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Surface ruptures induced by the Wenchuan earthquake: Their influence widths and safety distances for construction sites

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ABSTRACT

Surface ruptures studied in this paper refer to those induced by the 2008 Wenchuan earthquake. They mostly appear as two prominent surface rupture zones: one is about 240 km long, distributed along the Central Fault; and another about 70 km long, along the Front Mountain Fault. The influence width of a surface rupture is an important factor to determine the safety distance for construction sites to keep away from it. In measuring the influence width, the shortening amount or rate must be paid enough attention to. The statistical analysis of 85 sets of practically measured data of surface ruptures shows that the influence widths are concentrated in the scope of 15 m and 60 m, and that there is a linear relationship between the vertical displacements (H) and influence widths (D) of surface ruptures, which can be approximately expressed as: $D = 11H + 14$. The influence scopes on both sides of a surface rupture are asymmetric and their proportion between the hanging side and the down side is generally from 3:1 to 2:1.

1. Introduction

The Longmenshan tectonic belt is mainly composed of three faults: the Back Mountain Fault (Wenchuan–Maowen Fault), the Central Fault (Yingxiu–Beichuan Fault), and the Front Mountain Fault (Peng–Guan Fault) from west to east. It has been considered that the Central Fault is the earthquake-generating fault of the Wenchuan earthquake of magnitude 8.0 on May 12, 2008 (Burchfiel et al., 2008). The earthquake brought about two prominent surface rupture zones: one is about 240 km long, extended and along the Central Fault; and another is about 70 km long, along the Front Mountain Fault (Figure 1). They are considered as the longest and most complicated earthquake surface ruptures at the eastern margin of the Qinghai–Tibetan Plateau in the intra-plate compressive setting (Liu et al., 2008; Xu et al., 2009). The maximum meizoseismal intensity (MMI) reached XI around Yingxiu Town, Wenchuan County, and Qushan Town, Beichuan County, where 80% of the houses collapsed during the quake. In lines the ruptures went through, most of the mountain ridges and water systems were dislocated and all of buildings were destroyed (Dong et al., 2008; Xu et al., 2008; Ma et al., 2009). The surface rupture zone distributed along the earthquake-generating fault, i.e., the Central Fault, is similar to that induced by the 1999 Chi-Chi earthquake of magnitude 7.6 in Taiwan. In the latter, all buildings within more than 10 m on both sides of the earthquake-generating fault plane were razed to the ground, while the buildings out of the range were largely intact (Kelson et al., 2001; Lee et al., 2001).

For the purposes of earthquake disaster assessment, and emergency rescue and recovery reconstruction, many researchers rushed to the earthquake region to carry out scientific investigations of the earthquake surface ruptures, and obtained large amounts of valuable first-hand data or information about the distributional characteristics of earthquake ruptures, rupture types, and coseismic displacements, which have contributed to realization of the earthquake rupture process and failure mechanism (Xu et al., 2008, 2009; Zhou et al., 2008; Lin et al., 2009; Liu-Zeng et al., 2009; Ma et al., 2009). Unfortunately, the above investigation results gave less discussion of the influence widths and safety distances of earthquake ruptures. Now, an important issue that concerns authorities at home and many researchers is how to keep away from surface ruptures and determine reasonable safety distances for the post-Wenchuan earthquake reconstruction. As an effort of policy, China's Ministry of Construction revised in time its Code for Seismic Design of Buildings (2008) after the Wenchuan earthquake. Based on their field investigation, Zhou et al. (2008) studied and discussed the safety distance on each side of the earthquake-generating fault of the Wenchuan earthquake, but limited to the data obtained, their result is just elementary, still.

In this paper, the systematically measured horizontal and vertical displacements and the widths influenced by surface ruptures along the Central Fault, the Front Mountain Fault, and the Xiaoyudong Fault (a NW fault between the foregoing two faults) have been reported. During the field work, the authors have amazedly noticed that some houses have been or are being or will be directly rebuilt within surface rupture zones without keeping away from them (Figure 2), that is, without considering safety distances. In a sense, this problem has encouraged our writing of this paper to stress the importance of safety distances.

