NEW THEORY OF THE EARTHQUAKE PREDICTION USING ANOMALOUS BEHAVIOR OF MICROSEISMS

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I. Kerimov
The Scientific Center of Seismology of the Presidium of the Azerbaijan National Academy of Sciences
S. Kerimov
Seismotech Globe B. V., Netherlands

A. BACKGROUND: DISCOVERY OF THE NEW REGULARITY OF SEISMIC NOISE BEHAVIOR

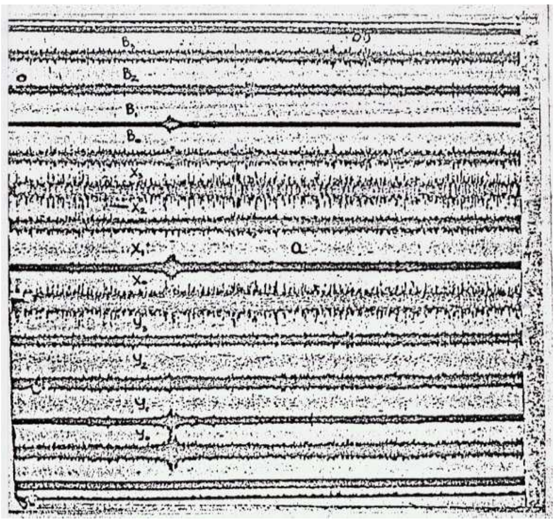
Our view of the causes of, and approach to solving the earthquake prediction problem and necessity of the special seismological and geophysical system creation are based on discovery of the previously unknown regularity of seismic noise (weak high-frequency Earth microseisms) emissions with unique characteristics during the earthquakes preparation period.
This led to new understanding of the physics of the source of earthquakes, the forms of energy propagation and transformation from the source, the processes which take place in the lithosphere, has shown the non-linear character of the microseisms propagation and interaction with the medium.
The new regularity was recognized in March 1988 as a scientific discovery by the USSR State Committee on Inventions and Discoveries with priority from May 1979: regularity of seismic emissions before an earthquake with multi-stage increase in intensity, decrease of their dominant frequency, polarization in the direction of the epicenter of the future earthquake and measurable at any distance from the epicenter zone.
The research on microseism anomalies as a tool for prediction of earthquakes based on the analysis of the structure of the microseisms fields and their parameters variations of in the earthquake preparation period, which permit recognition of the activation of the source processes long before appearance of the main shock and determination of the place of the future event.

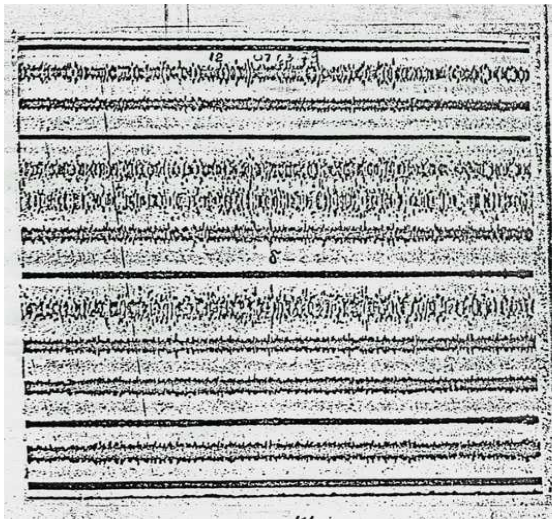
1. The microseism anomalies registrations by very sensitive and high magnification "Cherepakha" analog system.

Figures 1.1-1.7: examples of the regularities of seismic emissions invoked by different earthquakes, registered at different distances.

Fig. 1.1 Earthquake in East Caucasus, 02h 10m 47s, M= 5,1, on March 8, 1979. Sections of compressed seismograms 15 hours and 12 hours before the event, in the time of earthquake and 6 hours later

15h before 12h before





in time   6h after

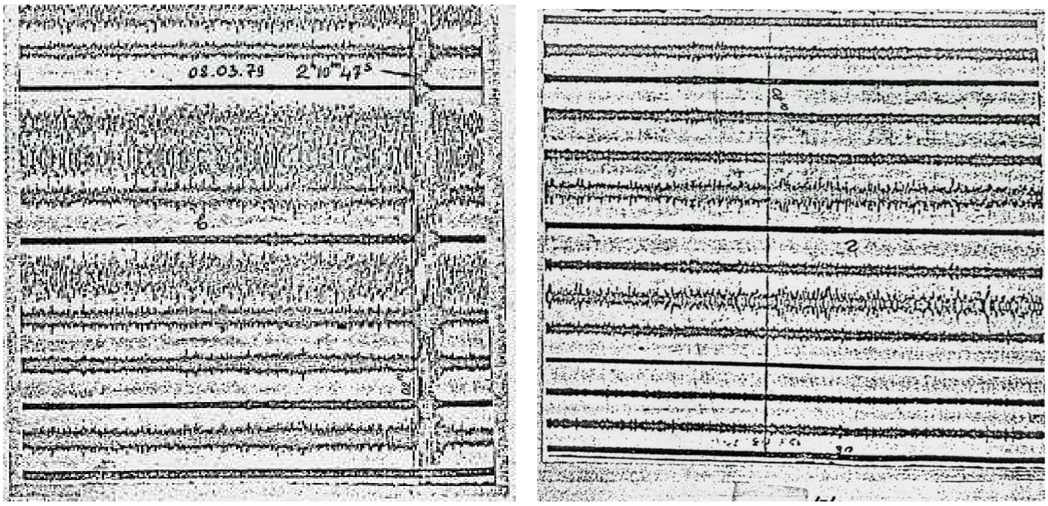


Fig. 1.2 Earthquake in Iran, Tebes, 19h 38m 21s, M=6.2, on September 16, 1978. Sections of compressed seismograms

