A MATLAB-BASED DATABASE OF SEISMIC INTENSITY FOR HISTORICAL EARTHQUAKE IN NORTH CHINA

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ABSTRACT:

Pre-instrumental recordings of earthquakes in North China can be traced back to Ming Dynasty about 500 years ago, with most of the destructive earthquakes above magnitude 6½ possessing good coverage of historical documents recording earthquake destruction. To facilitate the using of this set of information in the study of seismic zonation, strong ground motion, and source process, we developed a database of seismic intensity of historical earthquakes in North China. The region spans 30ºN~42ºN and 104ºE~125ºE and contains 33 earthquakes with magnitude larger than 6½. To serve various needs of seismological study, the database uses MatLab, with the functions of mapping, intensity indexing, and isoseismal contour plotting.

KEYWORDS: Isoseismal, North China, Historical earthquakes, Intensity

1. INTRODUCTION

Distribution of seismic intensity is not only important in engineering seismology but also contains information of focal mechanism and source process, as revealed by recent studies in strong ground motion seismology (Panza et al., 1991; Sirovich and Pettenati, 2004; Bakun, 2006; Pettenati and Sirovich, 2007). For historical earthquakes, intensity is the only information available to retrieve the focal mechanism and/or source process (Shebalin, 1973; Chen, 1975; Koyama and Zheng, 1991; Song et al., 1995).

North China is one of the important tectonic regions in eastern Asia, characterized by its intense intra-plate seismic activity, and the process of lithosphere destruction and change of stress state in geological times (Xu et al., 2002; Deng et al., 2003; Shen et al., 2004). Pre-instrumental recordings of earthquakes in North China can be traced back to Ming Dynasty about 500 years ago, providing earthquake catalogue complete down to magnitude 5, with most of the destructive earthquakes above magnitude 6½ having good coverage of historical documents recording destruction and/or secondary disasters (Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, 1986a, b). To facilitate the using of this set of information, we developed a database of seismic intensity for historical earthquakes in North China.

2. REGION FOR STUDY AND DATA PROCESSING

The region for study spans 30ºN~42ºN and 104ºE~125ºE, containing 33 earthquakes with magnitude larger than 6½. Figure 1 shows an example of the intensity distribution of historical earthquakes as documented in literature. From the figure it can be seen that there is rich information about earthquake destruction, reflecting the

properties of source process and site-effect. On the other hand, however, the printed information is hard to use in further analysis.

Figure 1 One example of intensity distribution of historical earthquakes in North China, from Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University (1986a). Shown in the figure is the 1556 Huaxian, Shaanxi Province, *M*8+ earthquake

Transition from destruction recordings in historical documents to intensity has been implemented based on the study of Chinese ethnic architectures and earthquakes in China (Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, 1986a, b). We use the results of the intensities in the literature and digitized the isoseismals for each earthquake. The data processing uses the tool of MapInfo (MapInfo Corporation, 2003). Calibration was conducted using geographical information such as locations of cities, coastlines, and rivers. The data files contain information exactly the same as that on the map (Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, 1986a, b), being the isoseismals using Chinese intensity scale which is similar to the European MMI scale (Hao and Xie, 2006), as shown in Table 1.

Table 1 Comparison between China Intensity Scale and MMI Scale

	VII	VIII	IX	X
China (1999) Acceleration (cm/s^2)	90-177	178-353	354-707	708-1414
MMI (1956) Acceleration (cm/s^2)	147-245	245-294	294-588	588-784
China (1999) Velocity (cm/s)	10-18	19-35	36-71	72-141
MMI (1956) Velocity (cm/s)	8-20	20-30	30-60	>60

3. THE DATABASE

An example of the database is shown in Figure 2, being the same earthquake as that in Figure 1. Isoseismal distribution is affected not only by source process of the earthquake but also by site geology. Considering the recent results which approx the v30 data by topography gradient (Wald and Allen, 2007), we also plot the topography in the figure.

