

# Historical earthquake investigation and research in China

Jian Wang

*Institute of Geophysics, China Seismological Bureau, Beijing, China*

## Abstract

China is one of the countries with the longest tradition of culture and has suffered many earthquake disasters, so many earthquake documents have therefore been conserved. In this paper we try to outline some basic information of historical earthquake investigation and research in China, such as collection of historical earthquake data from archives, historical earthquake catalogues, seismic intensity scales. We introduce briefly the huge accomplishments of historical research and discuss some problems encountered. Through examples, we illustrate the solutions to some typical problems. There are some suggestions on further work.

**Key words** *historical earthquakes – catalogues – intensity – isoseismals – China*

## 1. Collection of historical earthquake data from archives

### 1.1. Brief on historical earthquake documents

China is one of the countries with the longest history and abundant historical archives. Among various ancient writings from remote time, there are a great number of earthquake narratives. The earliest one was in the 23rd century B.C., with the description of «earthquake and springs gushing». Generally, early recordings were very simple. From the Ying Dynasty (16-11th century B.C.), there were official historians appointed by governors. Besides political events, natural phenomena including astronomy, weather and earthquakes were recorded. In the Qin Dynasty (221-206 B.C.), a united country was formed firstly, with a

regime consisting of central and local governments (canton and county). Meanwhile there was a reform and a standardization of the writing system. From the Western Han (206 B.C.- 24 A.D.), earthquakes had been recorded as «catastrophes» in official historical records. In the Yuan Dynasty (1271-1368 A.D.) there was a reform in the regime and provinces became the highest level of local government. From that time, the annals and varied records of differently ranked local governments became popular. Earthquake records increased greatly in number and their contents became more detailed.

### 1.2. Two large-scale collections of historical records

The first collection of earthquake records appeared in 977 A.D. A total of 45 earthquake items between the 11th century B.C. and 618 A.D. were compiled in a chapter of a book, which named as Taiping Yulan (Li, 1960).

In the 1950s, immediately after the founding of the People's Republic of China, there were about two hundred engineering projects which needed on-site assessment of seismic intensity. For this purpose, historians and seis-

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*Mailing address:* Dr. Jian Wang, Institute of Geophysics, China Seismological Bureau, 5 Minzu Daxue Nanlu, Haidian District, Beijing 100081, China; e-mail: wangjcsb@hotmail.com

mologists were organized by the Academia Sinica to collect historical earthquake records systematically. Through more than two years' hard work together, the historians and seismologists searched through more than eight thousand items of historical literature. Tens of thousands of historical earthquake records were found and picked out. After checking and analyzing, they compiled the records chronologically. A total of 26 provinces or municipalities were concerned. They put the results in a two-volume book: «Chronological Data of Historical Earthquakes in China», which was published in 1956 (Historical Earthquake Working Group of Seismological Committee of Academia Sinica, 1956).

From 1977, historians and seismologists were organized again by the State Seismological Bureau (SSB, nowadays renamed as China Seismological Bureau, *i.e.* CSB), the China Academy of Social Sciences and the Academia Sinica. Seismologist Xie Yu-shou and historian Cai Mei-biao were the editors in chief. This time they explored earthquake recordings in wider scope. Based on «Chronological Data of Historical Earthquake in China», a large amount of supplementary information was added, and amendments were made.

Some earthquake documents were found and translated from the Manwen (literature of Qing Dynasty) and Zangwen (literature of Zangzu, *i.e.* Tibet) archives. After five years' hard work, a five-volume «Compilation of Historical Materials of Chinese Earthquakes» was completed and published successively in eight books during 1983-1987 (Xie and Cai, 1983a,b, 1985, 1986, 1987). The historical records of the first volume covers the time period from the 23th century B.C. to 1367 A.D.; and the second and third volumes cover the period from 1368 A.D. to 1644 A.D., and 1645 A.D. to 1911 A.D. respectively. From 1912 A.D. there have been instrumental records and investigations on macro-intensity.

Meanwhile, most provinces, autonomous regions and metropolitan regions published their own regional compilation of earthquake materials.

Besides the two large-scale collections of historical earthquake records, there are some

collections done by individuals, but these are small scale and generally in local regions. The work to find new earthquake records from historical archives has never ceased in China.

