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Geophysics and Seismic Hazard Reduction

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1 Introduction to the International Research on Geophysics and Seismic Hazard Reduction

The earthquake is a natural phenomenon, which often brings serious hazard to the human life and material possession. It is a physical process of releasing interior energy of the earth, which is caused by interior and outer forces in special tectonic environment in the earth, especially within the lithosphere. The earthquake only causes casualty and loss in the place where people inhabit. Seismic hazard reduction is composed of four parts as seismic prediction, hazard prevention and seismic engineering, seismic response and seismic rescuing, and rebuilding.

Geophysics, which plays a critical role in human's survive and social development, is one of the important edging aspects which has been developing rapidly since the 20th century. Geophysics, by using various physical methods, e.g. mechanics, acoustics, electrics, magnetics, calorifics, optics and radiology, probes the earth's interior structure, geodynamics and evolution, and can be used in prospecting and exploring resource, predicting and preventing geological disasters, protecting ecosystem and monitoring pollution.

According to the estimation done by All-Russian Institute of Scientific and Technical Information, there are roughly more than 200 important research projects and about 400 symposia published in the aspects of international geophysics and seismology during the 20th century. The scientific funds of Europe and U.S. establish lots of crucial programs, including "Global Change Action Program", "Forwarding researches in the earth's environment by using satellite information", "European layout in selecting great projects of natural disaster and managing their budgets", among which many programs are closely related to geophysics and seismic hazard. Physical methods and measurements are used to study the temporal and spatial changes of geophysical field, e.g. mechanics, acoustics, electrics, magnetics, gravity and the crustal deformation, and to predict the earthquakes and alleviate the seismic hazard. The even-distributed global seismic networks provide a robot support for the prediction of the earth. There is much work needing to be done for the Earth informatics and the relations between the information of seismic wave spectrum and earth medium layers. Reusing the data from global underground nuclear explosion should be organized. The seismic hazard assessment needs the knowledge of seismic focus, energy equivalent, seismic wave energy propagation, the variety of earth medium property, map of stress distribution, physical chemistry effect and the evolution of the earthquake in the past time and present. The earthquake mechanism given by the experimental seismology and the accelerating mechanism of earthquake are the experimental knowledge for predicting earthquake and mapping the potential seismic source zone. Large amounts of data and research results of geophysical anomaly related to seismic hazard give the scientific fundament for governments and management departments to make suitable decisions on hazard reduction. As discussed above, geophysics plays various roles in different parts of hazard reduction.

2 The Function, Influence and Meaning of the Geophysics on the Seismic Hazard Reduction

2.1 Summary of funding programs of seismic hazard reduction in the aspect of geophysics

The geophysics and space physics subjects of the Chinese national natural fund mainly support the research directions as follows: geodesy (D0401), seismology (D0402), geomagnetism (D0403), geoelectricity (D0404), gravity (D0405), geothermics (D0406), deep geophysics (D0407), geodynamics (d0408), exploration geophysics (D0409), space physics (D0410), instrument and experiment (D0411), and space environment (D0412), etc. The mainly funded research directions of geophysics subjects since 1987 are listed in Table 1. Based on the reform of Chinese science and technology system since the 1990s, the development strategy of the

geophysics subject is established as (1) developing the theories and methods of the applied geophysics for the energy exploration and engineering construction; (2) developing the theories and methods of focus physics, earthquake prediction and environment survey for reducing the natural hazards of earthquakes, floods and environmental protection, etc; (3) enhancing the research on the synthesized geophysics investigation and experimental geophysics of the lithosphere, establishing quantitative models of Chinese lithosphere structure and its evolution, studying the material transformation in the earth's interior, the construction of tectonics, the resources and the deep process and dynamic mechanism of the occurrence and evolution of the natural hazards. In the past tens years, the funding programs on the seismic hazard reduction are listed in Table 2.