7h before the event   in the time of event

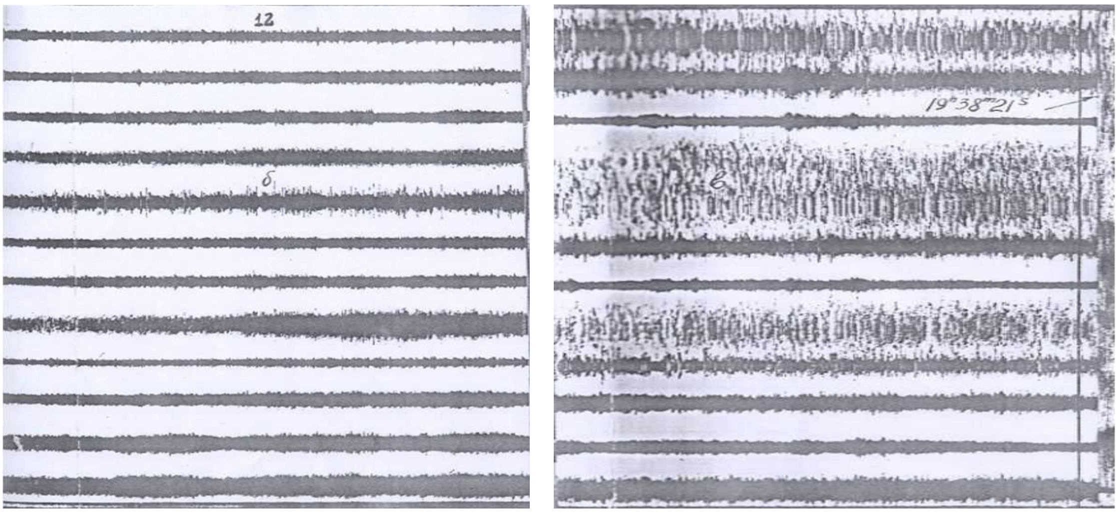
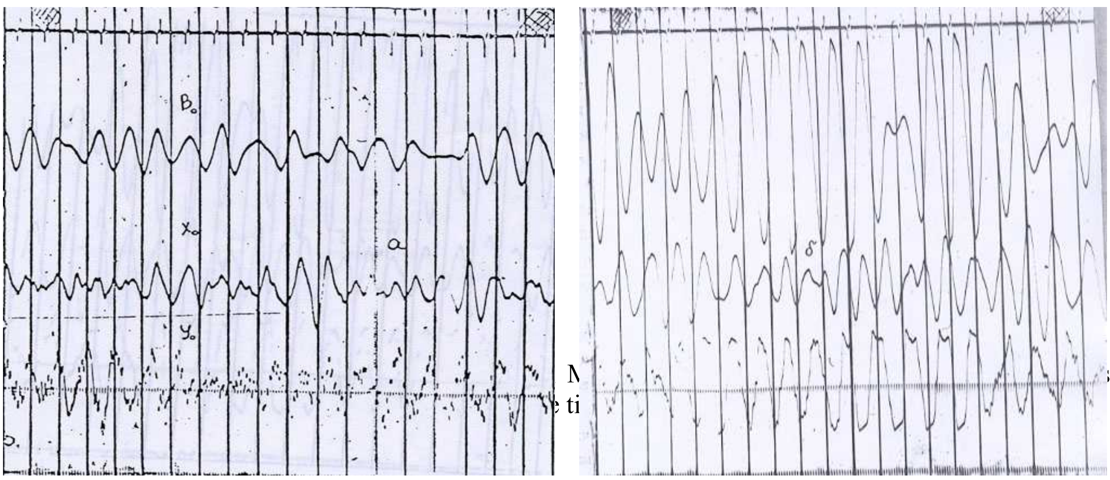


Fig. 1.3 Earthquake in Iran, Tebes, 19h 38m 21s, M=6,2, on September 16, 1978. Sections of real seismograms

13h before the event   3 hours before the event



24h before the event 7h before the event in the time of event

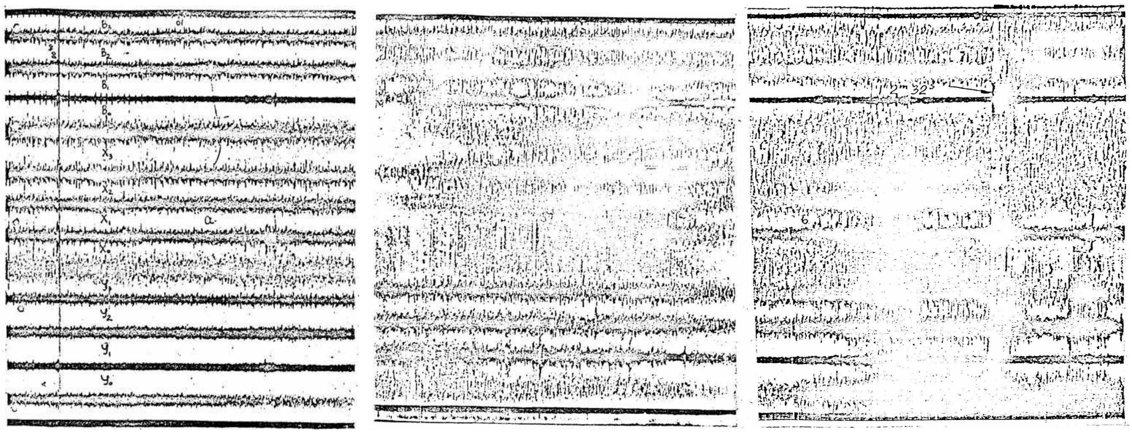


Fig. 1.5 Earthquake in island Honshu, 10h 27m a.m, M=6.5, on April 9, 1985. Sections of compressed seismograms 13 hours before and in the time of event

13h before the event in the time of event

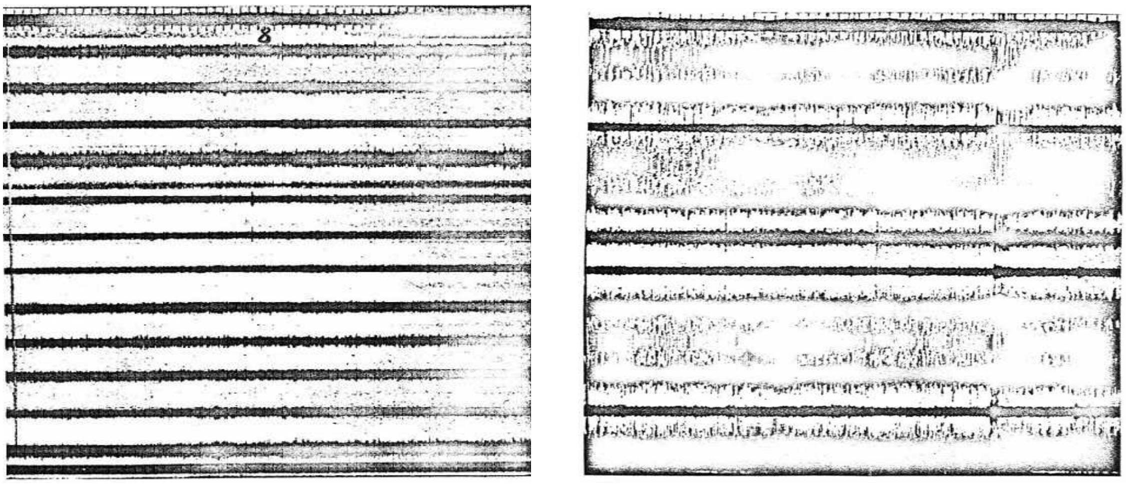


Fig. 1.6 Earthquake in Aegean Sea, 08h 48m p.m., on 6 August, 1983. Sections of compressed seismogramms 12 hours before and in the time of earthquake

