Tectonic stress pattern in the Chinese Mainland from the inversion of focal mechanism data

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The tectonic stress pattern in the Chinese Mainland and kinematic models have been subjected to much debate. In the past several decades, several tectonic stress maps have been figured out; however, they generally suffer a poor time control. In the present study, 421 focal mechanism data up to January 2010 were compiled from the Global/Harvard CMT catalogue, and 396 of them were grouped into 23 distinct regions in function of geographic proximity. Reduced stress tensors were obtained from formal stress inversion for each region. The results indicated that, in the Chinese Mainland, the directions of maximum principal stress were ~NE–SW-trending in the northeastern region, ~NEE–SWW-trending in the North China region, ~N–S-trending in western Xinjiang, southern Tibet and the southern Yunnan region, ~NNE–SSW-trending in the northern Tibet and Qinghai region, ~NW–SE-trending in Gansu region, and ~E–W-trending in the western Sichuan region. The average tectonic stress regime was strike-slip faulting (SS) in the eastern Chinese Mainland and northern Tibet region, normal faulting (NF) in the southern Tibet, western Xinjiang and Yunnan region, and thrust faulting (TF) in most regions of Xinjiang, Qinghai and Gansu. The results of the present study combined with GPS velocities in the Chinese Mainland supported and could provide new insights into previous tectonic models (e.g., the extrusion model). From the perspective of tectonics, the mutual actions among the Eurasian plate, Pacific plate and Indian plate caused the present-day tectonic stress field in the Chinese Mainland.

1. Introduction

Tectonic stress is one of the fundamental datasets in Earth Sciences comparable with topography, gravity, heat flow and others (Sperner *et al.* 2003). Thus, an investigation into the crustal tectonic stresses is a key point in earth geotectonic studies (Hou *et al.* 2006; Lunina and Gladkov 2007; Ju *et al.* 2013a, 2016; Baruah *et al.* 2013, 2016; Naimi-Ghassabian *et al.* 2015). Furthermore, knowledge of the tectonic stress field can be used in the hydrocarbon industry to foresee stability problems and tectonic fractures (Ju *et al.* 2013b, 2014, 2015; Ju and Sun 2016), and to optimize reservoir management through tectonic modelling (Sperner *et al.*

2003). In general, the focal mechanism data and their analysis allow and facilitate a revisiting of tectonic interpretations of the present-day stress field (Delvaux and Barth 2010; Naimi-Ghassabian *et al.* 2015). The stress patterns obtained from formal stress inversion of focal mechanism solutions can reveal many things in the stress field that were not captured by large-scale numerical models of previous studies.

China contains some of the most complex geology in the world, ranging from a number of ancient Archean cratons to active tectonic belts, and offshore marine basins (Tapponnier and Molnar 1977; Yin 2010; figure 1). During the past several decades, the number of focal mechanisms available

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for Chinese Mainland increased considerably due to a longer observation time, improvement of the seismic network and more detailed calculation procedures; therefore, it is possible to image the tectonic stress for Chinese Mainland.

In this study, initially, available well constrained focal mechanism data in the Chinese Mainland up to January 2010 (421 events) from the Global/Harvard CMT catalogue were compiled; after that, 396 of them were grouped into 23 distinct regions (boxes) in function of geographic proximity. Formal inversions were performed to determine the present-day stress field and discuss the tectonic stress regime and driving forces.

2. Data compilation and zonation

The Global CMT Project – formerly Harvard CMT (Dziewonski *et al.* 1987) – routinely determines focal mechanisms by moment tensor inversion of

both long period body- and surface-waves. In this study, altogether 421 focal mechanisms ($M_w \geq 5.0$) were compiled (listed in the [Appendix](#)) to perform stress inversions and discuss the results in terms of the Chinese Mainland tectonics. In the compiled database, the direction of horizontal stress (S_{Hmax} and S_{Hmin}) computed according to Lund and Townend (2007) and stress regime (NF: normal faulting, SS: strike-slip faulting, TF: thrust faulting, NS: intermediate between NF and SS, TS: intermediate between SS and TF, UF: unknown or oblique faulting) were given for each individual focal mechanism.

