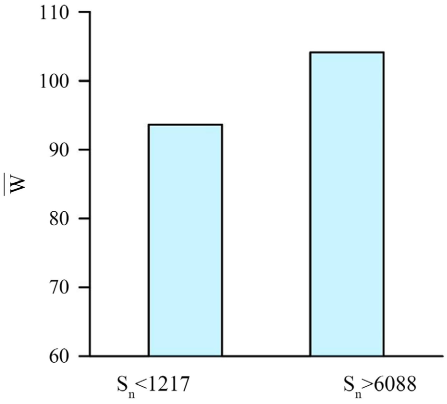


Figure 2. The average daily Wolf numbers W with weak and strong seismic activity (left and right columns respectively) [39].

Figure 3 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.

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 [40]. 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. The authors consider these results as evidence that high-frequency magnetic disturbances can be considered as a trigger mechanism of earthquakes.

These results agree well with observation [41] that after bursts of electromagnetic radiation, induced by solar plasma, there was statistically significant decrease in the number of earthquakes (**Figure 4**).

The geomagnetic and ionospheric effects of seismic activity were investigated during 1954 Sun spotless days (SSL) from 1995 to 2020 (676 events) by Gulyaeva [42]. The seismic activity was shown to have a tendency to increase towards the solar minimum when SSLs occur; it provides evidence that the effects of seismic activity experience decline of intensity at the time of EQ under SSL. The variations of solar activity were also shown by Duma *et al.* [43] to be in correlation with the earthquake activity. Hagen *et al.* [44] have noticed that the period 2003-2010 of extended solar minimum was mostly seismically active in the region of South Atlantic anomaly. Urata *et al.* [45] 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.

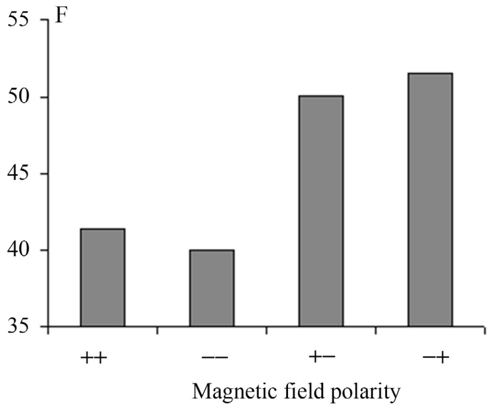


Figure 3. The frequency F of the earthquakes (in days^{-1}) in North California as a function of the interplanetary magnetic field polarity. The figure is composed of the data from catalogue of Northern California Earthquake Data Center (NCEDC) by Zotov and Guglielmi.

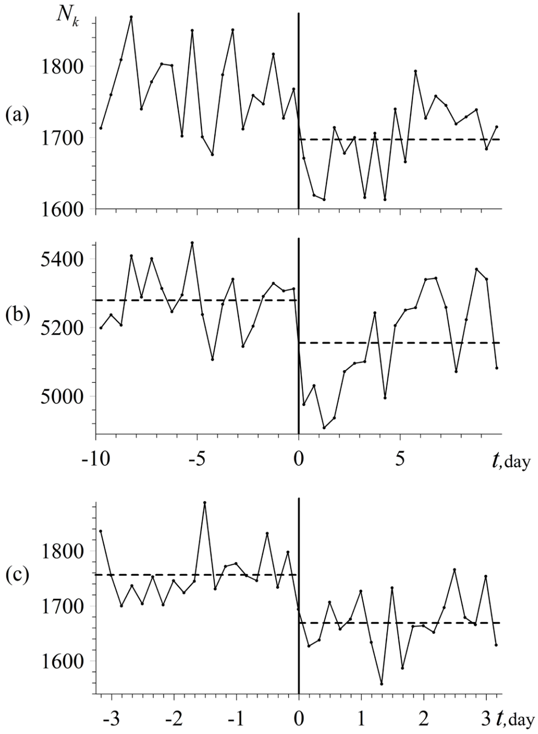


Figure 4. The time variation of the number of the earthquakes with magnitude $M > 4.4$ (a), of the total number of earthquakes (b), and of the total number of earthquakes with high time resolution (c) before ($t \leq 0$) and after ($t > 0$) splashes of solar radiation [41].

