Electromagnetic Phenomena Related to Earthquake Prediction

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Contents

$$B_{\min} = \frac{\left\{e_{ni}^2/n^2 + 4KTR\right\}^{1/2}}{\pi^{3/2} r^2 N \sqrt{Q\omega_0}} \left[T/\sqrt{\text{Hz}}\right], \tag{5}$$

where e_{ni} is input amplifier noise $[V/\sqrt{\text{Hz}}]$, Q is the overall value of the receiver selectivity, and r and R are respectively the radius and resistance of the coil.

For our case ($r = 0.5$ m, $N = 7000$, $Q = 255$, $n = 1/3$, $R = 1.2$ kΩ, and $e_{ni} = 10$ nV/$\sqrt{\text{Hz}}$), the minimum detectable magnetic field is 6.6×10^{-3} pT/$\sqrt{\text{Hz}}$, which is less than one-tenth that of the background daily radiation.

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Observation of Electromagnetic Ultralow-Frequency Lithospheric Emissions in the Caucasian Seismically Active Zone and Their Connection with Earthquakes

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Abstract. The results of magnetic components of ultralow-frequency lithospheric emissions (ULE) in frequency range from 0.1 to 10 Hz measured at Dusheti observatory during 1990–1991 and ULE differential measurements (with roughly 30 km between the measurement points) made during the period of aftershock activity in the epicentral zone of a $M = 6.9$ Racha earthquake are given. The existence of ULE and their connection with nearby (150 km) earthquakes of $M > 3.5$ are supported. The feasibility of using ULE polarization features to predict the location of the epicenters of future earthquakes is considered.

1. Introduction

Electromagnetic ULEs have been observed, at epicentral distances up to 500 km, both before strong earthquakes and during strong aftershock activity in different seismically active zones, and experimental and theoretical investigations of these emissions have recently attracted widespread attention by scientists concerned with the forecasting of earthquakes[1)–8)].

Since 1987 SPb IZMIRAN and IG ANG have collaborated in using highly sensitive magnetometers[3)] to make three-component ULE magnetic field measurements in Georgia. The results of measurements from November 1988 to March 1989 were presented, in connection with the strong Spitak earthquake[1),3),8)]. During this period 59 bursts of ULE (0.1 to 1 Hz) with amplitudes ranging from 0.03 to 0.2 nT and with durations ranging from several minutes to several hours were detected. The ULE spectra were of two types: noisy and quasisinusoidal.

2. Experimental Results

Since April 1989, when the strong aftershock activity of Spitak earthquake was over, ULE activity measured at Dusheti observatory (geographic coordinates $\varphi =$

42.10°N, $\lambda = 44.68$°E) has decreased sharply. Between April 1989 and April 1991 only 9 ULF events were observed at Dusheti. And according to data gathered in the Caucasus regional seismological network, only 10 moderate earthquakes ($3.5 \leq M \leq 5.0$) occurred during this period. Their epicentral distances ranged from 100 to 200 km.

On 29 April 1991, at 09h13m UT, there occurred a strong Racha earthquake ($M = 6.9$, $h = 6$ km, $\varphi = 42.49$°N, $\lambda = 43.67$°E) with its epicenter about 90 km from Dusheti. Before the main shock and during the aftershock activity (May–July 1991) there were no pronounced increases in ULF magnetic field background. However, a ULE burst (0.1–1 Hz) with duration of about 5 minutes and an intensity of 0.05–0.08 nT for all three magnetic components was observed at Dusheti 18 hours before the main shock.

For the period June–July 1991 we organized an expedition for three-component observation of the ULF magnetic field at two remote measurement sites located in the epicentral zone of the Racha earthquake. This expedition used magnetometers similar to those described in Ref. (3), and ULF magnetic fields were measured (over a frequency range from 0.005 to 10 Hz) at Nikortsmida ($\varphi = 42.46$°N, $\lambda = 43.10$°E) and at Oni ($\varphi = 42.58$°N, $\lambda = 43.44$°E) observatories 31 km apart. The time resolution of these measurements depended on the speed of the pen recorders and varied from 0.05 to 2 s.

