A NEW CONCEPTION FOR EARTHQUAKE PREDICTION

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Introduction

The past experience of earthquake prediction (Aki, 1996, Sobolev, 1993) shows the single methods used separately from each other are not successful. It is the reason for novel conception development. Test for the conception is being fulfilled in the active continental margin region, in the Far East area of Russia, Japan and Taiwan island. The conception includes joint interpretation of different precursors at different stages as the seismic source is progressing.

Scientific-organising principles

Data integration in the scientific earthquake prediction is realised both at the federal and regional level of the relevant organisations. This problem is not only of scientific, but much more practical interest for some seismic active regions, for instance, for the Far East of Russia, which is much influenced by strong earthquakes.

The main structural elements in the Russian forecast system include the interdepartmental Russian Expert Council on Earthquake Prediction and Seismic Hazard Assessment (REC), the Federal Centre of Earthquake Prediction - FCEP - (the Geophysical survey RAS and Emergency Ministry of Russian Federation), regional branches of FCEP in the main seismic active regions of the country. The regional branches of FCEP are aimed at collecting local seismic prognostic information and its primary evaluation in order to inform immediately the central FCEP through INTERNET network in a case of any trouble sighs.

The latter fulfils analysis of the information received, and if threatening evidences provide consideration of the seismic situation the REC meeting it is held. If REC declares the seismic alarm announcement in any region of Russia, this decision is immediately sent into Emergency Ministry of Russian federation, regional government bodies and Emergency Ministry special subdivisions. The information interaction among all the sections is fulfilled in interactive regime through the special locked site of the INTERNET network.

At present all the subdivisions of the system function. Improvement of their persistent cooperation will be done in the nearest future.

The models of earthquake source

In a framework of tectonophysical description an earthquake source model is considered as a structure of the discharge of long living tectonical stresses, causing elastic energy release and spontaneous, unstable spreading motion on ready, updated or newly arisen break-up (or weakened zone). It is important to note that a bifurcation of the process with returning considered system to the stable state may exist. This implies an important premise that prediction is of probabilistic nature.

Location of seismotectonic surface ruptures, distribution of the aftershocks, as well as other manifestation of strong earthquakes studied can evidence association of their sources with zones of the largest deep faults. The seismic active faults often demonstrate distinct creep mobility or moderate seismic activity for several years before the strong earthquake.

Moderate seismic events (M<6.0) are characterised by relatively simple source structure, which should be considered as a geological motion on the plane of large fault. More strong earthquakes with Ms=>6.0 demonstrate location of the sources in the zones of juncture or intersection of large faults. Herewith primary seismic ruptures and aftershock clouds indicate the planes of the faults, forming disjunctive knots. The high magnitude seismic sources are most complicated in the upper portion of the Zavarithsky-Benioff zones. The complex source structure is also typical to high magnitude earthquake swarms. Surficial and deep manifestation of such seismic events testifies to the volumetrical structure of the seismic source and associating of the separate earthquakes with large seismogenic block limits both sloped and subhorizontal tectonic, geological and geophysical boundaries bound these blocks from under the bottom (Rogozhin, 1993).

Precursor integrations

The adopted methodology of investigation on the seismic prognosis is based on the integrated use of a set of precursors in support to the operative evaluation of the seismic situation (Aki, 1996.). The various precursors are grouped dependently on different temporal manifestation. Identifying precursors characteristic for different stages of seismic source preparing, it is possible to realise in practice monitoring for the process of development of the seismic source area. Thus, from many and, frankly speaking, not quite reliable, uncertain or indistinct prognostic parameters there is formed more reliable and certain prediction. Use of existing schemes of general or detailed seismic zoning for the area under investigation makes the prognosis more reliable (Reisner, Ioganson, 1993; Rogozhin et all, 1998). The detailed information on the spatial position of expected earthquake sources allows to discriminate potential or real registered seismic sources, which occupy not more than 20-30% of the whole territory of the seismic active region. So it is possible to conduct precursors monitoring not in the areas of the whole region but in its rather limited part. So, it is possible to estimate the possible maximum energy of expected in one or other area earthquakes.

