Doi: 10.1007/s11589-009-0119-x

The seismicity and tectonic stress field characteristics of the Longmenshan fault zone before the Wenchuan M_S8.0 earthquake*

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Abstract The seismicity of Longmenshan fault zone and its vicinities before the 12 May 2008 Wenchuan M_S8.0 earthquake is studied. Based on the digital seismic waveform data observed from regional seismic networks and mobile stations, the focal mechanism solutions are determined. Our analysis results show that the seismicities of Longmenshan fault zone before the 12 May 2008 Wenchuan earthquake were in stable state. No obvious phenomena of seismic activity intensifying appeared. According to focal mechanism solutions of some small earthquakes before the 12 May 2008 Wenchuan earthquake, the direction of principal compressive stress P-axis is WNW-ESE. The two hypocenter fault planes are NE-striking and NW-striking. The plane of NE direction is among N50°–70°E, the dip angles of fault planes are 60°–70° and it is very steep. The faultings of most earthquakes are dominantly characterized by dip-slip reverse and small part of faultings present strike-slip. The azimuths of principal compressive stress, the strikes of source fault planes and the dislocation types calculated from some small earthquakes before the 12 May 2008 Wenchuan earthquake are in accordance with that of the main shock. The average stress field of micro-rupture along the Longmenshan fault zone before the great earthquake is also consistent with that calculated from main shock. Zipingpu dam is located in the east side 20 km from the initial rupture area of the 12 May 2008 Wenchuan earthquake. The activity increment of small earthquakes in the Zipingpu dam is in the period of water discharging. The source parameter results of the small earthquakes which occurred near the initial rupture area of the 12 May 2008 Wenchuan earthquake indicate that the focal depths are 5 to 14 km and the source parameters are identical with that of earthquake.

Key words: **Wenchuan earthquake; Longmenshan fault zone; focal mechanism solution; tectonic stress field**
CLC number: P315.5, P315.72+7 **Document code**: A

1 Introduction

The M_S8.0 Wenchuan earthquake occured at 14:28 on 12 May 2008 on the Longmenshan fault zone with NE trending in Sichuan province, China. This earthquake not only creates fatal destructions on the Longmenshan fault zone, but also brings large-scale destruction and death outside the zone. It is one of the most severe destructive earthquakes in the world history.

We select Longmenshan fault zone and adjacent fault zones as study area (29ºN–33.5ºN, 101ºE–106.5ºE) since the faults are distribution zones of Wenchuan M_S8.0 main shock and aftershock. Small earthquakes relatively more occurred. The distribution of the Longmenshan tectonic system and adjacent faults are shown in Figure 1. The Longmenshan fault zone locates along the merger zones of Tibetan plateau and Yangtze block, which are strong folded uplift regions since Cenozoic era. The tectonic characteristic is reversal and overthrust. The Longmenshan fault zone with the NE direction consists of three nearly parallel faults which are Dujiangyan-Jiangyou fault (Front-range fault), Yingxiu-Beichuan-Qinchuan fault (Central-range fault) and Maowen-Wenchuan fault (Back-range fault), respectively. The activity of the three fault zones has been inherited since Late Quaternary; at the same time, it also represents some characteristics of newborn. All fault zones present the thrust motion with the trending from NW to SE and with the component of right-lateral

* **Received** 21 August 2008; **accepted in revised form** 2 December 2008; **published** 10 April 2009.
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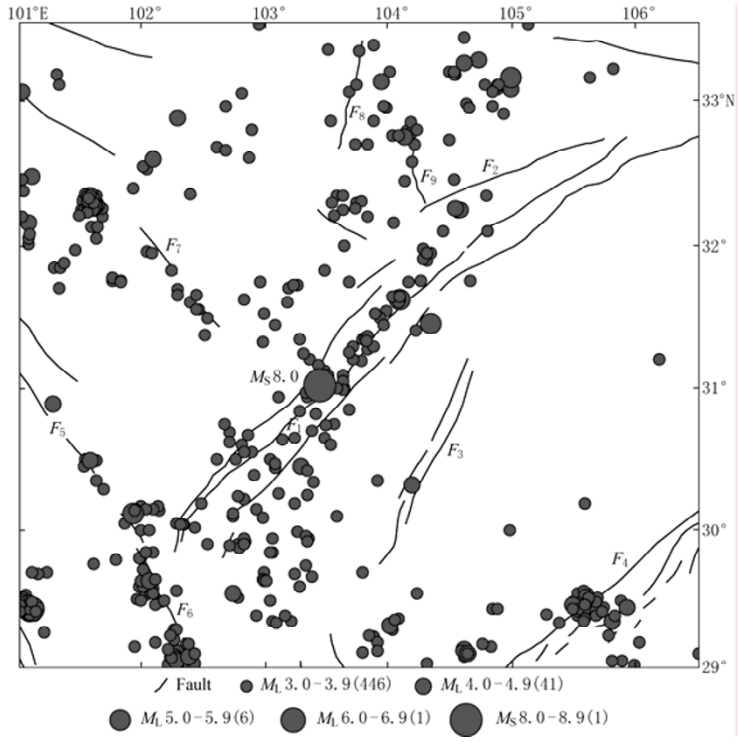

Figure 1 Seismicities on Longmenshan fault zone and its vicinities. The solid circles represent epicenters of earthquakes of $M_L \geq 3.0$ occurred in the period from 1 January 1998 to 11 May 2008. Numbers in brackets represent the earthquake number of different magnitude intervals in Figures 1. F_1. Longmenshan fault; F_2. Qingchuan fault; F_3. Longquanshan fault; F_4. Huarongshan fault; F_5. Xianshuihe fault; F_6. Anninghe fault; F_7. Fubianhe fault; F_8. Minjiang fault; F_9. Huya fault.

strike-slip (Zhu, 2008).