### 1.3. *Seismic field investigation*

Since 1900 many field investigations of destructive earthquakes have been carried out. A huge amount of intensity data and photographs of earthquake disasters were compiled and published in a two-volume book: «Investigation on China Earthquakes» (Shi *et al.*, 1987, 1990). In the same period, instrumental recording has been gradually increasing. Earthquakes with both intensity data and instrumental records are very important to build up relationships between intensity and magnitude. With these relations the parameters of historical earthquakes were estimated.

## 2. Catalogues of historical earthquakes and seismic intensity

### 2.1. *Methods and principles of editing historical earthquake catalogues*

In China, we define «historical earthquakes» as earthquakes whose parameters were inferred only from written records of historical archives. Generally, the methods of determining the parameters of historical earthquakes include the following steps:

i) In a region, putting together all sites with historical records at the same time. According to the records of each site, assessing the intensity.

ii) Utilizing the events with instrumental parameters and intensities to work out the statistics or empirical relations between earthquake parameters and intensities, especially epicentral intensity. Extrapolating the relations to infer the parameters of historical earthquakes.

iii) Generally, in the catalogue, the parameters of an earthquake include origin time, epicenter, maximum intensity and magnitude. If the data are enough, accuracy and depth may be inferred.

iv) For earthquakes recorded in a large region with no damage whatsoever, the empirical relation between the magnitude and the equivalent radius of the intensity IV isoseismal is used to estimate their magnitudes.

v) Generally, the center of the isoseismals or the site with most damage reports will be regarded as the epicentre.

vi) Besides earthquake origin time, epicentre and magnitude, the places where historical earthquakes were recorded are listed. If possible, isoseismals are given.

vii) Doubtful material and earthquakes with indeterminate parameters are listed in an appendix for further study.

## 2.2. Editions of historical earthquake catalogues in China

There are many kinds of earthquake catalogues in China; here we mention only the catalogues compiled mainly with historical records. Since the founding of the People's Republic of China, there have been four editions of the catalogue of Chinese historical earthquakes. Chinese seismologists have continually endeavored to study and revise the catalogues to make them more systematic and correct.

The first edition of «The Catalogue of Chinese Earthquakes» (CCE) was published in 1960 (Li, 1960). Prof. Li Shan-Bang (S.P. Lee) was the editor in chief. This catalogue has two volumes. Volume one is the catalogue of earthquakes with magnitude greater than 4.7, and covers the time period from 1189 B.C. to 1955 A.D. Total 1180 earthquakes were listed. The parameters of earthquakes before 1900 were determined mainly according to the «Chronological Data of Historical Earthquakes in China». The parameters of earthquakes after 1900 were compiled based on investigations and instrumental records. Volume two is the catalogue of counties. There were more than two thousand counties in China, while about one thousand and six hundred counties have historical records, most of them concentrated in the Eastern part of China.

The second edition of «The Catalogue of Chinese earthquakes» was published in 1971

(China Seismological Working Group, 1971). This four-volume catalogue covered the time period from 1177 B.C. to 1969 A.D. The total number of earthquakes listed with magnitude greater than 4.7 is 2257.

The third edition of «The Catalogue of Chinese earthquakes» was published in 1983 (Gu *et al.*, 1983). Prof. Gu Gong-xu was the editor in chief, Lin Ting-huang and Prof. Shi Zhen-liang were vice editors in chief. This two-volume catalogue contains 3187 earthquakes, which covered the time period from 1831 B.C. to 1969 A.D.

The fourth edition of «The Catalogue of Chinese earthquakes» comprises two parts. Part one «The Catalogue of Chinese Historical Strong Earthquakes» was published in 1995, with earthquake parameters determined mainly from historical records (Min *et al.*, 1995). This catalogue is arranged chronologically, beginning from the 23rd century B.C. and ending at 1911, with a time span of more than 4100 years. It contains 1034 earthquakes with magnitude greater than 4.7 (fig. 1). Prof. Min Zi-qun was the editor in chief. Part two «The Catalogue of Chinese Present Earthquakes» was published in 1999, with earthquake parameters determined from investigations and instrumental records (Wang *et al.*, 1999). This catalogue covers the time period from 1912 to 1990. Prof. Wang Su-yun, Prof. Wu Ge and Shi Zhen-liang were the editors in chief.