The database may produce .mif files of intensity distribution. Figure 3 displays the homepage of the database and the instruction of using the .mif files. Shape analysis (Kronrod et al., 2000; Sirovich et al., 2002; Molchan et al., 2002, 2004) can be conducted conveniently using the .mif files. Shown in Figure 4 is an example of the shape analysis using the approach of Molchan et al. (2002; 2004).

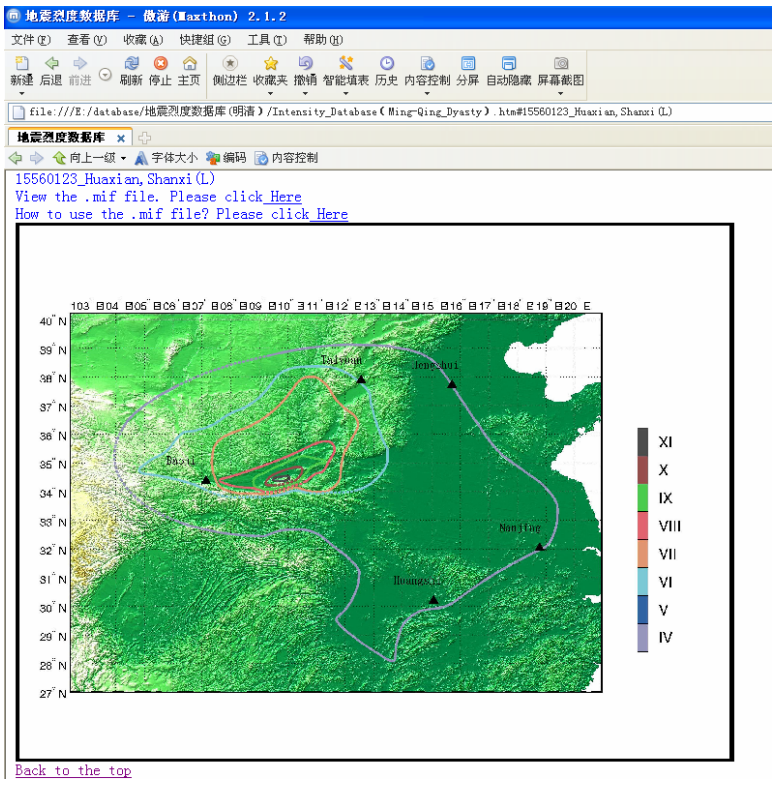

Figure 2 One example of intensity distribution of historical earthquakes in North China digitized in the database. Shown in the figure is the 1556 Huaxian, Shaanxi Province, *M*8+ earthquake, being the same as Figure 1. Original isoseismal data is from Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University (1986a). Clicking the buttons to the upper left of the figure gets the .mif file and the guidelines for using the data file.

Figure 5 shows the distribution of historical earthquakes collected in the database. From the figure it can be seen that among the historical earthquakes in this region there are 28 earthquakes (as shown by the blue dots) containing at least 2 complete isoseismal contours. Other 80 earthquakes contain less than 2 complete isoseismal, which are difficult to use in retrieving the source process but still provide useful information.