In the Chinese Mainland, the focal mechanism data vary in terms of stress regime and stress orientation; therefore, they cannot be inverted altogether. In the present study, the region was divided into sub-areas to study regional changes in stress orientation and stress regime (Barth *et al.* 2007; Delvaux and Barth 2010). In view of this, the

Figure 1. Tectonic map of the Chinese Mainland and adjacent regions (after Tapponnier *et al.* 1986 and Zhang *et al.* 2003).

zonation of the Global Seismic Hazard Assessment Program (GSHAP) was applied as a starting point, which took into account the recent and historic seismicity and hence defined areas with a common seismic risk (Zhang 1993; Giardini 1999; Zhang *et al.* 1999; Delvaux and Barth 2010). In addition, the China National Seismic Zonation Map (CNSZM; Gao 2003) also contributed to the subdivision.

In this study, 396 of the total 421 data were assembled into 23 boxes (listed in Appendix) on the basis of their geographical proximity and geological setting.

3. Tectonic stress inversion

The determination of present-day tectonic stress and stress regime based on the inversion of earthquake focal mechanisms has been studied by several authors (e.g., Angelier 1984, 1989; Gephart and Forsyth 1984; Delvaux *et al.* 1995). The inversion is mainly based on the assumption that (a) the stress field is uniform and invariant in space and time, and (b) slip on a plane occurs in the direction of the maximum resolved shear stress (Bott 1959; Etchecopar *et al.* 1981; Delvaux and Barth 2010; Baruah *et al.* 2013; Naimi-Ghassabian *et al.* 2015).

In general, the state of tectonic stress at any point of the Earth can be defined by six independent parameters, e.g., three angles specifying the orientation of the stress tensor's eigenvectors and three corresponding eigenvalues (Lund and

Townend 2007). However, stress tensor estimation using earthquake focal mechanism does not retrieve all the six independent components. The four parameters, the orientation of the three orthogonal principal stress axes σ_1 , σ_2 and σ_3 (where $\sigma_1 \geq \sigma_2 \geq \sigma_3$) and the stress ratio R , of the reduced stress tensor that models best the state of stress of a given region can be determined. The stress ratio R , which shows the magnitude of σ_2 relative to the magnitudes of σ_1 and σ_3 , can be expressed as follows (equation 1; Etchecopar *et al.* 1981; Gephart and Forsyth 1984; Delvaux and Sperner 2003; Cortes and Angelier 2005):

$$R = \frac{\sigma_2 - \sigma_3}{\sigma_1 - \sigma_3}. \quad (1)$$

The four parameters estimated from focal mechanism inversions are sufficient to estimate the direction of the maximum horizontal stress axis and stress regimes based on the guidelines and terminology first presented by Zoback (1992) and the formula of Lund and Townend (2007).

In the present study, the Win-TENSOR program (the Windows version of the TENSOR program; version 5.8; Delvaux and Sperner 2003; Delvaux and Barth 2010) was used for tectonic stress inversion. Initially, the 'Right Dihedron Method (RDM)' was used for determination of the range of possible σ_1 and σ_3 orientations. The results acted as starting points for the iterative 'Rotational Optimization Method (ROM)' (Delvaux and Sperner 2003), which

Stress tensor types	Extensive					Strike-slip				Compressive			
Stress symbols													
R	0.00	0.25	0.50	0.75	1.00	0.75	0.50	0.25	0.00	0.25	0.50	0.75	1.00
R'	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
Relationship	R' = R					R' = 2 - R				R' = 2 + R			

Figure 2. Types of stress regimes and their representations (after Delvaux *et al.* 1997). Arrows indicate the azimuth of horizontal stress axes, with their length according to the relative stress magnitude. While outward arrows indicate extensive deviatoric stress axes, black inward arrows indicate compressive deviatoric stress axes. Vertical stress axes are symbolized by a solid circle for extensive regimes (σ_1 vertical), a dot for strike-slip regimes (σ_2 vertical) and an empty circle for compressive regimes (σ_3 vertical).

is based on the testing of a great number of different stress tensors with the aim of minimizing a misfit function (misfit function F5 in the Win-TENSOR program; version 5.8).

In general, the minimization function has the following form (equation 2):

$$F_j = \frac{\sum(f_j(i) \times w(i))}{n \times \sum w(i)}, \quad (2)$$

where $w(i)$ is the weight of the individual data and $f_j(i)$ is the function that has to be minimized.