12 hours before in the time of event

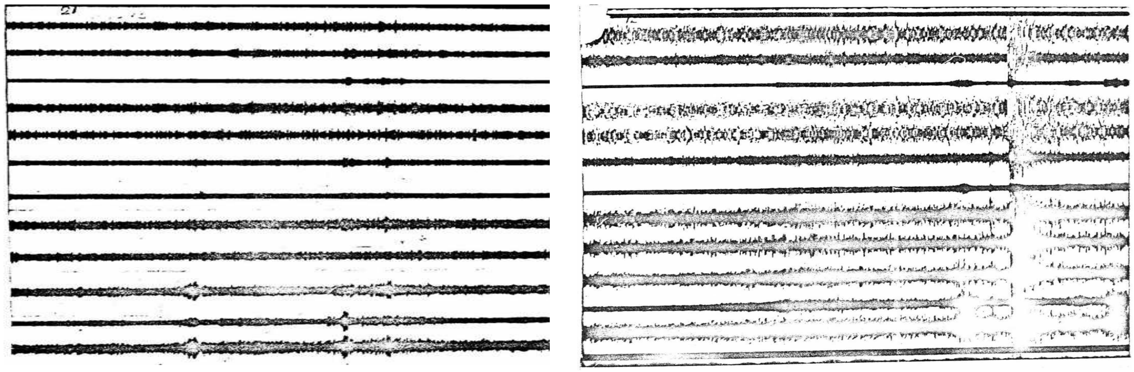
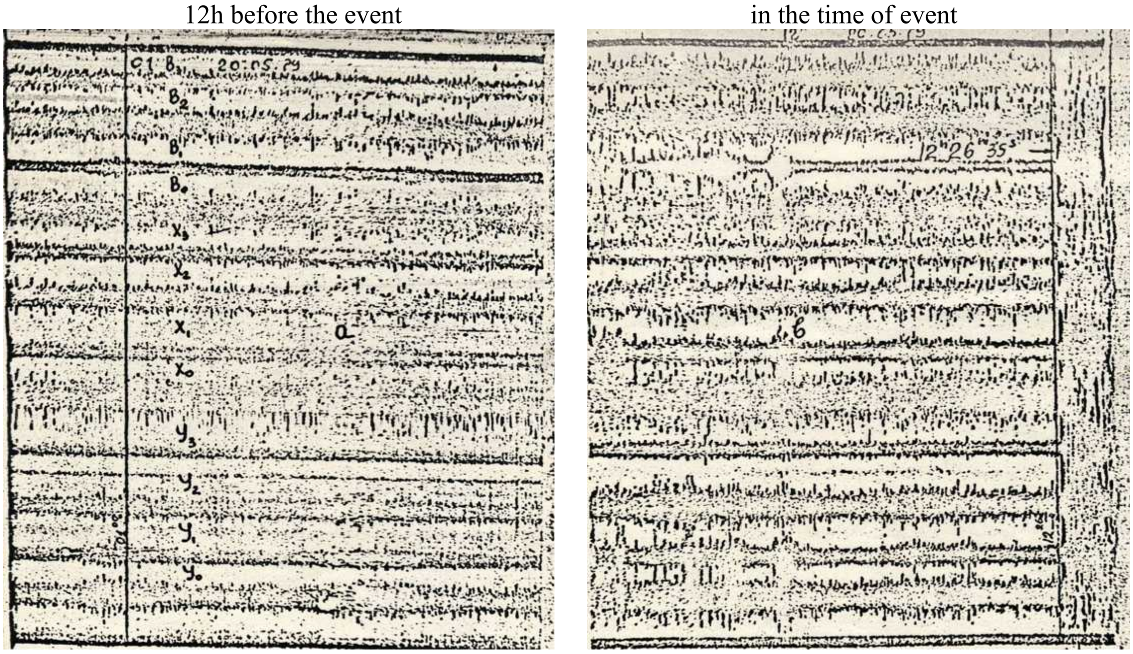


Fig. 1.7 Earthquake in Alaska, 12 h 26m 35s, on May 20, 1979. Sections of compressed seismograms 12 hours before and in the time of earthquake:

12h before the event in the time of event

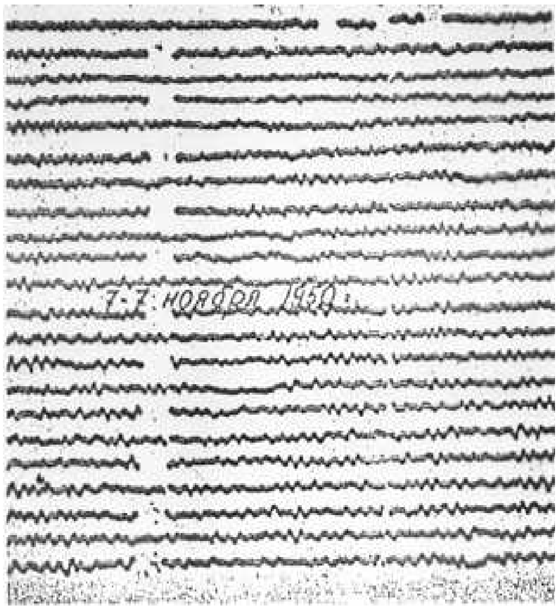


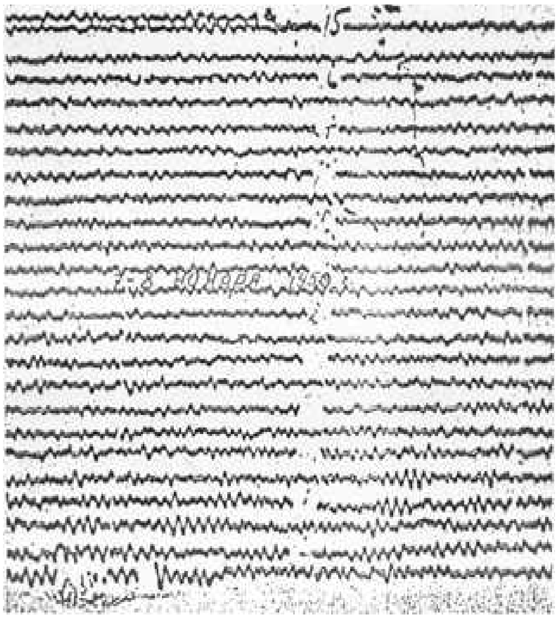
2. The microseism anomalies registered by ordinary network analog seismic stations

While analyzing archive data we found out more than seven hundred examples of the same kind of microseisms behavior changes registered event by the ordinary network stations with very low sensitivity but before the catastrophic events with magnitudes more than M=7.0,. Figures 2.1-2.2: examples of the catastrophic events registered by station "Baku".

