A PRELIMINARY STUDY ON THE MOTION CHARACTERISTICS OF LONGMENSHAN FAULT BEFORE AND AFTER THE M8.0 WENCHUAN EARTHQUAKE

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ABSTRACT :

This paper utilizes the mobile short-line leveling data from various observation sites across the Longmenshan fault to analyze the variation characteristics before and after the Wenchuan earthquake. By analyzing the motion type and stress pattern of the Longmenshan fault we investigate the seismogenic process and mechanism of the earthquake. The preliminary result is as follows. a) Before the Wenchuan earthquake the cross-fault short-line leveling measurements showed the activity of Longmenshan fault around 2006, and they all showed a characteristic of accelerated movement to different degrees before the earthquake. b) Before the earthquake the short-line leveling measurements across different faults indicated that the middle-south segment of Longmenshan fault showed reverse faulting movement, and the fault deformation was of backward "S" type. c) Before and after the Wenchuan earthquake the cross-fault displacement measurements reflected the spatial-temporal evolution of the accumulation and release of regional ground-surface stress, the interpretation of their mechanism is basically consistent with the focal mechanism solution.

KEYWORDS: Wenchuan, Longmenshan fault, cross-fault displacement,

1. INTRODUCTION

According to the report of Chinese Seismograph Network a great earthquake of magnitude 8.0 occurred at 14h28m (Beijing time) on May 12, 2008, in Wenchuan county of Sichuan province (31.0N and 103.4E). This earthquake affected a large area and caused serious disasters. It is the most destructive earthquake since the establishment of P. R. China. To investigate the characters of fault motion before and after this earthquake has very important meaning for understanding the processes of earthquake genesis, occurrence, and post-seismic adjustment, as well as for judging the situation of future earthquakes. Before this great Wenchuan earthquake the short-line leveling sites Gengda and Qipangou across the Wenchuan-Maowen fault of the Longmenshan Fault Belt showed significant displacement variation from 2006. The Shuanghe leveling site across the Shuanghe fault (belonging to Longmenshan Fault) and the Guanxian leveling site across the Guanxian-Anxian fault showed large-amplitude variations after the earthquake. These phenomena have important value for studying the stress state before and after the earthquake, the characteristics of Longmenshan fault movement, as well as the post-seismic stress adjustment. This paper utilizes the mobile short-line leveling data from the observation sites across the Longmenshan fault to analyze the variation characteristics before and after the earthquake and study the seismogenesis mechanism of the great M8.0 Wenchuan earthquake.

2. AN OUTLINE OF THE SEISMOGENIC STRUCTURE

This great earthquake took place on the Longmenshan Fault, which is a famous reverse fault belt in the northwest of Sichuan Province. This fault starts from Luding and Tianquan in the south, extends northeastwards through Baoxing, Guanxian, Jiangyou, and Guangyuan, and reaches to Mianxian of Shanxi Province. The total length is about 500 km, width 40~50 km. This fault belt consists mainly of three faults; from northwest to southeast they are the (the Rear Longmenshan Fault), Yingxiu-Beichuan Fault (the Central Longmeshan Fault), and Guanxian-Anxian Fault (the Frontal Longmenshan Fault). The overall strike of the fault belt is N45°E, dip angle 50~70° towards NW. This fault belt is not only the boundary between Ganqing Block and South China Block, but also the boundary between the mountains and basin of west Sichuan. It is a large-scale fault belt in a special location.

The Longmenshan fault belt was formed in the Mesozoic, and was partially reactivated in the Yanshan stage. Since the Cenozoic the collision between Indian plate and Eurasian plate generated intensive compressional force, which caused large-scale tectonic deformation of overthrust nappe in this area; the Longmenshan Mountains were continuously uplifted, the piedmont was intensely depressed, giving rise to multiple denudation surfaces (Tang and Han, 1993). In the late Quaternary (Late Pleistocene to Holocene) the Longmenshan fault belt continues to be active; GPS measurements indicate that the EW-shortening rate of the fault belt is not significant (Lu et al., 2003).

