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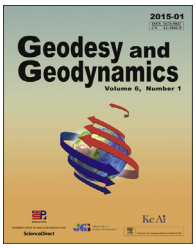

Three-dimensional crustal deformation before and after the Wenchuan earthquake in Guanzhong and adjacent regions☆

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ABSTRACT

The recent plethora of GPS observations compensates for the 20-year-old lack in vertical displacement data for the Guanzhong region. The 2001–2007 three-dimensional (3D) crustal deformation data suggest regional movement with a horizontal velocity of 3–7 mm/a, predominantly from SSE in the west to SE in the east, and vertical inherited movement with velocity of −7 mm/a to 4 mm/a. After the Wenchuan earthquake, the GPS data suggest that the effect of the earthquake on the regional deformation is greater in the west than the east. The horizontal displacement increased during 2007–2008; however, the reverse was observed in 2008–2009. The vertical displacement in the western part of the region increased in 2008 and has been gradually returning to normal since 2009; however, in the eastern part, the effect of the earthquake remains.

1. Introduction

Guanzhong area (Guanzhong area and Weihe Basin are used usually according to our habit) is located in the middle of Shanxi Province, which connects the stable Ordos Block in the north and the Qinling orogenic belt in the south. In the Fenwei seismic zone that lies in the east, two strong earthquakes occurred in the past; the catastrophic and deadliest on record Huaxian Ms8¼ earthquake in 1556, and the Linfen Ms8.0 earthquake. The western part of the area belongs to the North–South Seismic Belt where both the Haiyuan Ms8.5 and Tianshui Ms8.0 earthquakes occurred [1]. The Guanzhong area is an important tectonic boundary that divides the North China and South China blocks. Several large-scale structures in the east and west converge in the region. The regional tectonic stresses are affected by the Qinghai–Tibet and North China plates, and suggest stress increase or decrease in the

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North China plate. The Indian plate collision pushes the Qinghai–Tibet plate in the NE direction. Approximately 20% of the stress is toward the North China plate. The Pacific plate affects the North China plate via deep processes.

Guanzhong area records crustal movements owing to tectonic stresses from different plates [2,3]. For instance, before and after the Tangshan Ms7.8 earthquake in 1976, the regional leveling deformation during 1971–1977 and 1977–1980 was significantly and abnormally variable, whereas during 1980–1986 and 1986–1996 the deformation variations were small [4,5].

The Ms8.1 earthquake in 2001 west of the Kunlun Mountain pass is also another example. Gravity data for 1992–2005 suggest that the gravity trend sharply reversed in 2001–2002 and this presumably relates to the earthquake and the subsequent regional stress adjustment [6].

The Ms8.0-strong Wenchuan earthquake affected Baoji and the western parts of southern Shanxi. Earthquakes with magnitude greater than Ms5 were more frequent in Hanzhong, Ningqiang, and the surrounding areas after the Wenchuan earthquake. Moreover, small earthquakes also increased markedly in the eastern parts of the region [7]. In 2009, an Ms4.4 earthquake occurred at the junction of Lintong and Gaoling (34.49° N, 109.15° E). Crustal deformation data show that the Wenchuan earthquake caused large horizontal coseismic displacement in the NE direction [8]. Deformation is monitored with survey leveling, GPS, and mobile gravity data. The Shanxi GPS network comprises approximately 37 stations set up by the Crustal Movement Observation Network of China and the Earthquake Administration of Shanxi Province, operating since 2001. In contrast to the plethora of horizontal displacement data, the last vertical leveling data for the whole region were collected in 1996. Presently, fixed observation and short-term leveling stations recorded the vertical deformation across faults in the region. Only the long-term leveling profile in the eastern of the region cannot reflect the regional movement well. Thus, we study the 3D movement in the area according to GPS observations for the period of 2001–2011.

2. Data and processing

Presently, the deformation data in the region are from GPS monitoring stations and leveling sites (Fig. 1). The stations beginning with D, G, H, or JB belong to the Network Project and have been operating since 1999. The ones beginning with letter S belong to the Earthquake Administration of Shanxi Province and are operational since 2001. Observations are mostly conducted on August and September each year (Table 1). We process the observation data from 11 campaigns during 2001–2011 using the GAMIT/GLOBK 5.17 GPS analysis software developed at the Massachusetts Institute of Technology (MIT) and Scripps Institute of Oceanography (SIO), San Diego University of California. We obtain the 3D movement in the ITRF2008 framework and the horizontal displacement relative to the Eurasia plate.

3. 3D crustal movement before and after the Wenchuan earthquake

The GPS network covers Guanzhong and the adjacent regions, and the stations are relatively well distributed. More than ten campaigns have been conducted since 2001, and hence, we obtained the 3D crustal movement characteristics. Especially for the vertical displacement, the data fill the gap of

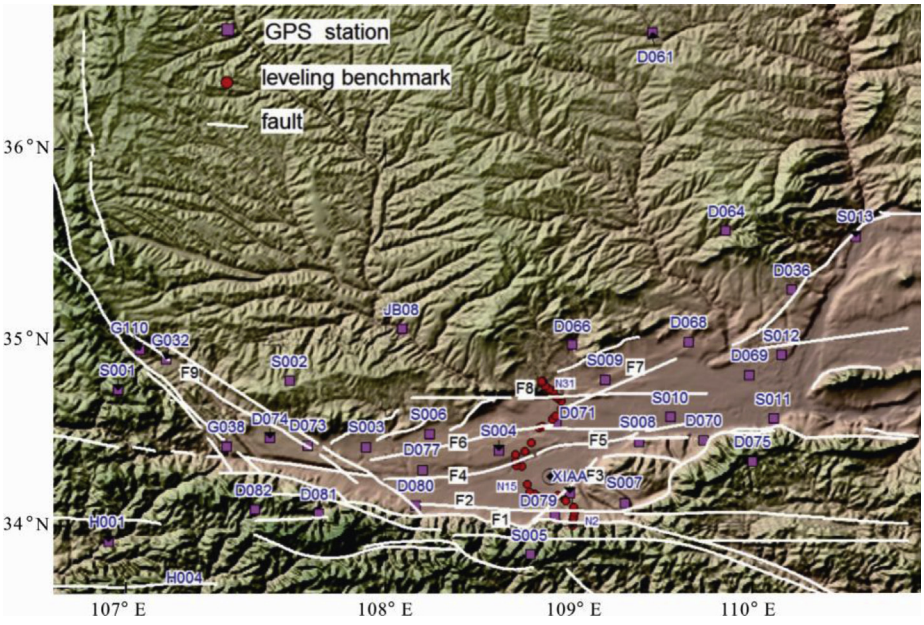

Fig. 1 – Deformation monitoring stations (D) and main faults (F) in Guanzhong and adjacent regions. (F1: Qinling Piedmont Fault; F2: Zhouzhi–Yuxia Fault; F3 : Lintong–Changan Fault; F4: Weihe Fault; F5: Jingyang–Weinan Fault; F6: Fufeng–Sanyuan Fault; F7: Qianxian–Pucheng Fault; F8: Kouzhen–Guanshan Fault; F9: Longxian–Qishan–Mazhao Fault).