Geodesy and Geodynamics 2011,2(3):50 – 55

http://www.jgg09.com
Doi:10.3724/SP.J.1246.2011.00050

Recent crustal movement and great earthquakes in Qinghai-Tibet sub-plate

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Abstract: Crustal movement and incremental-movement data observed repeatedly at GPS stations during 1999 – 2009 were analyzed to study the effect of two earthquakes of *M*s8.1 and *M*s8.0 that occurred in 2001 and 2008, respectively, in Qinghai-Tibet sub-plate and its eastern margin. The result revealed certain anomalous pre-earthquake deformation and some large co-seismic changes. Prior to the 2008 Wenchuan *M*s8.0 earthquake, the seismogenic Kunlunshan fault zone became a geographic boundary between different regional movements. At the time of the earthquake, there was an average cross-fault crustal shortening of –1.04 m and an average right-lateral strike slip of 0.76 m along the ruptured segment, as well as a strain-energy release of –62.66 × 10.7.

Key words: Qinghai-Tibet sub-plate's movement field; tectonic activity; movement incremental field; earthquake deformation; strain energy; Wenchuan earthquake

1 Introduction

Two $Ms \geqslant 8$ earthquakes (*M*s8.1 to the west of the Kunlun Mountain Pass on 2001-11-14; Wenchuan *M*s8.0 on 2008-05-12) occurred during the past decade in the Chinese mainland, and they both were located in or bordering the Qinghai-Tibet sub-plate, which is the southern part of the Eurasian plate. To study the characteristics of current crustal-movement field and tectonic activity in this currently most active region in Chinese mainland has important practical significance on disaster reduction and earthquake prediction. A large network of GPS stations has been constructed and in operation since 1999, and repeated measurements were carried out in 2001, 2004, 2007 and 2009. The accumulated large amount of data has been used by experts to study the deformation and the earthquake-related movements in this region[1-5]. In this paper, we report on an analysis of the incremental movements and earthquake-related deformations in the Qinghai-Tibet sub-plate, based on results of the multi-stage GPS observations.

Received: 2011-03-25; Accepted: 2011-06-14
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This work is supported by Basic Research Projects of Tianjin (08JCZDJC18900), National Seismic Hazard Maps Program Planning of China, China Earthquake Administration, National Science and Technology Supporting Plan of the Eleventh Five-Year (2006BAC01B02-02-03).

2 Methods

Previous studies on earthquake tectonics showed that most $Ms \geqslant 7$ earthquakes were located in fault zones bordering class Ⅰ and Ⅱ active blocks. This fact illustrates that the development of great earthquakes is the result of block activities, or a process of energy accumulation and release in the earth's crustal-block interaction. Therefore, when analyzing seismicity and crustal deformation, we should try to capture information of anomalous changes on a scale comparable to the corresponding blocks. Also in GPS deformation studies, significant results have been obtained through calculation and analysis with block-movement models, which highlighted the deformation of the blocks, rather than smaller local changes. The following analysis is mainly based on the result of calculation, using a linear-elastic-block-motion model expressed by[6]:

$$\begin{bmatrix} v_e \\ v_n \end{bmatrix} = r\begin{bmatrix} -\sin\varphi\cos\lambda & -\sin\varphi\sin\lambda & \cos\varphi \\ \sin\lambda & -\cos\lambda & 0 \end{bmatrix}\begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} + \begin{bmatrix} A_0 & B_0 \\ B_0 & C_0 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \frac{1}{2}\begin{bmatrix} \xi_1 & \xi_2 \\ \zeta_1 & \zeta_2 \end{bmatrix}\begin{bmatrix} x^2 \\ y^2 \end{bmatrix} + \begin{bmatrix} \xi_3 \\ \zeta_3 \end{bmatrix} xy \quad (1)$$

where ω_x, ω_y, ω_z are block-rotation parameters, and $A_0, B_0, C_0, \xi_1, \xi_2, \xi_3, \zeta_1, \zeta_2, \zeta_3$ are strain parameters. Equation (1) shows that the block movement consists of two parts, an overall rotation and internal deformation. Following is a description of our result of applying this model to the analysis of current activity of Qinghai-Tibet sub-plate.

3 The overall-movement field

We obtained the overall-movement field in the sub-plate during 1999 – 2009 (Fig. 1) by subtracting the overall rotation parameters from the observed site velocities in the global framework, using the calculated results of the GPS measurements during this period. From figure 1 we see that the velocity was greater in the southwestern and the southern part, and gradually decreased towards north and east to a minimum in Qaidam-Western Qinling region. The movement field in the central and southern parts showed a clockwise rotation around the Assam tectonic node, west of which the movement direction gradually changed from NNW to N and NE direction, while north of the node the movement was in east direction. In the eastern part, from north to south, the direction gradually changed from the southeast to south and southwest. In the northern part, in Qilian Mountain and areas near the Altun fault, the direction turned northwest.

North of the South Qilianshan fault the region was in northwest movement, while on the south side of the fault the Qaidam-West Qinling block was moving northward, indicating a left-lateral movement of the fault. The same tendency was shown for the Kunlunshan fault zone, the north side of which moved northward while the south side moved northeastward. The velocity on the north side of Hoh Xil-Yushu-Xianshuihe fault zone was slower than the south side, indicating that the western segment of the fault zone had a tendency of compression, while the eastern segment a tendency of left-lateral movement. The eastward movement of the northern side of Bangong Lake-Jiali fault was faster than the southern side, so the fault showed a tendency of right-lateral movement.

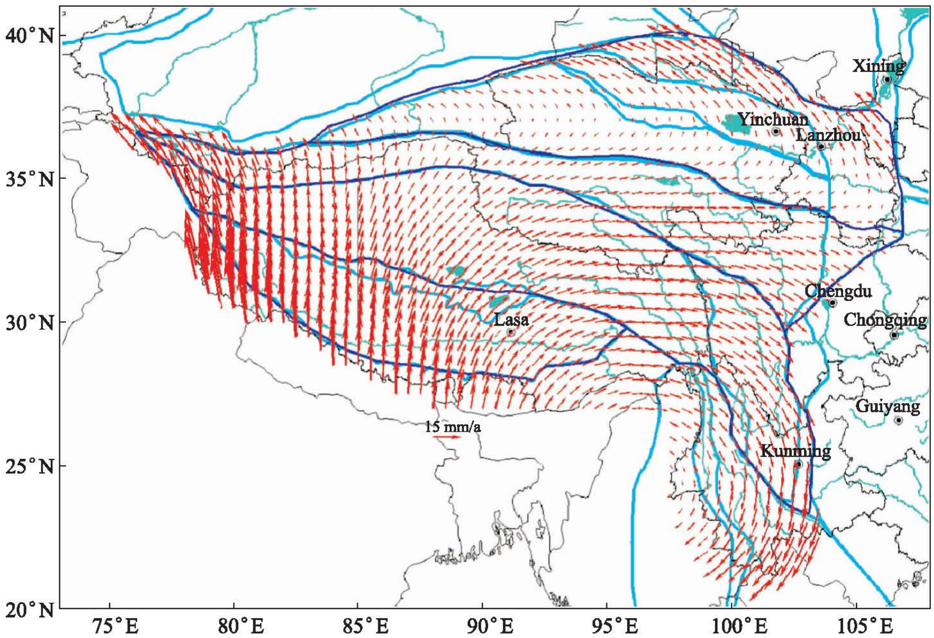

Figure 1 Movement field of Qinghai-Tibet sub-plate (1999-2009, non-rotational datum)