The Wenchuan M_S8.0 earthquake just occurred on Yingxiu-Beichuan-Qingchuan fault. Zipingpu dam (30.9°N–31.1°N, 103.2°E–103.7°E) is 17 km apart from the epicenter of Wenchuan earthquake. The water area of this dam locates in the initial rupture area. The basin area formed by the Zipingpu dam is 22 662 km^2 and the normal water level is 877.00 m above sea level. The volume of the Zipingpu dam is 998 000 000 m^3. According to the historical earthquake data, the frequency and intensity of strong earthquakes are not high along Longmenshan fault zone. There were only three M_S>6.0 strong earthquakes at middle-south segment of Longmenshan fault zone before Wenchuan earthquake, which are Wenchuan M6 earthquake in 1657, Beichuan $M6\frac{1}{5}$ earthquake in 1958 and Dayi west $M6\frac{1}{4}$ earthquake in 1970, respectively (*A Compilation of Sichuan Earthquake Data* editorial group, 1981).

According to seismic wave data recorded by Sichuan Seismic Network before this great earthquake, we try to analyze and study basic characteristics of the pre-earthquake activities, tectonic stress fields and seismic source parameters on Longmenshan fault zone. By comparing the results from this study with some characteristics of the main shock (Chen et al, 2008), we present the latest understanding of pre-earthquake tectonic stress fields.

2 Small earthquake activities and focal mechanism before the Wenchuan M_S8.0 earthquake

2.1 Small earthquake activities before main shock in study areas

Figure 1 shows the distribution of earthquakes in the last 10 years in study area before Wenchuan earthquake occurred along three seismic belts, which are Longmenshan seismic belt, Xianshuihe seismic belt and Chuanbei seismic belt. Chuanbei seismic belt is located in the north region of Longmenshan fault zone. Seismic networks in Sichuan and adjacent provinces started operation on June, 1970. Till May 2008, earthquake catalogues with the magnitude $M_L \geq 2.5$ on Longmenshan

seismic zone, with the magnitude M_L≥3.0 in Xianshuihe and Chuanbei seismic zones are complete. Small earthquakes were active and had a high frequency in these three seismic zones.

This paper analyzes the small earthquake activities occurred before the Wenchuan earthquake. The time series of the earthquakes on the Longmenshan fault zone are shown in Figure 2. From Figure 2 we can see a continuous activity of small earthquakes before the Wenchuan earthquake. The level of seismicity was from M_L4.0 to M_L5.0 in last 38 years. Earthquakes with magnitude M_S≥5.0 occurred in 1976, 1990, 1999 respectively while in other periods the magnitudes were less than M_L5 (Figure 2a). The mean value of monthly frequency with magnitude of M_L≥2.5 is 2.5 and the two times mean square deviation is 6.5. There are 13 months in which earthquake number exceeds 6.5, and it just accounts for 2.8%. In Figure 2b, monthly frequency of M_L≥2.5 earthquakes is less than two times mean square deviation from October 2004 to May 2008. We calculate *b*-value of earthquake activity in this area by using maximum likelihood method with the time length of six months in one group as well. Figure 2c shows the calculation results of *b*-value, which shows the mean value of the curve is 1.11 and the curve fluctuates within the limit of one time mean square deviation, namely, it is between 0.81 and 1.42.

Our analysis result shows that seismic activity is steady and earthquakes with magnitudes from 3 to 4 occurred often in each year along the Longmenshan fault zone. Before the Wenchuan earthquake, the changing tendency of abnormal phenomenon of seismic activity increasing or seismic activity quiet was not apparent and seismic parameter values describing seismic activity varied within the normal interval.

