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Seismic hazard assessment of the Three Gorges Project

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Abstract: Seismic monitoring data for the past 50 years in the Three Gorges Reservoir area show that the reservoir head area is a typical weak seismic region with low seismicity before impoundment and that the epicenters were concentrated in the east and west sides of the Zigui Basin, most of which were natural tectonic earthquakes. After impoundment, the seismic activity shifted to the segment between Badong and Zigui along the Yangtze River, mainly within 5 km of the reservoir bank. The seismogenesis was categorized into four types: Karst collapse earthquakes, earthquakes caused by Karst gas explosion, mining tunnel collapse earthquakes, and rock (terrane) slip earthquakes, all of which are related to the lithology, structure, and tectonics of near-surface geological bodies of the area. Compared with the seismicity before impoundment, the seismic frequency increase was remarkable, with most of the magnitudes below *M*s2.0. Therefore, the intensity of the earthquakes remained at a low level. On November 22, 2008, a magnitude 4.1 earthquake, the largest earthquake recorded since impoundment, occurred in Quyuan Town, Zigui County. The intensity and PGA of reservoir-induced earthquakes are higher than those of tectonic earthquakes with equal magnitude, but the peak intensity of reservoir-induced earthquakes is not likely to go beyond that of the estimated range from earlier studies.

Key words: Three Gorges Project; reservoir; induced earthquake; seismic hazard assessment

1 Introduction

The Three Gorges Reservoir is the largest water conservancy project for harnessing the Yangtze River, and the project has received worldwide attention. The project will be beneficial to the area in many ways. It will help protect the lower-reaches of the Yangtze River from flood disasters by regulating the river's flow, it will transmit large quantities of clean energy to central and east China, and it will help improve the Yangtze River shipping conditions. Therefore, the Reservoir will greatly benefit the Chinese economy.

The Three Gorges Reservoir is a narrow valley reservoir that is built in the lower section of the upper reaches of the Yangtze River. The reservoir is 660 km long and 1.0 - 1.5 km wide and has a total area of 55000 km^2 and a water surface area of 1048 km^2. When the water level in the reservoir reaches 175 m, the reservoir can store up to 39.3 billion m^3 of water. The water head has increased nearly 110 m, making it a large reservoir with a high dam[1].

Long-term studies on the Yangtze Three Gorges area found that the crust in or around the dam site is stable, but a tectonic background exists that could induce seismic activity[2]. The Three Gorges Reservoir area, situated at the Yangtze Para platform, consists mainly of three types of rock: granite, which the dam is built on, limestone, which exists mainly in the canyon area, and clastic rock, which is the major rock in the riverbed of the middle-upper reaches[3]. We identified three sets of regional faults (NE-NNE, NNW-NW, and NWW-oriented), located at Huangling Anticline and the surrounding area.

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The monitoring of recent deformation indicates that these faults twist horizontally at an average speed of less than 0.1 mm/a, while the average vertical displacement rate is less than 1 mm/a. However, the faults' function in controlling medium intensity earthquakes cannot be ignored. A problem that should be taken into account is that after impoundment, the pressure will rise sharply, thus making water permeate along the faults. This action could possibly trigger a strike-slip displacement and deformation, and could potentially cause earthquakes. Consequently, the induced earthquake monitoring system was established in the Three Gorges Reservoir area of the Yangtze River by the China Three Gorges Project Corporation. The induced earthquake monitoring system includes a digital telemetry seismic network, a crustal deformation monitoring network, and a well network that observes underground water behavior. A series of scientific studies on reservoir induced earthquake have been conducted using these networks[4,5].

The water level of the Three Gorges Reservoir reached 135 m on June 15, 2003, and power generation began in July. On May 20, 2006, the height of the dam was increased to 185 m, and on October 27, the water level rose to 156 m. On November 5, 2008, the water level reached 172.30 m. The Three Gorges Project (TGP) was finally finished in 2009, at which time the water level was 175 m. Earthquake monitoring in the TGP Reservoir area has been ongoing for the past 50 years. During this time, a large number of reservoir-induced earthquakes have been triggered by the variation of medium stress states, medium physical property, and regional stress fields in the dam area caused by the impounding and water fluctuation in the reservoir.

2 Seismicity monitoring system in the Three Gorges Reservoir area

The earthquakes occurring in the TGP Reservoir area have been monitored for 50 years, which is a rarity in the world's hydropower project history. Currently, the monitoring system has three pieces. The first piece was built in 1958 and is composed of 8 seismic stations. The second piece was built in the reservoir head area in 1997 is composed of 15 attended stations, and can efficiently monitor earthquakes with a magnitude larger than 0.5. The third piece is a digital telemetry seismic network that was completed in 2000 and consists of 24 telemetric stations (Fig. 1). Compared to the first two analogue systems, the third system has following advantages: a wide dynamic range, high resolution that can reach up to 3×10^{-5}, a low distortion degree (usually is 1‰), easier data storage and exchange, use of a computer, and the systems' convenient use for seismicity research.

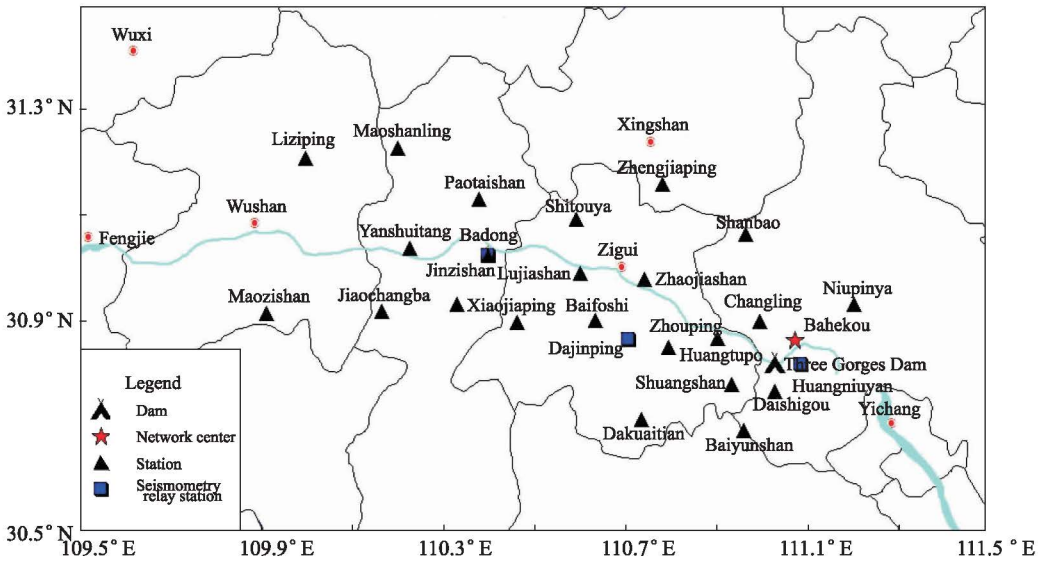

Figure 1 Distribution of digital telemetry seismic network in TGP of Yangtze River