The strong correlation between solar activity and large earthquakes was analyzed by Marchitelli *et al.* [46]; 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 [47]; 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 ≥ 6) energy shows a periodic variation of ~27 days, which is the mean rotational period of the Sun.

Finally, one may conclude, that the natural magnetic perturbations (magnetic storms, solar winds) accelerate transport of dislocation, inducing transformation of elastic energy into the safe plastic deformation of crust in EQ focus. Later we will show that the similar effects may be induced artificially, by hand-made means.

5. Chemical Physics of Magneto-Seismicity

Mechanical properties of diamagnetic crystals (hardness, deformation, plasticity) are known in solid state physics to depend on the magnetic field. This phenomenon, called magneto-plasticity, seems to be enigmatic because crystals exhibiting this phenomenon have no magnetic components. Its physics was elucidated by idea of the two-spin, magnetically sensitive electron pair in captured, trapped dislocation [15] [48] [49] [50].

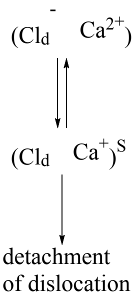
The idea is illustrated by **Scheme 1** for the particular case of dislocation trapped by Ca^{2+} ion in the NaCl crystal.

The scheme implies energy allowed electron transfer between partners (dislocation is presented by its anionic element Cl^- ion; index d points out that the ion belongs to dislocation). It generates spin pair: each partner carries unpaired electron. It is in the singlet spin state S because electron transfer does not change spin; the back electron transfer is spin allowed, so that the initial trapped dislocation may be restored. It is remarkable that in the spin pair Coulomb interaction is switched off, Coulomb trap disappears; the stopper does not hold dislocation, it is now free and starts new motion.

It is a first step to the magneto-plasticity. Magnetic field produces conversion of the spin pair from singlet spin state S into the triplet state T_0; it occurs as the spin dephasing by precession of individual spins as shown in **Figure 5**.

The arrangement of electron spins S_1 and S_2 in singlet and triplet states is presented in **Figure 6**.

Magnetic field executes two functions: first, it produces reversible S-T_0 conversion with the rate $\Delta g\beta H$, as shown in **Figure 5** and, second, it splits triplet state into the three states T_0, T_+ and T_-; these states differ by spin projections: 0, +1 and −1 respectively, as shown in **Figure 7**. Both functions are illustrated by **Scheme 2** and **Figure 7**.



Scheme 1. Electron transfer in the system dislocation-stopper.

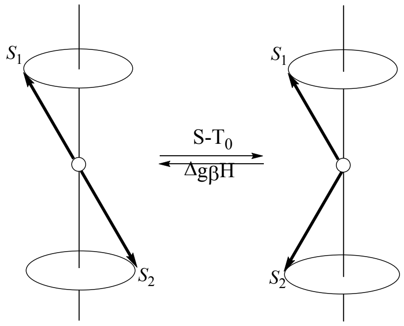


Figure 5. Spins S_1 and S_2 are located on the partners of the spin pair. They oscillate (precess) with Zeeman frequencies $g_1\beta H$ and $g_2\beta H$ respectively, where g_1 and g_2 are g-factors of partners. The rate of S-T_0 spin conversion is the difference of these Zeeman frequencies $\Delta g\beta H$, where $\Delta g = g_1 - g_2$ [48].

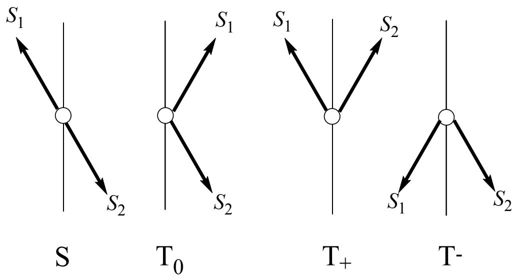


Figure 6. Schematical presentation of the electron spins S_1 and S_2 in singlet and triplet states [48].