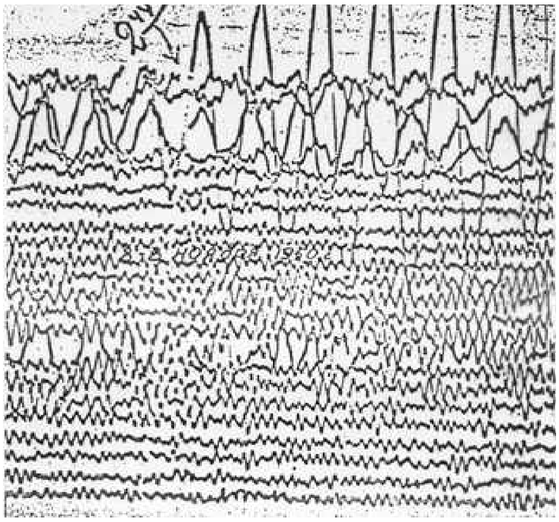
Fig. 2.1 Earthquake in Solomon Islands, 14h 18m, M=7.2, on November 8, 1950. Sections of seismograms registered 24 hours, 12 hours and 1 hour before and in the time of earthquake, 6 hours 12 hours after the event

24h before 12h before

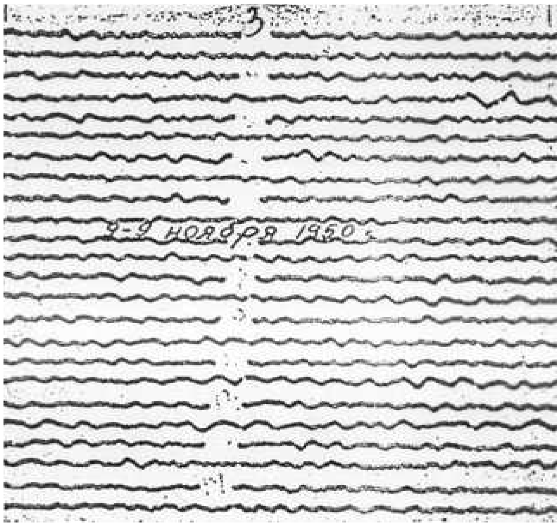




1h before



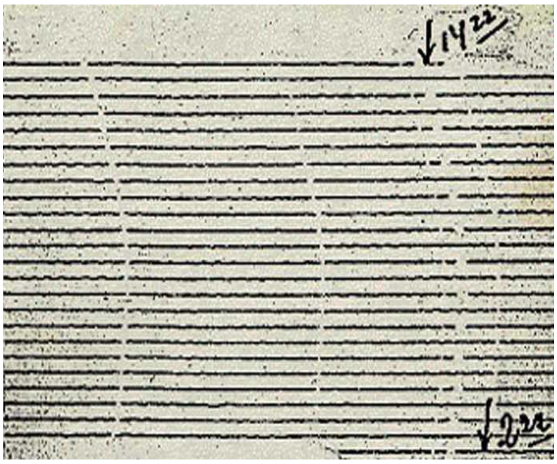
12h after



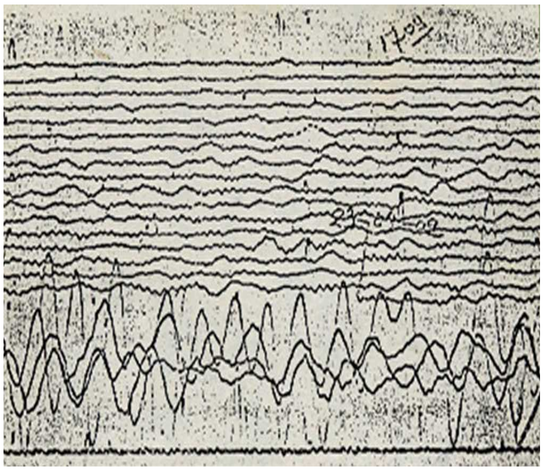
6h after

Fig. 2.2 Earthquake in Kurils islands, 08h 48m p.m., M=8.7, on November 6, 1958. Sections of seismograms registered 36 hours and 6 hours before and in the time of earthquake, 6 hours and 24 hours after the event:

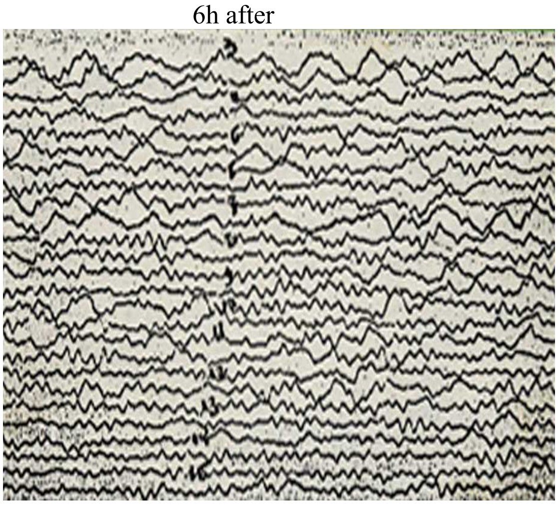
36h before



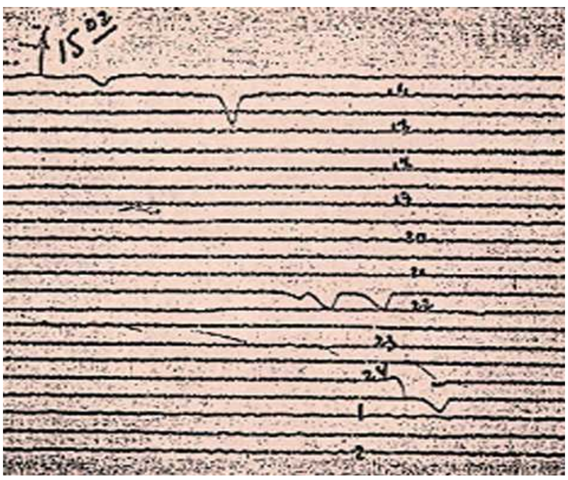
6h before



6h after



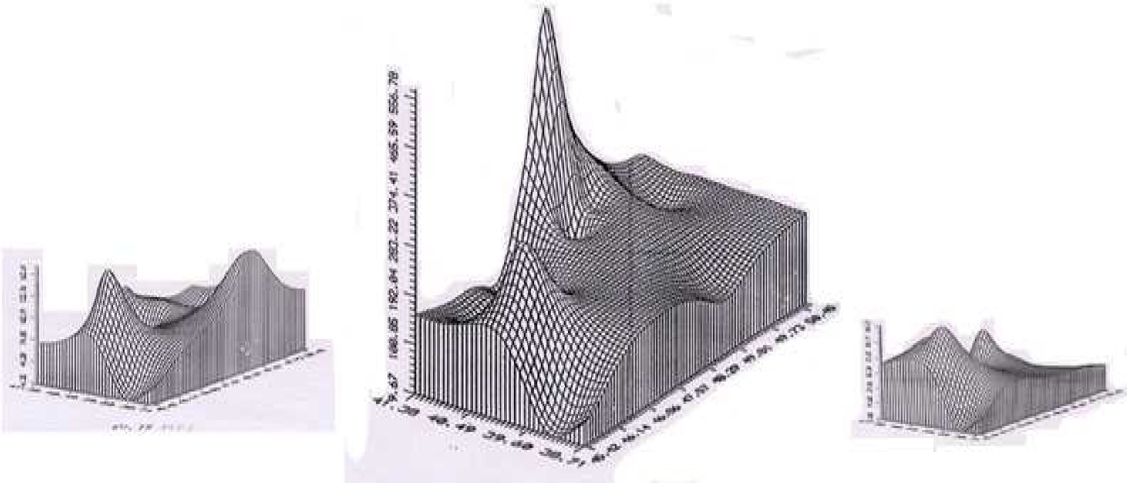
24h after



3. The microseism anomalies registrations by the group of ordinary Caucasian network analog seismic stations (placed at the territory 550 km x 350 km).

