

Electromagnetic “seismic calm” effect in the Baikal rift zone

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Abstract

The paper presents the results of long-term observations of the parameters of the natural impulse electromagnetic field of the Earth (NIEMFE) in the VLF range in the Baikal rift zone. The electromagnetic “seismic calm” effect has been observed, and possible reasons of changes in daily variations of magnetic components on the day before an earthquake have been analyzed.

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1. Introduction

The problem of excitation and propagation of seismo-genic electromagnetic emissions is topical in connection with the development of short-term electromagnetic methods for the forecast of earthquakes (Hayakawa and Molchanov, 2002). At present there is no doubt that abnormal electromagnetic radiations appear in a wide range of frequencies before a majority of earthquakes. The overwhelming majority of publications on seismo-electromagnetic phenomena are based on the abnormal increase in intensity of the electromagnetic signal before the earthquake (Bella et al., 1992; Rulenko et al., 1996; Migunov et al., 1991). The article by Verbin et al. (2002) is an analysis of results for a search of short-term precursors of earthquakes as based on abnormal variations of VLF phase of radiowaves ($f = 11.9$ kHz) on Novosibirsk–Komsomolsk-on-Amur path, crossing the East Transbaikalia seismoactive region (Baikal rift zone). Verbin et al. (2002) come to the conclusion that the VLF range is appar-

ently unsuited for observations of the short-term electromagnetic precursors of earthquakes in anthropogenous (technogenous) fields. Verbin et al. believe that the electromagnetic precursors of earthquakes undoubtedly exist, but all their manifestations most likely are not connected in any way to the ionosphere. They are formed by the electric charges collecting in the troposphere before a seismic impact. The increased radiation level on the ground layer resulting from radon emanations modifies, first of all, the high-altitude distribution of a parameter of refraction of air within the troposphere. Meanwhile in a parameter of refraction there is a small component of conductivity (dielectric permeability becomes complex). For the observation of this phenomenon Verbin et al. (2002) suggest the use of the radio engineering systems, enabling them to outline terrestrial wave against the background of multiplicative noise – wave reflected from the ionosphere.

2. Seismicity of the Baikal rift zone

In this paper the same area as in the work by Verbin et al. (2002), the Baikal rift zone is considered. The rift zone is characterized by regular seismic activity. The regular tool

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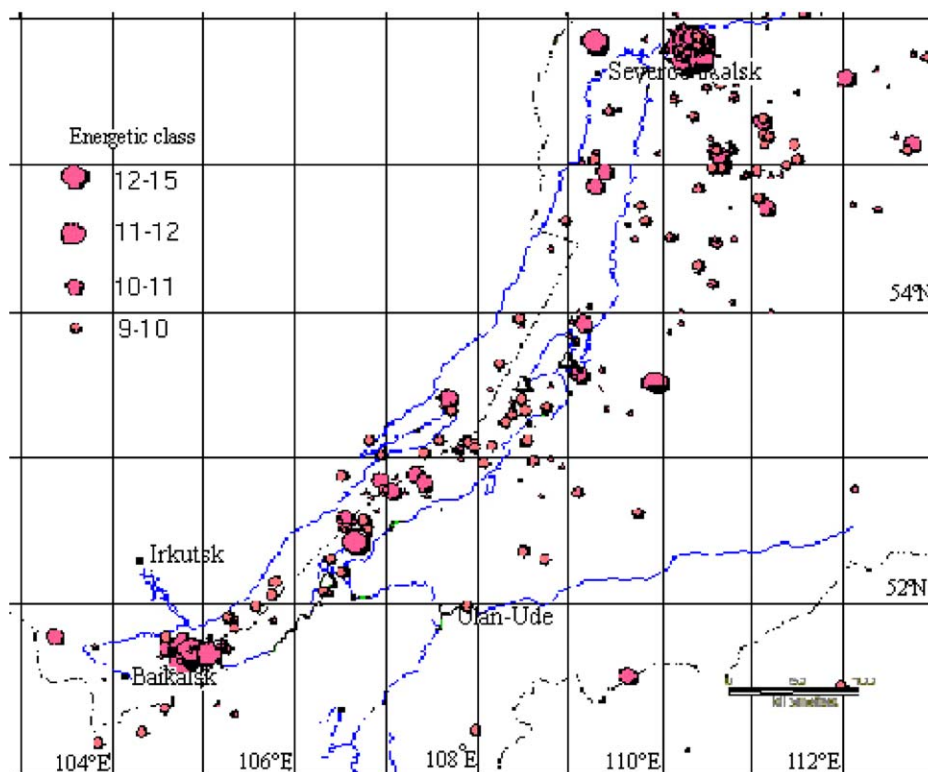