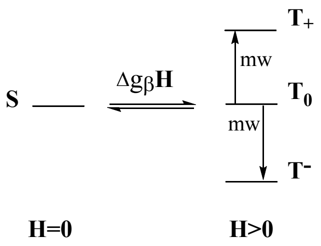
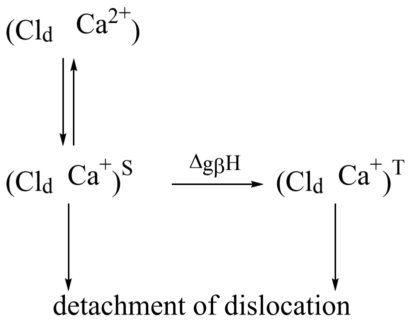


Figure 7. The scheme of Zeeman levels in zero (H = 0) and high (H > 0) magnetic field. Microwave irradiation mw induces transitions from T_0 into T_+ and T_- states [49].



Scheme 2. Magnetic field converts singlet state S into the triplet state T.

The second step to the magneto-plasticity and magnetic control of EQ is accomplished by microwaves. They convert T_0 into T_+ and T_- and populate these states of spin pair. It is extremely important to note that 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, it is doomed to leave these long living T_+ and T_- states of spin pair. This is a key point, where magnetic control of the EQ is implemented, where transformation of elastic energy into the energy of plastic deformation occurs.

The strict spin physics of the trapped dislocation was developed with taking into account of dipolar inter-electron interaction in the spin pair [51]. It is shown that the transitions T_0-T_+ and T_0-T_- fall in the low frequency region, which covers almost continuous band in the range of kHz frequencies; due to their penetrability in crust these low frequency waves are efficient in the stimulating trapped dislocations. Thus, magnetic fields, both permanent and electromagnetic, accelerate and catalyze the motion of dislocations and this magnetic catalysis creates magneto-plasticity as a physical phenomenon. Namely these kHz frequencies are responsible for the magnetic acceleration of dislocations and magnetic control of the earthquakes.

6. Earthquake Control by Human-Made Means

Now we will discuss, is it possible to influence on the earthquakes by human-made means; as an example we will consider artificial exposure of the earthquake focus to electromagnetic irradiation by discharges of magneto-hydrodynamic generator. Figure 8 demonstrates behavior of tectonic deformation ε under irradiation of the earthquake focus by magneto-hydrodynamic generator; these experiments were carried out in Central Asia regions Garm and Bishkek [52] [53]. 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

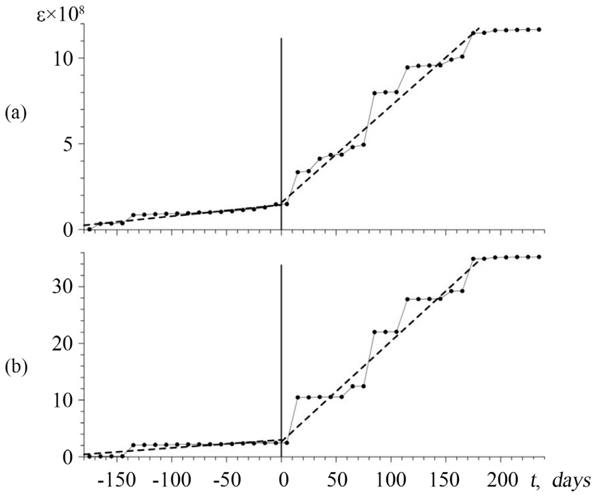


Figure 8. Total tectonic deformations ε (a) and deformations of the upper layer (b) before irradiation by electromagnetic pulses from magneto-hydrodynamic generators ($t < 0$) and after it ($t > 0$). The instant of pulses corresponds to $t = 0$ [53].

by electromagnetic irradiation, in perfect agreement with magneto-plasticity as a means of magnetic control.

Figure 8 clearly demonstrates that the tectonic deformation ε drastically increases after irradiation of the focus by magneto-hydrodynamic generator. The rates of deformation were also increased by 10 - 20 times; thus, in Garm the deformation rate before irradiation was 2.42 (in generally accepted conventional units), while under irradiation the deformation rate (38.8) was almost 20 times higher. These observations unambiguously demonstrate slow plastic deformation of the EQ focus induced by electromagnetic pulses.