Fig. 3.1 Combined Caucasian maps of microseisms intensity changes 3 days and 1 day before and 1 day after earthquake in Caucasus on 07.12.1988 registered by group of Caucasian stations. They show that even 3 days before the events the level of microseisms intensity was anomalous.

3 days before 1 day before 1 day after

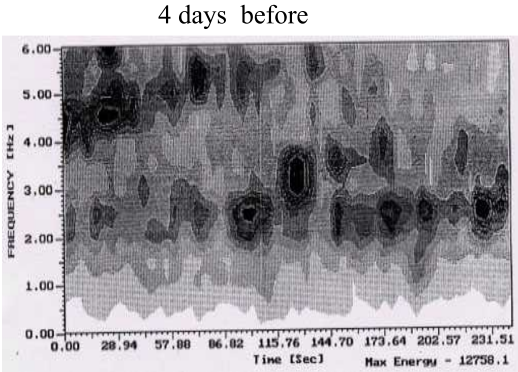


New physical notions on characteristic seismic emissions associated with earthquakes have led to development of criteria for the diagnosis and control of the stress state of earthquake source media

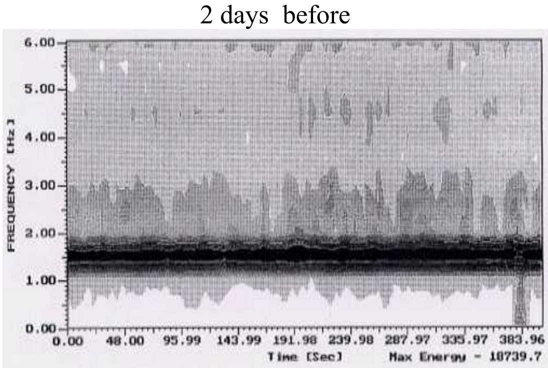
4. The microseism anomalies registrations by digital seismological system "9690"

Fig. 4.1 Spectral – temporal analysis of the microseisms anomalies invoke by the earthquake in Ismailly region of Azerbaijan 15/10/1993, registered before and after the event.

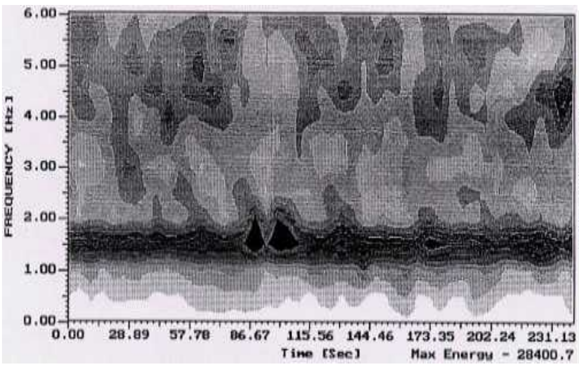
4 days before



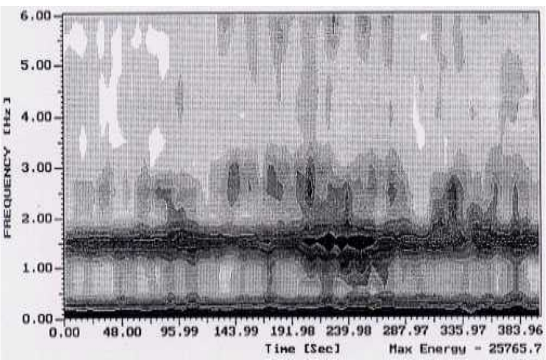
2 days before



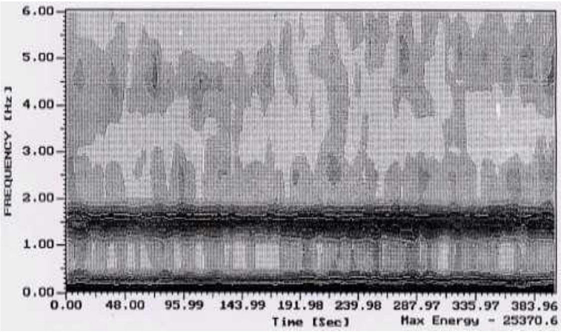
6 hours before



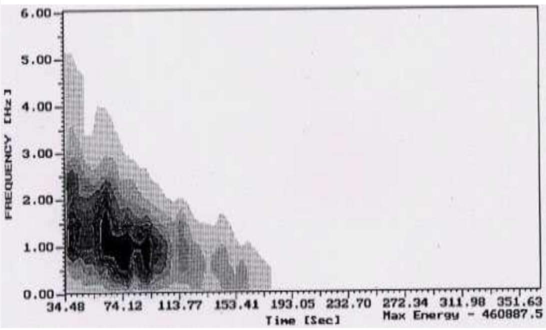
20 minutes before



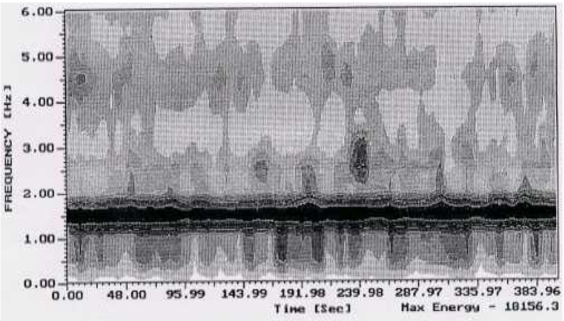
14 minutes before



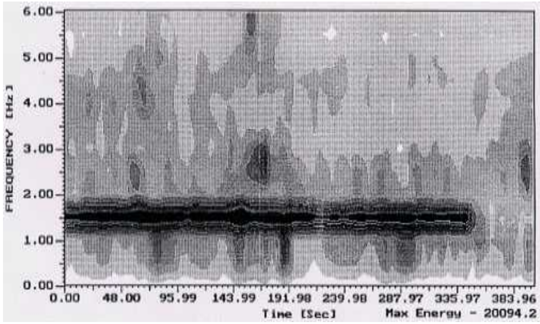
In the time of event



16 minute after



28 minutes after



5. Table 1 Number of revealed anomalies of weak high-frequency noises, microseisms, invoked by registered earthquakes, occurred in different regions of the World during the period 1977 – 2005.

