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Source rupture process inversion of the 2013 Lushan earthquake, China

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Abstract: The spatial and temporal slip distribution of the Lushan earthquake was estimated using teleseismic body wave data. To perform a stable inversion, we applied smoothing constraints and determined their optimal relative weights on the observed data using an optimized Akaike's Bayesian Information Criterion (ABIC). The inversion generated the source parameters. Strike, dip and slip were 218°, 39° and 100.8°, respectively. A seismic moment (M_0) was 2.1×10^{20} Nm with a moment magnitude (Mw) of 6.8, and a source duration was approximately 30 second. The rupture propagated along the dip direction, and the maximum slip occurred at the hypocenter. The maximum slip was approximately 2.1 m, although this earthquake did not cause an apparent surface rupture. The energy was mainly released within 10 second. In addition, the Lushan earthquake was apparently related to the 2008 Wenchuan earthquake. However, the question of whether it was an aftershock of the Wenchuan earthquake requires further study.

Key words: source rupture process; teleseismic wave; Lushan earthquake

1 Introduction

On April 20, 2013 (UTC 00:02:48), a major earthquake with magnitude of M7.0 occurred in Lushan county, Sichuan province. This earthquake was the largest seismic event since the 2008 Wenchuan earthquake in this area and caused more than 190 human deaths and injured millions of people. The China Earthquake Administration determined that the epicenter was at 30.284° N and 102.955° E at a shallow depth of 12.3 km. The mainshock was followed by hundreds of aftershocks, the largest of which was M5.4.

The study area is located in the eastern margin of the Tibetan Plateau. Tectonically, this area belongs to the intersection of the Songpan-Ganzi block (SP-GZ block) and the Sichuan basin (SC basin). The main active faults in this area are the Longmenshan fault (LMS fault), Xianshuihe fault (XSH fault), and Anninghe fault (ANH fault). The Lushan earthquake occurred on the Longmenshan fault, which is also the seismogenic fault of the 2008 Wenchuan earthquake. The Longmenshan fault is a NE-striking fault, starting at Luding, passing through Maowen, Beichuan, and Guangyuan, terminating near Mianxian. And the length and width are approximately 500 km and 30 – 40 km, respectively. The fault can be divided into three segments: the segment from Beichuan to Mianxian is the northeastern part, the section from Beichuan to Dujiangyan comprises the middle segment, and the reach from Luding to Kangding constitutes the southwestern segment (Fig. 1). Since the Cenozoic Era, the Longmenshan fault has remained active, and GPS monitoring has

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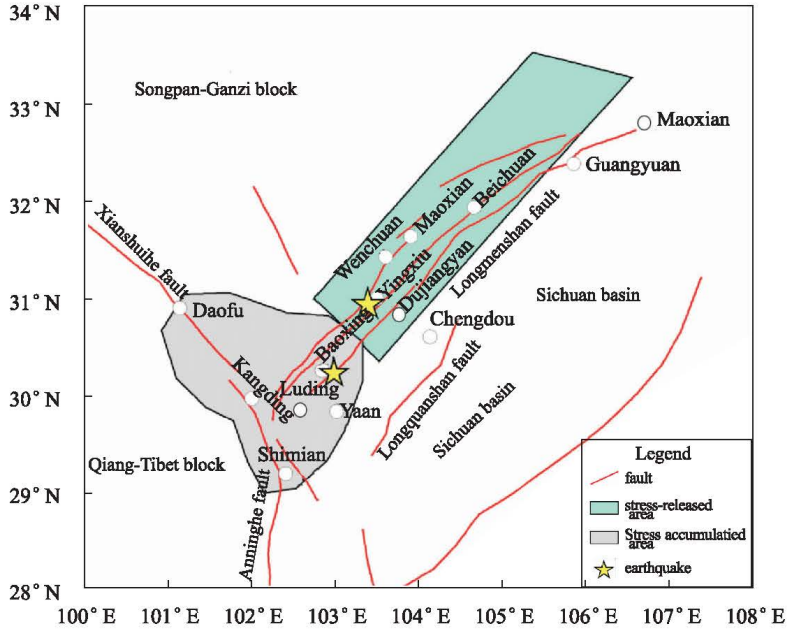

Figure 1 Geotectonic setting and schematic map showing the location of the geostress measurement sites

shown that the middle and southwestern segments are more active than the northern part. The intersection of the Longmenshan, Xianshuihe and Anninghte faults is an earthquake-prone region, which deserves further study[1].

The purpose of this study was to estimate the source rupture process of the Lushan earthquake and preliminarily discussed the relationship with the 2008 Wenchuan earthquake.

2 Methodology and data

Earthquake source process is used to determine the physical behavior of an earthquake. Using kinematic source rupture process inversion, we can obtain an understanding of the coseismic slip distribution. In general, seismic sources can be modeled as point or finite fault sources. Point source modeling is suitable for representing small earthquakes, because its size approaches zero, the magnitude is small with a short duration and the slip is assumed to be uniform. For large earthquakes, however, we should consider the spatiotemporal variation of the slip distribution. Therefore, finite fault model is appropriate, which can be approximated by multiple point sources. A fault plane is divided into many subfaults, where a point source is located at the gravity center of each subfault. In addition, each point source may have a different source time function $\Delta(t)$ or moment rate function $M(t)$. The displacement caused by multiple point sources on a finite fault is

$$U_n(x,t) = \sum_{i=1}^{N} \hat{U}_n^i(x,\xi_i,t)\Delta\dot{U}^i(\xi_i,t) \quad (1)$$

where $U_n(x,t)$ is the displacement in time and space, N is the total number of point sources, $\Delta\dot{U}^i(\xi_i,t)$ is the time derivative of the fault slip history for i-th point source located at ξ and $\hat{U}_n^i(x,\xi_i,t)$ is the displacement caused by one unit fault slip for the i-th point source located at ξ.

Here, we used teleseismic body wave data to estimate the source rupture process of the Lushan earthquake. In general, teleseismic body waves contain information on the overall moment release rate and depth range of the rupture area, whereas near-source waveforms contain detailed information on the source area. Therefore, to obtain a detailed and stable source process, it is preferable to use both teleseismic body wave data and near-source data[2]. However, after a large earthquake, it is difficult to obtain strong ground motion data within a short period of time. Therefore, in this study, only teleseismic wave data were used for the inversion to derive the preliminary source process.

We retrieved teleseismic body wave data recorded at