Table 1 Catalog of Ms≥6.0 earthquakes on the Longmenshan fault (from –780 to 2008.5).

No.	Date (Year-month-day)	Latitude (N°)	Longitude (E°)	Magnitude (M_s)	Location
1	1327-09-	30.10	102.70	6.0	Tianquan, Sichuan
2	1657-04-21	31.30	103.50	6.5	Wenchuan, Sichuan
3	1958-02-08	31.50	104.00	6.2	Around Maowen-Beichuan
4	1970-02-24	30.65	103.28	6.2	West of Dayi, Sichuan
5	2008-05-12	31.00	103.40	8.0	Wenchuan, Sichuan

Note: Earthquake catalog from “The catalog of strong earthquakes in China” compiled by China earthquake Administration in 2005.

3. MOBILE SHORT-LINE LEVELING SITES ALONG LONGMENSHAN FAULT AND OBSERVATION DATA

There are 5 mobile short-line leveling observation sites on the middle and south segments of Longmenshan Fault (Fig.1, Table 2). The starting time and repeating period vary from site to site; after 1990 there are generally 3 measurements each year (increased to 10 in 1996). These observation lines cross respectively the Wenchuan-Maowen Fault (the Rear Longmenshan Fault), Guanxian-Anxian Fault (the Frontal Longmenshan Fault), and Xinjin-Pujiang Fault.

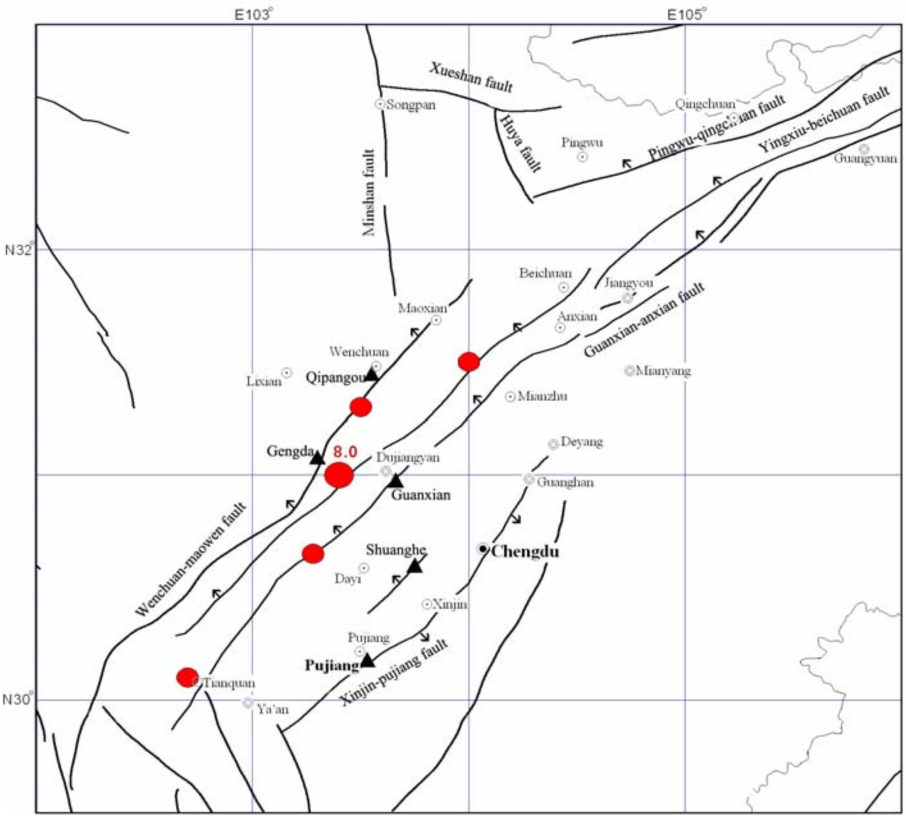

Fig.1 Distribution of *Ms*≥6.0 earthquakes and mobile short-line leveling sites along the Longmenshan fault. (Circles are earthquakes, triangles are leveling sites.)