2.2 The effects, influences and meaning of the programs funded by the geophysical section in the seismic hazard reduction

The pregnancy and occurrence of the earthquake in the mainland and offshore are caused by the special tectonic environment of China. The reason and deep background of various regional earthquakes are different. It is important to study the detailed structure of the lithosphere, the fault's extension, type and property in order to understand the deep medium background and motion process of earthquakes' occurrence and pregnancy. To study seismic mechanism, prediction and engineering is also important for the research of global earthquakes.

The plenteous results have come from the hard work in the past tens years. The theories, techniques and methods programs on the geophysical field observations enhance the abilities of observing Chinese geophysical field, and give a more reliable knowledge of Chinese geophysical fields. The results conceive a steady basis for the seismic pregnancy. The theories, techniques of earthquake observations and the research on seismic in-

Table 1 The funding programs of the geophysics and space physics section course since 1987

Section code	D0401	D0402	D0403	D0404	D0405	D0406	D0407	D0408	D0409	D0410	D0411	D0412
No.of free applications	84	120	59	30	17	10	79	70	213	146	31	2
No.of Key programs	3	5	3	0	0	0	8	4	2	7	0	0

Table 2 Since 1987 the related programs on seismic hazard reduction supported by the geophysics section

Study realm and directions	1987—1990	1991—1994	1995—1998	1999—2003	Total
The research programs on observational theory and technology and methods	30	49	36	70	185
The observation and research programs of the whole country and regional geophysical fields	32	27	39	34	132
The programs on the Tibet plateau	2	4	7	15	28
The instrument and experiment programs related to geophysical field observations	12	3	7	15	37
The research program on the theory, technology and methods of the earthquake observations	8	14	14	18	54
The research programs on the earthquake pregnancy mechanism, seismic source process and seismic activities	1	7	12	10	30
The research programs on earthquake pregnancy experiments, seismic experimental fields and seismic observational intruments	1	2	1	4	8
The observation and research programs on earthquake pregnancy environment	6	3	7	11	27
The programs on earthquake prediction methods	2	6	3	0	11
The programs on seismic hazard prevention(including the earthquake risk analysis and seismic hazard prediction)	2	2	1	1	6
The programs on earthquake relief	0	0	1	1	2

struments enhance the earthquake observation abilities. And the observation and research in seismic activity, earthquake pregnancy environment, the experiments on the earthquake pregnancy and seismic fields give data foundation for pregnancy mechanism and seismic source process, and the work is very significant for the earthquake prediction, seismic hazard (including the seismic hazard analysis, hazard prediction and strong motion) and earthquake relief, etc.

The seismic observation ability is improved by deploying the digital seismic recording system controlled with laser, the broadband portable seismic recording system and the theory and technique of the acceleration earthquake detector combined with optical integration. The precision measurement of solid tide for earthquake precursor is possible because of the work on the horizontal fold pendulum measurement method for the tilt solid tide and the minimized cylinder symmetry two dimensional fold pendulum instrument.

Making use of the joint inversion results from the seismic sounding, natural earthquake,gravity,geo-electricity and geo-thermics, the continent lithosphere structure of the north China and the crust and upper mantle structure of the west and south-west edge of the Ordos were inverted and the tectonic evolution process and dynamic mechanism of the crust and upper mantle structure in the region were discussed. The relation between the courier thermal program, Bouger gravity anomaly, and the earthquake activity was studied and the relation between the continent magnetic characteristics and the intraplate earthquake was given as well. The deep environment and structure of the formation of strong earthquakes were studied. The geodesy technique has been extended to the physics of the Earth's interior and the mathematical model for the time-space evolution of the strain field of the north China was discussed for the regional crust motion nowadays. The methods combined with the technique of GPS, seismology, geophysics and geology was considered to be an effective method for studying the structure of the Earth's interior and the method could also be used to monitor the crust motion and the earthquake occurrence. Further work on the modern crust motion is very important for the lithosphere dynamics, the pregnancy environment of strong earthquakes and the seismic hazard prevention (Lu Yang, 49674209). Based on the GPS observation data from 1996 to 2003 in the Jiashi, Xinjiang and the adjacent regions, the modern crust motion displacement field and stress field with the uniform high accuracy and high resolution were obtained with the advanced technique of the InSAR (Qiao Xuejun, 0304002). The detailed crust structure was probed with the modern deep geophysical sounding techniques (Liu Qi-yuan, 49834050). Using the near-field records of the earthquake cluster in Jiashi, Xinjiang in 1997, the accurate portraits of the main events were inverted by using the method of strong motion synthetic seismogram and the detail rupture process and basic characters of the Jiashi Earthquake cluster were analyzed systematically and the formation mechanism of strong earthquakes was specified (Zhou Shiyong, 40174015). Combined the data with geodesy measurements, geology, seismology and geophysics, the time-space distribution and kinematics and dynamic evolution of the Jiashi strong earthquake cluster were studied, the deep tectonic pregnancy background in the region was recognized and the transport rule of the strong earthquakes in this region and triggering mechanism among strong earthquakes, the seismogenic pattern of the Jiashi strong earthquakes and the cause of the strong earthquakes were discussed. The results offered an important reference for the earthquake hazard analysis in this region.