The seismicity characteristics of study areas are summarized as follows. ① Small earthquakes occurred along the fault zone; ② the seismic activities of the higher seismic magnitude in short-term occurred on the adjacent fault zones, which were located in the southeastern segments of the Xianshuihe fault zone. For example, Kangding M_L5.0 earthquake on February 2008, Luhuo *M*7.6 earthquake in 1973 and Daofu *M*6.9 earthquake in 1981; ③ M_L5.0 earthquakes seldom occurred later. For instance, there are only two earthquakes with magnitude of M_L5.0 from January 1982 to May 2008, and M_L5.0 earthquakes were Daofu M_L5.0 earthquake on 2 June 1988 and Kangding M_L5.0 earthquake on 27 February 2008. Through analyzing the seismicity at the southeastern segment of the Xianshuihe fault zone, it can be seen that the trend of seismic activity intensifying appeared at the southeastern segment of Xianshuihe fault zone. There were four earthquakes occurred in recent years, such as M_L4.9 earthquake on December 2003, M_L4.5 earthquakes on October 2005 and May 2006 respectively, M_L5.0 earthquake on February 2008. Based on the seismic active intensity and strain release, a few abnormal phenomena appeared at the southeastern segment of the Xianshuihe fault zone. But the abnormality of seismic activities is not obvious on the Longmenshan fault zone of NE direction, while the seismicity of the moderate earthquakes appeared enhancement at southeastern segment of the adjacent fault zone such as Xianshuihe fault zone with NW direction, which makes it difficulty to analyze the short-term precursory anomaly.

In this paper we analyzed carefully medium- and short-term seismic activities data before the Wenchuan earthquake on the Longmenshan fault zone. We found earthquakes with magnitude M_L3.7, M_L3.3 and a series of small earthquakes occurred in the middle segment of the Longmenshan fault zone near the Zipingpu dam and the monthly frequency is relatively high. The epicenters of these earthquakes are located in the initial rupture area of the Wenchuan earthquake. Therefore it is necessary to study information of seismic source parameters in this study area.

2.2 The pre-earthquake focal mechanism solution and tectonic stress field

Our major work can be divided into two parts. The first part is to select 29 earthquakes with magnitude from 3.0 to 5.0 recorded by relatively more seismic stations between 23 and 50. The observation period is from 1 January 2007 to 11 May 2008 before the Wenchuan earthquake. These earthquakes mainly distributed at the middle segment of the Longmenshan fault zone. Compared with the middle segment of the Longmenshan fault zone, the northern segment had a very weak seismicity.

The other part is to select the initial rupture area of the Wenchuan earthquake as another study area. The water area of the Zipingpu dam just locates near the initial rupture area. The Zipingpu dam is on the east 20 km of microscopic epicenter of the Wenchuan earthquake. We choose 13 waveform data of earthquakes recorded well by the seismic stations with magnitude M_L2.5–3.7 in order to research source parameters. The earthquake time is from water storage to 11 May 2008 before the Wenchuan earthquake.

In order to calculate focal mechanism solutions, we analyzed all seismograms and recognized the initial motion and arrival times of P waves. Based on the location parameters of source determined by Sichuan Seismic Network, we used the velocity model of the Longmenshan fault zone provided by Zhao et al (1997) to re-modify epicenters, focal depths and origin times. The hypocenters mainly distribute on the Longmenshan fault zone with depths from 5 km to 14 km in the crust. Most of earthquake magnitudes were M_L3. No M_L4 earthquakes occurred. Seismicities before the Wenchuan earthquake were obviously different from usual understanding that the moderate M_S5–6 earthquakes may occur before the great earthquake.

2.2.1 Calculating the foca l mechanism solutions of small earthquakes

According to the point-source dislocation models in the layered medium proposed by Liang et al (1984),

