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STATISTIC ANALYSIS OF EARTHQUAKE PRECURSORS

Abstract.

11 strong regional (M≥6.0) and 7 local perceptible (3.7≤M≤5.0) earthquakes, occurred from 1983 to 2002 in the territory of Armenia and adjacent countries were tested for the purpose of current seismic hazard assessment [1]. For the first time Catalog of tested earthquake anomalies-precursors, included 167 anomalies on 15 monitoring parameters was composed. Tests are distinguished by analysis results of 656 anomalies.

Based on the results of these researches, a full probability of all tested earthquake precursors is calculated; it was considered in what degree the quantity of precursors has influence on value of full probability of precursors seismic realization; determined the frequency and relative frequency of development of various values of probability of precursors seismic realization, included in Catalog. It was considered a value (statistic part) of complex of five more importance parameters, and also the part of one tested anomaly-precursor in this complex.

The same level of statistic importance of parameter complex as for strong regional earthquakes as for local perceptible earthquakes indicates that operating Multiparameter monitoring network of NSSP is capable of react both on preparedness of local perceptible and strong regional earthquakes. In other words, in whole it is universal network in meaning of uses of receiving data for current seismic hazard assessment.

Introduction.

The probability of precursors seismic realization is expressed by (as) ratio P=m/n, where m - a quantity of realized anomalies, i.e. those anomalies after which seismic events has occurred; n – total quantity of similar anomalies at given station and for given parameter. The probability was determined: 1) on every method (parameter) for every type of anomaly; 2) on all types of anomalies for every method (parameter), separately for M≥6.0 and 3.7≤M≤5.0 earthquakes; 3) on precursor complex for M≥6.0 and 3.7≤M≤5.0 earthquakes.

In Table 1 values of average probabilities P_{av} are shown on precursor complex for M≥6.0 and 3.7≤M≤5.0 events [1].

Methods and study results.

Based on before given studies, full probability of all precursors of 11 strong regional (M≥6.0) and 7 local perceptible (3.7≤M≤5.0) earthquakes is calculated, using a formula of full probability [2]:

$$P\{A\} = \sum_{n=1}^{N} P\{B_n\} P\{A|B_n\} \qquad (1),$$

where A – event (forthcoming earthquake);

$B_1, B_2, \ldots, B_N$ – events (anomalies-tests) consisting a full group;

P –probability, that event A will occur.

During a calculation the formula (1), quantity of test anomalies-precursors (see Table 1) and values of seismic realization probabilities P=m/n of all tests on every earthquake are used, which are given in Catalog of test anomalies-precursors [1]. Results of calculations are given in Table 2.

Table 1

N	Earthquakes	Tests numbers	Pav.
1	*A. Strong regional (M≥6.0)*: Ardebil M=6.7, 1997	5	0.27
2	Baku M=6.5, 2000	16	0.57
3	Barisakho M=6.4, 1992	11	0.53
4	Bolu M=6.2, 1999	5	0.32
5	Bolvadin M=6.2, 2002	16	0.37
6	Izmit M=7.4, 1999	23	0.38
7	Narman M=6.8, 1983	4	0.69
8	Racha M=7.1, 1991	3	0.29
9	Roudbar M=7.7, 1990	6	0.52
10	Spitak M=7.0, 1988	16	0.54
11	Erzindjan M=6.9, 1992	5	0.48
	In average on regional earthquakes	10	0.45
12	*B. Local perceptible (3.7≤M≥5.0)*: Ashotsk M=4.1, 1996	8	0.57
13	Bavra M=4.2, 1994	7	0.49
14	Javakhet M=4.3, 1999	7	0.33
15	Martuni M=5.0, 1992	7	0.48
16	Noemberian M=4.4, 1997	14	0.38
17	Parakar M=3.7, 1997	4	0.46
18	Tsovagyugh M=3.8, 1993	8	0.49
	In average on local earthquakes	7.9	0.46

As shown in Table 2, Pfull for strong regional earthquakes is changed within 29,7-69,0%, and for local perceptible earthquakes –within 36,0-61,0%. It should be noticed, that in Catalog of tests electrical, electromagnetic, hydrogeodynamic, radon, geochemical, geomagnetic, ionosphere, biological precursors and atmosphere pressure are given. Group of seismic and geodesic earthquake precursors aren't considered there, as during seismic events testing of these parameters weren't considered by us, as they have special specific character of their processing. Values of full probability would be much higher, if also seismic and geodesic precursors are included in mentioned complex of parameters and methods.

