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Fault activity characteristics in the northern margin of the Tibetan Plateau before the Menyuan Ms6.4 earthquake

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ABSTRACT

Fault deformation characteristics in the northern margin of the Tibetan Plateau before the Menyuan Ms6.4 earthquake are investigated through time-series and structural geological analysis based on cross-fault observation data from the Qilian Mountain–Haiyuan Fault belt and the West Qinling Fault belt. The results indicate: 1) Group short-term abnormal variations appeared in the Qilian Mountain–Haiyuan Fault belt and the West Qinling Fault belt before the Menyuan Ms6.4 earthquake. 2) More medium and short-term anomalies appear in the middle-eastern segment of the Qilian Mountain Fault belt and the West Qinling Fault belt, suggesting that the faults' activities are strong in these areas. The faults' activities in the middle-eastern segment of the Qilian Fault belt result from extensional stress, as before the earthquake, whereas those in the West Qinling Fault belt are mainly compressional. 3) In recent years, moderate-strong earthquakes occurred in both the Kunlun Mountain and the Qilian Mountain Fault belts, and some energy was released. It is possible that the seismicity moved eastward under this regime. Therefore, we should pay attention to the West Qinling Mountain area where an Ms6–7 earthquake could occur in future.

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1. Introduction

According to the China Digital Seismograph Network (CDSN), an Ms6.4 earthquake hit Menyuan Hui Autonomous County, Haibei Tibetan Autonomous Prefecture, Qinghai Province at 1:13 on January 21, 2016. The earthquake's epicenter was located at 37.68°N, 101.62°E, at a depth of 10 km. The earthquake was called the "Qinghai, Menyuan Ms6.4 earthquake." Its epicenter was located about 35 km from the Menyuan County and approximately 110 km from Xining; it was strongly sensed in both areas. Before the earthquake, cross-fault monitoring sites in the Qilian Mountain—Haiyuan—West Qinling structural belt where the epicenter was located displayed abnormal responses. The epicenter lies in the Qilian Mountain Fault belt at the northern margin of Tibet Plateau, and the huge extruding force from the collision between the Indian Ocean with the Eurasian Plate provides a major power source for this earthquake. Research on the Quaternary deformation of the northern margin of Tibet Plateau led to the correlation between the genesis of huge crustal deformation and frequent earthquakes in the northern Tibet Plateau [1–6]. Moreover, the northern margin is comprised of multiple plates and blocks, which shapes its complex geological structures. Cross-fault measurement is a real-time, high-precision, and quantified crustal deformation monitoring tool and one of the most direct and effective methods of fault activity monitoring [7–9]. In the present study, we combine cross-fault temporary site data from the northern margin of the Tibet Plateau with seismic tectonic data to analyze the deformation characteristics of regional faults before the Menyuan Ms6.4 earthquake and discuss the high-risk regions for future earthquakes.

2. Regional geology and seismology

The epicenter of the Qinghai, Menyuan Ms6.4 earthquake lies near the Lenglongling Fault in the Qilian Mountain Fault belt. Associated with the subduction of the Indian Ocean Plate under the Eurasian Plate, collision/joining and extruding shaped the very thick Tibet Plateau, i.e., "The Third Pole." Meanwhile, a series of significant structural belts were formed in the periphery of this large plateau. Massive fault systems were developed between the northern margin of the Tibet Plateau and Alxa block to the north, which include the Qilian Mountain Fault belt [1,2]. This region lies in the collision/joining area of multiple secondary plates and blocks with complicated tectonic attributes; structural lines extend mainly NW–SE, dominated by strike-slip reverse faults (Fig. 1).

The epicenter is close to the Lenglongling Fault, which is a Holocene active fault and reverse-fault and strike-slip. At present, this seismogenic fault is considered a small-scale, buried fault between the Minle–Damaying Fault and the Lenglongling Fault.

Since 1900s, five earthquakes bigger than Ms5 hit within the 100 km range of the epicenter, the largest one was the Gulang Ms8.0 earthquake with an epicenter about 50 km from this earthquake. The Menyuan Ms6.5 earthquake in 1986 was closest (10 km) to this earthquake location. The latest large earthquake was the Qilian Ms5.2 earthquake in 2015.

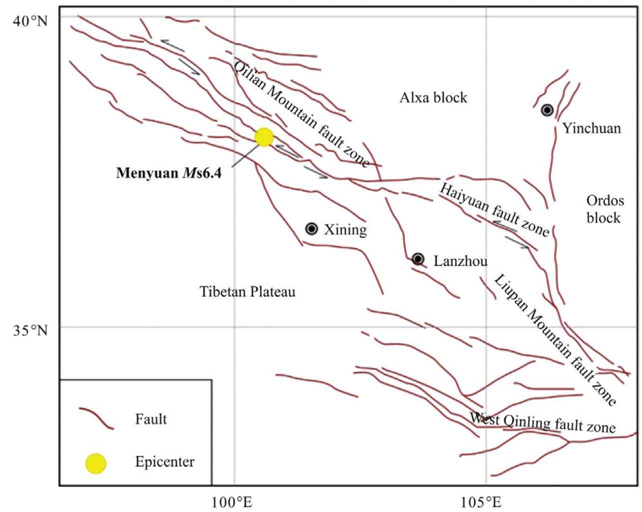

Fig. 1 – Geologic structure diagram of the study area.

3. Material and methods

3.1. *Cross-fault sites*

More than 70 cross-fault sites were selected in the Qilian Mountain–Haiyuan Fault belt and the West Qinling Fault belt in the study area to obtain data for the analysis. The observation sites were built during 1970s–1980s; thus, at least 30 years of complete and continuous observation data were accumulated. Site deformation monitoring mainly adopts short-leveling observation. Moreover, more than ten comprehensive sites covered by infrared baseline distance measurements in the Qilian Mountain Fault belt are found (Fig. 2). This area is mainly under the charge of the Second Crust Monitoring and Application Center of China Earthquake Administration (CEA).

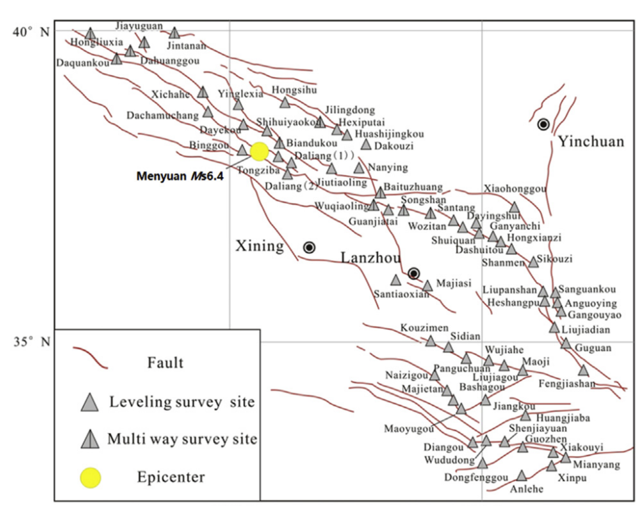

Fig. 2 – Distribution of cross-fault site.