The Gengda leveling site is located in the Gengda Commune of Wenchuan County and crosses the Wenchuan-Maowen Fault. The observation line A-B is 440 m long, divided into 12 pieces. The observation started from May 6, 1985. The data indicate that from 1990 to 2002 the fault motion was mainly compressional; after 2003 some extensional variations appeared, especially Δ=-1.53mm in 2006 and Δ=-2.13mm in 2007 (Constructions around the observation site may have certain effect on the result(su et al., 2007). The Qipangou leveling site which crosses the same fault is located in Qipangou of Wenchuan County, about 48 km apart from the Gengda site. It's A-C line crosses obliquely the fault and is 460 m long in 16 pieces, the observation started from May 1986. The data showed obvious annual variations with an average amplitude up to 1.07 mm. From Table 2 it is seen that its movement is not totally consistent with that of Gengda site.

The Guanxian leveling site across the Guanxian-Anxian Fault is located in Erwangmiao of Guanxian County. The line 4-3 is 270 m long in 8 pieces, the observation started from Feb.1, 1978. The data shows that in 1993~1994 the fault was obviously extensional, the variation amplitude was up to 2.23 mm, which corresponded to the Doujiangyan M4.4 earthquake of Dec.30, 1993. The Shuanghe leveling site across the same fault is located in the Shuanghe Commune of Dayi County, the observation started from July 15, 1977. The line 1-2 is 360 m long in 14 pieces. The annual variation is apparent with an average amplitude of 0.97 mm. The fault motion is compressional.

The Pujiang leveling site across the Xinjin-Pujian Fault is located in the Dongbei Commune of Pujiang County. The line 1-2 is 200 m long in 8 pieces; the observation started from July 27, 1977. The data is relatively stable with an average annual variation of 0.35 mm. The data indicated an inherited extensional motion of the fault. In 1994~1995 the data showed significant variation with an amplitude up to 1.58 mm, which corresponded to the Mabian M5.7 earthquake of Dec.30, 1994, and the Muchuan M5.1 earthquake of April 26, 1995.

Since 1990 two M5.0 earthquakes occurred on the Longmenshan Fault, i.e., the Mianzhu M5.0 earthquake on Sep. 4, 1999, and the Anxian M5.0 earthquake on Nov. 30, 1999. They all occurred in the central part of the fault. It can be seen from Fig.2 that before the earthquakes the data observed at Gengda, Qipangou, and Shuanghe leveling sites all showed variation to some extent.

Table 2 Observation sites of mobile short-line leveling and motions of Longmenshan fault.

Site	Location		Fault occurrence	Fault lithology		Fault motion type	Data period (y-m-d)	Vertical movement △(mm/a)
	Lat. (N°)	Lon. (E°)		Upper wall	Lower wall			
Gengda	31.08	103.30	N30°E/NW ∠70-80°	Schist, sericite -schist	Diorite	Transpression	1990~ 2002	+0.04
							2003~ 2007	-0.84
							2006	-1.53
							2007	-2.13
							2008-01-19	-0.31
Qipangou	31.45	103.55	N35°E/NW ∠65-70°	Dolomitic limestone	Slate	Compression plus dextral torsion	1990~ 2002	-0.07
							2003~ 2007	+0.20
							2006	+0.06
							2007	+0.48
							2008-01-19	-0.91
Guanxian	31.00	103.62	N60-70°E/ NW∠50-55°	Sandstone, siltstone	Sandstone, psephyte	Compression plus dextral torsion	1991~ 2002	-0.26
							2003~ 2007	+0.06
							2006	+0.04
							2007	+0.16
							2008-01-19	-0.40
							2008-05-27	-8.18
Shuanghe	30.60	103.75	N35°E/ NW∠70°	Limestone	Sandstone, psephyte	Transpression	1991~ 2002	+0.04
							2003~ 2007	+0.004
							2006	+0.11
							2007	-0.22
							2008-01-18	+0.97
							2008-05-18	-7.77
Pujiang	30.18	103.53	N50°E/ SE∠40°	Feldspathic silicarenite	mudstone	Compression plus dextral torsion	1990~ 2002	-0.16
							2003~ 2007	-0.04
							2006	-0.79
							2007	+0.29
							2008-01-18	+0.47
							2008-05-18	+0.50

Note: Sign "-" means extension of the fault, "+" means compression.

