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Seismic hazard assessment for greater North China from historical intensity observations

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ABSTRACT

Seismic hazards in greater North China were estimated from 500 years of intensity observations. Historical intensity observations were collected, the completeness of the earthquake catalog was tested, and aftershocks were deleted. The intensity data were digitized and placed in a geographic information system (GIS). Finally, the digitized intensity data were analyzed to determine the frequency–intensity relationship (i.e., seismic hazard curve). Seismic risks were also estimated, assuming a Poisson distribution for earthquake occurrence in time. The results show that greater North China faces significant seismic hazards and risks. The results also show that the current design peak ground acceleration (PGA) for greater North China might not be adequate, particularly for the Beijing, Tianjin, and Tangshan areas.

1. Introduction

Greater North China, including the cities of Beijing and Tianjin and the provinces of Hebei, Shandong, Shanxi and Jiangsu (Figure 1), has a long history of earthquakes. Large earthquakes affecting greater North China include the 1556 Huaxian (Ms $8\frac{1}{4}$), 1668 Tancheng (Ms $8\frac{1}{2}$), 1679 Sanhe-Pinggu (Ms8), and 1976 Tangshan (M_w7.8) events (Figure 1). These large earthquakes caused heavy casualties and huge economic losses. For example, the 1556 Huaxian earthquake (Ms$8\frac{1}{4}$) killed more than 830,000 people (the highest casualty in the world history) and the 1976 Tangshan earthquake (M_w7.8) leveled all of Tangshan City, killed more than 240,000 people, and caused huge economic losses.

Greater North China is also the political, economic, and cultural center of the country. Even a moderate earthquake could cause significant economic losses in the area. For example, the 1983 Heze earthquake (Ms5.9) in Shandong Province caused losses of more than 500 million Chinese yuan (National Bureau of Statistics of China, Civil Affairs Bureau, 1995), and the 1999 Yanggao earthquake (Ms5.6) in Shanxi Province caused losses of about 250 million Chinese yuan (Group of Disasters Assessment of the Earthquake in Datong Yanggao, 2000). With rapid economic development and growing population in major cities, the area is facing significant seismic risk.

Recent earthquakes, including the 2008 Wenchuan, China, 2009 L'Aquila, Italy, 2010 Haiti, 2011 Christchurch, New Zealand, and 2011 Japan events, showed that seismic hazards and risks were significantly underestimated by probabilistic approaches, probabilistic seismic hazard analysis in particular (Geller, 2011; Stein et al., 2011, 2012; Kossobokov and Nekrasova, 2012; Peresan and Panza, 2012; Wang et al., 2012). As shown in Fig. 2, the predicted intensities (<VII) in the Wenchuan and Yushu areas were much less than the observed intensities (>IX) in the epicentral areas. These underestimations might lead to under preparation and disaster.

The world was shocked when a prison sentence of 6 years was handed down by an Italian court to six scientists, including seismologists, for their inadequate seismic risk assessment and poor communication before the 2009 L'Aquila earthquake. The inadequate seismic risk assessment and poor communication confused the public and left them unprepared for the quake. Thus, not only it is important for earth scientists to conduct scientifically defensible seismic hazard and risk assessments, but also to communicate the assessments clearly and understandably to the public.

In this paper, we will explore some key issues in current seismic hazard and risk assessment and present an alternative approach for seismic hazard and risk assessment by utilizing historical intensity observations from greater North China.

2. Seismic hazard and risk

The basic concepts of seismic hazard and risk must be discussed in order to better assess and communicate seismic hazard and risk. Although seismic hazard and risk have often been used interchangeably, they are fundamentally different (Reiter, 1990; McGuire, 2004; Wang, 2006, 2007, 2009a, 2011; Wang and Cobb, 2012). Seismic hazard is

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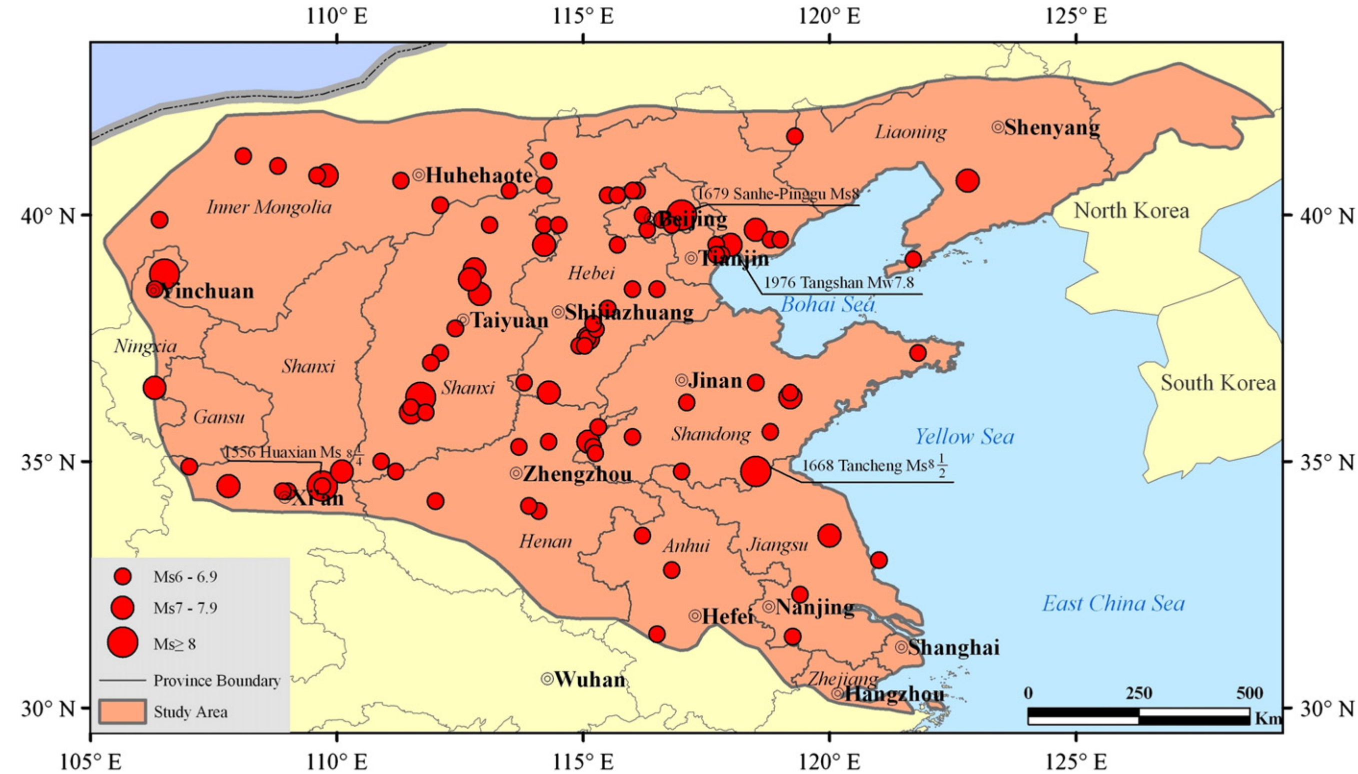