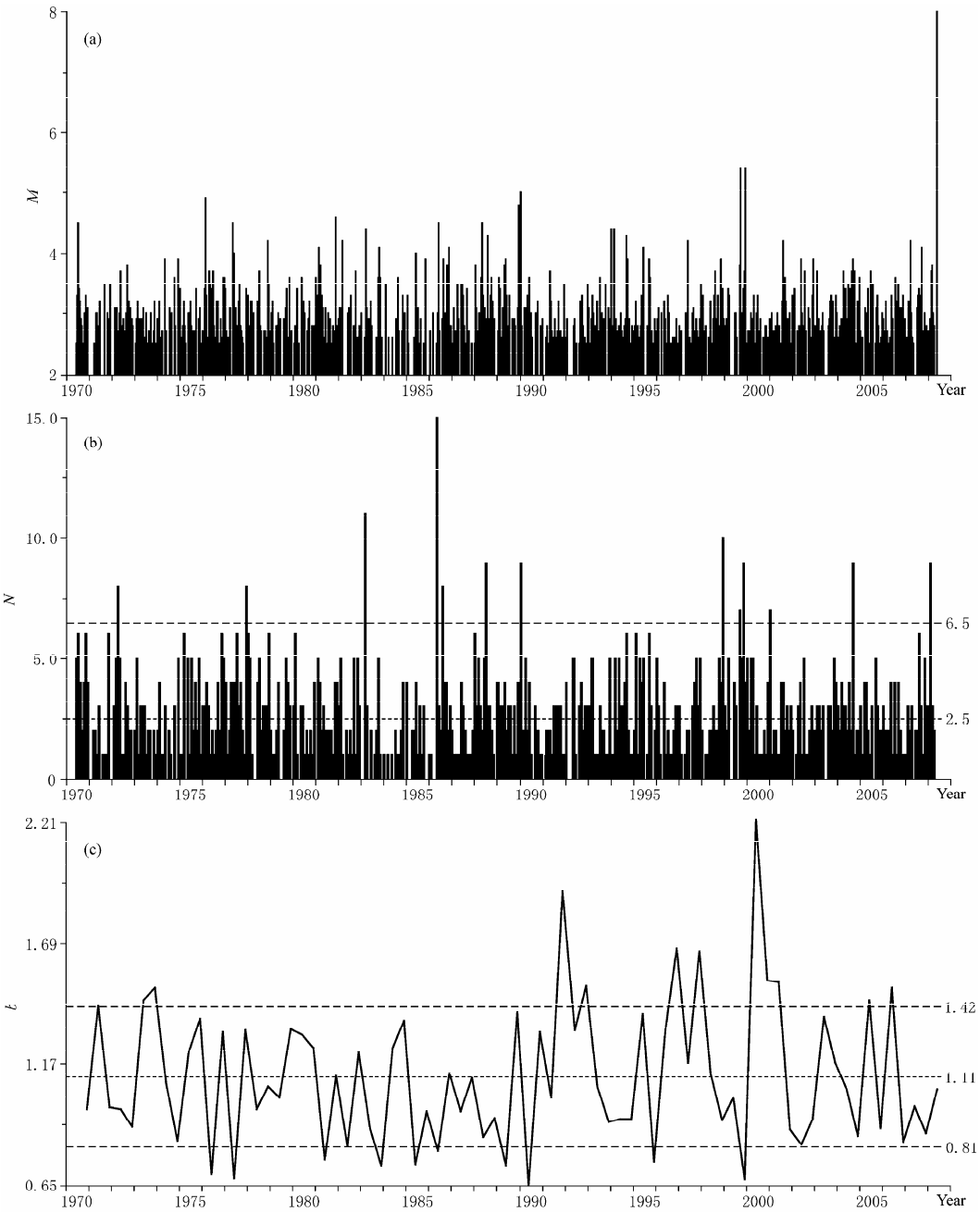

Figure 2 Seismicities on the Longmenshan fault zone from June 1970 to May 2008. (a) Magnitude M vs. time t; (b) Monthly frequency N vs. time t; (c) b-value vs. time t for earthquake with $M_L \geq 2.5$.

Diao et al (1993) reimproved the calculation programs, which are based on both the algorithm of generalized transmission coefficient and the maximum amplitude ratio of direct waves simulated from theory synthetic seismograms method. Then we used both the displacement amplitude ratio of Pg and Sg waves, seismic data with clear initial motion and DIAO's programs to calculate focal mechanism solutions with small earthquakes distributed on the Longmenshan faults and its vicinities. The calculation parameters are listed in the Table 1.

Table 1 The focal mechanism solution parameters of small earthquakes distributed on the Longmenshan fault zone and its vicinities before the Wenchuan M_S8.0 earthquake

No.	M_L	Depth /km	Nodal plane I			Nodal plane II			P-axis		T-axis		B-axis	
			Strike/°	Dip/°	Rake/°	Strike/°	Dip/°	Rake/°	Az/°	Pl/°	Az/°	Pl/°	Az/°	Pl/°
1	3.5	12	23	59	99	5	32	75	106	14	317	74	198	8
2	3.2	8	20	59	88	24	31	93	111	14	284	76	21	2
3	4.2	9	104	36	–159	357	78	–56	302	46	61	25	168	33
4	3.0	10	111	85	–138	196	48	–6	343	32	236	25	116	47
5	4.3	5	27	81	–35	123	55	–168	339	31	80	17	194	54
6	3.2	5	256	61	–176	344	87	–29	116	22	214	17	338	61
7	3.1	9	32	51	171	127	83	39	253	21	357	32	135	50
8	3.0	14	150	51	–3	242	88	–141	113	28	9	24	245	51
9	3.3	6	59	59	174	153	84	31	282	17	21	26	162	58
10	4.3	10	355	24	–54	317	71	–105	25	62	238	24	142	14
11	3.4	9	3	20	61	34	72	100	296	26	139	62	30	10
12	3.2	5	341	36	23	232	77	124	297	24	178	47	44	33
13	3.3	5	148	48	21	44	75	136	102	17	357	41	208	44
14	4.1	8	349	60	–151	243	65	–33	204	40	297	3	30	50
15	3.3	5	254	56	–154	149	69	–37	107	41	204	8	303	48
16	3.0	9	107	66	–79	262	26	–113	38	67	189	20	283	10
17	3.0	8	81	73	–157	344	68	–18	303	28	212	3	116	62
18	3.3	5	124	90	130	47	40	1	181	33	66	33	303	40
19	3.2	6	129	33	93	125	57	88	36	12	208	78	306	2
20	3.7	12	160	49	3	68	88	139	121	26	16	29	246	49
21	3.3	14	350	64	29	66	64	151	118	1	208	38	27	52
22	4.4	9	310	72	–32	50	60	–159	267	35	2	8	103	54
23	5.0	5	10	73	115	313	30	36	82	24	312	55	183	24
24	3.2	5	48	50	170	145	82	40	270	21	15	33	153	49
25	3.8	9	307	60	156	50	69	32	177	6	271	37	79	52
26	3.1	9	168	77	5	257	85	167	123	6	32	13	238	76
27	3.0	9	315	33	169	54	84	57	171	31	293	42	58	32
28	3.5	10	120	89	–21	211	69	–178	74	15	167	13	296	69
29	3.3	5	350	31	93	167	59	88	258	14	72	76	168	1
30	8.0(M_S)	14	228	33	141	352	70	63	102	20	226	56	2	25