4. CHARACTERISTICS OF DATA VARIATION BEFORE AND AFTER THE WENCHUAN EARTHQUAKE

In order to facilitate the analysis of observational data and suppress the interference of annual variation, formula (4.1) is used to smooth the observation curves of each leveling site.

$$\overline{H_i} = \frac{A_{i,1} + A_{i,2} + \ldots A_{i,n}}{n} \tag{4.1}$$

It can be seen from Fig.2 that after the Mianzhu and Anxian earthquakes in 1999 the observation curves showed almost synchronous turning in 2003, and the variation amplitudes increased around 2006. At the Gengda site, which is 13 km from the epicenter of Wenchuan earthquake, the fault showed apparent extensional motion from May 2006 to January 2008; the amplitude was as large as 4.67 mm. At the Qipangou site about 52 km from the epicenter, the fault showed enhanced compressional motion from 2006.9 to 2007.5. The Guanxian site is 21 km from the epicenter, however, the fault motion before the earthquake was not obvious. The Shuanghe site is 55.7 km from the epicenter; from May 2006 to January 2008 the fault motion turned from extension to compression. The Pujiang site is 92 km from the epicenter; on a background of continuous extensional motion the fault showed compression in nearly two years from 2005 to 2006, and from 2006.9 to 2008.1 the fault showed compressional motion again.

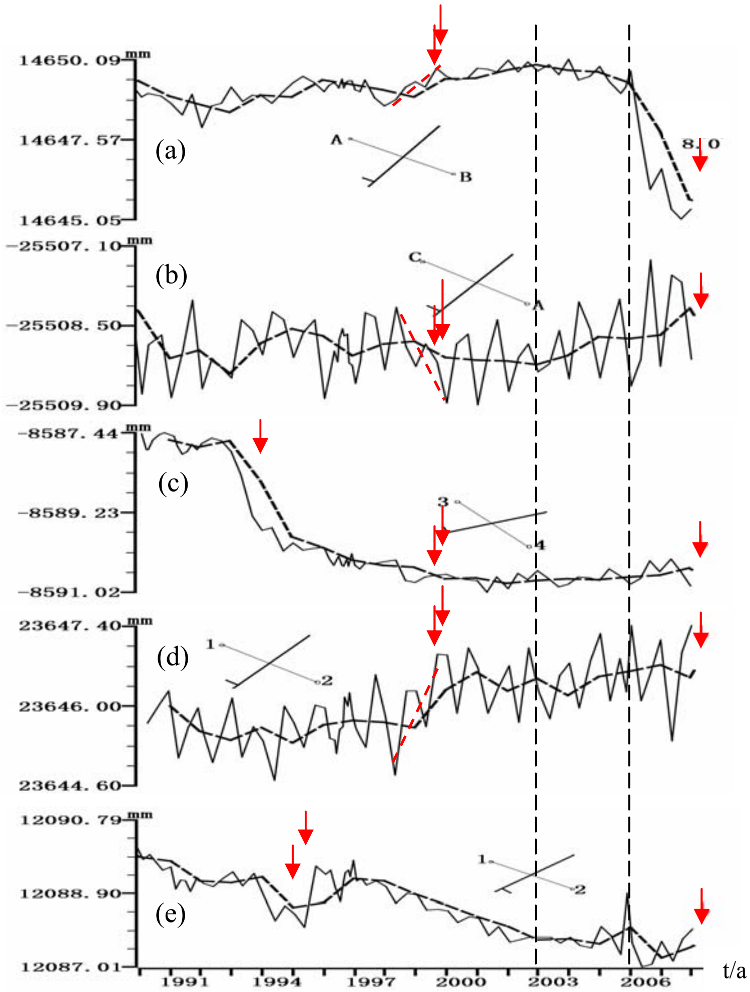

Fig.2 Observation curves of short-line leveling before the earthquake.
(a) Gengda; (b) Qipangou; (c) Guanxian; (d) Shuanghe; (e) Pujiang.
Broken lines are smoothed curves, solid lines are observed curves.

