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Earthquake as a Coherent Electromagnetic Emitter. Its Electromagnetic Voice May or May Not Sound

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Abstract

The idea of the earthquake (EQ) focus as a coherent electromagnetic (EM) emitter is suggested. This idea elucidates enigmatic properties of the EM voice of the focus: its emission is not continuous, occurring periodically in flashes, which are structured as the pulses occurring in bursts; the EM activity increases starting approximately two weeks before the EQ and becomes very weak or completely disappears one day before the EQ (gap of silence). The mechanism of coherency starts with electric discharges of any mini-cracks as a mini-capacitor, which generates EM waves; the latter induces discharges of other cracks, multiplying the amplitude of the wave and creating the pulse of seismic EM signal. It is an avalanche-like mechanism of coherency, which transforms even weak EM signals into intensive EM seismic flashes.

Keywords

Earthquake, Electromagnetic Signal, Mini-Cracks, Discharges, Coherency, Seismic Flashes, Gap of Silence

1. Introduction

In modern seismology, it is irrefutably established that the seismic and electromagnetic (EM) phenomena accompany each other. Extensive and highly convincing studies of EM-seismicity may be found in many previous publications [1]-[12]. The relation between magnetic and seismic events certifies two facets of magneto-seismicity: firstly, these events identify earthquake (EQ) focus as a micro-

wave generator, an emitter of seismic electromagnetic signals (SEMs) and, secondly, as a microwave receiver, as a giant mechanically stimulated chemical macroreactor under the magnetic control [13]-[17]. The first seems to be the most important because it supplies a means to monitor, at least approximately, the state of the EQ focus in order to forecast seismic events; so the analysis of SEMs is the subject of this paper.

2. EQ Focus as a Generator of EM Signals

The energy in the EQ focus is known to be created by anisotropic deformation of the earth crust induced by tectonic motion and stress [18]; it is accumulated and stored mostly in the dislocations trapped by impurities in crystal lattice, by neighboring dislocations or crystal interfaces. The dislocations are finally transformed into the mini-cracks; this transformation is magnetically sensitive, and it is a key of magneto-seismology [13]. It is based on physics of magneto-plasticity, the remarkable phenomenon, which implies generation of the electron spin pairs on the trapped dislocations, in which the Coulomb interaction is switched off. Microwave irradiation at Zeeman frequencies in these pairs stimulates the motion of dislocations, inducing release of elastic energy into the safe plastic deformation. The detailed mechanism of this phenomenon is discussed and experimental proofs are given in terms of magneto-plasticity as a feasible means to control EQs [14].

In the deformable environment the born mini-cracks become the charged mini-capacitors; their electric discharges generate EM noise. The growing crack was shown by direct measurements to transfer charges from 10^{-7} to 10^{-5} C per crack, and each crack generates EM field of power of 10^{-20} – 10^{-17} W [19]; it means that the EQ focus is indeed an EM emitter.

There is no doubt that the EM emission from the EQ focus is the result of the discharge between the plates of micro-cracks as the micro-capacitors. The EM radiation emitted by EQ focus was reproduced experimentally by fracturing many solids, minerals and rocks in numerous researches (see, for instance, review papers [20]-[22]). The mechanical properties, mineral composition, cracking morphology of the solids were shown to have crucial influences on the waveform, amplitude and frequency of the EM signals during fracturing. These EM signals induced by fracturing, are supposed to imitate EM signals of the EQ focus. These observations certify also that the discharge of cracks is the dominating source of SEMs.

3. EQ Focus Emits EM Signals

Numerous observations unambiguously demonstrate that the EQ focus is an emitter of EM radiation, which span a broad spectral range from Hz to MHz. The EM signals emitted by the focus are suggested to consider as an indication of the "ripening" of the focus, as a precursor of the coming and expectative catastrophe, and possibly as a means to forecast an EQ. The characteristic features of the EM signals are discussed in many papers; here some illustrations will be given.

By measuring low frequency magnetic noise prior to the M_S 7.1 Loma Prieta EQ of 17 October 1989 the authors [23] revealed a substantial increase in the EM signals in the range 0.01 - 10 Hz starting two weeks before the EQ, which was accompanied by anomalous decreasing intensity starting one day ahead of the EQ. Finally, there was an increase in intensity up to an exceptionally high level of activity starting about three hours before the EQ. Low-frequency EM signals before strong EQs with almost similar features were detected and described by other authors for different EQ case studies [24]-[27].

The large collection of EM fields generated by EQs was presented by Johnston [28]. Similarly, the records of EM emission from the powerful Asian EQs were summarized by Li *et al.* [29]; the precursory EM signature of the Kobe EQ was also analyzed [30]-[33]. Similar signature effects of the Guam and Izu EQs were detected and described in [34] [35].