The works on the fracture micro-mechanism of rock and the theory of fuzzy strength (Zhang Yuzuo, 48900032), brittleness solid fracture process and mechanism (Guo Ziqiang, 49070220), the shear fracture energy measurement of rock under high temperature and high pressure (Zhang Liu, 48770246), the non-linear dynamics and the rupture process fractal Geometry of rock samples (Chen Yong, 48970233), etc., were supported. The composite 3-dimensional fracture experiment of surface crack II-III under the uniaxial compressional loading was designed to explain the non-coplanar, multiplicity and goose-queued outcrop of the earthquake faults (Li Shiyu, 49774217). The damage mechanics and non-continuum mechanics were used to construct the relation between the inner variation parameters of the micro-crack, micro-hole and their variations and the macro-stress-strain, and to investigate the theory and methods for calculating the inner stress field variation in crust and micro-crack parameter variation from the data of gravity observations near surface and the GPS observation. The theoretical relation between the stress-harm couple effect of the seismogenic process and the surface gravity variation was given by Zhang Yongzhi (49774214). The non-steady and non-linear

signal processing method was used to analyze and process the nine earthquake sequences, such as Tangshan earthquake, the sequences in circum-capital region, and macro-rock sample experiment series through three aspects. It is found that there are non-linear logarithm relations between the earthquake nucleation time and the magnitude, between the earthquake nucleation critical dimension and the magnitude, and the velocity of the metastable rupture propagation in the earthquake nucleation process is the order of magnitudes between millimeters and centimeters. These results are used to the earthquake monitoring in the capital region and the rock-burst experiment in the order of some kilometers (Zheng Zhizhen, 49774215). On the base of the recent development of broadband digital seismology, dynamic problem on the source process of natural earthquake was inverted and used to investigate the earthquake mechanism, seismogenesis, seismic hazard and prediction. On the base of the new source parameters obtained from the digital seismic data, the seismic source complexity was studied from the dynamic aspect (Chen Yuntai, 49774218). The focal mechanism solutions inverted by the methods, such as genetic algorithm, were used to analyze the seismogenic tectonics of the Nan'ao earthquake in Guangdong in 1918 (Lin Banghui, 49574209). The infinite particles theory of the probability is beneficial to establish the space theoretical model for the earthquake activity evolution with time. With the existing experiences, the nonlinear admixture model can be constructed by combining the earthquake activity and kinds of geophysical observational data. Based on the all kinds of testing, the kernel function is used to obtain the probability estimation which varies with time. The physical process of the seismogenesis and occurrence could be obtained by analyzing the character of earthquake activity quantitatively (Ma Li, 40074013). It is possible to construct a discrete mathematical model for the rupture process of the obviously discontinuous geological media on the basis of the rock fracture experiment and earthquake observation; to study the rule of time-space variation of earthquakes and the factors on the seismogenesis process while the process is modeled with super-computer, to study the earthquake fracture mechanism, to seek the possible precursor of a significant earthquake, and to discuss and examine the self-organizational critics and the critical point theory by combining the rupture failure results of solid material in the statistic physics and damage mechanics (Wang Yuchang, 40004002). The precisely locating method on the global 3-dimensional structure and regional lithosphere structure is proposed by using multi-phases data and non-linear technique. And the earthquake process from the beginning of rupture to nucleation, the interaction among faults and the strain converting mechanism were discussed by the precise earthquake location and the analysis of focal mechanism of the Lijiang and Ninglang earthquake series with the observed data from the domestic and international seismic networks. All the work will improve the earthquake location accuracy with digital seismic data (Chen Qifu, 40174014).