The focal mechanism solutions of small earthquakes on the Longmenshan fault zone and at the south segments of the Xianshuihe fault zone are shown in Figure 3a. Based on digital seismic waveform data, the M_L≥3.0 earthquakes obtained from the focal mechanism solutions before the Wenchuan earthquake distribute mainly at the middle and south segments of the Longmenshan fault zone. The M_L≥3.0 earthquakes on the Qingchuan fault and north segment of the Longmenshan faults occurred seldom. Therefore, the earthquakes with focal mechanism solutions are also less. The focal mechanism solutions of most earthquakes show that the principal compressive stress direction of the Longmenshan fault zone is NW, which is presented in Figure 3b.

The Wenchuan earthquake results from a unilateral fault fractures with NE trending of the Longmenshan faults. The distribution of aftershocks shows the NE trending as well. The fracture length of this great earthquake is 330 km. According to arrival time data of seismic wave, epicenters or initial rupture is determined. The Zipingpu dam locates near the initial rupture of the Wenchuan earthquake. Small earthquakes near the Zipingpu dam increased before the Wenchuan earthquake. Some focal mechanism solutions results from the M_L3.7 and M_L3.3 earthquakes on 14 February 2008 near the Zipingpu dam (earthquake serial numbers are 20 and 21). Based on seismic wave data from seismic network of the Zipingpu dam, the focal mechanisms of 13 small earth-

quakes before the Wenchuan earthquake near the Zipingpu dam are determined. The water area of the Zipingpu dam covers the initial rupture area of the Wenchuan earthquake. The focal mechanism distribution of this area is presented in Figure 4. The aftershock distribution scope of the Wenchuan earthquake is longer, which presents obvious segmentation characteristic of focal mechanisms. The epicenter of the Wenchuan earthquake locates near the water area tail of the Zipingpu dam, the M_L3.7and M_L3.3 earthquakes on 14 February 2008 are several kilometers apart from the south of the Zipingpu dam, and they all belong to the Longmenshan tectonic system with NE direction between central faults and front-range faults. The focal mechanism solutions of small earthquakes in initial rupture certainly reflect the micro rupture mechanism before the great earthquake. These results are important for analyzing pre-earthquake tectonic stress fields.

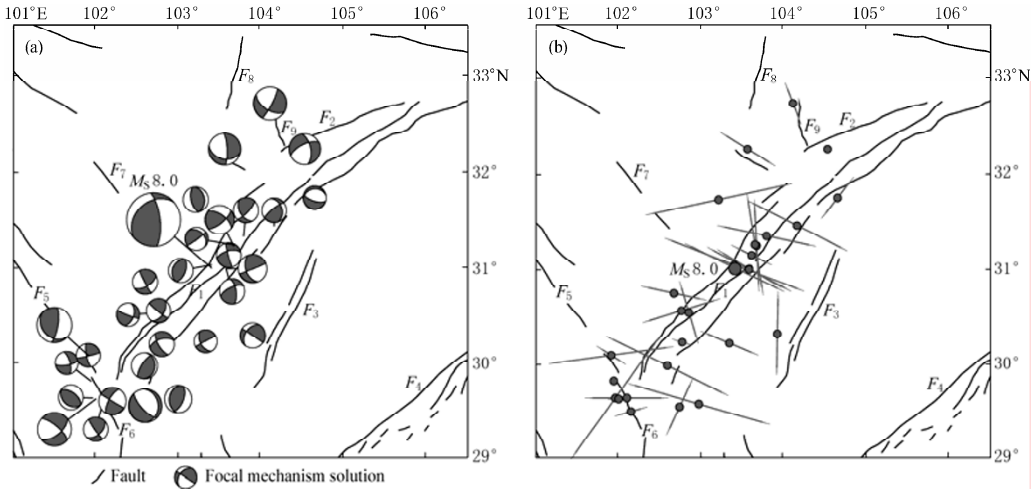

Figure 3 The focal mechanism solutions of earthquakes (a) and the distribution of the principal compressive stress direction (b) on Longmenshan fault zone and its vicinities. The name of fault zone is the same as that in Figure 1.

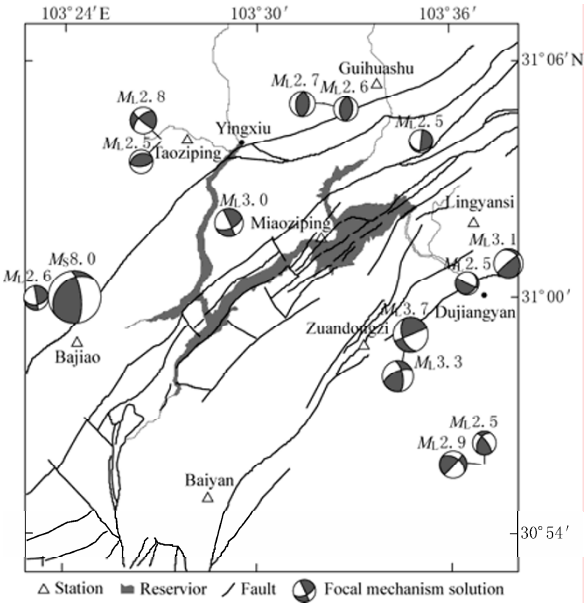

Figure 4 The distribution of station network and focal mechanism solutions in the Zipingpu dam region.