From fig. 1, we can notice that the distribution of historical earthquake documents is not uniform. Most of them concentrated in the east part of China, especially in the Huanghe River (Yellow River) and the Changjiang River (Yangtse River) areas. The completeness and reliability of historical earthquake documents depended on many elements, such as dynasty changes and wars. In some cases, even individual inclinations of governors might have affected the documents.

In order to compile the Seismic Intensity Zoning Map of China (1990), the Concise Catalogue of Chinese Earthquakes (CCCE) was published in 1988, covering the time period from 78 B.C. to 1986 A.D. Total 5142 earthquakes with magnitude greater than 4.7 were listed. Prof. Min Zi-qun was the editor in chief.

The former catalogues, four editions of CCE and the CCCE, were all sponsored by governments and recognized in the whole country. There are some catalogues edited by individuals and local branches of the China Seismological Bureau (CSB), which are not included in this paper.

### 2.3. *Seismic intensity and Atlas of isoseismals*

The China Intensity Scale is a twelve-degree system. It was created by Prof. Li Shan-Bang (Li S.B, 1954) and rewritten by Prof. Xie Yu-sou (Xie, 1957). When rewriting the new intensity scale, besides investigating historical records in China, Prof. Xie Yu-sou also compared the data with various intensity scales in the world, including the intensity scale of the former Soviet Union in 1952 and the Modified Mercalli Intensity Scale. The China Intensity Scale was supplemented and simplified by Prof. Liu Hui-xian in 1978 (Liu, 1978), taking account of new kinds of modern buildings destroyed by strong earthquakes in recent years both in China and elsewhere in the world.

In China Intensity Scale, seismic intensity was described according to four kinds of damage phenomena: houses; structures (including special ancient Chinese buildings, such as memorial archways, pagodas, steles, ramparts, etc.); residual phenomena in the ground and changes of surface and subsoil water conditions, and other phenomena. Accounts taken from historical records describing earthquake damage were included to help estimate intensity from archive documents (Li, 1989).

Some atlases of isoseismals were compiled in China. Prof. Min Zi-qun compiled an atlas of isoseismals including 64 earthquakes (Min, 1957). As an important database for seismic intensity zoning, the Atlas of Chinese Earthquake Isoseismals was published in 1979 (Compilation Group of China Seismic Intensity Zoning Map SSB, 1979). Total isoseismals of 151 earthquakes were delineated in this atlas, covering the time period from 1125 A.D. to 1976 A.D. More complete and detailed work was done by cooperation between seismologists from the Institute of Geophysics SSB and his-

torians from the Institute of Chinese Historical Geography, Fudan University.

The three-volume «Atlas of the historical earthquakes in China» was the result of cooperation of seismologists, historians and geographers (Institute of Geophysics, SSB and Institute of Chinese Historical Geography, Fudan University, 1986, 1990a,b).

## 3. Review and prospects of historical earthquake research

### 3.1. *Accomplishments of the past half century*

From the 1950s, a huge amount of work and research has been done in historical earthquake investigation and research. Great accomplishments have been achieved.

The investigations and researches can be summarized as follows:

- i) Collection of historical earthquake documents;
- ii) Besides the textual research, field investigations have been done on many important historical earthquake sites. Much evidence was found on buildings, steles, pagodas and tombs;
- iii) Research on the intensity scale. Estimating seismic intensity and isoseismal distribution inferring careful from historical documents;
- iv) Utilizing earthquakes with both instrumental parameters and intensities to get the statistics or empirical relations between intensity and earthquake parameters;
- v) Compilations of historical earthquake catalogues and isoseismal atlases;
- vi) Application: the historical earthquake data prolong the time and extend the space, in which seismicity can be analyzed more reliably. The results are applied to long- to mid-term earthquake prediction, seismic hazard analysis, seismic intensity zoning, etc.;
- vii) Institutional Organization and Cooperation: the China Historical Earthquake Committee was established in 1987, as a branch of the China Seismological Association. Every two years, there is an assembly of the China Seismological Association and historical earthquake is one of the subjects. Besides the regular meetings, there are some seminars and