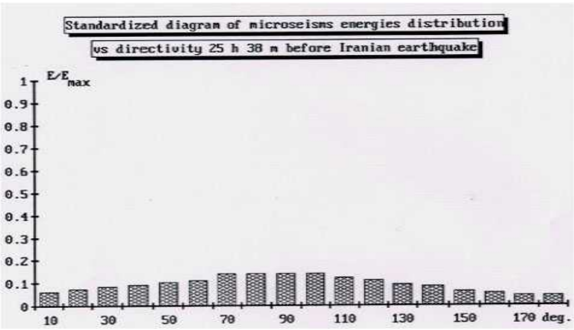
1. Number of anomalies registered by analogues seismological system		> 3000
2. Number of anomalies simultaneously registered by analog system		
- Azerbaijan – Tajikistan	(1.5 months, 1977)	24
- Azerbaijan – Belarusian	(3.0 months, 1979)	27
- Azerbaijan – Yakutia	(3.0 months, 1985)	78
- Azerbaijan – Kyrgyzstan	(1.5 months, 1986)	12
- Azerbaijan – Uzbekistan	(3.5 months, 1987)	93
- Azerbaijan – Tadzhikistan	(3.0 months, 1988)	22
- Azerbaijan – Kyrgyzstan	(0.5 months, 1988)	6
- Azerbaijan – West Ukraine	(2.5 months, 1989)	35
- Azerbaijan – Tatarstan	(1996-2005)	> 500
3. Number of anomalies simultaneously registered by digital system		
- Azerbaijan – South Ukraine	(3.5 months, 1991)	8
- Azerbaijan – North Iran	(2.0 months, 1993)	5
4. Number of anomalies revealed during the analysis of strong and catastrophic earthquakes, registered by Azerbaijan regular seismological net from 1950 (archive data)		> 700
5. Number of anomalies revealed during the analysis of NORSAR net data and records of the seismological system "9690" Earth Data ltd.		> 200
6. Cases of coincidence of registered anomalous manifestations with meteorological events		5 – 7 %
8. "Missing of the aim"		3 – 5 % (M>5.5)
9. "false alarm"		5 – 10 %

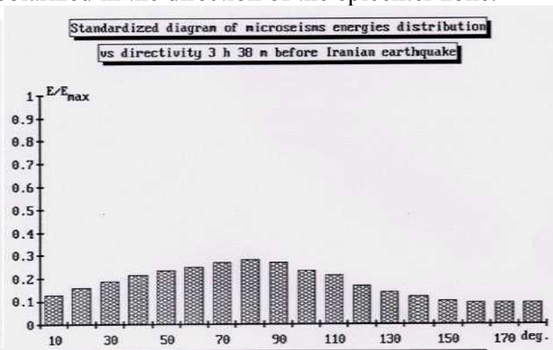
B. THE MAIN PARAMETERS OF ANOMALOUS MICROSEISMS.

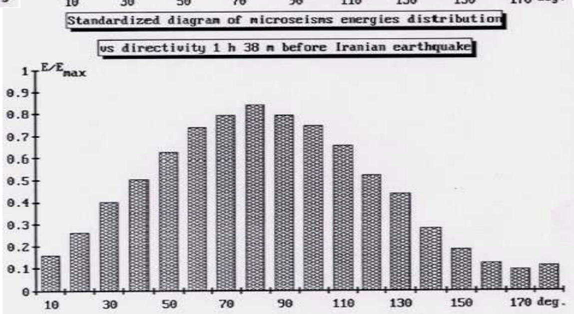
The main characteristic of the seismic emissions regularity before an earthquake: simultaneous decreasing of their dominant frequency; multi-stage increase in intensity; arising of the recurring impulses oscillations that are increasing in intensity and decreasing in time between their appearances; polarizing in the direction of the epicenter of the future earthquake.

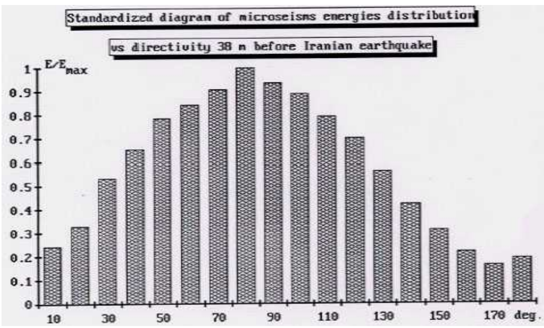
1. Polarization properties

Fig. 1.1-1.4 Examples of seismic emissions 25h38m, 3h38m, 1h38m, 0h38m before an earthquake in Iran, Tebes, 19h 38m 21s, on September 16, 1978 polarized in the direction of the epicenter zone.





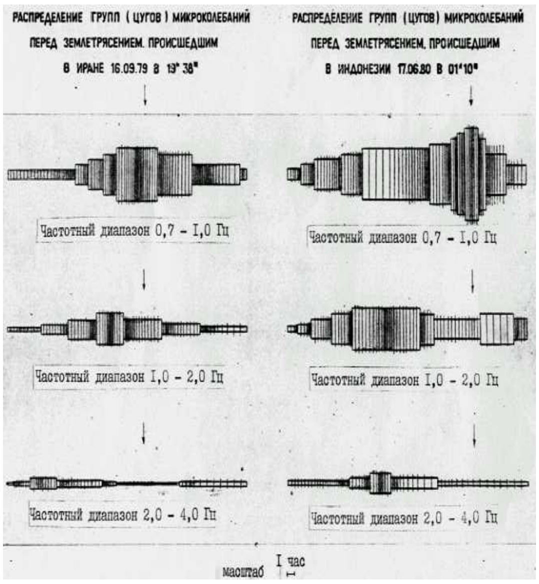


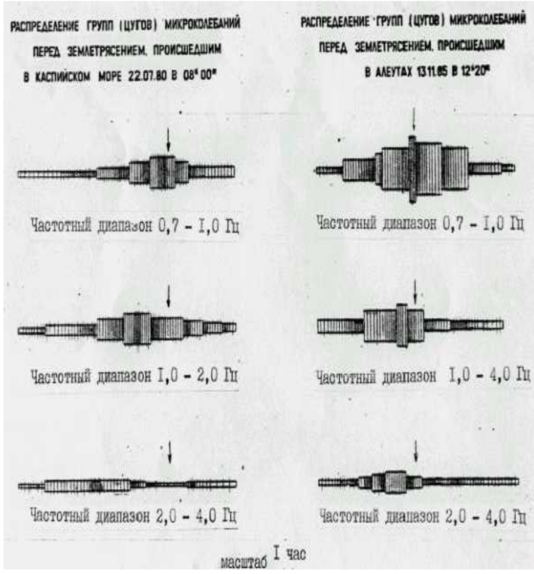


Examples based on observations clearly show the stability of polarization of the seismic signals in microseism anomalies and of the possibility of accurate determination of the prospective source.

2. Multi-stage increase in intensity of seismic emissions before an earthquake

Fig. 2.1-2.4 Micro-impulses distribution in different frequency range and time before the earthquakes: Iran 16.09.79, 19:35; Indonesia 17.06.80, 01:10; Caspian Sea 22.07.80, 08:00; Aleuts 13.11.85, 12:20





It has been revealed that several days or hours before the seismic events, depending on their magnitude, epicenter distance and geological conditions at the earthquake source sites, specific wave packets and groups of wave packets of micro-vibrations and separate short splashes of single waves are recorded. As time passes, they are replaced by a group of micro-impulses making a continuous chain, an appearance of a swarm with similar amplitudes. Then, against the background of this swarm, spasmodically appear separate micro-impulses with higher amplitude number, making a new swarm.

Afterwards, as spasmodically as before, separate micro-impulses appear with much bigger amplitude, which again transform into a swarm and so on, until an appearance of the main earthquake shock.

C. MICROSEISM INTENCITY DISTRIBUTION ON EARTH SURFACE

1. Role of microseisms in the study of the nature of a seismic gap

Conventional views of (and approaches to solving) the earthquake prediction problems are based on models of the Earthquake Source as an isolated, self-regulated, independent body. We propose a more holistic view where the Earthquake Source is considered a part of an entire system, in constant energy exchange with its containing environment. Analysis of microseisms behavior above and outside the earthquake zone has shown that seismic processes do not die out during the so-called "seismic gap" but are actually intensifying as seismic sources.

