Part III. Training "Geomagnetic precursors"

STUDY OF GEOMAGNETIC VARIATIONS IN GEORGIA AND ESTABLISHMENT OF ANOMALY NATURE OF EARTHQUAKE PRECURSORS

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Abstract

Before strong earthquake magnetic precursors denoted by many authors, but must to say, that more of them don't satisfy stern criterions. There are many examples of geomagnetic anomaly in Georgia too: a few weeks before earthquakes in Spitak, anomaly grows of low frequency geomagnetic pulsation amplitudes were fixed in Geophysics Laboratory of Dusheti. The, "When, where and how" earthquake prediction problem is not solved but is an actual problem for a long time. From 1989 researches on possible connection between geomagnetic variations and incoming earthquake started in INRNE. (Mavrodiev S. Cht., Thanassoulas C., Possible correlation between electromagnetic earth fields and future earthquake, INRNE-Bas, Seminar proceeding, July 23-27, 2001, Sofia, Bulgaria, ISBN 954-9820-05-X,2001). From February 2006 Ukraina was included in INRNE, BAS geomagnetic and Earthquake monitoring. From January 2009 Georgia with its Geomagnetic observatory of Dusheti was also included in INRNE, BAS. For estimation of the geomagnetic variations as a reliable precursor the specific time analysis was discovered for digital definition of Geomagnetic Quake and proposed a way for interval defined from the extremum of local tide variations [S. Cht. Mavrodiev, 2001]. Georgian Geomagnetic stations can input important information for space dependences of precursor intensity as part of complex regional NETWORK of PrEqTiPlaMagInt

collaboration (Prediction Earthquake Time Place Magnitude Intensity). We introduce the primary work-up results of data received from the Dusheti Magnetic Observatory which was worked up for investigation of earthquake prediction on the basis of geomagnetic variations.

Keywords: precursor; geomagnetic quake; earthquake; tide difference; tidal extreme; density of earthquake radiated energy.

1. Introduction

Georgia is a part of the far-extending seismically active region, which includes the whole Caucasus, Northern parts of Turkey, and Iran. These territories witnessed several intense destructive earthquakes. Thus carrying out possible short-term prognosis of earthquakes is very important for the country.

Before strong earthquake magnetic precursors denoted by many authors, but must to say, that more of them do not satisfy stern criterions. There are many examples of geomagnetic anomaly in Georgia too: a few weeks before earthquakes in Spitak, anomaly growth of low frequency geomagnetic pulsation amplitudes was fixed in Geophysics Laboratory of Dusheti.

The problem of „when, where and how" earthquake prediction cannot be solved only on the basis of seismic and geodetic data(Aki,1995; Pakiser and Shedlock,1995; et al., 1997; Ludwin,2001).

The possible tidal triggering of earthquakes has been investigated for a long period of time.

Including of additional information in the precursors monitoring, such as the analysis of the electromagnetic field variations under, on and above the Earth surface, can contribute towards defining a reliable earthquake precursor and estimating the most probable time of a forthcoming earthquake.

Simultaneous analysis of more accurate space and time measuring sets for the earth crust condition parameters, including the monitoring data of the electromagnetic field under and over the Earth surface, as well as the temperature distribution and other possible precursors, would be the basis of nonlinear inverse problem methods. it could be promising for studying and solving the „when, where and how" earthquake prediction problem.

Some progress for establishing the geomagnetic filed variations as regional earthquakes' precursors was presented in several papers (Mavrodiev, Thanassoulas, 2001; mavrodiev, Pekevski, Jimsheladze, 2008). The approach is based on the understanding that earthquake processes have a complex origin. Without creating of adequate physical model of the Earth existence, the gravitational and electromagnetic interactions, which ensure the stability of the Sun system and its planets for a long time, the earthquake prediction problem cannot be solved in reliable way. The earthquake part of the model have to be repeated in the infinity way "theory- experiment- theory" using nonlinear inverse problem methods looking for the correlations between fields in dynamically changed space and time scales. Of course, every approximate model (see for example Varotsos, 1984, a, b, Varotsos et al, 2006; Thanassoulas, 1991; Thanassoulas et al., 2001a, b; Eftaxias at all, 2006, Duma, 2006) which has some experimental evidence has to be included in the analysis. The adequate physical understanding of the correlations between electromagnetic precursors, tidal extremums and incoming earthquake is connected with the progress of the adequate Earth's magnetism theory as well as with quantum mechanical understanding of the processes in the earthquake source volume before and during an earthquake.