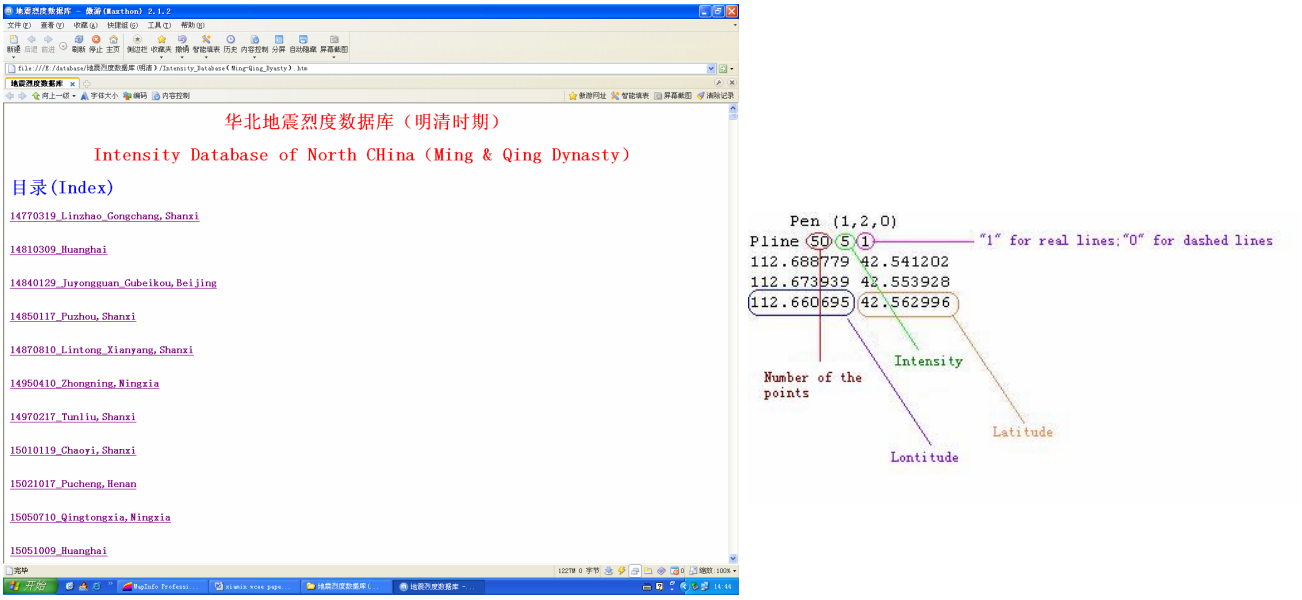

Figure 3 Homepage of the Intensity database of North China in Ming and Qing Dynasty (left) and instruction of using the .mif file (right) as shown in the database when clicking the button to the upper left of the isoseismal plot in Figure 2.

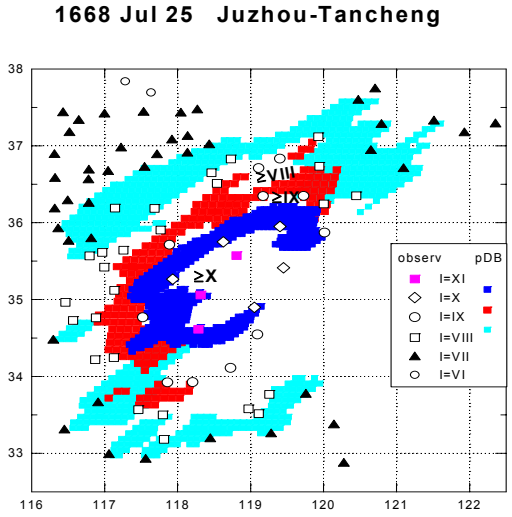

Figure 4 An example of the shape analysis of isoseismals, using the method of Molchan et al. (2002, 2004) to the database. Shown here is the Juzhou-Tancheng *M*8+ earthquake in 1668 (Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, 1986a), courtesy of Profs. T. L. Kronrod and G. F. Panza.