The earthquake source mechanism is acting to an energy pump, constantly absorbing energy from the medium (the Earth), thereby increasing its intrinsic energy. More energy is absorbed by the earthquake source and less released to the ambient medium. The intensity of microseisms noise at the earth's surface above the source reduces constantly during this period, explaining the observed decrease in pre-earthquake background seismic noises - the seismic "gap".

2. Influence of stress state of the medium

Having revealed the real nature of seismic gap effect, the researches showed that distribution of microseisms intensity on the Earth's surface is such that the most intensive seismic noises are registered not in seismic areas but in aseismic, quiet zones. Moreover, whereas in the period of earthquake preparation, on the surface above the seismic area a reduction of noise level is observed, outside the seismic area an uninterrupted increase of its intensity is registered.

Table 2 Microseisms intensity distribution on the Earth's surface in the seismic and aseismic zones

№	Period of registration	Background level of microseisms (dB)	Place of registrations	
			Regions	Country
Seismic zones				
1	16.07.77-02.09.77	6-18	Kulyab, Pamir,	Tajikistan
2	06.06.80-17.07.80	12-24	Siazan,	Azerbaijan
3	15.07.80-23.09.80	12-18	Ismailly,	Azerbaijan
4	14.05.81-10.09.81	12-18	Ismailly,	Azerbaijan
5	14.05.81-10.09.81	18	Shemakha,	Azerbaijan
6	14.05.81-10.09.81	15	Padar,	Azerbaijan
7	14.05.81-10.09.81	18	Tirdjan,	Azerbaijan
8	14.05.81-10.09.81	18	Pirkuli,	Azerbaijan
9	01.12.81-15.01.82	6-12	Ismailly,	Azerbaijan
10	14.04.86-27.05.86	3-6	Bishkek,	Kyrgyzstan
11	04.05.86-29.07.86	6-12	Tiksi, Saha-Yakutia,	Russia
12	14.06.87-30.09.87	6-9	Pap,	Uzbekistan
13	10.06.88-20.08.88	6-9	Batken,	Tajikistan
14	01.10.88-15.10.88	3-6	Osh,	Kyrgyzstan
15	12.06.89-25.08.89	3-6	Mukachevo,	Ukraine
16	26.06.91-09.10.91	6-9	Feodosya,	Ukraine
17	20.09.93-30.11.93	6-12	Tebriz,	Iran
18	10.02.00-12.05.00	12-18	Saatli,	Azerbaijan
19	01.03.02-12.10.04	18	Shemakha,	Azerbaijan

№	Period of registration	Background level of microseisms (dB)	Place of registrations	
			Regions	Country
Aseismic zones				
1	09.06.77-19.10.77	24-30	Ganja,	Azerbaijan
2	21.10.77-25.12.77	30-36	Kuba,	Azerbaijan
3	15.11.77-25.11.77	36-42	Yalama,	Azerbaijan
4	09.09.78-13.12.78	24-36	Samur,	Azerbaijan
5	01.02.79-25.05.79	24-36	Gyadik,	Azerbaijan
6	25.08.79-22.11.79	24-42	Rechitsya,	Belarusian
7	12.11.79-24.12.79	30-36	Gobystan,	Azerbaijan
8	15.11.80-25.11.80	24-36	Gendob,	Azerbaijan
9	10.06.82-25.12.82	24-36	Gobustan,	Azerbaijan
10	10.06.82-20.12.82	36-48	Atbulag,	Azerbaijan
11	08.07.83-30.12.83	30-36	Gendob,	Azerbaijan
12	24.12.83-27.04.84	36-48	Atbulag,	Azerbaijan
13	05.05.85-15.10.85	30-42	Navagi,	Azerbaijan
14	10.01.83-15.08.86	30-36	Gendob,	Azerbaijan
15	29.05.84-20.09.86	18-24	Divichi,	Azerbaijan
16	10.11.84-15.12.87	30-42	Lokbatan,	Azerbaijan
17	29.05.86-26.02.92	36-42	Gendob; Apsheron,	Azerbaijan
18	25.02.87-15.02.94	36-48	Binagadi,	Azerbaijan
19	01.03.94-20.09.95	30-33	Nabran,	Azerbaijan
20	01.09.95-30.09.96	30-36	Apsheron,	Azerbaijan
21	20.10.96-30.05.05	21-30	Elabuga, Tatarstan,	Russia
22	10.09.99-10.02.04	24-30	Mingechevir,	Azerbaijan
23	10.10.99-15.03.05	28-33	Haldan,	Azerbaijan

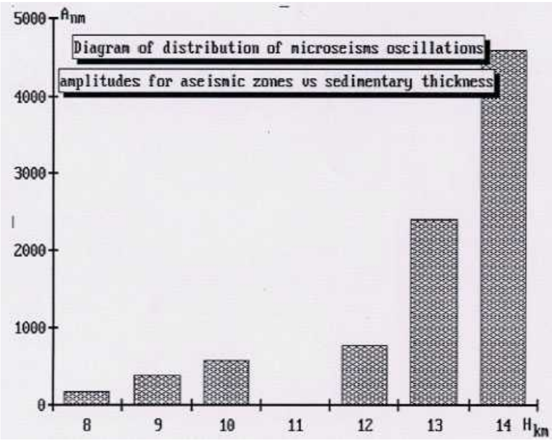
The physics of these effects is connected with the fact that a stressed zone screens wave radiation coming from without. As the level of stress state of the medium increases during the period of earthquakes' sources activation, level of noise field on earth surface permanently decreases. Thus, the specificity of seismic noise intensity change revealed by us allows judging the level of stress state of the medium. Comparison of levels of seismic noises for 19 seismic areas and 23 aseismic regions showed that seismic noise in quiet areas is considerably higher than in active zones, approximately in 4-12 times. From that point of view becomes understandable a physical meaning of so called seismic gap before earthquake. In active area exactly in the period of preparation of earthquake the level of its own micro-vibrations increases, which has a shield (absorbent) influence on seismic radiation coming from outside, and is observed taking into account above mentioned correlation, as a seismic gap before discharging. Thus in the active zone the intensity of microseisms above the surface always will be less then in non active zone. The revealed phenomena gives new idea where seismic network should be developed for earthquake prediction purposes.

D. EARTHQUAKE PREDICTION SEISMOLOGICAL SYSTEM

1. Influence of sedimentary layer thickness

Why so little progress has been made in earthquake prediction using seismic data? The answer to this question appeared after many years of registrations strong and weak signals in different geological situation and different stress state. The comparison of the all collected data could explain such phenomena.

Fig. 1.1-1.2 Distribution of microseisms intensities in aseismic and seismic zones vs sedimentary layers thickness.