The achievement of the Earth's surface tidal potential modeling, which includes the ocean and atmosphere tidal influences, is an essential part of the research. In this sense the comparison of the Earth tides analysis programs on Venedikov et al.., 2003; Milbert,2011) is very useful.

The role of geomagnetic variations as precursor can be explained by the hypothesis that during the time before the earthquakes, with the strain, deformation or displacement changes in the crust there arise in some interval of density changing the chemical phase shift which leads to an electrical charge shift. The preliminary Fourier analysis of geomagnetic field gives the time period of alteration in minute scale. Such specific geomagnetic variation we call geomagnetic quake. The last years results from laboratory modelling of earthquake processes in increasing stress condition at least qualitatively support the quantum mechanic phase shift explanation for mechanism generating the electromagnetic effects before earthquake and others electromagnetic phenomena in the time of earthquake (Freund et al, 2002; St-Laurent et al, 2006, Vallianatos et all, 2003, 2006)

The future epicentre coordinates have to be estimated from at least 3 points of measuring the geomagnetic vector, using the inverse problem methods, applied for the estimation the coordinates of the volume, where the phase shift arrived in the framework of its time window. For example the first work hypothesis can be that the main part of geomagnetic quake is generated from the vertical Earth Surface- Ionosphere electrical current. See also the results of papers (Vallianatos, Tzanis, 2003 ; Duma, Ruzhin, 2003, Duma, 2006) and citations there.

In the case of incoming big earthquake (magnitude > 5 - 6) the changes of vertical electropotential distribution, the Earth's temperature, the infrared Earth's radiation, the behaviour of debit, chemistry and radioactivity of water sources, the dynamics and temperature of under waters, the atmosphere conditions (earthquakes clouds, ionosphere radioemitions, and etc.), the charge density of the Earth radiation belt, have to be dramatically changed near the epicentre area.

The achievements of tidal potential modeling of the Earth's surface, including ocean and atmosphere tidal influences, multi- component correlation analysis and nonlinear inverse problem methods in fluids dynamics and electrodynamics are crucial for every single step of the constructing of the mathematical and physical models.

3. Method

In the paper (Mavrodiev,2004) the geomagnetic quake was defined as a jump of the day mean value of the signal function Sig:

$$Sig = \sum_{m=1}^{M} \sigma_{Hm} / M, \qquad \delta Sig = \sum_{m=1}^{M} \delta\sigma_{Hm} / M, \tag{1}$$

Here *σHm* is the standard deviation of geomagnetic field component *Hh, and δσHm* is the corresponding error,

$$\sigma_{Hm} = \sqrt{\sum_{t=1,N} \frac{(H_t - H_m)^2}{N}}, \qquad \delta\sigma_{Hm} = \sqrt{\sum_{t=1,N} \frac{(\delta H_t - \delta H_m)^2}{N}},$$

Hm is one-minute averaged value of geomagnetic vector projection Hi,

$$H_m = \sum_{i=1}^{N} \frac{H_i}{N} \qquad \delta H_m = \sum_{i=1}^{N} \frac{\delta H_i}{N},$$

M=1440 minutes per day, and N=60 are the samples per minute.

