1991—1994

CHINA NATIONAL REPORT

ON

Seismology and Physics of the Earth's Interior

for the XXIth General Assembly of IUGG
Boulder, Colorado, USA, July 1995

Chinese National Committee
for the International Union of Geodesy and Geophysics
Beijing, China

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Chen Yun-tai
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FOREWORD

The Chinese National Committee for IUGG is pleased to present the 1991—1994 quadrennial Chinese National Report on Geodesy and Geophysics to the membership of the International Union of Geodesy and Geophysics.

The current National Report is the fourth in a series beginning in 1983. It reviews the work accomplished in China during the past four years and provides the record of Chinese contributions to geodesic and geophysical research. This record is intended to be a working reference for researchers, teachers, students, and administrators.

The Report contains seven separate parts, each covers a special area in geodesy and geophysics. These seven parts are respectively: Geodesy; Seismology and Physics of Earth' s Interior; Volcanology and Chemistry of the Earth' s Interior; Geomagnetism and Aeronomy; Meteorology and Atmospheric Sciences; Hydrology; and Physical Sciences of the Oceans.

Different parts of the Report are prepared by different subcommittees of Chinese National Committee for IUGG and written by different authors. They are thus not quite balanced in size and the arrangements of the texts are not similar to each other.

We would like to thank very much the Chinese Association for Science and Technology which supported us in preparation of this Quadrennial Report.

Beijing, China

May 1, 1995

LIU Guangding

President of Chinese National Committee
for IUGG

ZHANG Tao

Secretary General of Chinese National Committee
for IUGG

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EARTHQUAKE PREDICTION AND EARTHQUAKE DISASTER REDUCTION RESEARCH

ZHU Chuanzhen

Institute of Geophysics, State Seismological Bureau, Beijing 100081, China

and *FU Zhengxiang*

Center for Analysis and Prediction, State Seismological Bureau, Beijing 100036, China

I. EARTHQUAKE PREDICTION

China is a country where seismic activities are very active. The recent research shows that the seismicities in the Chinese mainland appear to be an increasing tendency with fluctuations in the last decade of this century. This will bring serious damages to the Chinese economy which is developing fast. In order to reduce earthquake disasters as possible as we can, earthquake prediction research has become one of the priority subjects in geosciences which is the foundation of earthquake disaster reduction science. After a series work of earthquake prediction for data sort out, select and optimization during 1987—1989, the State Seismological Bureau of China continued to organize key task researches and observations for earthquake prediction in the whole China from 1991 to 1995. The purpose is to raise the scientific level in earthquake prediction; make the experiential and probabilistic predictions to develop towards physical prediction; deepen the cognition for earthquake preparedness and occurring regulations; and develop the concerned earthquake prediction theory (Mei et al., 1993).

Here is a summary about the main results in earthquake prediction research obtained in China in the past four years.

1. *Earthquake Precursors and Comprehensive Prediction*

To pick out and identify the repeatable precursors effectively from a large amount of complex anomalies is a key scientific problem in earthquake prediction, especially in short and imminent predictions. The understanding for earthquake precursors has been developed further in recent four years through the key task research of predictions and the applications of high technology in the precursor observations etc.

In precursor observation, more than 40 sites have been set up to observe geothermal precursors and obtained continuous observing data with high accuracy, a series software of index criteria and anomaly recognition of geothermal precursors is formed (Wang et al., 1994); A systematic work has baen carried out to observe and pick out the anomaly from fault gas (the content of Hg, H_2, CO_2 etc.). It is found that the variations of fault gas are associated with the variations of stress-strain of rock body (Wang et al., 1994). Many significant attempts have been done to explore earthquake precursors with high advanced techniques, such as thermal infrared radiation

by satellite, CT, and perspective observations for earth electromagnetic profiles with high accuracy etc. Important results have been obtained to apply the remote sensing technique in the experimental study of rock rupture precursors (Geng et al., 1992; Cui et al., 1993; Deng et al., 1993). It is found by the experiment a new effect of rock mechanics that the spectra of infrared radiation temperature and the infrared thermal imaging change with the stress state. A further research finds that the brightness and temperature of microwave radiation of rocks increase rapidly before failure (Deng et al., 1993), which may be a kind of precursors before rock failure.