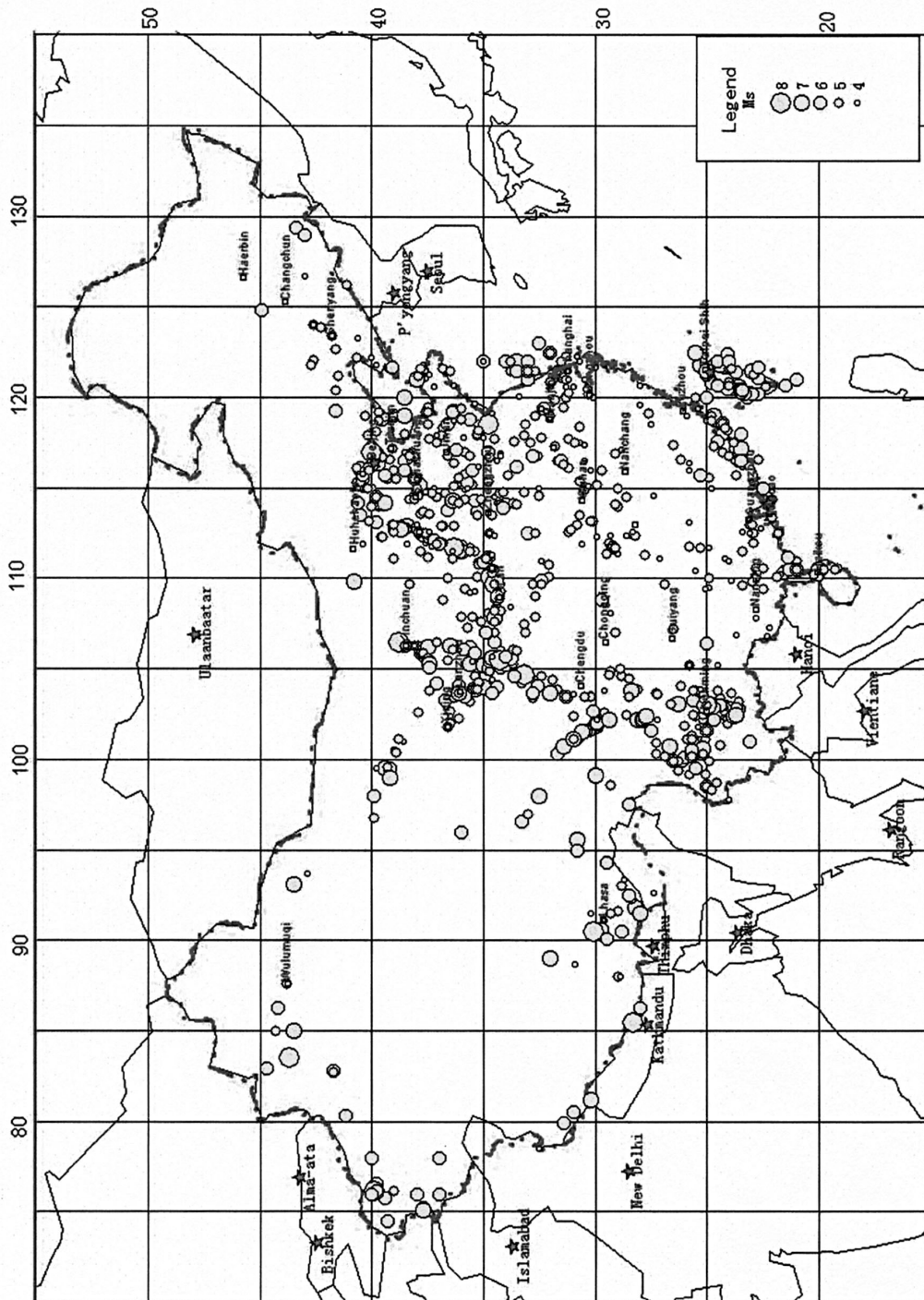


Fig. 1. Distribution of Historical Earthquakes in China.

workshops on special topics (Min *et al.*, 1989; Guo *et al.*, 1991). There are some special researches on historical earthquakes of Japan and the Korean Peninsula (Gao, 1991; Lu, 1991).

A cooperative project between seismologists of China and North Korea on historical earthquakes was carried out from 1987 to 1988, supported by the two governments (Shi and Li, 1989). There were cooperation projects with the former Soviet Union, the United States, Japan and Korea on historical earthquake research.