The angle between the calculated shear stress τ and the slip vector d is the fit angle α . Thus, the corresponding misfit function to be minimized for each earthquake i is the misfit angle α (equation 3):

$$f(i) = \alpha(i). \quad (3)$$

In addition, it is also common to use a least-square function for the minimization (equation 4; Angelier 1984, 1989; Delvaux and Barth 2010), which implies a Gaussian-type distribution of individual misfits.

$$f(i) = \sin^2 \left(\frac{\alpha(i)}{2} \right). \quad (4)$$

Initially, both the nodal planes for each focal mechanism are inverted to a stress tensor, then the plane that is best explained by the stress tensor (namely smaller value of function F5 in the program) is selected and viewed as the actual focal plane. After the separation, the following inversion then includes only the focal planes that are best fitted by a uniform stress field (Gephart and Forsyth 1984; Delvaux and Barth 2010; Naimi-Ghassabian *et al.* 2015).

The stress index R' is defined from a combination of the stress ratio R and the nature of the most vertical principal stress axes (Delvaux *et al.* 1997; Delvaux and Sperner 2003). Based on the stress index R' , we can define all types of stress regime systematically. It is ranging from 0 to 3 as follows (equation 5 and figure 2; Delvaux *et al.* 1997; Delvaux and Sperner 2003; Zhang and Wang 2004):

$$\begin{aligned} R' &= R, \text{ when } \sigma_1 \text{ is vertical} \\ &\quad (\text{extensional stress regime}); \\ R' &= 2 - R, \text{ when } \sigma_2 \text{ is vertical} \\ &\quad (\text{strike-slip stress regime}); \\ R' &= 2 + R, \text{ when } \sigma_3 \text{ is vertical} \\ &\quad (\text{compressive stress regime}). \end{aligned} \quad (5)$$

Figure 3. Focal mechanism data assembled into boxes for stress inversion. Boxes – 1: northeastern China region; 2: northern China region; 3: eastern China region; 4: southwest Junggar Basin; 5: Aksu region; 6: eastern Kaxgar region; 7: western Kaxgar region; 8: Hotan region; 9: Gansu region; 10: Sichuan region; 11: northwestern Yunnan region; 12: northern Yunnan region; 13: southwestern Yunnan region; 14: northwestern Qinghai region; 15: central Qinghai region; 16: eastern Qinghai region; 17: southern Qinghai region; 18: southwestern Qinghai region; 19: eastern Tibet region; 20: southern Tibet region; 21: southwestern Tibet region; 22: western Tibet region; 23: northeastern Tibet region.

It forms a continuous scale ranging from 0 to 1 for normal faulting regimes, 1 to 2 for strike-slip regimes and 2 to 3 for thrust faulting regimes (figure 2; Delvaux *et al.* 1995, 1997; Zhang and Wang 2004; Cortes and Angelier 2005; Delvaux and Barth 2010).

4. Present-day tectonic stress field

4.1 Results

In the present study, the present-day tectonic stress field and stress regime for each focal mechanism in the Chinese Mainland were studied based on the above method (figures 3, 4 and 5). The results indicated that (a) the average σ_1 orientation was $\sim$ E–W-trending in the eastern Chinese Mainland (box-1–box-3), which agreed with previous studies (e.g., Yao *et al.* 1991; Xie *et al.* 2004). The stress regime was dominated by the SS, (b) the northwestern Chinese Mainland (box-4–box-8) was characterized with a TF regime, and the σ_1 orientations ranged between NNW–SSE-trending and NNE–SSW-trending, (c) the Yunnan region (box-11–box-13) was dominated by a SS regime with NNW–SSE-trending to NNE–SSW-trending σ_1 orientations, (d) the southern Tibet region (box-20–box-22) was characterized with a NF regime, and the average

σ_1 orientation was $\sim$ N–S-trending, (e) the regions of Gansu and Qinghai (box-9–box-10 and box-14–box-17) were dominated by a TF regime with NE–SW-trending to NEE–SSW-trending σ_1 orientations, and (f) the northern Tibet region (box-18, box-19 and box-23) was characterized by NF and SS regimes, the σ_1 orientations varied between NNE–SSW-trending and NE–SW-trending.

4.2 Analysis of the misfit

In general, focal mechanisms have different values due to the number and distribution of recording stations, magnitude, determination technique, etc., it is important to check the stability obtained as a function of datum weight and quality (Audemard *et al.* 2005; Cortes and Angelier 2005). The quality evaluation of the results was done using the updated quality ranking system of the World Stress Map release 2008 (Delvaux and Barth 2010; Heidbach *et al.* 2010). It evaluates the azimuthal accuracy of S_{Hmax} obtained from the inversion of a well-constrained focal mechanism (N is the number of data in equation 6) with an average misfit angle α in close geographic proximity. In addition, the graphical output of the stress tensor is in an equal-area projection, which allows the evaluation of the overall quality.