In order to promote the comprehensive prediction for various kinds of precursors, a series of short-term prediction index for various precursors is determined first based on a systematic summary for $M>5$ earthquake cases in China, including precursors of deformation, the variations of groundwater, radon, geoelectricity and geomagnetism etc. The main criteria to judge medium-term to short-term prediction are established. Important results are obtained to change the measurements of various precursors into the unified strain parameters. For example, using air pressure effects of under water table to obtain the variations of vertical stress acting on aquifer. Using the magnetic effect theory of "dilatancy-strain", the proportional relation between magnetic field and body strain variations etc. was obtained. These provide a physcial foundation to compare, analyse and unify the index of various precursors.

Progresses made in the comprehensive prediction research by using various precursors (Li et al., 1994; Zhang and Zhang, 1992; Zhang et al., 1993) are as follows:

(1) The function method of comprehensive effect field is given i. e., under the condition of determining the occurring time preliminarily by various precursors given, the comprehensive effects of various parameters in seismology are used to judge the occurring location for a future earthquake is given.

(2) Carried out pattern dynamic research of earthquake precursors (Zhou, 1992; 1993). Based on the time sequence of observing many precursors and the data of repeated local measurements, through a synthetic of pattern genetic informations and energy tracing, obtain the evolving pattern of space and time structures of precursory field and its dynamic characteristics. Apply this in the evolving process of fault system, it reveals that the crust deformation field is characterized by fractals, the localized deformation is an index of unstable crust; there exists a dimension reduction, entropy decrease and ordered process before failure.

(3) Introduce the Projection Pursuit Regression technique (Zhu et al., 1994), project the higher dimensional data consisting of multi-independent and response variate to the lower dimensional space, and make statistic regression analysis. Seek out the ridge function in optimization which reflects the characteristics of data structure. The PP regression model of earthquake comprehensive prediction has solvad the non-normal and nonlinear problems of statistic data and the correlation problems between variates. It can remove the disturbance of mankind in judgement of anomaly, and this promotes earthquake prediction towards practical use.

Besides, new understandings are got for the possibility to apply fuzzy subordinate function and fuzzy neural network method in earthquake comprehensive prediction.

2. *Explore the Method of Medium-Term and Short-Term Prediction*

In the past four years, more attentions were paid to the new methods and new parameters for medium-term and short-term predictions of earthquakes with clear physical meaning. The main results obtained are as follows:

(1) Introduce the algorithmic complexity AC which analyses time sequence in nonlinear dynamics into the analysis of evolution characteristics of seismicity pattern. Lu (1994) presented a new parameter which comprehensively represents the evolution process of seismic activites in time, space, intensity, e. g. the evolution index YH of seismic activities. The efficiency of earthquake prediction can be raised significantly by using AC criteria and YH value under a background with seismic gap as the medium-term anomaly. Meanwhile, design present fault, in the celluar automaton model of seismic activity and make simulation of rupture process, this provides a new tool to trace evolution of seismicity pattern, and also provides an experimental base for AC and YH (Lü et al., 1993; Lu and Lü, 1994; Zhang and Lu, 1994).

(2) The research of foreshock activities and its recognition is very important to promote earthquake prediction in actual use and to deepen the understanding for the regularity of earthquake occurrence. By statistics, earthquakes with foreshocks occupy 48.5% of the 165 earthquakes of $M>5.5$ in the Chinese mainland, while the probability of $M>7$ earthquakes is 67% (Lin et al., 1994) which is obviously higher than the statistical results by Jones and Molnar (1979). Lin et al. (1994) introduces a physics quantity $-F$ value which represents the average degree of series energy release with different average strengths. The result shows that F value can be used as an index to discriminate comprehensively foreshock sequence. A systematic research of multifractal structures is carried out for the space and time distributions of earthquake activities of generalize foreshocks (Wang and Zhu, 1994; Zhu and Wang, in press; Wang et al., 1993). After calculating the spectrum of fractal dimension D_q and power spectrum index β of the sequence, it is found that high dimension D_∞ decreases obviously about one year before earthquake; D_∞ of precursory earthqukae swarm is lower compared with ordinary swarm; $\beta\approx 1$ for direct foreshock sequence and $\beta<1$ for aftershock sequence. This result is tested by AE experiments of large-scale rock samples (Zhu et al., 1994) in laboratory.