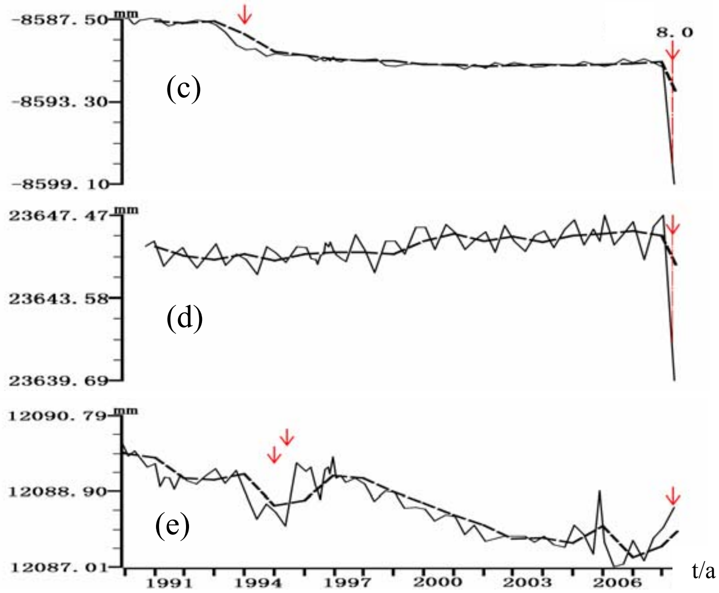

Fig.3 Observation curves of short-line leveling after the earthquake.
(c) Guanxian; (d) Shuanghe; (e) Pujiang.
Broken lines are smoothed curves, solid lines are observed curves.

After the Wenchuan earthquake the observation has not been resumed at the Gengda and Qipangou sites; Fig.3 shows the intensified observation curves on the other sites. It can be seen from the figure that after the Wenchuan earthquake the data of Shuanghe on May 18 and Guanxian on May 27 all indicated remarkable extension of the fault, the amount was respectively –7.77 mm and –8.18 mm; whereas the Pujiang site maintained the motion character before the earthquake. Table 2 shows the cross-fault vertical movement before and after the Wenchuan earthquake.

5. ANALYSIS OF FAULT MOTION AND EARTHQUAKE MECHANISM

Earthquakes are closely related to the activities of faults; fault deformation reflects the process of regional stress accumulation, concentration, and release. Fig.4 shows the annual variation of vertical movement at the short-line leveling site across the Longmenshan Fault before and after the Wenchuan earthquake. It is seen that before the earthquake the cross-fault leveling measurement detected the activity of Longmenshan Fault around 2006. The data observed in January of 2008 before the Wenchuan earthquake pointed out the following scenario. Before the earthquake the northeastward motion of Tibetan Plateau was obstructed along the Sichuan Basin by the South China Block, which produced northwesterly compression from the Sichuan Basin; taking the seismogenic fault (Beichuan-Yingxiu Fault) as a boundary, to its southeast side the Guanxian site was under extension, while the Shuanghe and Pujiang sites were under compression; correspondingly the southeastward compression from the Tibetan Plateau caused the local uplift of Longmenshan Fault (source region), the Gengda and Qipangou sites across the Wenchuan-Maowen Fault showed extensional phenomenon, only the extension at Gengda was obviously weakened in comparison with that during 2006-2007. The stress was highly accumulated on the Longmenshan overthrust belt until the Beichuan-Yingxiu Fault was suddenly offset, giving rise to the M8.0 great earthquake. After the earthquake the Shuanghe site showed significant extension, while the Guanxian site kept its large-amplitude extensional motion; the Pujiang site across the Xinjin-Pujiang Fault maintained compressional motion as before the earthquake. From the analysis we conclude that before the Wenchuan earthquake the short-line leveling measurements across different faults manifested the reverse faulting motion of the middle and south segment of the Longmenshan Fault; the ground surface showed a backward “S”-type deformation pattern as shown in Fig.5.