Forty-seven bursts of ULE, both of noisy and quasisinusoidal types, from 0.1 to 10 Hz, with intensities up to 2 nT, and with durations ranging from several minutes to several hours were observed at both observatories. Twenty-three of these bursts were recorded 1–4 days before the strong ($M = 6.2$) aftershock occurred on 15 July 1991. Epicentral distance of both observatories for $M \geq 3.5$ aftershocks ranged from 20 to 70 km.

Only ULF signals similar to those mentioned in Refs. (1), (3), and (8) and essentially different both from geomagnetic pulsations and from industrial noise were taken into account.

The spatial distribution of the intensity of the ULE bursts differed between the noise and the quasisinusoidal spectral types. Quasisinusoidal ULE bursts were generally observed only at one station, whereas ULE bursts of the noise type were almost always observed simultaneously at both observatories. This indicates different origins for noise and quasisinusoidal ULE. The spatial distribution of noise-type ULE parameters is in a good agreement with the source model proposed in Ref. (6). ULE bursts of the quasisinusoidal type are of essentially directional character. Figure 1 shows a noise-type ULE bursts observed at both stations before one of the aftershocks ($M = 4.0$, $\varphi = 42.44$°N, $\lambda = 43.52$°E). In Fig. 1 one can see the effect of seismical vibrations on magnetometers at the shock moment (S.M.), which is indicated by an arrow.

On 15 June 1991 at 0h50m UT, there was a strong aftershock ($M = 6.2$, $\varphi = 42.37$°N, $\lambda = 43.96$°E). For 1–4 days before the shock 16 bursts of ULE in the frequency range from 0.1 to 10 Hz, with durations ranging from several minutes to several hours, and with intensities up to 0.7 nT were recorded at Nikortsmida (about 70 km from the epicenter). The bursts were both of noise and quasisinusoidal types.