(3) Pick out medium-term and short-term prediction informations from seismic waves

Develop new prediction methods and ohtain some results. Combine with fuzzy recognition technique, the variation characteristics of time linear degree γ and space linear degree α of initial P wave form are approached. The results show that both γ and α of P wave of small earthquakes in the epicentral regions before strong earthquakes appear anomaly decreasing obviously (Feng et al., 1993). Moreover, the Q value of coda wave, the main frequency width and the predominant frequency variations etc. are continuously studied (Feng et al., 1994). The concept of coda entropy is put forward (Gu et al., 1993). It is found preliminarily that there exists an entropy decreasing process before $M>5$ earthquakes while the entropy is stable under normal condition.

(4) Using the respond ratio theory of loading and unloading by the energy released by earthquakes, earthquake cases are tested continuously in a broad range. After a test for about one

hundred earthquake cases, precursory anomalies can be calculated for 80% of them. Meanwhile, this method is also used in practice, and obtain some significant results (Chen and Yin, 1994). Besides, the research to calculate respond ratio for various geophysical observing data is also carried out, such as for deformation, tilt, gravity and ground water etc. ; as well as some related experimental research (Yin et al. , 1993), such as simulate rock fractrue characteristics under tidal force etc. (Shi et al. , 1994).

(5) It is very significant to judge the earthquake potential and sequence type rapidly after the occurrence of a medium or strong earthquake both in scientific research and in organizing disaster rescue.

Using the series data of 3 days after an earthquake and applying the fuzzy cluster method and pattern recognition, make a comprehensive research to judge whether there will be an earthquake with the same magnitude or larger within 3 months in future (Han et al. , 1994; Han et al. , 1993). Through analyses, evaluations and extrapolation tests for 90 cases, much better results have obtained than those obtained by simple method (Han et al. , 1993). Use the self-similarity characteristics of time and space distribution of earthquake sequence and take the degree of order as the discriminate index of earthquake type, the correctness for judging types of earthquake sequence can reach over 80% through the difference of degree of order at the early stage (seven days after the earthquake) (Wang et al. , 1993).

(6) To analyse earthquake precursors and develop new prediction methods by using the concepts and approaches of nonlinear theory has become the key points concerned by the seismologists in China in recent years. In order to reveal the complexity and nonlinear characters of earthquake prediction, various kinds of investigations are carried out (Wang et al. , in press; Peng and Chen, 1993; Chen and Ji, 1992; An et al. , 1992; Chen, 1993; Hong, 1992; Hong and Hong, 1993; 1994; Hong et al. , 1994). From the view point of prediction, more researches are focused on the fractal structures of seismic activities (Chen, 1993; Zhu et al. 1994; Hong et al. , 1992). Hong presented a self-similarity comparison method in order to determine objectively the "non-scale interval", by which the fractal dimension of earthquakes can be calculated reliably (Hong et al. , 1993). Hong (1993) modified the basic limitations to calculate the attractor dimensions by G-R method. He also started the research on the analysis of nonlinear time series of earthquakes (Hong, 1994).

(7) Based on the significant variations of AE during the process of rock fracture experiment, new parameters—GT value (Gao et al. , 1993) and seismic strength factor Mf (Wang et al. , 1994) is presented which can describe the inhomogeneity of medium and small earthquake distribution in time and space before strong earthquakes. These parameters are all effective in medium-term and short-term prediction. Moreover, based on the expert system of medium-term and short-term predictions, an expert system for earthquake prediction in site (KPSES) has been further developed (Wang and Zhuang, 1994).

3. *Theoretical Research on Earthquake Prediction*

In order to reveal the physical nature of strong earthquake preparedness and deepen the un-

derstanding for the regularities of earthquake precursor distributions in time and space, set up a physical model of seismogenic process finally, and gradually realize predicting earthquakes on physics, China has strengthened the basic research on earthquake prediction theory in recent years.