The study of Chen et al. after the Wenchuan earthquake indicated that this earthquake was dominated by reverse thrust with a small right-lateral strike-slip component; the strike of fault was 229°, dipping NW. The stress state derived from leveling data across Longmenshan fault before and after the Wenchan earthquake is shown schematically in Fig.5; it is seen that the cross-fault displacement measurements reflected the spatio-temporal evolution of the ground surface during the seismogenic process, and the mechanism is basically consistent with the focal mechanism solution given in (Chen et al.,2008).

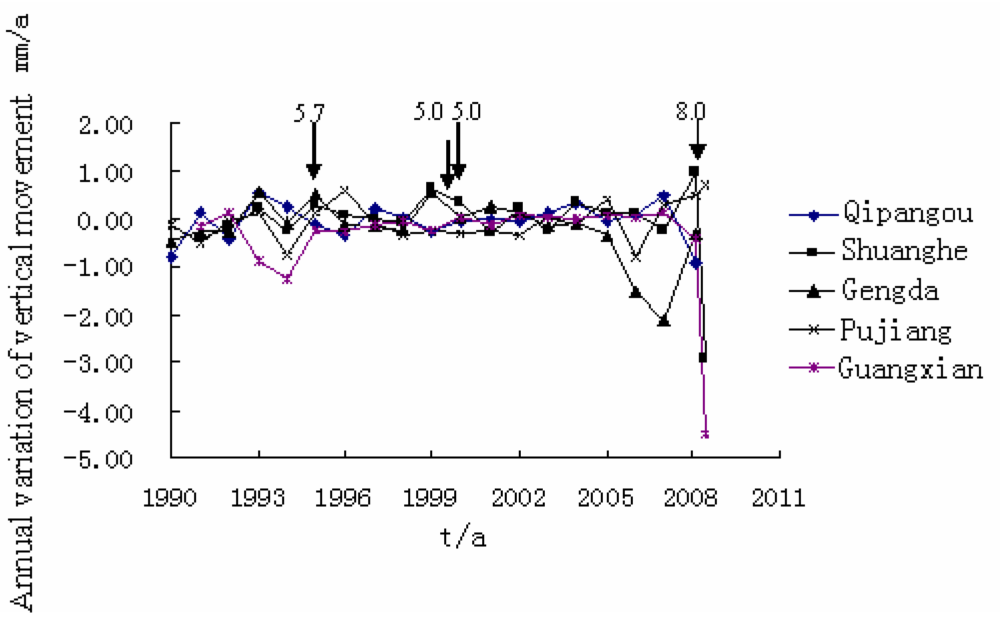

Fig.4 Annual variation of vertical movement of the mobile short-line leveling sites before and after the Wenchuan earthquake.

6. PRELIMINARY CONCLUSION AND DISCUSSION

(1) Before the Wenchuan earthquake the cross-fault short-line leveling observations detected the motion of Longmenshan Fault around 2006, and all showed accelerated preseismic activities to some extent.

(2) Before the Wenchuan earthquake the leveling sites across different faults indicated that the motion of the middle-south segment of Longmenshan Fault was a reverse faulting, and the ground deformation showed a backward “S” pattern.

(3) Before and after the Wenchuan earthquake the cross-fault displacement measurements reflected the spatio-temporal evolution process of regional stress accumulation and release, which was basically consistent with the focal mechanism solution.

(4) This paper carried out a preliminary analysis of partial cross-fault mobile leveling data; comprehensive and systematic analyses should be further made on the cross-fault displacement data in other areas of China to investigate the dynamic and seismogenic process of the Wenchuan earthquake.