2.2.2 Characteristics of pre-earthquake tectonic stress field

The focal mechanism parameters are calculated from small earthquakes occurred before the Wenchuan earthquake. We use a moving window with the 10° interval to calculate the normalization frequencies. The statistical results are shown in Figure 5. The source fracture planes of small earthquakes before the Wenchuan earthquake present two strikes of NE and NW directions. The plane of NE direction is among N50°–70°E, the dip angles of fault planes are all steep, from 60° to 70° (Figure 5a). The P-axis direction of principal compressive stress is WNW-ESE. The dip angles are from 0° to 50° and predominant directions of principal stress T tensile axis are NNE and NS. Most of dip angles are from 20° to 50°. The dip angles of intermediate stress B-axis are from 30° to 60°. The direction is NNE (Figure 5b). Based on slip angles, we analyze hypocenter mechanical modals. Most of hypocenter mechanical models are dominantly characterized by dip-slip reverse, right-lateral dip-slip reverse or

left-lateral dip-slip reverse faulting and another portion of earthquakes are strike-slip fault type.

Near the Zipingpu dam regions, the source fault plane parameters are obtained with above method. The strikes of two nodal planes are NE and SN directions respectively. The dip angle of nodal plane is less than 45°. The principal compressive stress *P*-axis direction is also near WNW-ESE. The dislocation type of source fault presents a right-lateral dip-slip reverse. It can be seen that the whole characteristics of small earthquake mechanism solutions near the Zipingpu dam are almost identical with the results of the Longmenshan tectonic system. The pre-earthquake activities along the Longmenshan fault zone show that this block is controlled by the horizontal compressional stress of WNW-ESE direction during this period, the dip of stress axis is less than 45^{o}.

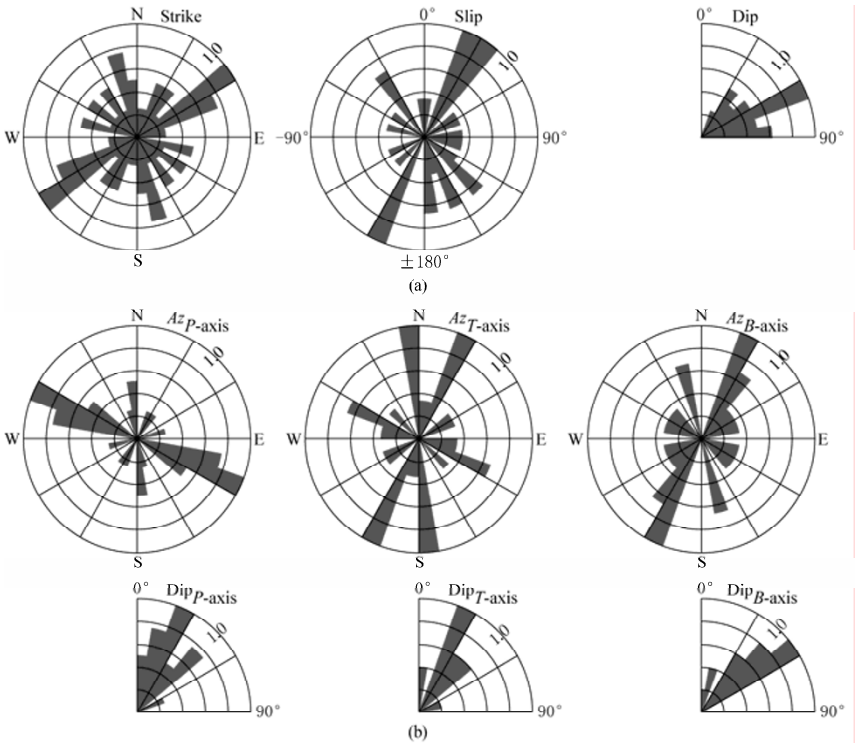

Figure 5 The nodal plane (a) and stress axis parameters (b) analysis of pre-earthquake focal mechanism solutions on the Longmenshan fault zone.

We further use the calculating method of stress axis tensor (Zhong and Cheng, 2006) to calculate mean principal stress axis σ_1, σ_2 and σ_3 of the Longmenshan fault zone before the Wenchuan earthquake from multiple focal mechanism solutions (Table 2). The azimuth of maximum principal stress axis σ_1 is 116°, which differs by 8° from the result (98°) based solely on P-wave motion data of moderately strong earthquakes along the Songpan-Longmenshan tectonic belts (Zhong and Cheng, 2006). With the same method, the azimuth of maximum principal stress axis σ_1 near the Zipingpu dam is 132.6°. By comparing with the results of Longmenshan fault zone, it can be seen that the principal compressive stress direction of the Zipingpu dam and entire fault zone are almost identical.