Fig. 1. Earthquakes of Pribaikalye for 1996–2001. The energetic class K is given in Gladyshev et al. (2002).

observations on the earthquakes in the Baikal region have been organized in the last 50 years of the last century (Potopov et al., 2005). Now the network of seismic stations registers about 9000 earthquakes per year, among them only $\sim 0.5\%$ are felt by people. In the Baikal–Mongolian region all the strongest earthquakes were accompanied by aftershocks. So, in a zone including the South-Baikal hollow, the Tunkinsky region and Prehubsugul, for a period of ~ 150 years in the heart areas of earthquakes with magnitude $M > 6.5$ there were from many hundreds up to several thousands of aftershocks. Among them is the Thsagan earthquake of 12.01.1862 with epicenters coordinates 52.3°N , 106.7°E and the magnitude $M = 7.5$; the Baikal earthquake of 26.11.1903 (52.7°N , 107.6°E) with the magnitude $M = 6.8$; the Mondri earthquake of 04.04.1950 (51.8°N , 101°E) with the magnitude $M = 7$; the Middlebaikal earthquake of 29.08.1959 (52.68°N , 106.98°E) with the magnitude $M = 6.8$ and the Prehubsugul earthquake of 27.12.1999 with coordinates 50.98°N , 98.08°E and magnitude 6.8. These earthquakes characterize the full energy release during several centuries. The epicenters earthquake are basically concentrated in the top half of the earth's crust. Fig. 1 illustrates a part of the map of the Baikal region pointing the earthquake epicenters during the year of 1996–2001 and their energetic class.

3. Methods of observations

We use the multi-channel automated station “Katyusha-5” for continuous observations of parameters of natural

impulse NIEMFE in the VLF range in the Baikal rift zone. It is based on a technique of counting the impulses exceeding a given threshold. The structural scheme of the “Katyusha-5” station is given in Fig. 2. The station allows for carrying out synchronous measurements of the magnetic (in the directions of “North–South” and “West–East”) and electric components of the NIEMFE, microseismic noises, the atmospheric electric field and electrotelluric currents. The magnetic component of the NIEMFE is measured at the frequency of ~ 17 kHz ($\Delta f = 4$ kHz) with sensitivity not lower than $100 \mu\text{V}$ at input. The data-acquisition equipment was installed in the vicinity of Ulan-Ude at “Verkhnyaya Berezovka” and “Nadeino” stations.

4. The analysis of results

Round-the-clock registration of the NIEMFE enables us to obtain a chance to study daily variations of the NIEMFE components. As an example, Fig. 3 displays the record of daily variations of impulse stream of magnetic components in the directions of W–E and N–S during the period from July 16 to July 25, 2001.

The basic features of change of the impulse stream are found to repeat depending on local time, i.e., we observe the steady daily variations with a minimum at 7–10 h local time and a maximum at 15–18 h local time. In addition to a precise afternoon maximum, local maxima at night and at dawn (23–2 h) are observed. To establish a correlation between electromagnetic and seismic processes, joint