Figure 4. Focal mechanism data represented as S_{Hmax} axes. A colour-coded central square indicates the tectonic regime – red: NF; blue: SS; green: TF.

A-quality:

 S_{Hmax}/S_{Hmin} within $\pm 15^\circ$; $N \geq 15$ and $\alpha \leq 12^\circ$;

B-quality:

 S_{Hmax}/S_{Hmin} within $\pm 15-20^\circ$; $15 \geq N \geq 8$ and $12 \leq \alpha \leq 20^\circ$;

C-quality:

 S_{Hmax}/S_{Hmin} within $\pm 20-25^\circ$; $8 \geq N \geq 6$ and $20 < \alpha$. (6)

In the present study, the average misfit ranged from 5.21 to 12.41, indicating that the qualities of

Figure 5. Lower-hemisphere equal-area stereo-plots of the selected focal planes and associated slip lines (black dot with outward arrow for normal faulting, inward arrow for reverse faulting and double semi-arrows for strike-slip faulting). Stress inversion results are represented by the orientation of the three principal stress axes (a dot surrounded by a circle for σ_1 , a triangle for σ_2 , and a square for σ_3). The related S_{Hmax} and S_{Hmin} orientations are represented by large arrows outside the stereogram. White arrows: σ_3 is sub-horizontal, green arrows: σ_2 is sub-horizontal and red arrows: σ_1 is sub-horizontal. Outward arrow indicates extensional deviatoric stress and inward arrows for compressional deviatoric stress. The vertical stress is symbolized in the small circle on the upper left corner of the figures by a solid circle for extensional regimes, a dot for strike-slip regimes and an open circle for compressional regimes. The histogram on the lower left corner of the figures represents the distribution of the misfit angle, weighted arithmetically according to the magnitude.

Figure 5. (Continued.)

all the boxes fell into B- or A-level (table 1 and figure 5). Generally, A-, B- and C-quality stress indicators are considered reliable for the use in

analyzing stress patterns and the interpretation of geodynamic processes (Naimi-Ghassabian *et al.* 2015); therefore, the present results are reliable.

Table 1. *Stress inversion results for the 23 boxes (parameters for stress map).*

Box definition			Reduced stress tensor parameters							SH		Misfit, regime and quality rank			
No.	Location	Data	σ_{1pl}	σ_{1az}	σ_{2pl}	σ_{2az}	σ_{3pl}	σ_{3az}	R	Max	Min	Misfit (aver)	R'	Regime	Q
1	Northeastern China region	7	06	266	66	012	22	174	0.28	086	176	12.41	1.72	SS	B
2	Northern China region	15	14	079	75	261	00	169	0.66	079	169	8.09	1.34	SS	A
3	Eastern China region	5	04	269	78	020	11	179	0.19	090	000	11.29	1.81	SS	B
4	Southwestern Junggar Basin	11	00	359	01	269	87	111	0.32	179	089	10.99	2.32	TF	B
5	Aksu region	15	11	166	03	075	78	328	0.64	167	077	5.75	2.64	TF	A
6	Eastern Kaxgar region	29	35	209	54	033	01	300	0.96	031	121	9.93	1.04	SS	A
7	Western Kaxgar region	17	04	176	74	070	15	267	0.16	176	086	7.87	1.84	SS	A
8	Hotan region	5	41	026	00	295	48	204	0.85	115	025	6.33	2.85	UF	B
9	Gansu region	14	06	039	13	130	74	284	0.12	039	129	7.18	2.12	TF	A
10(a)	Sichuan region	10	61	089	28	260	03	352	0.92	083	173	8.17	0.92	NF	A
10(b)	Sichuan region	30	00	090	78	183	11	000	0.09	091	001	8.68	1.91	SS	A
11	Northwestern Yunnan region	15	24	338	65	149	03	246	0.89	157	067	9.49	1.11	SS	A
12	Northern Yunnan region	13	04	335	85	128	02	245	0.81	155	065	5.71	1.19	SS	A
13	Southwestern Yunnan region	19	13	198	76	027	01	289	0.87	019	109	7.59	1.13	SS	A
14	Northwestern Qinghai region	9	02	200	29	108	60	295	0.20	020	110	7.28	2.20	TF	B
15	Central Qinghai region	19	01	026	03	116	86	277	0.14	026	116	9.25	2.14	TF	A
16	Eastern Qinghai region	11	01	222	30	131	59	314	0.11	042	132	7.93	2.11	TF	B
17	Southern Qinghai region	8	10	053	79	226	01	323	0.84	054	144	10.51	1.16	SS	A
18	Southwestern Qinghai region	20	23	042	52	167	27	299	0.33	039	129	10.35	1.67	UF	A
19	Eastern Tibet region	20	45	018	44	192	02	285	0.76	016	106	5.21	0.76	NS	A
20(a)	Southern Tibet region	11	78	010	11	191	00	101	0.81	012	102	7.86	0.81	NF	A
20(b)	Southern Tibet region	19	84	012	05	183	00	273	0.28	003	093	5.55	0.28	NF	A
21	Southwestern Tibet region	21	76	357	13	174	00	264	0.63	174	084	7.64	0.63	NF	A
22	Western Tibet region	24	58	186	30	350	07	084	0.70	175	085	6.47	0.70	NF	A
23	Northeastern Tibet region	29	13	016	72	237	10	108	0.87	018	108	9.86	1.13	SS	A