Table 2.

N	Earthquakes	Pfull, %	N	Earthquakes	Pfull, %
1	*A. Strong regional (M≥6.0)*: Ardebil M=6.7, 1997	29,7	12	*B. Local perceptible 7≤M≤5.0)*:. Ashotsk M=4.1, 1996	61,0
2	Baku M=6.5, 2000	57,0	13	Bavra M=4.2, 1994	48,0
3	Barisakho M=6.4, 1992	57,0	14	Javakhet M=4.3, 1999	36,0
4	Bolu M=6.2, 1999	34,0	15	Martuni M=5.0, 1992	49,0
5	Bolvadin M=6.2, 2002	35,0	16	Noemberian M=4.4, 1997	57,0
6	Izmit M=7.4, 1999	37,0	17	Parakar M=3.7, 1997	46,0
7	Narman M=6.8, 1983	69,0	18	Tsovagyugh M=3.8, 1993	45,0
8	Racha M=7.1, 1991	28,0		In average on local earthquakes	48,9
9	Roudbar M=7.7, 1990	59,0			
10	Spitak M=7.0, 1988	53,0		In average on all earthquakes	47,5
11	Erzindjan M=6.9, 1992	48,0			
	In average on strong earthquakes	46,1			

It is important to notice that average values of full probability on regional and local earthquakes are common in whole (46,1 and 48,9). It is indicate that operating Multiparameter monitoring network of NSSP to an equal degree is able to respond to preparedness of local perceptible and strong regional earthquakes. Otherwise, in whole it is universal network in a sense of using receiving data during current seismic hazard assessment. Such results have formerly received on values of average probability P_{av} on precursor complex for M≥6.0 and 3.7≤M≤5.0 earthquakes given in Table 1.

It should be consider in what degree quantity of anomalies-tests (Table 1) influence on value of full probability of precursor seismic realization (Table 2). Its ratio has been get.

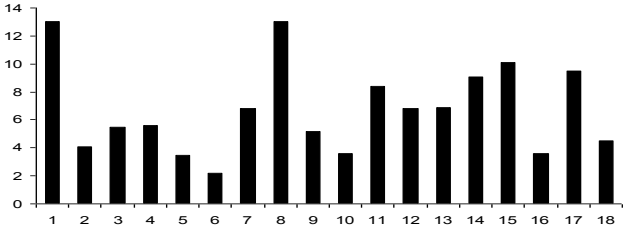

Fig.1. Diagram of ratio between the value of full probability of precursor seismic realization (Pfull) and tests numbers (in %). Numbers of earthquakes are shown on absciss axis.

Depending on numbers of tests tendency of value increase of full probability is observed (fig.1). However, this tendency concerns not all seismic events, both local and regional. In one site, this means that the more precursors, of course, the easier to predict the forthcoming earthquake. In other site, no rational increasing of monitoring points, doesn't guarantee an identically prediction of impending earthquake.

It should be consider how often one or another values of P=m/n, given in Catalog of separate anomaly-tests (MP) are to be found and with what frequency (W=MP/∑). Data are given in Table 3 and on fig.2. As we see, anomalies with values P=m/n, equal to 1\1, 1\2, 1\3, 1\4 and 1\5, that is with high enough values of P and, consequently, with high degree of seismogenius are to be found in Catalog of test precursors. It means that during the current seismic hazard assessment, current anomalies will be dedicated more confidently by comparison with enough effective test anomalies-precursors.

Table 3

N	Basis (P=m/n)	Frequency (MP)	Relative frequency (W=MP/∑)	N	Basis (P=m/n)	Frequency (MP)	Relative frequency W=MP/∑)
1	1\1	26	15,6	16	1\22	1	0,5
2	1\2	23	13,7	17	2\2	2	1,2
3	1\3	21	12,5	18	2\3	7	4,1
4	1\4	17	10,2	19	2\4	4	2,3

5	1\5	11	6,5	20	2\5	4	2,3
6	1\6	6	3,5	21	2\6	3	1,7
7	1\7	7	4,1	22	2\7	1	0,5
8	1\8	3	1,7	23	2\11	2	1,2
9	1\9	1	0,5	24	2\12	1	0,5
10	1\10	5	2,9	25	2\21	2	1,2
11	1\11	1	0,5	26	3\3	3	1,7
12	1\12	2	1,2	27	3\4	1	0,5
13	1\13	1	0,5	28	3\5	4	2,3
14	1\15	2	1,2	29	5\9	5	2,9
15	1\16	1	0,5			∑=167	