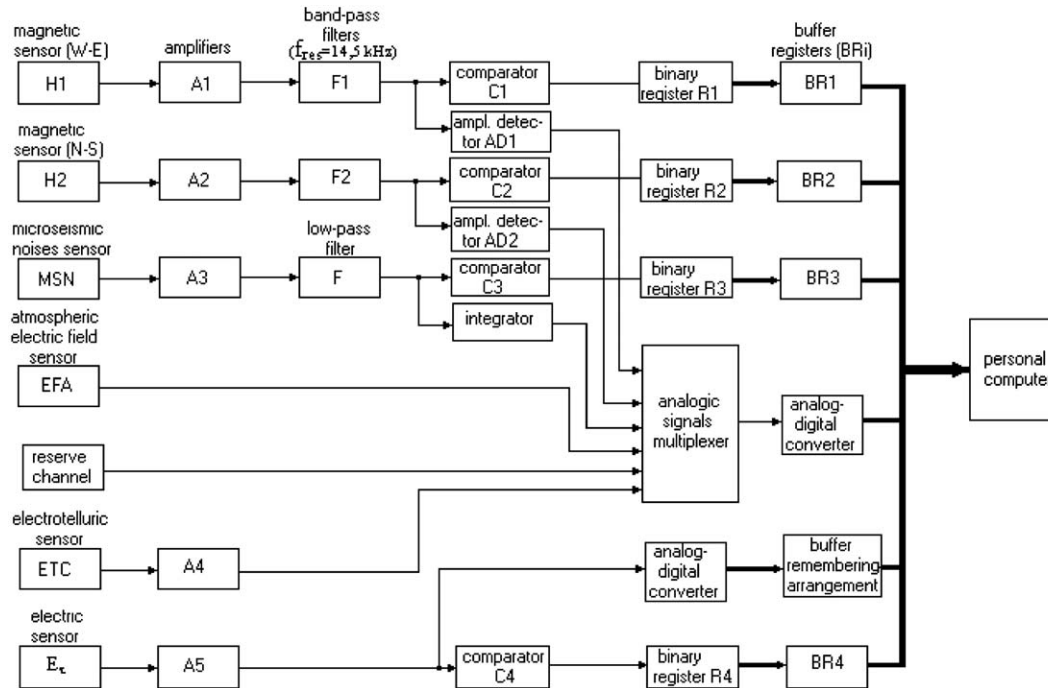


Fig. 2. The structural scheme of the “Katyusha-5” station.

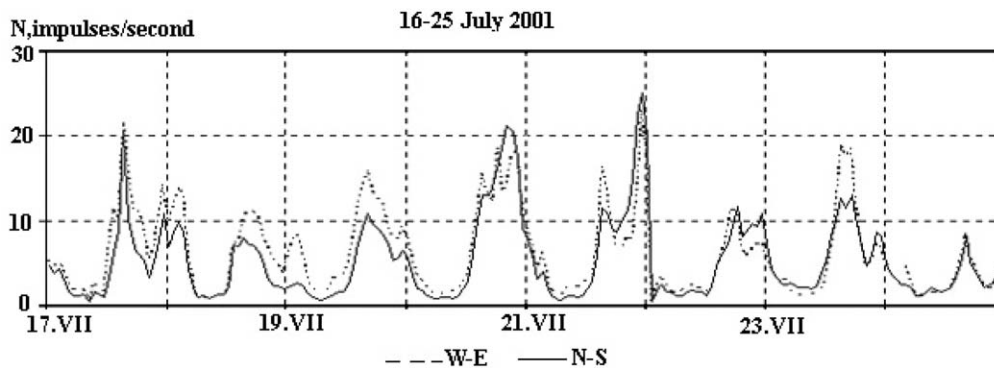


Fig. 3. Daily variations of the NIEMFE magnetic components.

processing of variations of the electromagnetic field according to “Katyusha-5” data and seismic events was carried out. The seismic event catalogue (time, coordinates and intensity – energetic class) was kindly provided us by the Geological Institute of the Siberian Branch of the Russian Academy of Science.