Based on the analysis of seismogenic process for large earthquakes, the evolution of seismic patterns, the precursor distribution in time and space, the dynamic evolution, the relation between the velocity structure of crust medium and the distribution of strong earthquakes, a seismogenic model of "solid inclusion" in North China (Mei, 1994) and a seismogenic model of grouping tectonic blocks are put forward (Li et al., 1994; Zhang et al., 1994). These provide important ideas to understand the characteristics of grouping activities, the precursors of continental earthquakes. Shi et al., (1993, 1994) considered the nonlinear anisotropic characteristics of rocks caused by dilatancy during seismogenic process. Through numerical simulation, they calculated the variations of stress, deformation pore pressure, and wave velocity etc caused by fault creep and discussed their influences on the precursory characteristics which is helpful for understanding earthquake precursors. They aslo used a net model of spring-slider-damper to discuss the characteristics of nonlinear dynamics of seismic activities. This kind of net model is not limited to research the seismic activities in a single fault, it can be used to study continental earthquakes occurring in many faults (Shi et al., 1993; Zhang et al., 1993; Geng et al., 1993). Niu et al. (1994) applied the numerical solution which is for seismogenic dynamic equations of medium with water-bearing pores, to the seismogenic process of Tangshan earthquake. It reveals that non-elastic dilatancy and acceleration softening phenomena appeared several times during the seismogenic process of Tangshan earthquake. The variation shapes of precursors (such as water table, geoelectricity resistance, radon etc.) depend not only on the constitution law of the local site, but also controlled by the variation behavior of the whole seismic field. The complex evolution patterns of precursory field are in accordance with the evolution of seismogenic field on the one hand, at the same time, they are illustrated by not synchronous with pore pressure, body strain, the maximum shear stress. etc. Feng et al. (1994) used 3-D finite element method to calculate the precursory evolution characteristics in time and space under the conditions of the elastic hierarchy medium with fault, asymmetric applied loading and of various inclusions. This explains the precursory phenomena of Tangshan earthquake in a certain degree.

Using water-bearing limestone samples with different structures, Chen (1993) carried out experimental research on the dynamic variation of pore pressures under the initial condition with different confining pressures during the deforming process. The results show that the attitude and size of the surface, the loading rate compressed on the sample and the initial pore pressure can significantly influence the dynamic variation of pore pressure of rock sample, there even exist some regulations. It brings a new understanding for the physical mechanism of complex patterns of precursory groundwater.

Cooperated with Russian scientist, Lu et al. (1993) performed failure experiments of water-bearing limestone samples with large-scale ($0.5\times0.5\times1.0$ m^3) under uniaxial loading. He researched the precursory variations of apparent resistivity. The results show that the anomalous

variations of apparent resistivity are observed before rupture at various sites with different orientations of the rupture surface. The variation shapes are complicated. It has a close relation with the fissure development and fluid transition.

II. SEISMIC HAZARD ANALYSIS AND RESEARCHES OF EARTHQUAKE LOSSES

1. *Long-Term Seismic Hazard Analysis*

The first and second generation of Chinese seismic zoning maps had been respectively done in 1957 and 1976, which are based on the method of deterministic long-term seismic hazard analysis with time scale of one hundred years or more. In order to response the new development in antiseismic design and seismology, the third generation of Chinese seismic zoning map (unit: 0.2°×0.2°, scale with 1/4 000 000) has been done in the beginning of 90' by using the developing probabilistic method (Compiling Committee Group of Seismic Zoning Map in China, 1992), based on the model of heterogeneous seismicity in space and time.

The new seismic hazard zoning map gives a risk level of exceeding probability 10% of intensities $I<$Ⅵ, $I\geqslant$Ⅵ, $I\geqslant$Ⅶ, $I\geqslant$Ⅷ and $I\geqslant$Ⅸ in the forthcoming 50 years. And the area with intensity $I\geqslant$Ⅶ is 41% of the Chinese area, it is necessary to make antiseismic countermeasures and disaster reduction, in the area with intensity Ⅶ. The map could be applied to earthquake resistant design of small and medium civil engineering buildings, plan of national land use, the countermeasure for earthquake disaster mitigation and protection.

In the long-term seismic hazard analysis, the uncertainty of the analysis, its sources and the way of dealing with it have been paid more attention. Hu et al. (1991) has pointed out that some uncertainties of the seismic hazard analysis might come from incompleteness of the earthquake knowledge and could be studied comprehensively by Bayesian method. Shen et al. (1993) has divided the uncertainties of seismic hazard analysis into two kinds of subjective and objective one, the former results from inherent randomness of the events, and the latter one from the differences between theoretic and practicing prediction model. Ding et al. (1991) Analyzes the influences of uncertainties in seismicity parameters on the seismic hazard based on a model of fault rupture.

2. *Researches on Intermediate-Long-Term Earthquake Prediction*

In 1991 State Seismological Bureau, China, has organized Chinese seismologists to do the researches on predicting earthquakes in Chinese continent before 2005, including not only comprehensive analyses of geophysical setting, active faults and historical seismicity, but also non-Poison processes of grouping earthquakes with time scale of ten years and intermediate-long term precursory seismicity pattern (such as seismic gap and crustal deformation). After researches of four years Guo (1994) has proposed a united probabilistic model of predicting earthquakes. Wen (1993) introduces uncertainty of seismicity into the time predictable model, and considers quiet period after an earthquake occurrence as random variable correcting with the dislocation size of the earthquake. Fu (1994) has proposed a time-dependence probabilistic method for earthquake magnitude based on the Benoulli random trails.