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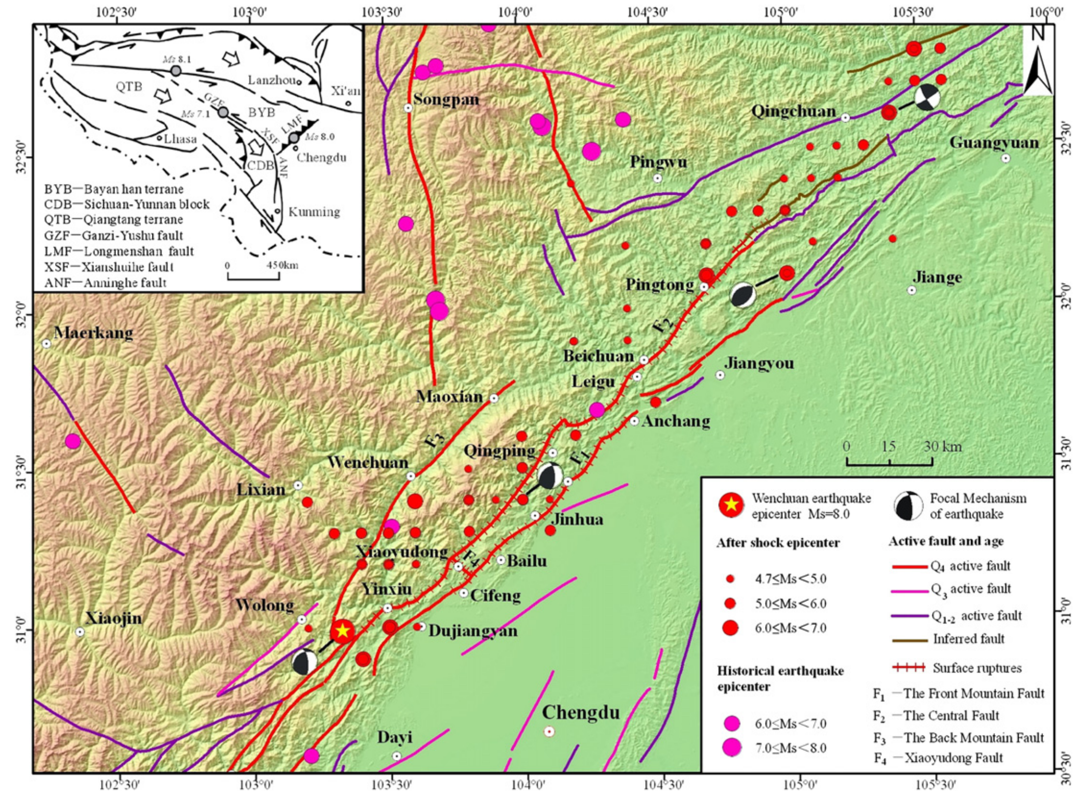

Fig. 1. Distribution of surface ruptures caused by Wenchuan earthquake.

2. Surface ruptures

2.1. Characteristics

Surface ruptures studied in this paper are those caused by the 2008 Wenchuan earthquake. They are different in principle from the earthquake-generating faults or related faults but can be used as markers to identify the latter faults. In a few cases, they are not excluded just to be those faults. Most of them are visible on the surface; some appear as changes of land form such as small folds, waves, scarps or ridges, and even some are hidden.

The surface ruptures may occur as single ruptures or a set of ruptures or a rupture zone. They easily occur in soft strata such as the Xujiahe Formation and loose soil such as valley and piedmont sediments. If so, they usually have larger fault displacements. For a surface rupture zone, the hanging side was usually deformed seriously, so buildings on the hanging side were damaged more seriously than those on the down side (Figure 3).

Fig. 2. A row of houses built within a surface rupture zone without considering a safety distance: arrows showing the rupture scarps.