The tectonic deformations induced by electromagnetic discharges were also detected by Chelidze *et al.* [54] [55]; moreover, by using an elegant experimental technique of sliding a sample of rock placed on the supporting sample, 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, 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.* [56] [57]; 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. Extensive experiments with magneto-hydrodynamic generators for many years have also detected correlation between magnetic and seismic events [53] [58]. For example, by measuring the number of EQ 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 EQ, but this ratio $m/n < 1$ (about 0.8 - 0.9) for the low-magnitude EQ. At first glance, these effects seem to be enigmatic and contradictory. But these two effects are not independent: the suppression of a large-magnitude EQ means simultaneously its transformation into a small-amplitude EQ. The increasing the number of weak earthquakes is a direct consequence of decreasing the number of the powerful earthquakes. Such a synchronism suggests that magnetic perturbations stimulate release of elastic energy of the earthquake focus by stimulation of trapped dislocations [59].

The temporal structure of seismicity of the North Tien Shan (Central Asia) under influence of strong electromagnetic discharges is shown in **Figure 9**: the pulses induce earthquakes; the effect attenuates in time in agreement with magneto-plasticity physics [52] [60].

It is evident, that the magneto-seismic effects produced by human-made means (magneto-hydrodynamic generator) and stimulated by natural means (magnetic storms, solar wind) are expectantly identical.

7. Earthquake Prediction

Many books have been written about the ultimate goal of seismology to find means to predict expected earthquake (see, for example, the most informative books [4] [61] [62] [63] [64] and papers [65]-[70]). There are significant achievements on the way to this goal: there is a fairly clear understanding of the chemical physics and mechanics of the EQ and its time evolution, there is convincing evidence of the existence of indicators and precursors of the expected seismic events. Moreover, there is reliable evidence that magnetic control of the earthquake focus may be implemented by microwave exposure of the earthquake focus by hand-made means (such as magneto-hydrodynamic generator).

However, this understanding remains a purely intellectual achievement, because there are very little hopes to realize this knowledge in practical activity. It

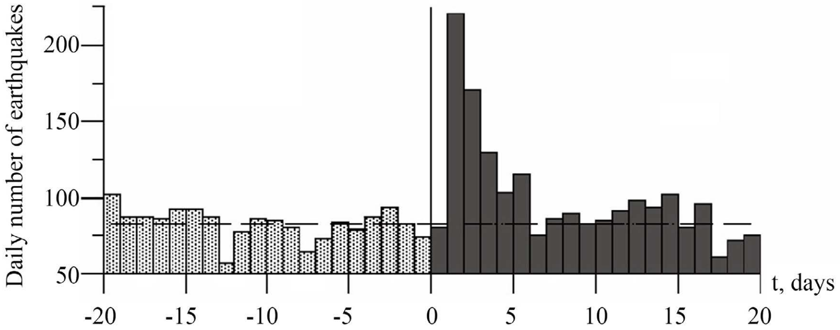


Figure 9. The daily number of the earthquakes before and after of high energy electromagnetic pulses; the moment of pulses refers to $t = 0$ [60].

looks like highly desirable but hardly attainable purpose. Earthquake prediction is unattainable like absolute zero temperature: you can approach it, but never reach. Earthquake can be forecast, but it is impossible to predict it, just as it is impossible to guess the explosion of the 2:1 mixture of hydrogen and oxygen, despite the fact that in this mixture all chemical reactions and their rates are known with high accuracy. The critical analysis of the earthquake prediction problem, given by Geller [71], remains to be fair and up-to-date. Of course, there is a positive experience of reducing the magnitude of earthquake using magneto-hydrodynamic generators, but it is rather limited and hardly may be implemented in practice.

8. Conclusion

Magnetic control of the earthquake focus by microwave exposure is a unique but rather limited means to decrease magnitude of the earthquake; it hardly may be practically realized. The answer to the question, standing in the title, is positive in principle, but is not feasible in practice. Despite the impressive progress of tectonic physics, it is hardly possible to locate accurately enough the focus of the upcoming, expected earthquake to kill it by irradiation of magneto-hydrodynamic generators; it seems to be unfeasible project. The author is perfectly aware that in contrast to the intriguing and promising title of the paper this conclusion is disappointing and even discouraging. It agrees well with general modern tendency in seismology to focus efforts on the search and monitoring the reliable forecasting factors of expected earthquake; it seems to be the most promising way in modern seismology.

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Conflicts of Interest

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

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