As a result of this processing of continuous NIEMFE records, for the first time in the Baikal rift zone the effect of electromagnetic “seismic calm”, similar to that discussed in Malyshev and Dzhumabaev (1987) was detected: several days before an earthquake there is an abnormal simultaneous decrease of intensity of the impulse stream of the magnetic component along the N–S and W–E directions of reception. After the earthquake the density of the impulse stream in a daily variation of the magnetic component returns to the usual “average” level. At the same time, practically we observe no essential changes of amplitude of impulses of the magnetic component.

The abnormal daily variations given in Fig. 4 and recorded at “Nadeino” observation station, represents an example of the given effect. Several days before the earthquake of $M = 4.0$ magnitude, which took place on July, 25, 2000 at 3:15 local time at a distance of ~ 160 km the number of impulses of the magnetic component on the reception channels W–E and N–S has shown 2–4 times decrease. After the earthquake the typical daily variations of intensity of the magnetic component was restored. For comparison Fig. 3 is intended to display the daily variations of the NIEMFE magnetic component exactly one year later, that is, in July, 2001.

5. Discussion of the results

For an explanation of the electromagnetic “seismic calm” effect it is possible to assume the following processes to take place during a preparing process of the earthquake.

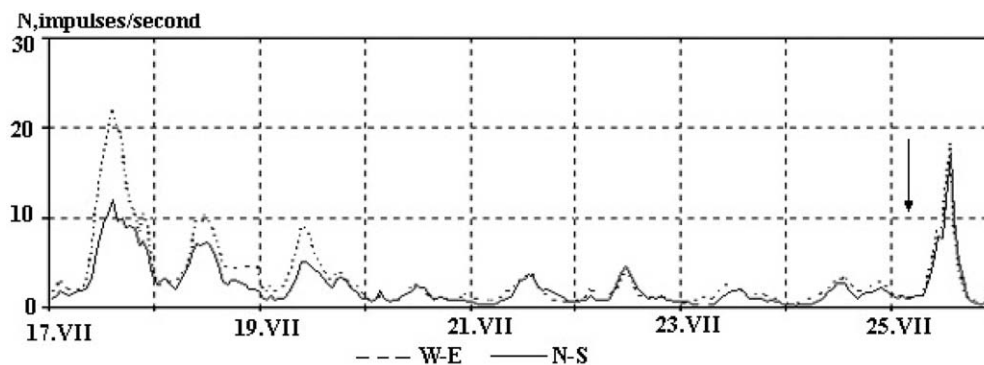


Fig. 4. Changes in intensity of the impulse stream of the magnetic component prior to the earthquake on July 25, 2000. An arrow indicates the moment of the earthquake.

- (1) propagation conditions of atmospheric in the “Earth-ionosphere” waveguide (Migunov et al., 1991) change;
- (2) there is a shielding radiation of lithospheric nature as a result of occurrence of storms of electric conductivity of the Earth’s crust in a zone of an associated with the process of rock destruction preparation earthquake (<http://eos.wdcb.ru/news/>);
- (3) there is a dependence of the spectrum of the electromagnetic radiation at the destruction of lithosphere upon the frequency and time – S-diagram of EM-emission (Kurlenja et al., 2000).

It is known that a majority of registered signals are atmospheric, whose occurrence is caused by lightnings in the local and distant centers of the storm activity. During the preparation of seismic event the distribution of a signal in the Earth-ionosphere waveguide can become abnormal as a result of the changes in the waveguide walls parameters (Hayakawa et al., 1993). The change of distribution conditions, in particular the change of ionospheric height, can be caused by the action of ionization sources of the waveguide in the field of earthquake preparation because of the mechanoelectric (electrokinetic, piezoelectric, etc.) phenomena in solid-rocks. During preparation of earthquakes there is a rise of underground waters and the 2–4 times increase of radon content, which is one of the basic sources of ionization of ground atmosphere (Fuks and Shubova, 1994; Martynenko et al., 1994; Sorokin and Yashenko, 1999). According to Martynenko et al. (1994), Migunov et al. (1991), and Sorokin and Yashenko (1999), the increase of conductivity of ground atmosphere causes the growth of vertical current of conductivity leading to a change of electron concentration, and, therefore, a change of height of a reflecting layer of ionosphere. As a result, superposition of the direct and reflected waves changes in the area of an earthquake preparation. Thus, one should not exclude an opportunity that the electromagnetic “seismic calm” effect, that is, reduction in intensity of stream of impulses during the preparation of an earthquake, is caused by interferential attenuation of the NIEMFE. However, taking into account a random character of impulse stream,

the decrease in amplitude of impulses (or their suppression) below the threshold level of “Katyusha-5” station is hardly possible.