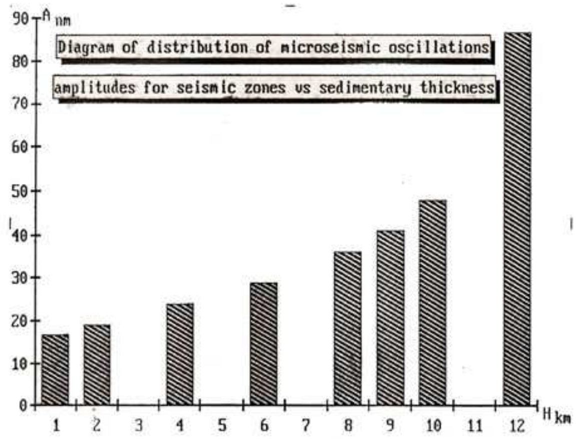
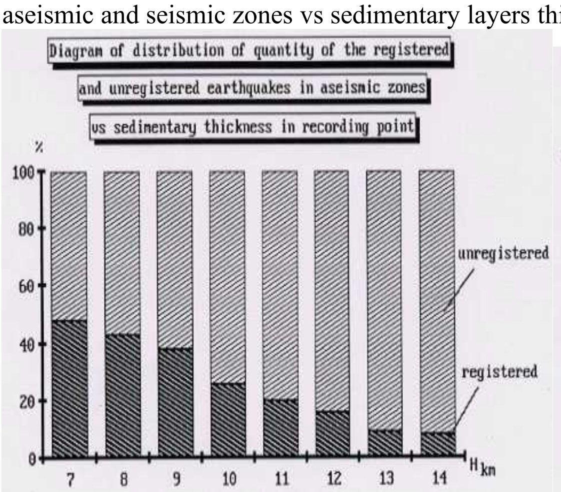
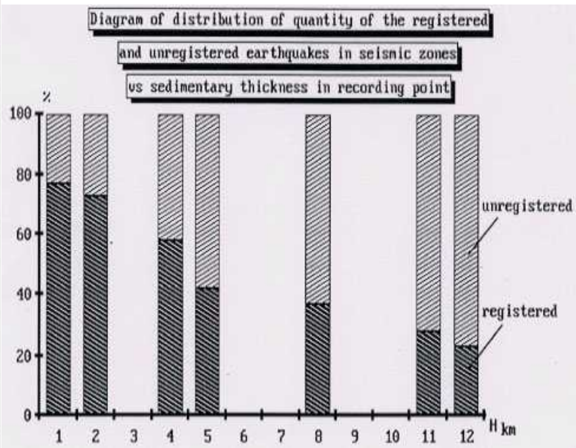


Fig. 1.3-1.4 Distribution of quantity (in %) of the registered and non registered earthquakes in aseismic and seismic zones vs sedimentary layers thickness.





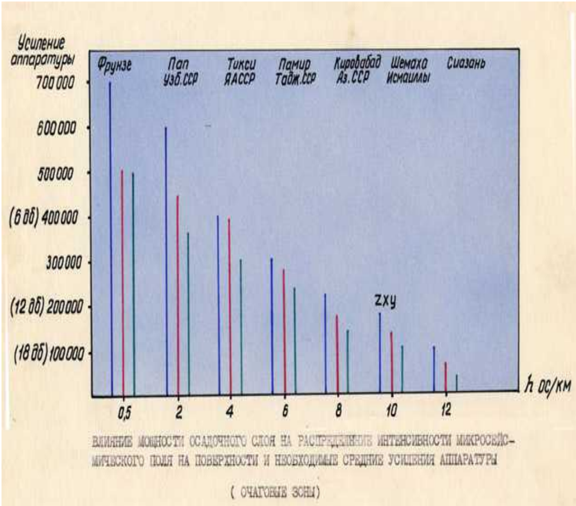
Our long term observations in different seismic and aseismic regions shown that existing seismological networks do not meet these criteria. The ordinary seismologic observation network set up to monitor strong seismic events like earthquakes and explosions. This network should be set up on basement rock with a minimum thickness of sedimentary column as this arrangement significantly absorbs the intensity of strong signals. The requires for networks for recording weak precursory signals with intensity close to the Earth's natural background seismicity at the point of observation are different. Seismic networks set up for forecasting earthquakes conversely must be placed in aseismic regions with thick sedimentary column which are natural amplifiers of weak signals.

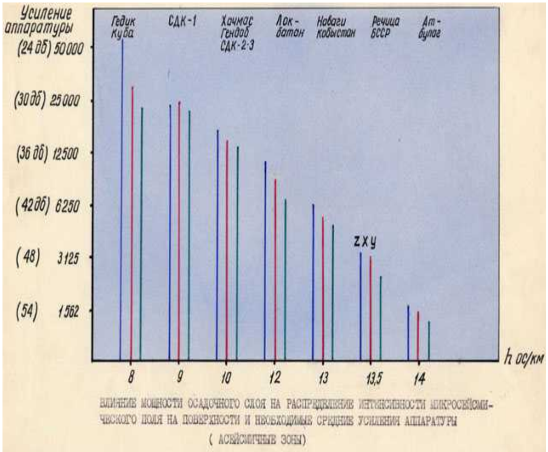
Analysis of the dependence of seismic noise intensity distribution on sedimentary layer thickness for aseismic zones has shown that when thickness changes from 1 to 15 km the noises' level changes from several hundred to several thousand units. The analysis of the same dependence for seismic zones has shown that the noises' level changes from 15-20 to 85-90 units. The opposite situation is observed during registration of strong signals: earthquakes and explosions.

The analysis of the percentage of distribution of the number of registered seismic events to unregistered (occurred in the same period of time) depending on sedimentary layer thickness, showed, firstly, that an increase in sediment thickness leads to a decrease in the number of registered events and, secondly, that the quantity of registered events in seismic zones exceeded greatly the quantity of events registered in an aseismic zones.

Fig. 1.5-1.6 Influence of the sedimentary layers thickness on distribution of microseisms intensities at the Earth surface and **required amplifications of the seismic stations for registrations microseisms anomalies.**

Seismic zones Aseismic zones





2. Relationship between seismological and other geophysical fields

We have also reviewed the conventional approaches to earthquake prediction. It requires measurement of the multiple geophysical fields, requiring that one precursory field observation must be confirmed by changes in other fields. But we have shown that they cannot all appear at the same time. The decrease of the dominant frequency of anomalous microseisms over various periods of time is a major factor which activates one or more of the precursory events in other geophysical fields. A change in one geophysical field predicting a chain of precursory, and the time of the main shock related (depending of the magnitude of the events) with the time delay between different geophysical precursors.

CONCLUSION:

1. We have discovered a reliable seismic precursor;
2. Have studied its amplitude, frequency and timing manifestations in period prior to earthquakes;
3. Have studied the influence of the stress state of medium on microseisms behaviour and distribution on the earth surface;
4. Have studied the influence Influence of sedimentary layer thickness on weak (microseisms) and strong (earthquake, explosions) behaviour and distribution on the earth surface;
5. Have studied requirements for amplifications of the seismic stations for registrations microseisms anomalies in seismic and aseismic zones with different thicknesses of the sedimentary layers.
6. Offered a methodology for earthquake prediction using a complex of geophysical fields;
7. Have worked out criteria of seismic system to predict earthquakes on the bases of discovered precursor.

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