The predicted earthquake is identified by the maximum of the function proportional to the density of the earthquake radiated energy in the monitoring point. The analytical size of this function is:

$$\mathbf{SChtM = 10M / (D+Depth + Distance^2),} \tag{2}$$

Where the distances are in hundred km, fit parameter D = 40 km and M is the earthquake magnitude

Thus, if we have a jump of signal function Sig and its error δSig is such that satisfies numerically the next condition:

$$\mathbf{SigToday - SigYesterday > (\delta SigToday + \delta SigYesterday) / 2,} \tag{3}$$

In the next tidal extreme time the function SChtM will have a local maximum value. The earthquake for which the function SChtM has a maximum can be interpreted as predicted earthquake.

The probability time window for the incoming earthquake or earthquakes is approximately ± 1 day for the tidal minimum and for the maximum- ± 2 days.

The analytical size of the function SChtM as well as one minute time period for calculating the unique signal for geomagnetic quake which is reliable earthquake precursor was established by ***Dubna inverse problem method*** (Dubna Papers).

In the case of vector geomagnetic monitoring, one has to calculate the minute standard deviation as a geodynamical sum of standard deviations of the tree geomagnetic vector components:

$$\delta_{\mathrm{Hm}} = \sqrt{(\delta^2{}_{Hmx} + \delta^2{}_{Hmy} + \delta^2{}_{Hmz})}$$

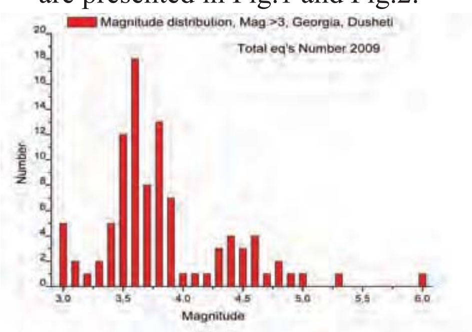
Dusheti Geomagnetic Observatory is located in Dusheti town (Georgia, Lat 42.052N, Lon44.42E), Alt900m). It is equipped with modern precise Fluxgate Magnetometer Model LGI and it accomplishes non-stop registration of X, Y, Z elements. The data includes minute and second records of the field elements. It is measured with 0,1nT accuracy daily.

4. Data

For the research of geomagnetic signal as earthquake precursor was used the following:

1) Minute data of Geomagnetic fields elements received from Dusheti Geomagnetic observatory or 60 samples per hour, with 0,1nT accuracy.
2) Coordinate of Dusheti Geomagnetic observatory: 42.052N, Lon44.42E Alt900m.
3) There was analyzed earthquakes data in region with Lat42.052N and Long44.42E for 2009, reported in USGS, NEIC: Earthquake research results, magnitude range from 3.0 to 9.0, data selection 97 earthquakes.

The distributions of earthquakes' magnitudes and depths, (Mgnitude >3.0) are presented in Fig.1 and Fig.2.



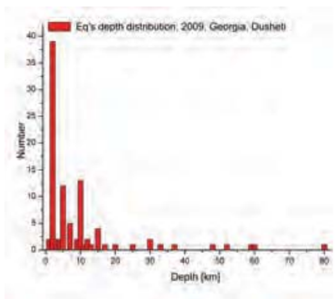


Fig.1Magnitude distribution

Fig.2 The earthquake's depth distribution

Fig3. Presents the SChtM and magnitude distribution for all occurred earthquakes in the region earthquakes as function of distance from the monitoring point with magnitude>3.