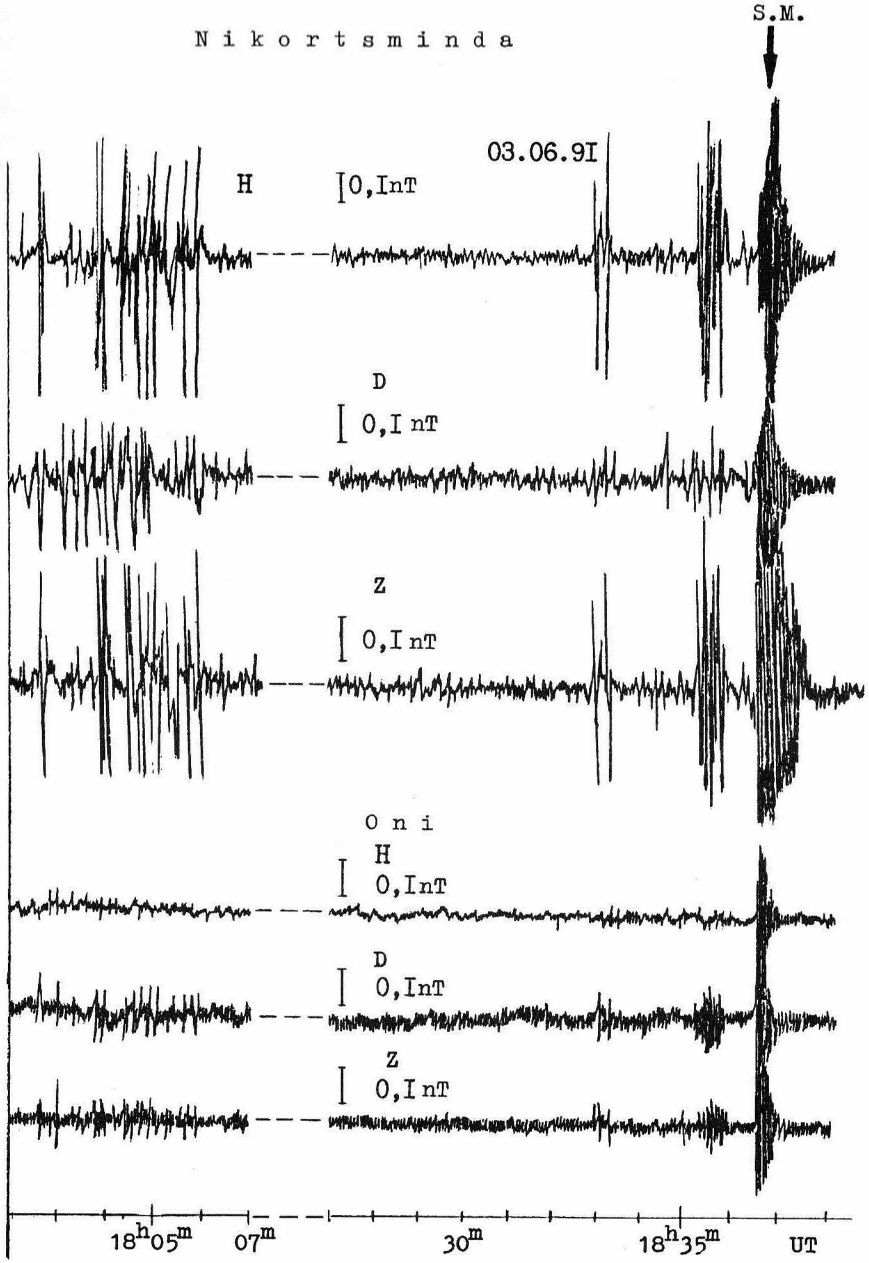

Fig. 1. Example of a noisy-type ULE burst observed at both stations before one of the aftershock ($M = 4.0$, $\varphi = 42.44$°N, $\lambda = 43.52$°E). One can see the effect of seismical vibrations on magnetometers at the shock moment (S.M.) indicated by an arrow.

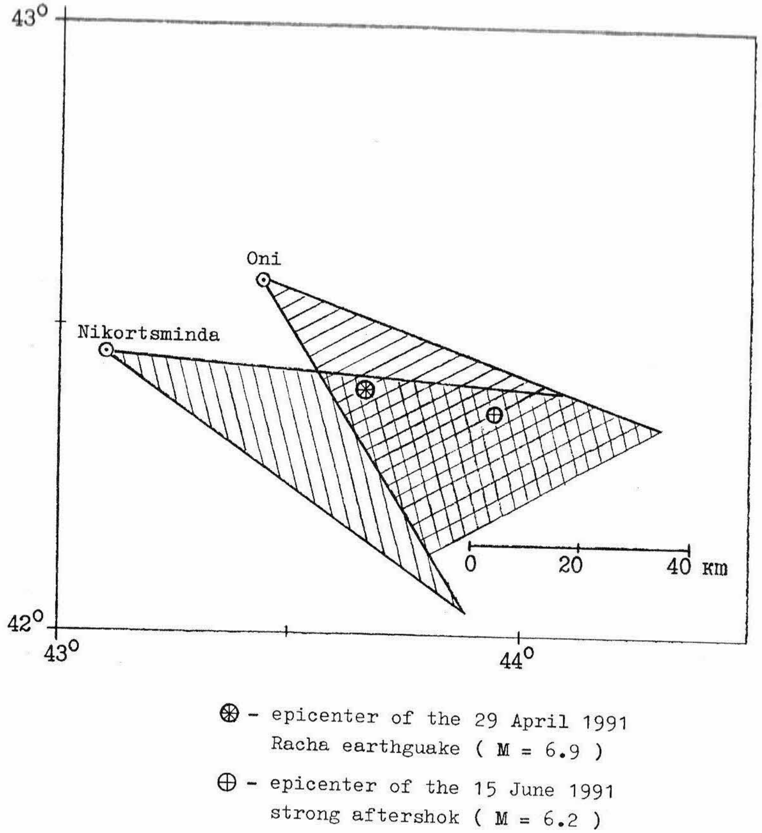

Fig. 2. Map of the epicentral zone of the Racha earthquake, showing the relative locations of the Nikortsminda and Oni observatories and the epicenters of the 29 April 1991 earthquake ($M = 6.9$) and the 15 June 1991 strong aftershock ($M = 6.2$). The angle sectors with the vertexes placed at Nikortsminda and at Oni indicate the ranges of angle variation for the direction of main axes of the quasisinusoidal ULE elliptic hodographs.

Five bursts of the quasisinusoidal type and with the frequencies of about 1 and 5 Hz were recorded with a high time resolution 3–5 days before the shock. The waveform of the H and D magnetic components of ULE were used to plot the horizontal temporal hodograph of the magnetic field vector for each of these five ULE bursts. All these hodographs were quasielliptic in form. In other worlds, the ULE bursts were elliptically polarized. The angle between the main axis of the ellipse and the geographic parallel varied from 15° to 25° for these bursts. The mean error of angle estimation is within ±10°. The main axes of the ellipses were oriented along lines running roughly from N-W-W to S-E-E.