3 Comparison of focal mechanism between small earthquakes and the Wenchuan earthquake

After the Wenchuan earthquake, some research institutions in China and abroad put forward the focal mechanism solutions, such as Chen et al (2008), Harvard University (URL:http://neic.usgs.gov/neis/eq_depot/2008/eq_080512_ryan/neic_ryan_hrv.html) and National Earthquake Information Center (NEIC) of United States Geological Survey (USGS) (URL: http://neic.usgs.gov/neis/eq_depot/2008/eq_080512_ryan/neic_ryan_cmt.html) (See Table 3). In Table 3 it can be seen that the

three results are almost identical. The direction of principal compressive stress is WNW. Focal mechanism solutions show that the strike of nodal plane I is NE direction and that of nodal plane II is near SN. The faulting of this earthquake is mainly characterized by thrust with the component of right-lateral strike slip.

Table 2 The results of the mean principal stress axis before the Wenchuan M_S8.0 earthquake in research areas

Regional name	σ_1		σ_2		σ_3	
	Az/°	Pl/°	Az/°	Pl/°	Az/°	Pl/°
Longmenshan fault zone	296.0	6.6	80.9	81.9	205.5	4.6
Zipingpu dam	132.6	12.3	40.0	11.7	267.7	72.9

Note: Az stands for azimuth, Pl for the dip angle, σ_1, σ_2, σ_3 represent the mean principal stress axes.

Table 3 The focal mechanism solutions of the Wenchuan M_S8.0 earthquake on 12 May 2008

Data source	Nodal plane I			Nodal plane II			P-axis		T-axis		B-axis	
	Strike/°	Dip/°	Rake/°	Strike/°	Dip/°	Rake/°	Az/°	Pl/°	Az/°	Pl/°	Az/°	Pl/°
Chen et al (2008)	229	43	123	7	55	63	116	7	222	67	23	22
Harward (2008)	229	33	141	352	70	63	103	20	47	57	2	25
NEIC (2008)	238	59	128	2	47	45	122	6	22	57	36	31

By comparing the results of tectonic stress field calculated from pre-earthquakes in study areas with that of the Wenchuan earthquake, the focal mechanism solutions show that principal compressive stress directions of the Zipingpu dam and the Longmenshan fault zone are WNW direction and the results of average principal stress axis are 132.6° and 116° respectively. The Wenchuan earthquake has a principal compressive stress azimuth between 103° and 122°. Source parameters calculated from both the Longmenshan fault zone and the initial rupture region of the Wenchuan earthquake show that the principal compressive stress directions are identical.

Source fault planes of seismic activities before Wenchuan earthquake present two strikes of NE and NW directions on the Longmenshan tectonic zone. The plane of NE direction is among N50°–70°E. These earthquakes are dominantly characterized by dip-slip reverse faulting. The focal mechanism solution of the Wenchuan earthquake shows the strike of the nodal plane is N49°–58°E and is a right-lateral dip-slip reverse faulting. It can be seen that in both strikes results of source fault plane and dislocation types are identical. It should be noted that by comparing the focal mechanism solutions of historical moderate-strong earthquake with the analysis results of seismic activity before the Wenchuan earthquake, both the focal mechanism solution of the Wenchuan earthquake and the basic characteristics of stress field on the Longmenshan tectonic zone are identical from the global aspect.

4 Discussion and conclusions

By analyzing and studying the seismic activity and tectonic stress field of both the Zipingpu dam region and Longmenshan fault zone before the Wenchuan M_S8.0 earthquake, we have drawn following conclusions.

1) There are neither moderate earthquakes nor the M_S5–6 earthquakes occurred before the great earthquake on the Longmenshan fault zone. The level and intensity of seismic activities before the Wenchuan earthquake are not high. Only $3 \le M_L \le 4$ earthquakes are fragmentary distributed. The phenomena of obvious abnormity enhancement or calmness did not appear.

2) By comparing the results from this study with the Wenchuan earthquake results, we analyze both tectonic stress field of the Zipingpu dam and the Longmenshan fault zone before the Wenchuan earthquake. The direction of principal compressive stress P-axis before main shock is WNW-ESE. The focal mechanism solutions of some earthquakes before the Wenchuan earthquake show that the principal compressive stress directions, the strikes of source fault plane and the dislocation types are consistent with that of the Wenchuan earthquake. Both the average stress field of micro-rupture along the Lomgmenshan fault zone before the Wenchuan earthquake and that calculated from the Wenchuan earthquake are identical.

3) Small earthquake activities appeared an increasing intendency at short period before the Wenchuan earthquake in vicinities of the Zipingpu dam, which is located near the initial rupture area of the Wenchuan

earthquake. The impoundment of the Zipingpu dam started in October 2005. Two high values of water level were on October 2006 and November 2007 (Figure 6). Then there were two $M_L \geq 3$ events and a series of small earthquakes on February 14, 2008 near the Zipingpu dam, during this period the Zipingpu dam was in the unload stage of water discharge. The increasing of small earthquake activities in vicinities of the Zipingpu dam is related to processes of water storing and discharging. These small earthquake activities may include the increasing of micro rupture near initial rupture area before the Wenchuan earthquake.