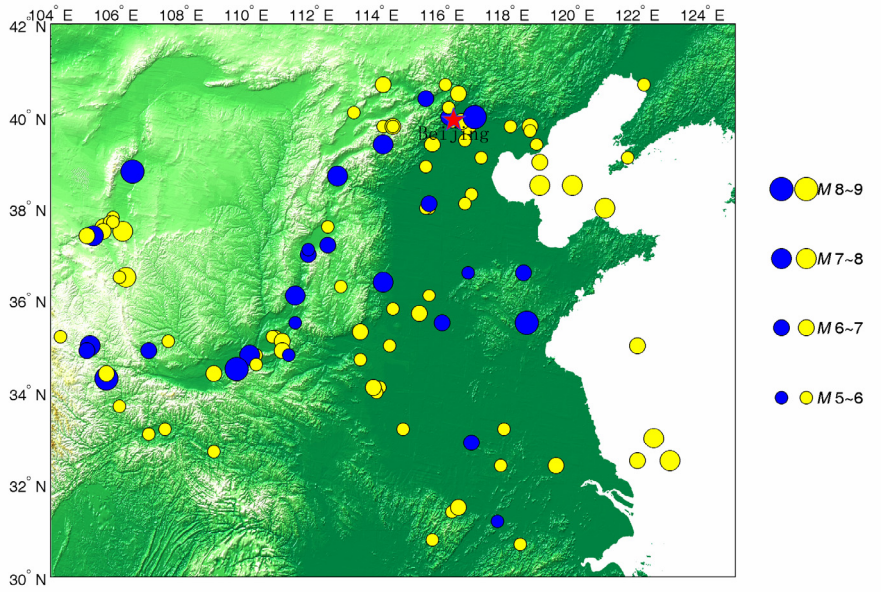

Figure 5 Historical earthquakes in North China (Ming and Qing Dynasty) with magnitude above 5, collected in the intensity database, blue dots show the events containing at least 2 complete isoseismal contours, and yellow dots show the events containing less than 2 complete isoseismal contours

4. CONCLUDING REMARKS AND DISCUSSION

There have been several works trying to construct the database of destructions and intensities (Jiang et al., 2004; Qu, 2008; Yu and Xie, 2003) using different tools such as GIS. In this work we built the database of seismic intensity for the historical earthquakes occurred in North China since the Ming Dynasty. The MatLab-based database is easy to use for the analysis of source properties and site effects. For using of this database contact xiamin06@mails.gucas.ac.cn.

Ideally when inverting source process using intensities, the isoseismal distribution should be transformed to ground motion parameters. In practice, however, since the distribution of intensity and the shape of isoseismal have a complex relation (Bormann, 2006), and the relation between intensity and ground motion is also complicated (Wald et al., 1999; Hao and Xie, 2006), in this database we just use the original isoseismals.

ACKNOWLEDGEMENT This work is supported by NSFC 40674018. Thanks are due to Profs. T. L. Kronrod and G. F. Panza for providing the result of Figure 4.

REFERENCES

Bakun, W. H. (2006). Estimating locations and magnitudes of earthquakes in southern California from modified Mercalli intensities. *Bulletin of the Seismological Society of America* **96:4,** 1278-1295.

Bormann, P., eds. (2006). IASPEI New Manual of Seismological Observatory Practice, GFZ, Potsdam, Germany (Chinese translation: Seismological Press, Beijing, China).

Chen, Y. (1975). On the determination of focal parameters of shallow earthquakes by means of macroseismic method. *Acta Geophysica Sinica* **18:4,** 246-255 (in Chinese with English abstract).

Deng, Q. D., Zhang, P. Z., Ran, Y. K., Yang, X. P., Min, W. and Chen, L. C. (2003). Active tectonics and earthquake activities in China. *Earth Science Frontiers* **10:supp,** 66-73.

Hao, M. and Xie, L. L. (2006). Research and suggestion of extent value of physical measure in seismic intensity scale of China. *Journal of Harbin Institute of Technology* **38:7,** 1041-1044 (in Chinese with English abstract).

Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University (1986a). Atlas of the Historical Earthquakes in China, the Ming Dynasty Period, China Cartographic Publishing House, Beijing, China (in Chinese).

Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University (1986b). Atlas of the Historical Earthquakes in China, the Qing Dynasty Period, China Cartographic Publishing House, Beijing, China (in Chinese).