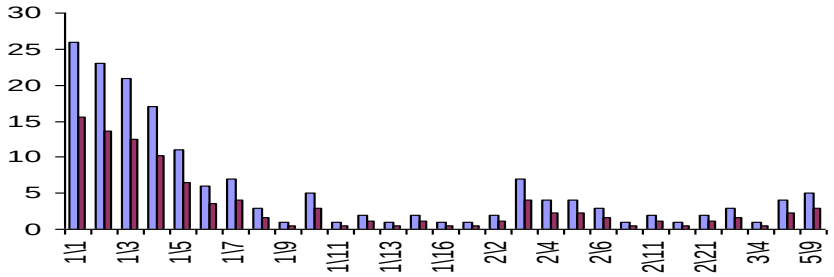

Fig.2 Diagram of frequency (light rectangle) and relative frequency (%) (dark rectangle) of basis P=m/n. Values of P are given on absciss axis.

We should estimate the full probability of seismic realization of the most important earthquake precursors. The same, to all appearances of numbers of test anomaly-precursors earthquakes given in Catalog, are hydrogeodynamic, radon, geochemical (helium consentration), electromagnetic and geomagnetic precursors. Full probability of these precursors complex by all 18 earthquakes calculated by the formula (1) is given in Table 4.

Table 4

N	Earthquakes	Pfull, %	N	Earthquakes	Pfull, %
1	*A. Strong regional (M≥6.0)*: Ardebil M=6.7, 1997	27,0	12	*B. Local perceptible (3.7≤M≤5.0)*: Ashotsk M=4.1, 1996	71,0
2	Baku M=6.5, 2000	64,0	13	Bavra M=4.2, 1994	49,0
3	Barisakho M=6.4, 1992	51,0	14	Javakhet M=4.3, 1999	36,0
4	Bolu M=6.2, 1999	15,0	15	Martuni M=5.0, 1992	54,0
5	Bolvadin M=6.2, 2002	38,0	16	Noemberian M=4.4, 1997	38,0
6	Izmit M=7.4, 1999	31,0	17	Parakar M=3.7, 1997	50,0
7	Narman M=6.8, 1983	65,0	18	Tsovagyugh M=3.8, 1993	48,0
8	Racha M=7.1, 1991	28,0		In average on local earthquakes	49,4
9	Roudbar M=7.7, 1990	67,0			
10	Spitak M=7.0, 1988	66,0		In average on all earthquakes	47,8
11	Erzindjan M=6.9, 1992	56,0			
	In average on strong earthquakes	46,2			

As it is shown in Table 4, Pfull for strong regional earthquakes are changed within 15,0-67,0%, and for local perceptible earthquakes - within 36,0-71,0%. These values are close to similar ones, got for all precursors complex (Table 2), which is evidence of that above enumerated five parameters, could be really considered as more important ones.

$$P\{B_n|A\} = \frac{P\{Bn\}\,P\{A|Bn\}}{\sum_{n=1}^{N} P\{B_n\}\,P\{A|B_n\}}, \quad n = \overline{1, N} \qquad (2),$$

Using the formula of Bayess (2), we can calculate statistic value (statistical part) of the complex of five more important parameters, and also a part of one test anomaly-precursors in the complex, by supposing of 100% earthquake prediction [2].

where A – event (forthcoming earthquake);

$B_1, B_2, \ldots, B_N$ – events (anomalies-tests) consisting a full group;

P – probability, that event A will occur;

$P\{Bn \mid A\}$- part of parameter (by %) by supposing of 100% earthquake prediction.

Results of calculations are given in Table 5 and on fig.3

Table 5

N	Earthquakes	$\sum B_i$	$P_A(B_{\sum i})$ (%)	$P_A(B_{\sum i})/B_{\sum i}$(%)
1	*A. Strong regional (M≥6.0)*: Ardebil M=6.7, 1997	2	15,0	7.5
2	Baku M=6.5, 2000	16	69,0	4.3
3	Barisakho M=6.4, 1992	7	59,0	9.9
4	Bolu M=6.2, 1999	5	33,0	6.6
5	Bolvadin M=6.2, 2002	11	61,0	5.5
6	Izmit M=7.4, 1999	18	52,0	2.9
7	Narman M=6.8, 1983	4	31,0	7.8
8	Racha M=7.1, 1991	3	30,0	10,0
9	Roudbar M=7.7, 1990	4	50,0	12.5
10	Spitak M=7.0, 1988	11	72,0	6.5
11	Erzindjan M=6.9, 1992	1	12,0	12,0
12	*B. Local perceptible (3.7≤M≤5.0)*: Ashotsk M=4.1, 1996	7	70,0	10,0
13	Bavra M=4.2, 1994	7	60,0	8.6
14	Javakhet M=4.3, 1999	4	33,0	8.3
15	Martuni M=5.0, 1992	5	27,0	5.4
16	Noemberian M=4.4, 1997	11	60,0	5.5
17	Parakar M=3.7, 1997	3	43,0	14.3
18	Tsovagyugh M=3.8, 1993	8	67,0	8.4