Three basic components of the forecast system

Technological base

The existing seismological observations, including global, national, regional and local levels, are that technologic base, which allows to realise the proposed strategy. In general these are presented by world and Russian network of seismic stations, as well as few geodynamic and seismic prognostic testing areas on the territory of our country, for example Kamchatka testing area (Kronothcoe..., 1998). Since it is difficult to expect in the near future essential extension of the seismological and geophysical observation networks, as well as equipping by some new observation systems, it appears to necessary base on more comprehensive analysis of observation data of the existing networks.

Potential seismic sources

The whole revealed totality of seismic source areas serves as natural geographical nodes required for spatial organisations of the monitoring system. In other words, forecast is formed not in the region in whole, but in concrete seismic source areas - both known and potential.

Distributed systems and INTERNET- technology

The system of the information transfer is based on INTERNET-technologies and ideology of distributed systems. Experts from different regions, as well as experts of REC and FCEP can submit their considerations in the mode of real time, placing them in their own servers, and thus form new integrated ideas through the system of the hyper references.

Potential source of earthquakes

Thorough research of epicentral sources of earthquakes for the past decades has shown that the source of strong and strongest earthquakes are of stable structure in geological environment. Seismic shocks repeat from time to time in the same sources. The average recurrence interval depends on geological tectonic position of source zones (Rogozhin, 1998).

It is of great significance that the same seismoactive structures with rare exception are characterised by the segments, giving rise great earthquakes and the segments that can be considered faintly dangerous seismologically. Moreover, both kinds of segments can be closely adjacent to each other. Thus, the concept of relatively compact potential sources of earthquakes - PSE can be used for seismic hazard assessment for any territory (Reisner et. al., 2000).

Method of potential seismic source distinguishing

Recently the over-regional seismotectonic method has been developed (Reisner, Ioganson, 1993), allowing to distinguish and map the potential seismogenic structures and also evaluate their prognostic seismic potential (predicted maximum magnitude of the expected earthquakes – *Mmax*, Reisner et al., 2000).

The over-regional seismotectonic method is based on typification of the Earth's crust which is performed using parameters of its modern structure and state (heat flow, thickness of the Earth's crust, height and contrast of the relief, isostatic anomalies, thickness of the sedimentary cover). Data processing is realised with using of the cluster analysis. These data allow also distinguishing the modern endogenous regimes. The obtained results prove that in the study area platform, orogenous, rift and tafrogenous endogenous (geodynamic) regimes are observed. The comparison of the obtained typification with seismological data allows to assign Mmax for separate types of Earth's crust.

Application of over-regional seismotectonic approach for the study area (most part of the Northern Eurasia) resulted in a new scheme of spatial distribution of seismic potential - *Mmax* which are determined for each elementary cells of 20'x30' grid in size.

Distribution of the predicted values *Mmax* relatively to such active (from geological and seismological points of view) structures, as faults, disjunctive knots and the Earth's crust blocks may serve as a base for spatial subdividing of potential seismic source zones (PSE).

Such schemes of the PSE position are performed for different regions of Russia, for instance, for the Kuril-Kamchatka region. Fractional typification of the Earth's crust and evaluation of maximum possible magnitudes for the expected earthquakes in the Kuril—Kamchatka island arc allows to map the concrete PSE, characterised by real orientation on surface of the Earth's crust according to stretching seismogenic structures and real size (length and width) of the potential sources depending on the position of the elementary cells, where *Mmax* has been evaluated.

If one has the information about the spatial position of stable seismic sources, occupying not more than 20-30% territory in seismic dangerous region, it is possible to carry out monitoring of precursors not on the whole region territory but within of its rather limited part. Therefore, possible maximum energy of the expected earthquake in one or another PSE can be predicted.

The integrated analysis of the geological-geophysical and seismological data, involving in the over-regional seismotectonic approach, has resulted in recognising zone PSE and estimating their maximum possible magnitude within a number of other vast regions of Northern Eurasia (Estern European platform, Kolsky peninsula, Timan-Pechora, Altai, Ochotia). It should be emphasised that in all cases these PSE occupy significantly lesser areas than traditional seismic source zones that makes the seismic hazard assessment more precise and concrete. Apart from this, comparison of the registered and potential strong earthquake sources within Ochotia (the Far East) shows that PSE zones are distributed wider than real seismic sources of the earthquakes occurred.