Jiang, L. X., Yang, M. D., Shuai, X. H., Yang, T. Q. and Zhang, J. F. (2004). Design and realization of history seismic disaster database. *Earthquake* **24:supp,** 103-109 (in Chinese with English abstract).

Kronrod, T. L., Molchan, G. M., Podgaetskaya, V. M. and Panza, G. F. (2000). Formalized representation of isoseismal uncertainty for Italian earthquakes. *Bollettino di Geofisica Teorica ed Applicata* **41:3-4,** 243-313.

Koyama, J. and Zheng, S. H. (1991). Seismic intensity distribution of shallow earthquakes due to rupture velocities and faulting modes. *Acta Seismologica Sinica* **13:2,** 190-201 (in Chinese with English abstract).

MapInfo Corporation, eds. (2003). MapInfo Professional 7.5 User Manual, MapInfo Corporation, Troy, New York, U.S.A.

Molchan, G. M., Kronrod, T. L. and Panza, G. F. (2002). Shape analysis of isoseismals based on empirical and synthetic data. *Pure and Applied Geophysics* **159:6,** 1229-1251.

Molchan, G. M., Kronrod, T. L. and Panza, G. F. (2004). Shape of empirical and synthetic isoseismals: comparison for Italian M≤6 earthquakes. *Pure and Applied Geophysics* **161:8,** 1725-1747.

Panza, G. F., Craglietto, A. and Suhadolc, P. (1991). Source geometry of historical events retrieved by synthetic isoseismals. *Tectonophysics* **193:1-3,** 173-184.

Pettenati, F. and Sirovich, L. (2007). Validation of the intensity-based source inversions of three destructive California earthquakes. *Bulletin of the Seismological Society of America* **97:5,** 1587-1606.

Qu, C. Y. (2008). Building to the active tectonic database of China. *Seismology and Geology* **30:1,** 298-304 (in Chinese with English abstract).

Shebalin, N. V. (1973). Macroseismic data as information on source parameter of large earthquakes. *Physics of the Earth and Planetary Interiors* **6:4,** 316-323.

Shen, Z. K., Wan. Y. G., Gan, W. J., Li, T. M. and Zeng, Y. H. (2004). Crustal stress evolution of the last 700 years in North China and earthquake occurrence. *Earthquake Research in China* **20:3,** 211~228 (in Chinese with English abstract).

Sirovich, L., Cavallini, F., Pettenati, F. and Bobbio, M. (2002). Natural-neighbor isoseismals. *Bulletin of the Seismological Society of America* **92:5,** 1933-1940.

Sirovich, L. and Pettenati, F. (2004). Source inversion of intensity patterns of earthquakes: a destructive shock in 1936 in northern Italy. *Journal of Geophysical Research* **109:B10,** B10309, doi:10.1029/2003JB002919.

Song, Z. P., Mei, S. R. and Xue, Y. (1995). The information development and utilization of seismic historical data in China. *Earthquake* **15:1,** 12-19 (in Chinese with English abstract).

Wald, D. J. and Allen, T. I. (2007). Topographic slope as a proxy for seismic site conditions and amplification. *Bulletin of the Seismological Society of America* **97:5,** 1379-1395.

Wald, D. J., Quitoriano, V., Heaton, T. H. and Kanamori, H. (1999). Relationships between peak ground acceleration, peak ground velocity, and modified Mercalli intensity in California. *Earthquake Spectra* **15:3,** 557-564.

Xu, X. W., Wu, W. M., Zhang, X. K., Ma, S. L., Ma, W. T., Yu, G. H., Gu, M. L. And Jiang, W. L. (2002). Neotectonics and Earthquakes of the Beijing Capital Circle Region. Science Press, Beijing, China (in Chinese).

Yu, H. Y. and Xie, L. L. (2003). Study on GIS system of strong motion and engineering seismic damage database. *Earthquake Engineering and Engineering Vibration* **23:5,** 1-7 (in Chinese with English abstract).