During the period 1–4 days before this shock seven bursts of ULE (six of the quasisinusoidal type) with durations ranging from several minutes to tens of minutes and with intensities up to 2 nT were recorded in the frequency range from 0.1 to 10

Hz at Oni (about 50 km from the epicenter). Five bursts of ULE of quasisinusoidal type with the frequencies of about 1 and 5 Hz and with intensities up to 0.3 nT were recorded with a high time resolution two days before the aftershock under consideration, and one burst with an intensity of about 2 nT and with a duration of about 10 minutes was observed 10 hours before this shock. Unfortunately, the record of H component for this burst was lost because the pen record for the H channel failed. There is therefore no way to plot an elliptic hodograph for this burst. Hodographs were plotted for the other five bursts, though, and the angle between main axis of ellipse and the geographic parallel ranged from 30° to 50° for these five ULE bursts. Again, the mean error of the estimated angle is ±10°. The main axes of the ellipses were oriented roughly from N-W to S-E. Figure 2 depicts the map of the epicentral zone of the Racha earthquake, showing the relative locations of the Nikortsminda and Oni observatories and the epicenters of the 29 April 1991 earthquake ($M = 6.9$) and the 15 June 1991 strong aftershock ($M = 6.2$). The angle sectors with the vertexes placed at Nikortsminda and at Oni indicate the ranges over which the direction of quasisinusoidal ULE elliptic hodographs' main axes varied. The epicenters of both strong shocks are located inside the angle sectors. This indicates the feasibility of using the ULE polarization features to predict the location of the epicenters of future earthquakes. Much more sophisticated direction findinding system has been proposed by Hayakawa *et al.*[9]

The relations $Z/H \geq 1$, $Z/D \geq 1$ holds for more than 50% of all ULE bursts recorded at the epicentral zone of the Racha earthquake.

3. Concluding Remarks

The following conclusions can be drawn from this research:

(1) ULE exists in a seismically active zone of the Caucasus and is related to nearby strong earthquakes.

(2) This ULE activity is intimately related to seismical activity.

(3) The ULE polarization features can be used to predict where the epicenters of future earthquakes will be located.

(4) ULE must be further investigated for use in forecasting strong earthquakes.

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Electromagnetic Background and Preseismic Anomalies Recorded in the Amare Cave (Central Italy)

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Abstract. Multichannel instrumentation has since 1987 been recording electromagnetic and seismoacoustic emissions in the Amare cave, in the southern slope of the Gran Sasso chain (Central Apennines). Equipment detecting RMC (Principality of Monaco) longwave broadcasting (216 kHz) has been operating in the same place. On 25 August 1992 an earthquake with $M = 3.9$ occurred in the Gran Sasso area and on 4 June 1993 an earthquake with $M = 4.5$ occurred in Umbria, 100 km north of the Amare cave. Before these earthquakes, electromagnetic, seismoacoustic, and RMC data showed anomalies. Here we present the observed phenomenology and discuss the possibility that the anomalies can be considered precursors of the earthquakes.

1. Introduction

To investigate earthquake precursory phenomena, multichannel equipment able to record electromagnetic and seismoacoustic emissions has been placed in natural caves. In 1987 analog equipment for measuring the electric component was put into operation in the Amare cave located in the Central Apennines[1)]. A digital acquisition system was set up later and new sensors were installed[2)]. The Amare cave is in the southern slope of the Gran Sasso chain, which is one of the largest karst areas of the Italian Apennines and is largely formed by limestones of different geologic epochs. This cave, located in a scarcely inhabited area, spreads more than one hundred metres from the mouth and reaches a depth of about eighty metres (Fig.1). The roof of the "Sala dei Colossi" (that is, the largest room of the cave) consists of irregular wedge-shaped limestone blocks of different sizes, from which hang short and thin stalactites. The floor of this room is made up of huge blocks that have fallen from the roof. A drip-drop exists in several spots of the cave. Many rock samples were collected in the cave and mineralogical analyses showed that the cave consists of rocks containing little quartz (about 0.1%).