The ratio between the response rates of the loading and unloading in the resource regions is used to describe the material failure degree (Yin Xiangchu, 49070185). A series of important qualitative and quantitative results were obtained by inducing the catastrophe theory to the catastrophe failure model of the fractured zone and the failure mechanism of fault earthquake can be recognized well (Kang Zhongyuan, 49070199). The geo-electric anomalies before earthquakes, co-seismic geo-electric effects, and the precursor mechanism of strain-resistivity and related theoretical formula were studied. With the results, the theoretical foundation of geoelectric method for earthquake prediction is formed and the models of mid-term and short-term precursors were obtained. Some new methods for earthquake prediction can be found correspondingby.

The genetic algorithm with the multi-dimensional analysis method is used to study the earthquake prediction (Shi Yaolin, 49374213). The effects of the Coriolis force in the solid geophysics were used to discuss the locations of the significant earthquakes and the earthquake prediction methods on the strong aftershock prediction and seismic intensity zoning (Chen Jiachao, 49474210). The seismic peak ground acceleration calculated with the tectonic stress field makes a new way for studying the strong seismic attenuation. The new direction for the earthquake prediction is based on the significant earthquake risk zone determined by the distribution patterns of tectonic environmental stress field (Chen Peishan, 49474222). The double quadrant phenomenological earthquake prediction model, a space-time relativity analysis method of seismogenesis with the introduction of extended probability method was established and its suitable range was discussed (Wang Shibiao, 49604051).

The risk analysis method based on the planar

source activity was regarded (Chen Yong, 49774216). The macro-economic indictors were used to the seismic hazard assessment and the software with GIS has been applied to the seismic hazard reduction. The map of the global earthquake risk and hazard predictions was published for the first time by the Chinese seismologists (Chen Yong, 49574207).

In combination with the artificial intelligence and the earthquake counter-measurement, the theory of the earthquake relief and experience were discussed and three artificial intelligent systems on the hazard predication, the quick loss estimation and the direction and decision for the earthquake relief, the related knowledge base, database, plan scenario base, and the designing theory and methods of reasoning machine and interpreter were given. The related software was also invented (Zhu Yueqing, 49674215). The ultra broadband electromagnetism surveying method has been invented and used for the earthquake relief services, such as the search and rescue of urban disasters (Wang Xuben, 40374027).

3 The Future Funding Programs and Strategy Target in Geophysical Section

The future strategy targets in the geophysical section is to expand the applied geophysical theories, methods to the energy exploring and engineering, develop theories and methods on the physics of earthquake source, earthquake prediction and environment exploration for reducing the natural disasters, such as earthquakes, floods, etc., and environment protection, enhance the researches on the synthetic geophysical survey in lithosphere and experimental geophysics and establish the quantitative models of the Chinese continent lithosphere construction and evolution, and discuss the deep process and dynamic mechanism of the material transferring, geological tectonic structure, resources and disaster origination and progress.

The funding programs of seismic hazard reduction mainly aim at the following fields: the theories and methods on the physics of seismic source; the techniques for enhancing the abilities of the seismogenic environment, earthquake observations, predictions and relieves; the researches on the seismic source processes, mechanisms, activities under different seismogenic environment through the analysis of some important earthquakes. The researches on seismic hazard predictions, quick assessments of earthquake losses and the theories and methods of the direction and decision systems will be supported moderately too. We believe that geophysicists will do much work for the seismic hazard reduction.

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