Hierarchical levels of prediction

Macro-level. Macro-level deals with a space-temporary distribution of hypocenters of earthquakes for the current stage. There are revealed trends of grouping (dig earthquakes and so-called "chains" earthquakes). Probability of the activation one or another tectonic active structures is evaluated. First of all, these structures are marked by deep faults, tectonic steps, particularities of gravity field, etc. So, for instance, in the long-term aspect (scale of 5-50 years) so called "age" of the source area is studied. The “age” is counted from a moment of the last strong earthquake and normalised for a recurrence interval (range of 0 - 1). Distribution of this parameter before the strong Kronotsk earthquake 1997 in the eastern Kamchatka region has allowed to define the position of “ripening” seismic source in advance. In this case the significant anomaly was observed in the region. The anomaly demonstrated entering of the potential source area in "critical age".

Meso-level. At this level the various structural reconstructions of the geological environment, grouping of earthquakes, occurrence of specific earthquakes with deep sitting hypocenters and other peculiarities of the local seismicity are studied (Rogozhin, Zakharova, 1998). Weak and moderate earthquakes themselves act as natural sensors, carrying information about the character of the fault zones activation, including their morphology, kinematics and other aspects (Yunga, 1996). So, for more than a year before the Kronotsk earthquake the moderate seismic events with untypical focal mechanisms were registered. As a result of the focal mechanism monitoring the approximate time and place of the arising seismic event were predicted.

As for the foreshocks of a main event, according to the Seismological bulletin of Geophysical Survey of Russian Academy of Sciences, concentration of weak seismicity within the source area was registered, where 27 quakes occurred approximately for a week before the main shock, referring as the foreshocks (Rogozhin, et al., 2000).

Micro-level. At this level the spectral composition of seismic waves is traditionally investigated. The sort of "hardness" of seismic source radiation is defined. It is also studied how typical (or anomalous) is the character of first arrivals of seismic S- and P-waves on the background of usually observed picture for similar pair of seismic source - seismic station.

The other kind of information about the present stage of the investigated source zone are electrical and electromagnetic precursors, which appear several days or several hours before expected strong seismic shock. So, for 40 days before the Kronotsk earthquake of December 5, 1997 in vicinity of city Petropavlovsk-Kamchatskiy (approximately in 250 km from the epicenter) the reliable and significant disturbances of elecrto-telluric field were registered by the instruments of the test area (Moroz et al., 1998). The other example is as follows: 4,5 hours before the Shicotan earthquake October 4, 1994 the prognostic station in Inubo, Japan (approximately in 1200 km from the epicenter) the sharp changing intensity of the pulsed electromagnetic radiation was observed (Shikotanskoye..., 1995).

Successful prediction of the earthquake

The Kronotsk Earthquake of December 5, 1997 is one of the strongest seismic events in the Kamchatka region. Among other similar events the earthquakes of 1737 and 1917 (M~=8) can be mentioned, as well as Petropavlovsk (M=7.2) and the Ust’-Kamchatka (M=7.8) earthquakes of 1971. The analysis of the Kronotsk earthquake precursors showed that significant variation of the number of prognostic signs simultaneously occurred (Kronotskoye..., 1998). This is the result of an essential modernisation both Kamchatka regional seismological network and systems of geophysical observations as a whole.

As stated above, the source of the Kronotsk earthquake is distinctly mapped in the system of potential seismic sources to east from Kamchatka peninsula. Its preparation and maturation were manifested on macro-, meso- and micro-levels. Comprehensive approach integrated to the analysis of the various temporal precursors under observation of the Kronotsk potential source has allowed 10 months before the seismic event to announce at the meeting of Russian Expert Emergency Council a seismic alert on Eastern Kamchatka and transfer in advance the prognostic information to the Emercom of Russia. The magnitude and time (within a year) were predicted rather precisely. The location of the epicenter was determined with an error of only 100 km. Thus, the successful scientific forecast of the strong earthquake was realised.

Conclusions

As stated above the new conception for earthquake prediction includes a set of organising and scientific approaches. The major scientific achievements involved are the new ideas on seismic source model as well as application of the over-regional seismotectonic method. The organising part of seismic prognosis is connected with proper functioning of relevant organisations aimed at obtaining qualitative data of observations and creating of reliable information system. The scientific novelty of the conception is also in the joint analysis of information about seismic hazard assessment (PSE) of investigated region and integration of various precursors of different nature and time stages of effect occurence.

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