By analyzing seismic events in California and Peru 2007-2010 Dunson *et al.* [36] discovered the increases in ultra-low frequency magnetic pulse activity starting two weeks before the seismic events and disappearing after the event. The EM signals preceding seismic events were shown to be structured as large amplitude pulses, which occur in bursts lasting many hours.

4. EQ Focus as a Coherent Generator of SEMs

In the dynamics of the EM signals emitted from an EQ focus, the two typical, almost universal features are revealed: firstly, the EM activity increases starting approximately two weeks before the EQ, and, secondly, it becomes very weak or completely disappears one day before the EQ (we call it "gap of silence") [23] [36]-[40]; below there will be suggested ideas to elucidate these features.

4.1. Coherent EM Emission

As shown in Section 2, the EM emission from the EQ focus is the result of the discharges of mini-cracks as the mini-capacitors, which are created continuously in the EQ focus, but the EM emission of the focus is not continuous in such a way that it occurs periodically in flashes, which are structured as the pulses occurring in bursts. This mysterious circumstance suggests the idea that EM radiation is indeed stimulated, it is coherent, and the focus may be considered as a coherent EM generator. The mechanism of coherence may be presented as follows. The electric discharge of any crack generates EM wave, which propagates in space and induces discharges of other cracks, multiplying the amplitude of the wave and creating the pulse of seismic EM signal. This mechanism creates the impulse of SEMs in terms of this avalanche-like mechanism because the EQ focus functions as a coherent EM amplifier. Rigorously, this is not quantum coherence; it is classical, electromagnetically stimulated coherence.

Evidently, the collection of mini-cracks as the mini-capacitors, is widely distributed over the sizes, distances between plates, chemical composition and charges on the plates. These broad distributions generate a superposition of coherent EM fre-

quencies, which is detected as the EM emission of the approaching EQ.

4.2. Gap of Silence

The idea of the coherent EQ focus explains the impulsive EM emission, but does not explain another enigmatic phenomenon – the gap of silence before the EQ itself. The leakage of trapped dislocations into the mini-cracks is accompanied by the discharge of mini-cracks and their integration, which is assumed to initiate rock sliding as the start of the quake itself. Moreover, the EM radiation generated by the discharge of mini-cracks, is supposed to stimulate the self-excitation of the EQ [16]. Perhaps, it is this period of sliding that is the period of silence of the EQ focus before the quake.

This conclusion is in perfect accordance with recent findings by Bletery and Nocquet [41]. These authors have measured and analyzed 3026 high-rate GPS time series displacements before 90 EQs of magnitude ≥ 7. They observed a signal that rose from the noise about 2 hours with exponential acceleration of slip before the moment of the EQ. Evidently, the time interval of slipping detected by GPS almost exactly coincides with the gap of silence in the EM voice of the EQ focus.

5. EM Voice of the EQ Focus

EM signals emitted by the EQ focus are indeed its voice; it may sound or may be silent. The generation of EM emission is created by mini-cracks. Their quantity and density as well as their sizes and lifetimes depend on the chemical nature and mechanical properties (hardness, elasticity, compressibility) of the rock. The electric charges on the plates of mini-cracks are mostly determined by the chemical nature of the rock. As a result of these factors, the intensity and frequency of EM emission depend on the density of mini-cracks, their sizes and the chemical composition. The combination of these factors can create conditions, when the EQ focus reveals itself either as a strong or weak emitter, or be silent. This is the reason for many contradictions in seismic electromagnetism.

There are many observations when EM emission did not precede an EQ, *i.e.* the EM voice of the EQ was silent. It means that the EM emission is not an unambiguous indicator of the upcoming EQ and that the statement about the reliability of EM emissions as a forecasting factor of EQ is overly optimistic and far from being reliable. As pointed out by Chen *et al.* [15], despite the fact that a number of statistical tests show that EM anomalies may contain predictive information for major EQs, with probability gains of approximately 2 - 6, it is still difficult to make use of SEMs efficiently in practical EQ prediction.

6. Conclusion

The detection of SEMs is an indicator of coherent unification of seismic magnetic noises, which are the most likely to be produced by mini-cracks as the charged mini-capacitors. This may be considered as evidence that the dominant mechanism for generating SEMs is the cracking of the earth crust in the EQ focus in-

duced by its shear deformation. Different lithological rocks generate different EM signals due to different geometry of cracks with different distances between the plates in cracks as the capacitors. This is the reason that the EM voice of the EQ may or may not sound. It means that the EM emission is not an unambiguous indicator of the upcoming EQ and that the statement about the reliability of EM emissions as a forecasting factor of EQ is too optimistic. In any case, these signals should be treated with critical caution.

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Conflicts of Interest

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

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