Comprehensive Study on Reservoir-induced Seismicity in the Xiaowan Reservoir, Yunnan Province, China

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Introduction

The Xiaowan reservoir is located in the middle section of the Lancang River in the west of Yunnan province, China, and the Xiaowan Reservoir Digital Seismic Station Network (XRDSN) had been in operation since 21 May 2005. Its filling operations took place in five phases, starting on December 16, 2008. The seismicity in the Xiaowan reservoir area after the impoundment has changed obviously with respect to the pre-impoundment. A notable increase in seismicity was only observed during the third filling phase, starting on July 15, 2010. Seismicity increase was mostly localized within two clusters, located to the northwest and west of the dam. Seismicity rates in these clusters showed a significant correlation with the water level increase, with the seismicity starting to increase when the water level reached the area covered by the two clusters, which additionally support they were induced by the reservoir impoundment. 3-D shear wave velocity images, measured by the local earthquake tomography method SIMUL2000, show that low-Vs anomalies after the impoundment can be found beneath and around the Lancang River and the Hehuai River in the reservoir area, where the two clusters are located. It may be related to the water loading and unloading and water permeation. We further investigate source parameters for 44 pre-impoundment earthquakes and 164 post-impoundment earthquakes with M $\geq$ 2.0. Corner frequencies, seismic moments, and stress drops are obtained based on the spectral analysis of regional data, upon corrections for geometrical spreading, frequency-dependent Q, and site effects. Our results show that during the post-impoundment phase reservoir-induced seismicity (RIS) inside the two clusters have systematically lower stress drops with respect to those occurring at further distance, and surrounding natural tectonic earthquakes, by a factor of about two to three times, suggesting a possible source characteristic that differentiate reservoir-induced seismicity from natural tectonic earthquakes.

Results

1. Relationship Between RIS and Reservoir Filling

2. 3-D shear wave velocity images in the Xiaowan reservoir area

3. Source parameters for events in the Xiaowan reservoir area

Conclusions

- The increase in seismicity in the Xiaowan reservoir was not obvious after the first filling until the third filling on 15 July 2010 and this evidently increased seismicity mainly concentrated in two clusters to the northwest and west of the dam. For these earthquakes in the west cluster after the second filling and those in the northwest cluster after the third filling, their seismicities showed strong unusual correlation with water level and the seismicity increased time is consistent with the time when the elevated water reached the area covered by these two clusters respectively, indicating that they were induced by reservoir impoundment.

- 3-D shear wave velocity images, measured by the local earthquake tomography method SIMUL2000, show that low-Vs anomalies after the impoundment can be found beneath and around the Lancang River and the Hehuai River in the reservoir area, where the two clusters are located. It can be related to the water loading and unloading and water permeation.

- Stress drops for the events inside cluster one and two before water filling are almost the same as those outside two clusters with the same magnitude range. However, RIS inside these two clusters after the third filling appear to have systematically lower stress drops with respect to these surrounding natural tectonic earthquakes, by about a factor of 2-3 times. The phenomena of lower stress drop for RIS are observed both in low and high seismicity region, indicating lower stress drop for RIS does not just result from lower background stress level and it may be considered as the pronounced characteristics that differentiate it from normal tectonic earthquake.

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