### 3.2. *Main problems encountered*

Owing to the long history and the huge area, there are various problems when we investigate and research historical earthquakes in China. Generally language is the first problem. Because the ancient word system is different from that used nowadays, special knowledge is needed to interpret historical documents. Besides Chinese characters, there are other writing systems of minorities, which need translation. Earthquake records are widely scattered in historical documents, so it is very difficult to search and pick them out. In our long history there are countless dynasty changes and wars, which might cause historical records lost or destroyed. Change of place-names is another problem, which may lead to misunderstandings. Transformation of topography and physiognomy is also a very important element to consider. Here we will illustrate the problems with a case of detailed investigation of an historical earthquake (Wang *et al.*, 1998).

According to historical documents, an earthquake occurred in 1046 A.D. (Song Dynasty) in the Jiaodong Peninsula, Shandong Province. Historical documents state that the earthquake occurred in the Juyu Mountain. While the earthquake was occurring, the stones of the Juyu Mountain were shaken and falling down directly into the sea. Because of changes of dynasties and wars, the place name today is completely different from then. We cannot recognize where the Juyu Mountain is nowadays, so we cannot determine the epicentre of the earthquake. After about one month of field investigation on the Jiaodong Peninsula, we were

lucky enough to find a stele of the Song Dynasty, which told us where the Juyu Mountain is. But another problem arose, for now the Juyu Mountain is about twenty kilometers from the coast. It is not possible that stones from the mountain fell down directly into the sea as described in the document. Searching through the historical documents, we found that from the Qing Dynasty (1644 A.D.-1911 A.D.) there had been continuous filling of artificial land between the mountain and the sea. That means the land between the mountain and the sea was formed later. Evidence from field investigation also proved this fact. With these problems solved, it is easy to determine the epicentre of the earthquake. Finally the epicentre was put at the junction of the Juyu Mountain and the ancient sea. This example tells us that information from documents and field investigations are equally important. Local documents and field investigations may be the keys to rediscover the ancient conditions, which are necessary to understand the historical documents precisely.

### 3.3. *Future work*

Although a lot of work and researches have been carried out, more effort is still needed.

Here we give our suggestions about further work:

i) Collection of scattered historical documents: after two large-scale collections, there are still historical earthquake documents remaining. Because these documents are scattered, it is more difficult to collect them.

ii) Detailed field investigations on historical earthquake sites. This kind of work is especially needed in the western part of China, where population and historical documents are sparse. With less man-made demolition and dry natural conditions, the traces of historical earthquakes can generally be maintained for longer. Cooperation between seismologists and geologists on historical earthquake research will bring more rewards.

iii) Utilizing the information of historical documents synthetically, especially the records of earthquake disaster distributions. These data are very valuable for anti-seismic design and mitigation of earthquake disasters.

iv) Developing new methods to determine the parameters of historical earthquakes. Continuously amending the Catalogue of Chinese Earthquakes. Compiling and publishing the catalogue of felt earthquakes, whose data have not previously been fully utilized.

v) Recording the experience and knowledge of elderly experts as a matter of urgency; some of them have already died and many are more than 70 years old.

vi) Making electronic versions of historical earthquake data, in case we lose what we al-

ready have; these are more convenient to use and safer to store. By translating and publicizing, let more experts world-wide be aware of and use this valuable information, which should belong to the whole world.

Chinese historical earthquake documents and researches are so abundant that it is not possible to cover them completely in one paper. In this short paper we just try to outline the main points. If there are some omissions or misunderstandings, please do not hesitate to contact me.

#### Appendix. Table of Chinese dynasties

Xia (21-16 cent. B.C.).	Eastern Jin (317-420).
Shang (Yin) (16-11 cent. B.C.).	Southern & Northern Dynasties (420-589).
Western Zhou (11 cent.-771 B.C.).	Sui Dynasty (581-618).
Eastern Zhou (770-221 B.C.).	Tang Dynasty (618-907).
Spring & Autumn Period (770-475 B.C.).	Five Dynasties & Ten Kingdoms (907-979).
Warring States Period (475-221 B.C.).	Song Dynasty (960-1279).
Qin (221-206 B.C.).	Yuan Dynasty (1271-1368).
Western Han (206 B.C.-24 A.D.).	Ming Dynasty (1368-1644).
Eastern Han (24-220 A.D.).	Qing Dynasty (1644-1911).
Three Kingdoms (220-280).	The Republic of China (1911-1949).
Western Jin (265-316).	The People's Republic of China (founded in 1949).

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