(5) Through the preliminary analysis of the preseismic motion of Longmenshan Fault and in view of Fig.3 and 4 we learned that it would be extremely difficult to predict such a great earthquake based on the previous experience and knowledge, it is “a new type of earthquakes which deserves much attention and in depth studies(Zhangpeizhen,2008)”. The earthquake raised many new questions and thoughts, which calls for multi-disciplinary and comprehensive studies.

(6) We propose to expand the scope and increase the sites of cross-fault displacement measurement (especially in western China), improve the current observation technique, and shorten the observation period. This observation method has a considerable value for improving intermediate-term earthquake prediction.

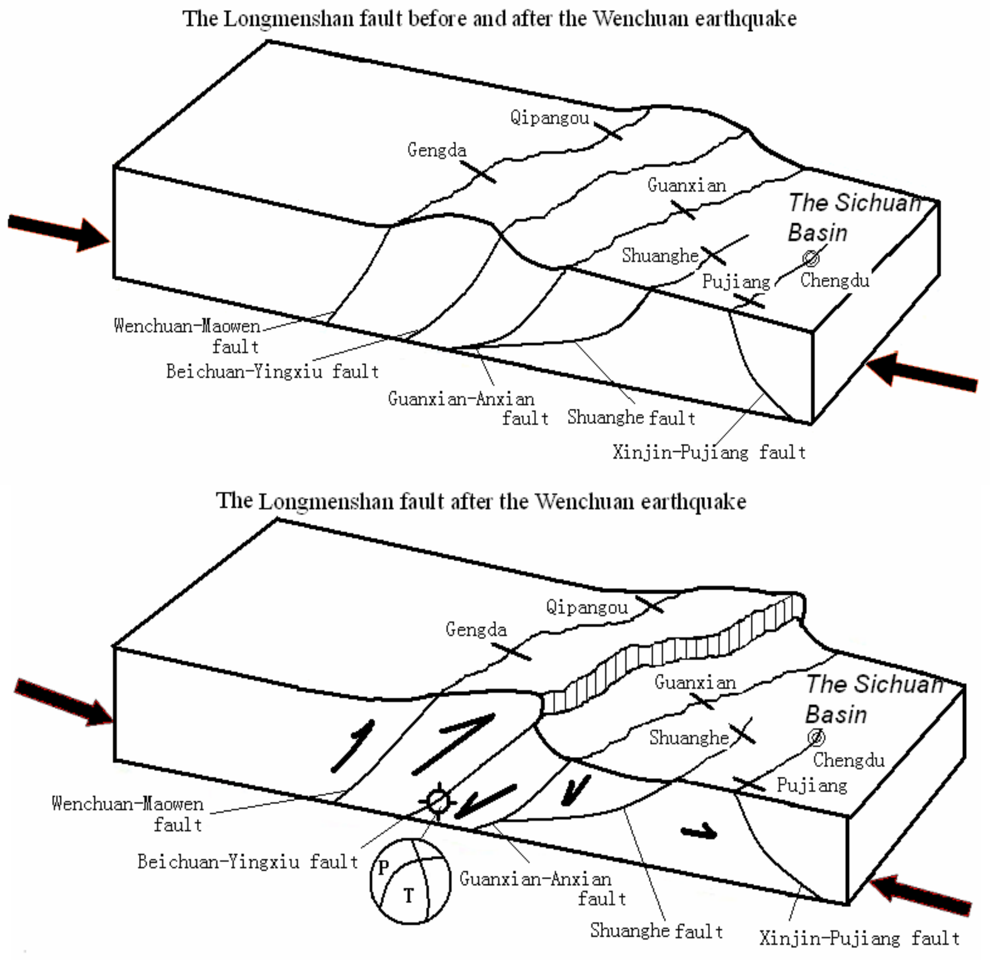

Fig.5 A schematic deformation model of the Longmenshan fault before and after the Wenchuan earthquake.

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