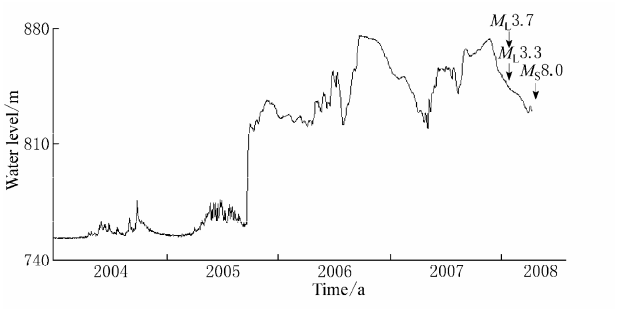

Figure 6 The water level and earthquakes in the Zipingpu dam.

4) There are two events of M_L3.7 and M_L3.3 on 14 February 2008 near the Zipingpu dam, the hypocenter depths of them are between 12 km and 14 km. The depth of the Wenchuan earthquake is between 10 km and 20 km. The depth is similar to that provided by Harvard CMT (Harvard, 2008), USGS (NEIC, 2008), and Chen et al (2008). Generally speaking, the depths of the small earthquakes induced by a dam are shallow and most of depths are several kilometers. However, the hypocenter depths of small earthquakes in our study are between 5 and 14 km as shown in Figure 7. In Figure 7a the focal depth profile of small earthquake before the Wenchuan earthquake along the Longmenshan fault zone is displayed. In Figure 7b the depth profile with the direction vertical to the strike of the Longmenshan tectonic zone is plotted. In these figures we can see that the hypocenter locations of small earthquakes are over the location of the Wenchuan earthquake. In other words, the hypocenter of the Wenchuan earthquake is lower than that of pre-earthquakes. Figure 7b also shows the wedge distribution characteristic which is spread from NW to SE. The seismic hypocenter distribution is a compressive reverse thrust character on the Longmenshan fault zone.

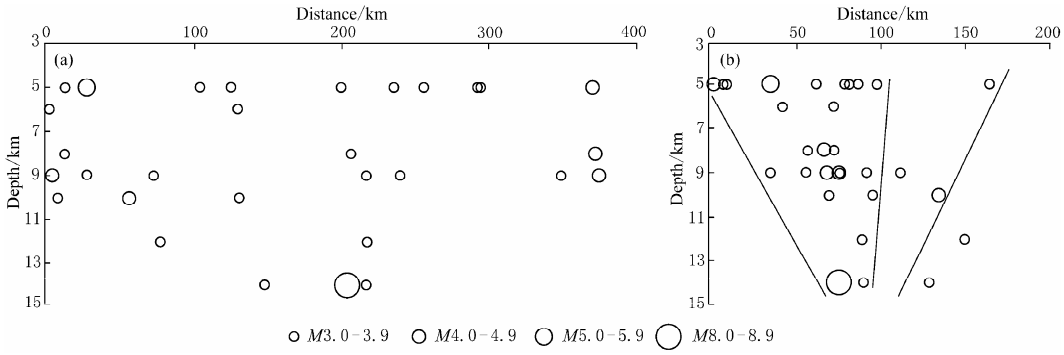

Figure 7 The focal depth distribution of pre-earthquakes on the Longmenshan fault zone. (a) Along NE strike of the Longmenshan fault zone; (b) Perpendicular to strike of the Longmenshan fault zone.

With the load and unload process of water storing and discharging in a dam, water infiltrates the fissure along tectonic zone. Then the friction is reduced to produce micro rupture. With the process of further water infiltrating and fissure weakening from shallow to deep, the strain energy suddenly release in pregnant construction area of existing great earthquakes. It is a very meaningful phenomenon. It is a slow process for fissure water to infiltrate. This infiltrating process induces a small earthquake. The increment of micro rupture is related with the load-unload process of water storing and discharging. Focal mechanism solutions of pre-earthquake micro-rupture are identical to that of main shock. It shows the consistency of the tectonic stress field before and after the great earthquake. The phenomena, such as water storing and discharging of a dam and small earthquakes, seem not be related to the M_S8.0 main shock. The water storing and discharging of the Zipingpu dam may affect the seismicity in earthquake-preparing tectonic zone. If we consider the micro

rupture phenomenon which may occur in initial rupture area of the Wenchuan earthquake, it may need even newer understanding from physics aspect. This article only makes a preliminary discussion on the relation among these three aspects. More evidences and new research work are needed.

Acknowledgements This study is supported by National Key Basic Research 973b and National Scientific technology support plan (2006BAC01B02-01-01). The authors would like to express our sincere thanks to Dr. Longquan Zhou, China Earthquake Networks Center, Prof. Guiling Diao, Earthquake Administration of Hebei province and Master Jian LÜ, Earthquake Administration of Jiangxi province, for their helps.

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