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# Post-seismic relaxation process and vertical deformation following the 2008 *Ms*8.0 Wenchuan earthquake, China

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**Abstract**: The post-seismic horizontal and vertical deformations following the 2008 *Ms*8.0 Wenchuan earthquake are inferred from GPS and precise leveling data. The post-seismic relaxation process is measured using GPS data from campaign stations located around the Longmenshan fault, and the derived decay time constant is 12 days. The evolution of the post-seismic vertical deformation is obtained from precise leveling data measured near the surface rupture. The results demonstrate that the hanging wall is uplifting and the foot wall is subsiding. The amplitude of the post-seismic deformation is lower than that of the co-seismic deformation. The region with the largest post-seismic displacement is located on the leveling route between Maoxian and Beichuan on the hanging wall.

**Key words**: post-seismic deformation; relaxation process; the Wenchuan earthquake; leveling

## 1 Introduction

On May 12, 2008, a destructive earthquake with a magnitude of *Ms*8.0 occurred in the Longmenshan belt, at the junction of the Sichuan basin and the Tibetan plateau. This earthquake generated two parallel surface ruptures with lengths of 240 km and 90 km, respectively. The maximum vertical and horizontal displacements (6.2 m and 4.9 m) were observed along the Beichuan-Yingxiu fault[1]. A variety of co-seismic rupture and slip distribution models have been proposed based on the observed co-seismic deformation and seismic waves[2-7]. The results of these models show that the dip angle of the Beichuan-Yingxiu fault gradually increases northeastward and that the northern section is nearly vertical. The southern section of the Beichuan-Yingxiu fault is characterized primarily by the thrust slip, and the northern section of the fault is dominated by the dextral component. Because of the viscoelastic response to the sudden stress changes in the crust and upper mantle, the ground surface deformation following a large earthquake can be measured using geodetic techniques[8-12].

Using GPS and precise leveling measurements taken between 2008 and 2011 around the Longmenshan fault, we investigate the post-seismic relaxation process and the evolution of the post-seismic vertical deformation, which can provide insight into the rupture mechanism of the earthquake and the physical mechanisms of the post-seismic deformation.

## 2 GPS, leveling data and processing

Immediately after the Wenchuan earthquake, the China Earthquake Administration (CEA) began a scientific investigation to observe the post-seismic deformation. Most of the GPS stations were observed within 3 - 4 days, and five stations were observed in the duration of 35 and 103 days. In 2009 and 2011, the stations were

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resurveyed as part of the Continental Tectonic Environment Monitoring Network of China (CTEMNC) project. In 2010, the Second Monitoring Center of the CEA surveyed these GPS sites again as part of the Integrated Geophysical Field Observation project. We have collected the GPS data from the campaign stations observed between 2008 and 2011 in the vicinity of the Longmen Mountain region (Fig. 1).

Many of the original national bench marks (BMs) were damaged by the earthquake, human activities and other causes. Two leveling routes, the Pingwu-Guixi-Beichuan-Mianzhu route (190 km) and the Guixi-Jiangyou route (24 km), were therefore surveyed in September and October of 2008. The 68 km Maoxian-Beichuan leveling route was surveyed in May 2009. These three leveling routes were resurveyed in April 2010 and May 2011 (Fig. 2). All of the leveling measurements were performed to first-order standards, and the leveling equipment was carefully checked before and after each measurement.

The GPS data were processed using the GAMIT/GLOBK software[13,14]. First, all of the observational data for a given day were combined, and the GAMIT software was used to solve for the loosely constrained daily station coordinates, polar motion and satellite orbits[13]. Second, the daily solutions for the local stations were combined with the loosely constrained global solutions from the Scripps Orbital and Position Analysis Center (SOPAC, http://sopac.ucsd.edu/) using the GLOBK software[14]. The stable global IGS sites throughout China were used as the reference stations for ITRF2008 to obtain tight constraints on the positions. Finally, the time series of positions with respect to ITRF2008 were obtained for each station.

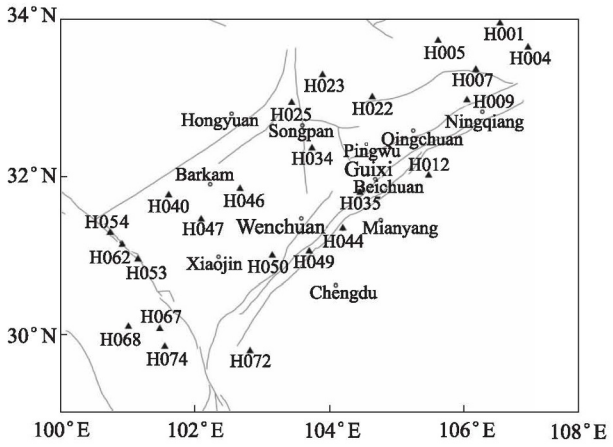


Figure 1 Locations of the GPS stations observed following the Wenchuan earthquake (Gray lines represent the active faults)

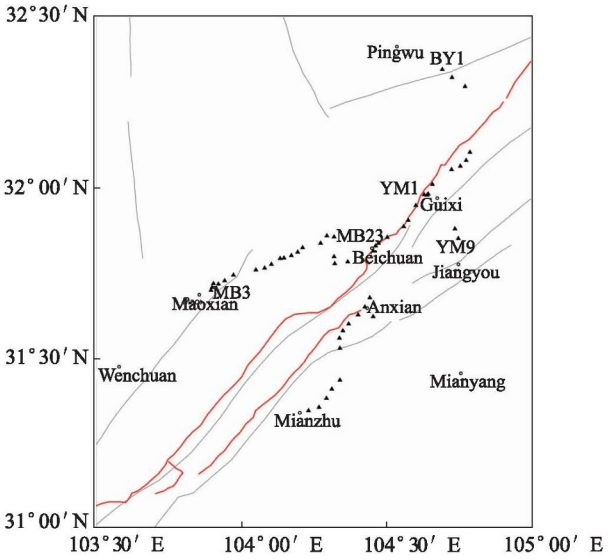


Figure 2 Locations of the leveling routes resurveyed following the Wenchuan earthquake (Gray lines represent the active faults; red lines represent the surface rupture caused by the Wenchuan earthquake)

## 3 Post-seismic relaxation time

Following a large earthquake, the surface deformation observed using geodetic methods displays a relaxation process[8-12]. The post-seismic displacement component $y(t)$ at time $t$ can be expressed as follows:

$$y(t) = y(t_{eq}) + v(t - t_{eq}) + D\log((t - t_{eq})/\tau) \quad (1)$$

where $t_{eq}$ is the moment at which the main shock occurred, and $t$ is the time after the main shock ($t > t_{eq}$). The station position immediately after the earthquake is given by $y(t_{eq})$, and $v$ is the constant secular velocity of the station. The terms $D$ and $\tau$ are the amplitude and time constant of the logarithmic relaxation, respectively. The unknown parameters are $y(t_{eq})$, $v$, $D$ and $\tau$.

To extract the characteristics of the post-seismic deformation, we remove the constant secular velocity of each station and obtain the time series of the post-seismic displacement (Fig. 3).