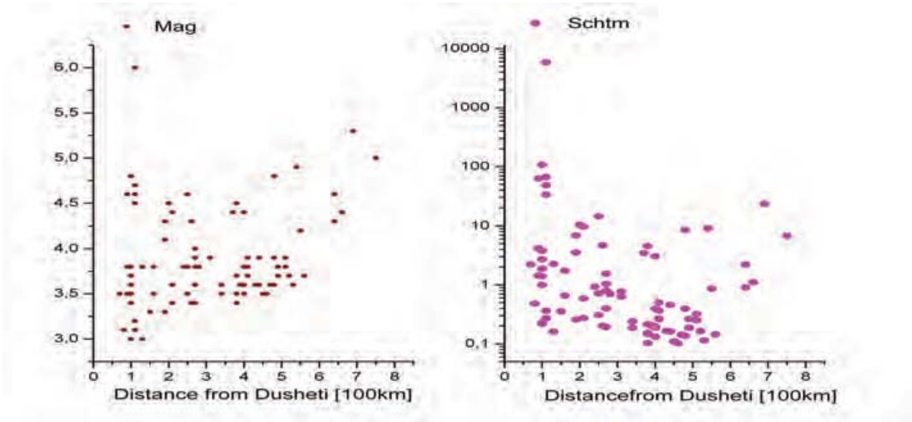


Fig.3. the distribution of SChtM and Magnitude (>3) on distances for all occurred earthquakes in the region

The comparison of the distribution in the Fig3 and Fig.4 can give some presentation for distance and magnitude sensibility of the geomagnetic approach.

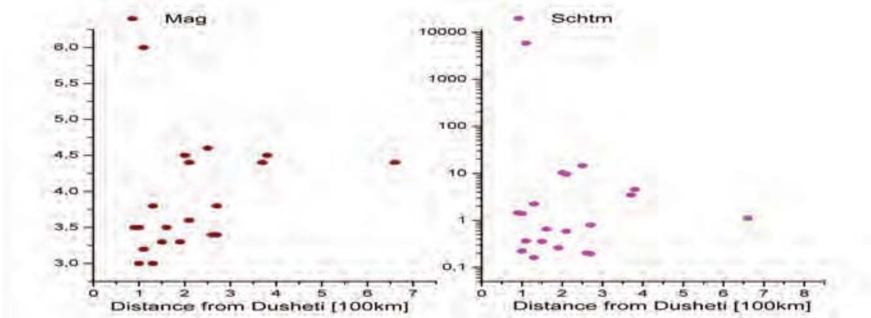


Fig.4. the distribution of SChtM and Magnitude (>3) on distances for predicted earthquakes

5. Analysis

The next Table contains the monitoring data for Dusheti and its analysis, described above, which illustrate that the geomagnetic quake is a reliable regional earthquake precursor. The columns present: the number of signals preceding he incoming tidal extreme data, information for the tidal minimum (1) or maximum (2), the time of tidal extreme, the time of occurred earthquake, latitude [degree], longitude [degree], depth [km], magnitude, distance from monitoring point [in 100 km], the value of function SChtM [J/km2], the difference between the time of tidal exstreme and the time of occurred earthquake [in days]. The table consists of data for the earthquake with magnitude grater then 3.