Fig. 1. Locations of large historical earthquakes in greater North China. Province names are in italics.

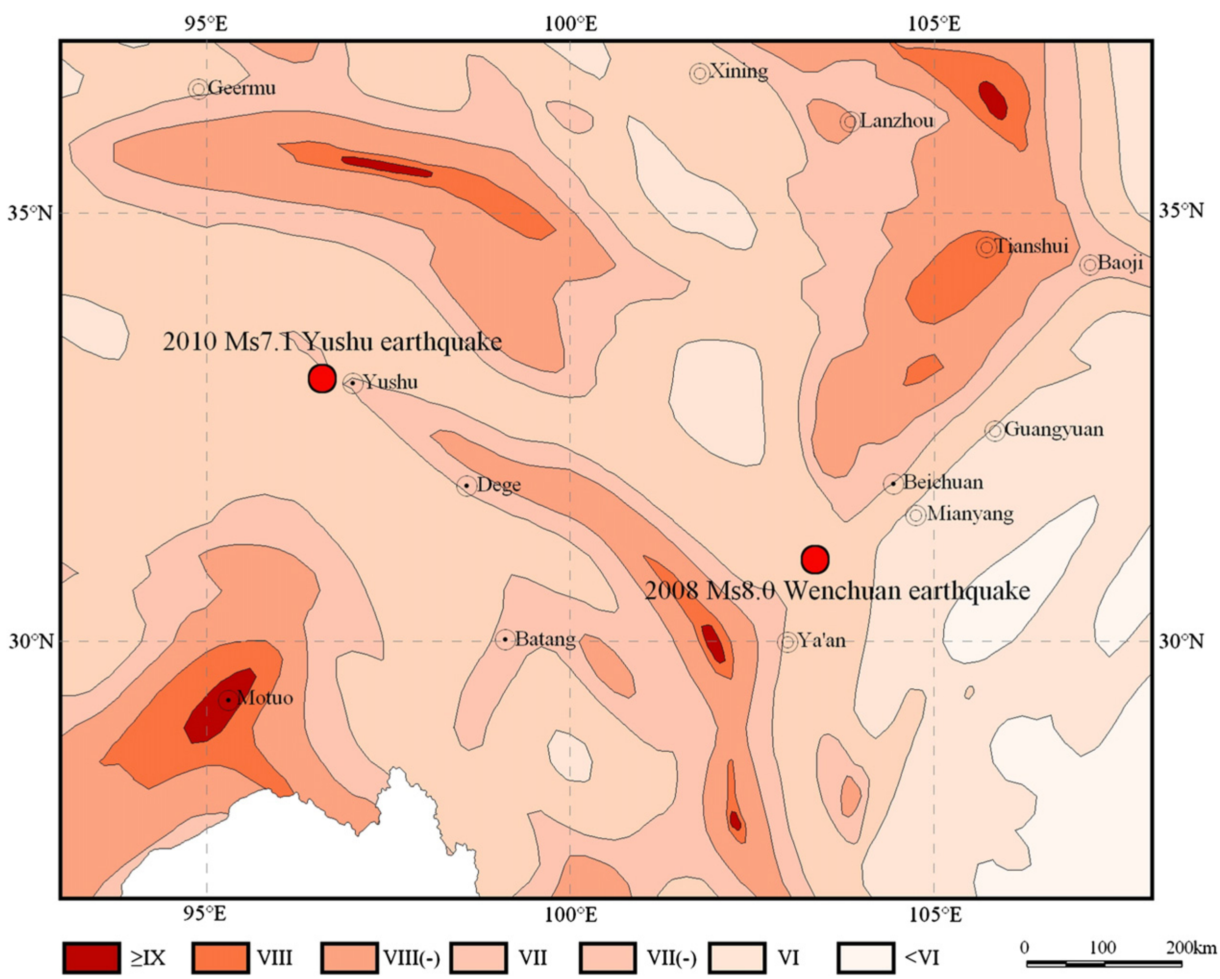

Fig. 2. Design intensity in the Wenchuan and Yushu areas (People's Republic of China National Standard, PRCNS, 2001).