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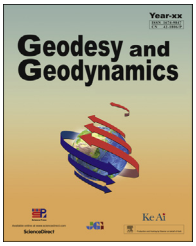

Characteristics of regional crustal deformation before 2016 Menyuan Ms6.4 earthquake

Weitao Chen[a], Weijun Gan[b,*], Genru Xiao[c], Yuebing Wang[a], Weiping Lian[a], Shiming Liang[b], Keliang Zhang[b]

[a] National Earthquake Infrastructure Service, China Earthquake Administration, Beijing 100036, China
[b] State Key Laboratory of Earthquake Dynamics, Institute of Geology, China Earthquake Administration, Beijing 100029, China
[c] Faculty of Geomatics, East China University of Technology, Fuzhou 344000, China

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ABSTRACT

On January 21, 2016, a strong earthquake with a magnitude of *Ms*6.4 happened at Menyuan, Qinghai Province of China. In almost the same place, there was another strong earthquake happened in 1986, with similar magnitude and focal mechanism. In this paper, we analyze the characteristics of regional crustal deformation before the 2016 Menyuan *Ms*6.4 earthquake by using the data from 10 continuous Global Positioning System (GPS) stations and 74 campaign-mode GPS stations within 200 km of this event: (a) Based on the velocity field from over ten years GPS observations, a regional strain rate field is calculated. The results indicate that the crustal strain rate and seismic moment accumulation rate of the Qilian-Haiyuan active fault, which is the seismogenic tectonics of the event, are significantly higher than the surrounding regions. In a 20 km × 20 km area around the seismogenic region, the maximum and minimum principal strain rates are 21.5 nanostrain/a (NW–SE extension) and −46.6 nanostrain/a (NE–SW compression), respectively, and the seismic moment accumulation rates is 17.4 Nm/a. The direction of principal compression is consistent with the focal mechanism of this event. (b) Based on the position time series of the continuous GPS stations for a time-span of about 6 years before the event, we calculate the strain time series. The results show that the dilatation of the seismogenic region is continuously reduced with a "non-linear" trend since 2010, which means the seismogenic region has been in a state of compression. However, about 2–3 months before the event, both the dilatation and maximum shear strain show significant inverse trends. These

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* *Corresponding author.*
E-mail address: wjgan@gps.gov.cn (W. Gan).
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abnormal changes of crustal deformation may reflect the non-linear adjustment of the stress–strain accumulation of the seismogenic region, when the accumulation is approaching the critical value of rupture.

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1. Introduction

On January 21, 2016, a strong earthquake with a magnitude of Ms6.4 happened at Menyuan, Qinghai Province of China. The epicenter is N37.68°, E101.62°, and the focal depth is about 10 km. The result of seismic moment tensor shows this event is thrust and strike-slip. The fault plane I has a strike of 335°, a dip of 53° and a rake of 98°, and the fault plane II has a strike of 141°, a dip of 38° and a rake of 79°. The epicenter is located adjacent to the Lenglongling Fault, which is a Holocene active fault with left-lateral and thrust slip, striking of NW (http://www.eq-igl.ac.cn/upload/images/2016/1/2191153838.jpg). Notice that in almost the same place, there was another strong earthquake happened in 1986 [1]. The USGS CMT shows that the parameters of the two fault planes of the earthquake are (strike 125°, dip 37°, rake 55°) and (strike 346°, dip 60°, rake 113°), respectively, which are similar to the 2016 event. (http://earthquake.usgs.gov/earthquakes/eventpage/usp0002xjb#moment-tensor?source=us&code=gcmt19860826094304). As the recurrence of these two Ms6.4 earthquakes in the same place may have the implication of "characteristic earthquake", we try to analyze the characteristic of regional crustal deformation before 2016 Menyuan Ms6.4 earthquake so as to find some precursors for the predication of the next characteristic earthquake in this area.

2. GPS data and data processing

In the northeastern margin of the Tibetan Plateau, two national scientific infrastructure projects named "Crustal Movement Observation Network of China" (CMONOC I) and "Tectonic and Environmental Observation Network of Mainland China" (CMONOC II) have deployed dense GPS stations, and accumulated high-quality GPS observation data since 1999 [2,3] (Fig. 1). Here we chose the data from 10 continuous GPS stations and 74 campaign-mode GPS stations within 200 km of the seismogenic region. The more detailed information about the GPS stations is listed in Table 1.

GPS data were processed with the software GIPSY/OASIS (Version 6.0) [4] from Jet Propulsion Laboratory (JPL), National Aeronautics and Space Administration (NASA), using the Precise Point Positioning (PPP) strategy and JPL products to obtain daily loosely constrained solutions. Then, we use the software QOCA of JPL [5], to perform joint adjustment for the daily loosely constrained solutions of all stations to get their coordinate time series and optimum estimations of velocity in the International Terrestrial Reference Frame (ITRF) 2008. The specific procedures are described below:

The linear combinations reducing or eliminating the effect of ionospheric delay are taken as observational variables. The satellite truncation altitude angle is 15°, and data sampling rate is 300 s. Fixed International GNSS Service (IGS) 08-based precise obits and clocks of JPL are adopted (http://sideshow.jp1.nasa.gov). The a priori global pressure and temperature model (GPT) and global-mapping function (GMF) are used [6]. Correction for ocean tide loading is made with the Finite Element Solution (FES) 2004 model with online calculation (http://holt.oso.chalmers.se/loading). During data processing, the self-consistency of the products are taken into consideration, such as the orbits, clock difference, satellite-dependent differential code biases (DCB), phase center of receiver antenna and phase center of satellite [7]. The estimation parameters include station coordinates, clock errors of receivers and troposphere delay. To improve solution accuracy, we apply the Ambizap software [8] for phase ambiguity resolving, in which various linear combinations of observational parameters are determined using the fixed point theorems, and the unique and self-consistent daily solutions with phase ambiguity resolved are generated in the end. Finally, through seven parameter transform, the daily solutions are converted into ITRF2008 reference system.

3. Interseismic GPS velocity field

Fig. 2 shows the GPS velocity field in a Eurasia-fixed reference frame, which clearly demonstrates that the velocities on the south side of the Qilian-Haiyuan fault system, the seismogenic tectonic of 2016 Menyuan Ms6.4 earthquake, are generally larger than those on the north side. The average crustal motion rate is 9.5 mm/a for the 45 stations in the south and 4.0 mm/a for the 39 stations in the north, which indicates a difference of 5.5 mm/a. That is, the Qilian-Haiyuan fault system accommodates a remarkable part of the NEE extrusion in this region.

In order to determine the slip rate of Qilian-Haiyuan fault system by GPS velocity field, especially for the left-lateral