Number of signals	Tidal min, max	Signal Time	Tidal min, max time	Eq Time	Lat	Long	Depth [km]	Mag	Distance [100]km	Schtm	Time difference [Day}
1	1	03.01.2009	03.01.2009 12:00	03.01.2009 4:29	41.8	49.0	10	4.5	3,8	4.56	-0.3
	2		10.01.2009 12:00	12.01.2009 05:04	43.8	46.5	30	3.8	2.5	0.716	1.7
1	1	29.01.2009	01.02.2009 12:00	31.01.2009 2:21	43.6	45.9	2	4.4	2,1	9.7	-0.4
1	1	31.01.2009	01.02.2009 12:00	01.02.2009 10:27	40.5	42.3	3	4.6	2,5	14.3	-0.1
	2		07.02.2009 12:00	06.02.2009 06:51	40.42	42.32	2	3.5	2,5	0.31	-1.2
1	2	23.02.2009	23.02.2009 12:00	25.02.2009 17:28	38.5	44.4	2	3.6	0,7	2.23	-1.7
1	1	27.02.2009	02.03.2009 12:00	03.03.2009 4:59	43.0	45.3	10	3.8	1,3	2.26	1.7
1	1	15.04.2009	18.04.2009 12:00	18.04.2009 3:32	41.8	46.3	10	3.8	1,6	1.74	-0.4
1	1	14.05.2009	18.05.2009 12:00	17.05.2009 15:03	43.3	46.1	48	4.5	2	10.5	-0.9
1	1	09.07.2009	14.07.2009 12:00	14.07.2009 18:46	41.0	43.3	7	3.5	1,6	0.66	0.3
1	2	03.08.2009	04.08.2009 12:00	07.08.2009 3:06	40.6	52.1	37	4.4	6,6	1.11	2.6
1	1	05.08.2009	11.08.2009 12:00	11.08.2009 4:20	39.3	42.7	2	3.5	3,4	0.19	-1.3
2	1	19.08.2009	26.08.2009 12:00	25.08.2009 11:12	43.3	46.1	13	4.1	1,9	3.54	-1
	1	22.08.2009	26.08.2009 12:00	25.08.2009 11:12	43.3	46.1	13	4.1	1,9	3.54	-1
1	2	03.09.2009	05.09.2009 12:00	07.09.2009 22:41	42.7	43.4	15	6	1,1	5875	2.4
		08.09.2009	10.09.2009 12:00	12.09.2009 9:41	42.7	43.4	10	4.6	1,1	48.4	1.9
2	2	13.09.2009	18.09.2009 12:00	21.09.2009 2:09	42.6	43.6	2	3.5	1	1.4	2.6
	2	17.09.2009	18.09.2009 12:00	21.09.2009 2:09	42.6	43.6	2	3.5	1	1.4	2.6
1	1	27.09.2009	27.09.2009 12:00	28.09.2009 18:57	42.5	43.5	5	3.7	1	2.72	0.3
1	2	29.09.2009	06.10.2009 12:00	07.10.2009 21:20	40.8	46.3	5	3.6	2,1	0.59	2.4
2	1	11.10.2009	13.10.2009 12:00	14.10.2009 2:47	41.5	46.1	2	3.3	1,5	0.36	0.6
	1	13.10.2009	13.10.2009 12:00	14.10.2009 2:47	41.5	46.1	2	3.3	1,5	0.36	0.6
1	2	15.10.2009	18.10.2009 12:00	17.10.2009 12:17	42.6	43.6	2	3.5	0,9	1.45	-1
1	1	08.11.2009	10.11.2009 12:00	10.11.2009 2:43	41.4	43.4	7	3.2	1,1	0.37	-0.4
1	2	14.11.2009	16.11.2009 12:00	16.11.2009 7:31	43.3	46.1	15	4.3	1,9	6.87	-0.2
1	1	21.11.2009	25.11.2009 12:00	24.11.09 18:35	43.2	46.1	2	3.3	1,9	0.26	-0.7

The following figures present the samples of material work-up for September 2009 Dusheti data. From up to down are presented the curve of tidal gravitational potential, density of earthquake energy (Schtm), earthquake's distribution at the same period, values of SigD and its standard deviation.

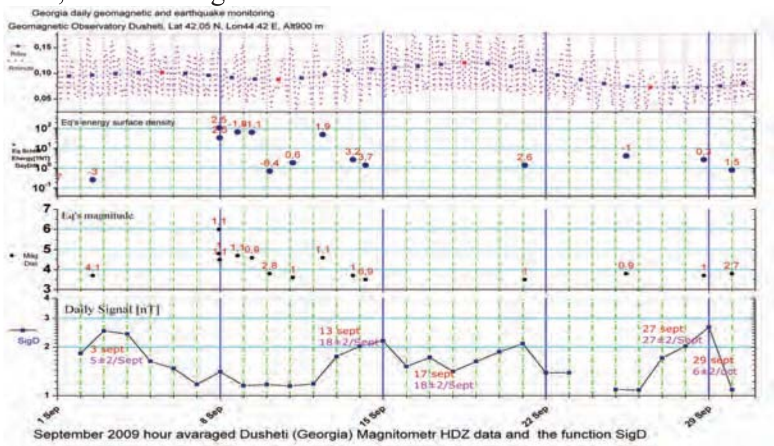


Fig.5 The reliability of the time window prediction for the incoming earthquake September, 2009, Dusheti region.