3. *Seismic Vulnerability Analysis*

Strong earthquakes destroy buildings and life line, and threat human life. In order to predict and reduce the looses from the forthcoming earthquakes, it is necessary to know not only the existing anti-earthquake capacity of buildings but also that in the future. It means that we have to study dynamic seismic vulnerability of buildings and structures. Yin (1994) proposes a probabilistic method to establish dynamic seismic vulnerability matrix of buildings based on the variation of characteristics for Chinese structures with time. And the dynamic seismic vulnerability matrixes for different kinds of structures (RC, brick and soil structure's *etc.*) before 2005 in different geographic areas, have been built by Yin (1994).

Zhou et al. (1994) study the seismic vulnerability of equipment and function of electricity power system, and get the vulnerability relation between damage rate and intensity.

Fu (1993) has analyzed statistically the damage data from the Xingtai, Hebei, China, earthquake ($M_S = 6.8$), of March 8, 1966 and pointed out that the casualty degree from the earthquake followed the normal probabilistic distribution, and the seismic vulnerability matrix of life in adobe has been built. According to the damage data from historical earthquakes in Yunnan Province, Zhou (1993) has gotten the statistical relationship between the casualty rates and intensities.

4. *Researches on Prediction of Earthquake Losses*

There were some researches and practices on prediction of earthquake losses for a part of China cities and counties in the eighty's, since that time the researches on probabilistic prediction of earthquake losses have been developed. (Research Group for Estimating Losses from Future earthquakes, 1992). The prediction of earthquake losses is based on the seismic hazard analysis and seismic vulnerability analysis. The map of expected economic losses of Chinese continent of buildings and fatality in the forthcoming 50 years has been structured based on the map of Chinese seismic intensity zoning and Chinese seismic vulnerability analyses of buildings and life (Research Group for Estimating Losses from Future Earthquake, 1992). At present a research on the seismic hazard and dynamic seismic vulnerability analysis in China before 2005 are baing made, the aim is to predict the economic losses and fatalities from earthquakes in the future 10 years, which would be the bases for government to make the countermeasure of anti-earthquake and damage reduction.

In addition the data bank of earthquake damage and intelligent computer system of predicting earthquake damage, including expert estimation system of earthquake damages of multi-story brick buildings and intelligent computer estimation system of earthquake disaster for existing buildings in cities of China, have been established (Yang, 1993). Another way to predict the earthquake loss is to use the statistical characteristics of earthquake damage data themselves. Fu (1993) has estimated the occurrence probability of fatality degree from future earthquakes using the relation between the frequencies and fatality degree from earthquakes in North China from 1800 A. D. based on Gumbel Extreme theory.

5. *Estimation of Post-Earthquake Losses*

The rapid estimation of post-earthquake losses is useful for available rescue action and making restructures plan. Lee (1993) and Yan (1991) have proposed a practice method of rapid estimation of post-earthquake losses, which includes the standard of dividing the building kinds and earthquake damage degrees, methods of loss examination and structure of computer data bank and software.

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DIGITAL SEISMOLOGY IN CHINA: DIGITAL OBSERVATION, NEAR-SOURCE STRONG GROUND MOTION STUDY, AND BROADBAND SEISMOLOGY

WU Zhongliang, *CHEN Yuntai* and *MU Qiduo*

Institute of Geophysics, State Seismological Bureau, Beijing 100081, China

I. INTRODUCTION

In the seismological studies in China, digital seismology is a developing branch. In the last four years interests in digital seismological observation, near-source strong ground motion study and broadband seismology have been increased. Developments in digital seismology have contributed much to the studies of lithospheric structure, seismic wave propagation, and the complexity of earthquake source process, as well as the physical understanding of the nature of earthquakes.

II. DIGITAL SEISMOLOGICAL OBSERVATION

Digital seismology, as a result of the development of micro- electronics, has a strong component of high technology. In the past four years, with the development of economy and society in China and in response to the process of the modernization of Chinese seismology, digital seismological observation has been playing an important role in the seismological studies of China.