It must be noticed that in the work (<http://eos.wdsb.ru/news/>) it is said that the effect of suppression of ultra low frequency (ULF) noise several days prior to strong seismic impacts is detected at Karymshino station in the centre of the Kamchatka peninsula. The authors explain the observed effect (dubbed a “minus four days” effect) by shielding radiation due to occurrence of electric conductivity disturbances on the earth’s crust in a zone of preparation of earthquake. These electric conductivity disturbances which tend to strongly increase are caused, in the final analysis, by an increase of gas and thermal streams from the seismic center. Thus the basic sources of natural ULF noises are located in the ionosphere.

There is another explanation of the electromagnetic “seismic calm” effect based upon the S-diagram of EM-radiation explaining the rock fracturing process. In a work by Kurlenja et al. (2000) it is experimentally shown that at various stages of the process of destruction of rocks in the spectra of lithospheric EM-radiations (EMR) both low-frequency and high-frequency components are present. For an initial stage of destruction, the increased frequencies of spectra connected to the occurrence of microcracks are characteristic. When microcracks accumulate and germinate, the EMR spectra are shifted to lower frequencies. At the stage of formation of cracks low frequencies prevail in the spectra. Then there comes a stage of branching of cracks. Alongside with low-frequency there are also the high-frequency components of spectrum caused by branching microcracks. At the end of this stage, the stage of origin of the main crack characterized by a significant high-frequency component of a signal follows. The last stage of the avalanche destruction is connected to the fast germination of a main crack and the increase of the low-frequency component in the EMR signal. The described process is graphically depicted in Fig. 5. Here relative frequency is on the horizontal axis, while time in relative units is shown on the vertical axis. In the same figure the experimental material presented in Kurlenja et al. (2000) is shown as points. From what was told above one can understand that

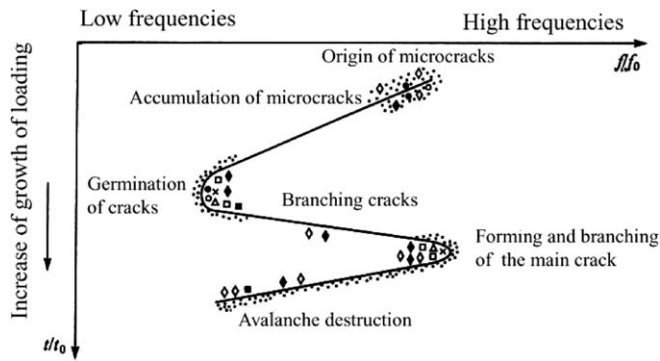


Fig. 5. Generalized S-diagram of a rock destruction process (after Kurlenja et al., 2000).

for each rock (any solid body) the individual curve similar to that given in Fig. 5 can be obtained. It can be accepted as a certain passport characteristic of the rock, describing the process of its destruction over time.

6. Conclusions

It is possible to make the following conclusions from the present analysis and discussion:

- (1) in the records of magnetic components NIEMFE a steady daily variation is precisely traced in the VLF range in seismoquiet period;
- (2) before the earthquake a dramatic decrease in intensity, an electromagnetic “seismic calm” effect, is observed in the daily course of magnetic components;
- (3) the earthquakes were fixed on the recession or when the anomalies ceased;
- (4) since the EM-radiation that is due to the mechanical pressing of rocks is an impulsive broadband process, the application of narrow-band station such as “Katyusha-5” may be not optimal. This research requires the broadband equipment to record appropriately the NIEMFE signals.

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