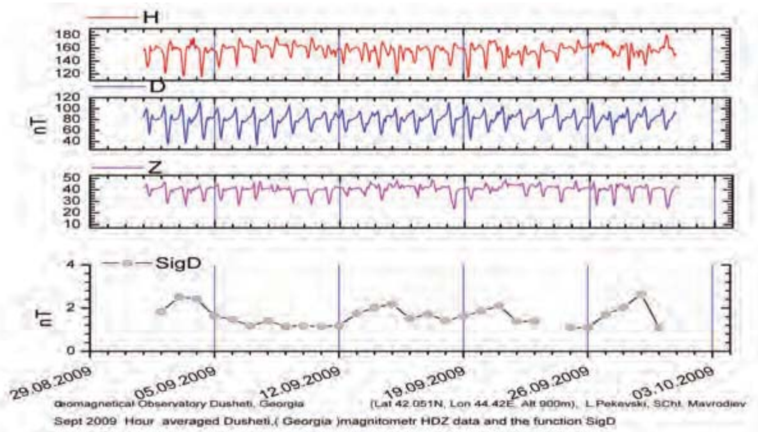


Fig.6 The „monthly monitoring" figure for September, 2009, Dusheti region.

Fig.7. Presents the comparison of the number of All occurred and predicted earthquake For Dusheti. Fig7. presents the map graphic for earthquakes with magnitude grater then 4 predicted simultaneously by Dusheti measurement.

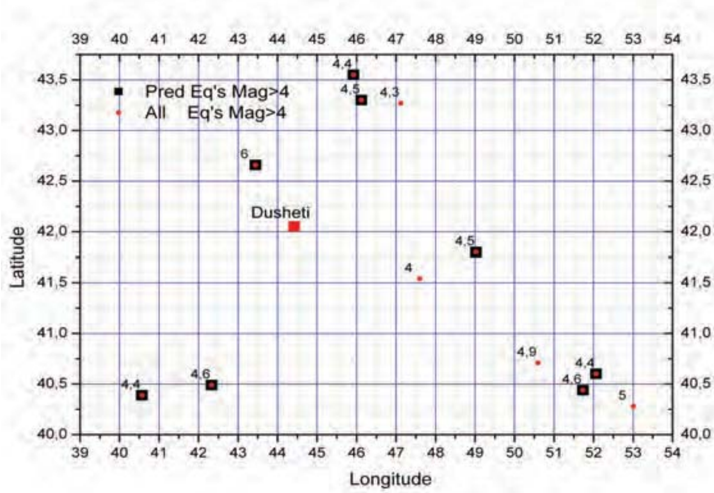


Fig.7 Map graphic for earthquakes with magnitude grater then 4 predicted simultaneously by Dusheti measurement.

It is clear from the picture that among 12 earthquakes for Mag>4, 8 of them were fixed by us. For the rest 4 earthquakes periods we do not have geomagnetic field data**.**

It is obvious that the occurred in the predicted time period earthquake with maximum value of function SChtM (proportional to the Richter energy density in the monitoring point) is the predicted earthquake. But sometimes there are more than one geomagnetic signals in one day or some in different days. It is not possible to perform unique interpretation and to choose the predicted earthquakes between some of them with less values of energy density. The solution of this problem can be given by the analysis of the vector geomagnetic monitoring data in at least 3 points, which will permit to start solving the inverse problem for estimation the coordinates of geomagnetic quake source as function of geomagnetic quake. The numbering of powers of freedom for estimation of the epicenter, depth, magnitude and intensity (maximum values of accelerator vector and its dangerous frequencies) and the number of possible earthquake precursors show that the nonlinear system of inverse problem will be over determinate.

5. Conclusion

The correlations between the local geomagnetic quake and incoming earthquakes, which occur in the time window defined from tidal minimum (± 1 day) or maximum (± 2 days) of the Earth tidal gravitational potential are tested statistically. The distribution of the time difference between predicted and occurred events is going to be Gaussian with the increasing of the statistics.

The presented results can be interpreted as a first reliable approach for solving the "when" earthquakes prediction problem by using geomagnetic data.

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