China Digital Seismograph Network (CDSN), built in 1986 as a Sino-U. S. cooperative project, has been working in excellent status and provided the seismological studies with a large body of high-quality data (Zhou et al., 1992). Studies were taken on the quality control and application of CDSN data (e. g., Li, 1991b, 1992a; Li et al., 1992; Mu, 1992; Yang and Lai, 1992; Yao, 1993, 1994; Chen et al., 1994; Gao et al., 1994; Lai et al., 1994; Wang et al., 1994; Zhu and Zhang, 1994; Zhu et al, 1994).

Using the CDSN data, extensive studies have been carried out by seismologists both in China and abroad. Hu et al. (1992) used CDSN long- period surface wave data to investigate the crustal structure of south-east China. Gao and Feng (1993) used short-period records of local earthquakes at BJI station of the CDSN to study the S-wave splitting associated with the 1989 Datong, Shanxi, China earthquake. Using SKS data from KMI station of the CDSN Li (1994) discussed the seismic anisotropy of the upper mantle in the region of Kunming, Yunnan, China. Analyzing the data from two short-period, three-component mobile digital stations and the WMQ station of the CDSN, Chen (1994) observed the temporal variation of shear wave polarization after the June 9, 1989, Shimian, Sichuan, China M5. 2 earthquake. Huang et al. (1994) analysed the CDSN LP data to study the surface wave polarization and lateral heterogeneities of the lithosphere in China. Hua et al. (1994) processed the short-period data at BJI

station of the CDSN to study the temporal variations of coda Q related to the 1990 Dahaituoshan, Beijing, China $M5.4$ earthquake. In analyzing CDSN LP records, Wang et al. (1994) applied polarization analysis in the recognition of the correlated phases from upper mantle discontinuities.

The CDSN data are widely used for the characterization of earthquake sources. Zuo et al. (1993a) analyzed the CDSN long-period surface wave data to discuss the standardization calibration of mantle wave magnitude. Chen and Duda (1993a) developed a technique for the estimation of spectral magnitude and radiated energy from the CDSN recordings. Using the CDSN long-period P waves in the range of 2° to 40° from the November, 1988 Lancang-Gengma, Yunnan, China earthquake sequence, Wang et al. (1991) determined the focal mechanisms of the mainshock and two aftershocks by synthetic seismograms and found that the mainshock was composed of three subevents, each with a different mechanism. Zhao et al. (1992) used the CDSN LP data to invert the focal mechanism of the October, 1989 Datong, Shanxi, China earthquake. Using the same method Fang and Chen (1993) inverted the CDSN LP data to get the focal mechanisms of six moderate earthquakes occurred in Chinese mainland from 1987 to 1990. Yao and others developed a technique for the moment tensor inversion of the CDSN and GDSN LP data, and argued from the inversion results that there may exist some volumic changes along with the source process of several earthquakes in the Chinese mainland (Yao and Zheng, 1994; Yao et al., 1994). The same technique was also applied by Zheng and Yao(1994) in the analysis of the CDSN and GDSN LP data to study the moment tensors of several Taiwan, China earthquakes and the tectonic implications. Ma(1994) developed a simple method for source parameter estimation and used it to determine the source parameters of the April 26, 1990 Gonghe, Qinghai, China earthquake from the CDSN data.

China participated in the international experiment focused on the exchange and analysis of seismic waveform data to demonstrate the feasibility of operating a global system for monitoring compliance with a nuclear test ban treaty, i.e., the GSETT project, organized by the United Nations Committee on Disarmament. Accordingly, Chinese seismologists has begun to pay attention to the study of nuclear explosions in the view of digital seismology (see, e.g., Wu et al., 1994).

Digital observation technique has been developed in recent years. Shao et al. (1992) developed CSJ delay trigger digital seismograph to record regional seismicity and explosions. Xie (1994) reported the A/D conversion system with 16-bit A/D for a digital telemetered seismic network. Intelligent waveform analysis is also under discussion (Xiao et al., 1992).

Studies were carried out using the data from local and regional digital seismograph networks, some of which were deployed and operated through cooperative projects between China and abroad. Sun et al. (1991, 1992) and Sun and Zheng (1993) used digital records of some of the aftershocks of the Tangshan, China earthquake recorded by a temporary local digital network to study the attenuation and source parameters as well as the shear-wave splitting. Zhang et al. (1993) studied the crustal structure of the Yang Yi geothermal field, Tibet, China using the converted waves from local events recordied by three-component digital seismometers. Yao et al. (1993) used the data from the Sino-France cooperative Zhangye digital seismograph network to