Table

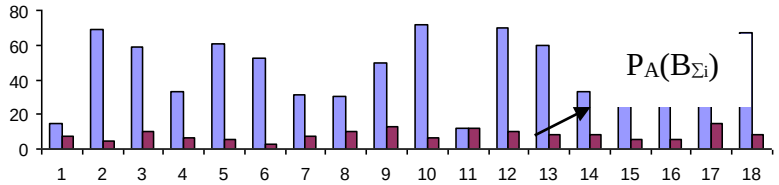

Fig.3 Part of five more important parameters complex (by %) by supposing of 100% earthquake [illegible] bers of earthquakes, $P_A(B_{\sum i})/B_{\sum i}$ – part of a test of all parameters (by %) supposing of 100% earthquake pr[illegible] N

Such calculations are carried out for each of these five parameters in the complex (hydrodyn[illegible] radon, geochemical – helium concentration, electromagnetic and geomagnetic precursors).

Conclusion

1. Full probability of seismic realizations of precursors occurred in the territory of Armenia for strong regional earthquakes is varied within 29,7-69,0 %, and for local perceptible earthquakes - within 36,0 – 61,0%.
2. Average values of full probability on regional and local earthquakes in whole are very close (46,1 and 48,9). Consequently, operating Multiparameter monitoring network of NSSP is capable of react both on preparedness of local perceptible and strong regional earthquakes. In other words, in whole it is universal network, in meaning of uses of receiving data for current seismic hazard assessment.
3. Depending on tests quantity, tendency of value increase of full probability is observed. However, it concerns not to all seismic events, both local and regional. In one site, this means that the more precursors, of course, the easier to predict the forthcoming earthquake. In other site, no rational increasing of monitoring points, doesn't guarantee an identically prediction of impending earthquake.

4. Precursors with high enough values of seismic realization probability and consequently, with high degree of seismogenius are more often to be found in Catalog of test precursors. It means that during the current seismic hazard assessment, current anomalies will be dedicated more confidently by comparison with enough effective test anomalies-precursors.
5. Statistic importance of complex of five more significant parameters is practically equal both for strong regional earthquakes (Baku, Spitak and others.) and local perceptible earthquakes (Ashotsk, Tsovagyugh and others) (Table 5 and fig.3). This also indicates that operating Multiparameter monitoring network of NSSP is universal in meaning of uses of receiving data for current seismic hazard assessment.
6. Statistic importance of:
- hydrogeodynamic (HGD) precursor is higher for strong regional earthquakes than for local perceptible ones;
- hydrogeochemistry (helium concentration) is much higher for strong regional earthquakes than for local perceptible ones;
- subsoil radon is practically equal both for strong regional earthquakes and local perceptible ones;
- electromagnetic precursor (INP method), with the single exception, is higher during local perceptible earthquakes;
- geomagnetic precursor is higher for strong regional earthquakes than for local perceptible ones.

7. Hydrogeodynamic precursor has maximum $P_A(Bn)/Bn$; then, in descending values, helium, radon, electromagnetic and geomagnetic precursors.

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წარმოდგენილია სომხეთის ტერიტორიაზე 20-მდე მიწისძვრის წინამორბედების სტატისტიკური ანალიზი.

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Results of the statistical analysis of precursors about twenty earthquakes in the territory of Armenia are represented.

СТАТИСТИЧЕСКИЙ АНАЛИЗ ПРЕДВЕСТНИКОВ ЗЕМЛЕТРЯСЕНИЙ./Петросян Г./.Сб.Трудов Института Гидрометеорологии Грузии. –2008. – т.115. – с. 376-383. – Анг.; Рез. Груз., Анг.,Рус.

Представлены результаты статистического анализа предвестников около 20 землетрясений на территории Армении.