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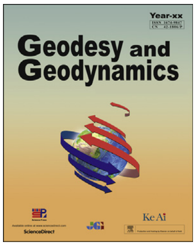

Representative value of cross-fault in the northeastern margin of the Qinghai-Tibet block and case analysis of the 2016 Menyuan Ms6.4 earthquake

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ABSTRACT

The equation for determining cross-fault representative value is calculated based on hanging wall and foot wall reference level surfaces. The cross-fault data reliability are analyzed base on the stability of reference datum and observation points, thereby facilitating plotting of the representative value curves after removing interference. The spatial and temporal characteristics of fault deformation abnormalities before the 2016 Menyuan Ms6.4 earthquake, as well as the fault-movement characteristics reflected by representative value, are summarized. The results show that many site trends had changed 1–3 years before the Menyuan Ms6.4 earthquake in the Qilian Fault, reflecting certain background abnormalities. The short-term abnormalities centrally had appeared in the 6 months to 1 year period before the earthquake near and in the neighborhood of the source region, demonstrating a significantly increased number of short-term abnormalities. Many sites near and in the neighborhood of the source region had strengthened inverse activities or had changed from positive to inverse activities in the most recent 2–3 years, which reflect stress-field enhancements or adjustment features.

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1. Introduction

On January 21, 2016, the Menyuan Ms6.4 earthquake occurred in Qinghai Province, Tibet, with an epicenter at 37.68° N and 101.62° E. The earthquake was thrust near the Lenglongling Fault. The earthquake was located in the deformation monitoring area, on the northeastern margin of the Qinghai-Tibet block, and there were more than 50 cross-fault observation sites. Most of the sites were routinely observed in March, July, and November every year, involving the Qilian-Haiyuan-Liupan Mountain Fault and the West Qinling area [1]. Previous studies showed that abnormal cross-fault deformation could be observed within a certain range of the epicenter prior to moderate and strong earthquakes. Anomalies mainly included accelerating, turning, kicking, stepping, etc. Cross-fault deformation precursory anomalies had several months to over 1 year of forecast significance [2–5]. There had been many short-term cross fault deformation precursory anomalies in the Qilian Fault before the Menyuan Ms6.4 event. After the earthquake, the Second Monitoring and Application Center, China Earthquake Administration, performed encrypted observation for seven sites near the earthquake zone that previously had obvious abnormalities, and the results demonstrated significant earthquake response [6].

Cross-fault deformation observation can directly reflect the fault-motion changes at observed sites. Practical observation data are able to provide a solid basis for analyzing fault movement and earthquake prediction. Actually, a cross-fault deformation observation value is comprised of two components. The first is tectonic deformation and the second is nontectonic deformation caused by environmental factors. Nontectonic deformation anomalies as a result of changes in the stability of measuring points frequently lead to misjudgment of earthquakes; thus, they should be excluded [7–9]. Environmental interference may affect the stability of the points, showing inconsistent or even significantly different cross-fault observation curves for the same site. In order to eliminate interference and to reduce the effect of random errors, etc., representative value of a cross-fault was estimated based on the concept of hanging wall and foot wall reference level surfaces in the present study to characterize tectonic movement. Through study of relative elevation curves of observation points, and of the stability of each hanging wall and foot wall reference datum, the unstable points or questionable observation sections were eliminated, thereby refining characterization of fault tectonics' representative value using reliable measurement segments. Thereafter, the characteristics of spatial and temporal fault deformation abnormalities and the fault-movement characteristics reflected by representative value before the Menyuan Ms6.4 earthquake are discussed.

2. Calculation of representative value of cross-fault

Owing to the small cross-fault precincts and short observation segments (only a few hundred meters to about 1 km), a fault can be theoretically viewed as two rigid bodies. Tectonic force causes different movement of two fault plates, while the relative displacement between measuring points in the same plate are the result of nontectonic stress. Supposing that both plates have level surfaces, the representative value is defined as the difference between the level surfaces of two plates, which can be calculated by averaging the heights of measuring points in the same plate. In this case, not only are the measuring points subject to random fluctuations caused by environmental factors and the observational error weakened, but the observational data are fully utilized as well. All observational data on one site are plotted in a curve so as to reflect the tectonic fault characteristics.

The calculation of representative value of cross-fault is described below, taking four symmetrically distributed measuring points as an example (Fig. 1a). i is the measured point or segment number, H is the elevation of the standard point, l is an observation segment (with the arrows indicating the direction of observation), and H_{up} and H_{low} represent upper- and lower-plate standard point average elevations, respectively. L_0 is the representative value of cross-fault, i.e., the relative activity of the lower plate to the upper plate. The point designated 1 on the lower plate is taken as the starting point, the elevation is H_1, and the elevations of other measuring points are, sequentially,

$$H_2 = H_1 + l_1 \tag{1}$$

$$H_3 = H_1 + l_1 + l_2 \tag{2}$$

$$H_4 = H_1 + l_1 + l_2 + l_3 \tag{3}$$

The average elevation of the upper and lower plates is

$$H_{up} = \frac{1}{2}(H_3 + H_4) = H_1 + l_1 + l_2 + \frac{1}{2}l_3 \tag{4}$$

$$H_{low} = \frac{1}{2}(H_1 + H_2) = H_1 + \frac{1}{2}l_1 \tag{5}$$

Then, the equation for calculating representative value of cross-fault can be obtained for the a-type measuring-point distribution as shown in Fig. 1:

$$L_0 = H_{low} - H_{up} = -\frac{1}{2}(l_1 + 2l_2 + l_3) \tag{6}$$

Similarly, the representative value of cross-fault for the rest of the measuring-point distributions shown in Fig. 1 can be calculated as:

$$\text{Type b}: \ L_0 = -\frac{1}{3}(l_1 + 2l_2 + 3l_3 + 2l_4 + l_5) \tag{7}$$

$$\text{Type c}: \ L_0 = -\frac{1}{2}(l_1 + 2l_2) \tag{8}$$

$$\text{Type d}: \ L_0 = -\frac{1}{2}(l_1 + l_2) \tag{9}$$

$$\text{Type e}: \ L_0 = -\left(\frac{1}{2}l_1 + l_2 + \frac{2}{3}l_3 + \frac{1}{3}l_4\right) \tag{10}$$

The calculation of representative value of cross-fault is simple and has clear physical meaning. The equations are different according to site routes. There are also inherent laws