Note: Box definition: box number, location and the number of data in the box; Reduced stress tensor parameters: plunge (pl) and azimuth (az) of the principal stress axes (σ_1 , σ_2 and σ_3) and stress ratio R ; SH: S_{Hmax} and S_{Hmin} ; misfit, regime and quality rank: average misfit angle, regime as in figure 2, Q – quality rank as in equation (6).

5. Discussion

5.1 Tectonic stress regime

The tectonic stress regime in the Chinese Mainland was analyzed (figures 6 and 7) based on stress ratio R and stress index R' (equation 5 and figure 2).

The stress inversion results of box-10(a), box-20(a, b), box-21 and box-22 indicated a NF regime with R' ranging from 0.28 to 0.92 (table 1). Values close to 0.50 denote a pure NF regime (figure 2; e.g., 0.63 for box-21: southwestern Tibet region), close to 0 denote a tendency towards radial extension (figure 2; e.g., 0.28 for box-20(b): southern Tibet region), and close to 1.00 indicate the presence of a strike-slip component (figure 2; 0.92 for box-10(a): Sichuan region).

The stress inversion results of box-1, box-2, box-3, box-6, box-7, box-10(b), box-11, box-12, box-13, box-17 and box-23 indicated a SS regime with R' ranging from 1.04 to 1.91 (table 1). Values close to 1.50 denote a pure SS regime (figure 2; e.g., 1.34 for box-2: North China region), close to 1.00 denote a tendency towards extension (figure 2; e.g., 1.04 for box-6: eastern Kaxgar region), and close

to 2.00 denote a tendency towards compression (figure 2; 1.91 for box-10(b): Sichuan region).

The stress inversion results of box-4, box-5, box-9, box-14, box-15 and box-16 indicated a TF regime with R' ranging from 2.11 to 2.64 (table 1). Values close to 2.50 denote a pure TF regime (figure 2; e.g., 2.64 for box-5: Aksu region), close to 2.00 indicate the presence of a strike-slip component (figure 2; e.g., 2.11 for box-16: eastern Qinghai region and 2.12 for box-9: Gansu region), and close to 3.00 denote a tendency towards radial compression.

To sum up, in the Chinese Mainland, the southwestern regions were mainly extensional regime, the northwestern regions were compressional regime, and strike-slip regime occurred mainly in the middle and eastern regions (figure 7).

5.2 Tectonic models and GPS observations

From the perspective of tectonic location, the majority of the Chinese Mainland belongs to Eurasian plate, and it is adjacent to Pacific plate on the east, Indian plate on the southwest

Figure 6. Map representation of the stress inversion results for each box in the Chinese Mainland. Stress regime – green: TF, blue: SS and red: NF.

Figure 7. Stress index (R') counter diagram in the Chinese Mainland. $0 \leq R' \leq 1$, extensional regime; $1 \leq R' \leq 2$, strike-slip regime; $2 \leq R' \leq 3$, compressional regime.

(Tapponnier and Molnar 1977; Wang *et al.* 1996; Yin 2010). Because of this special tectonic location, the mutual action among Eurasian plate, Pacific plate and Indian plate must have a great impact on the tectonic stress field of Chinese Mainland during the neotectonics period (Deng *et al.* 1979; Wang *et al.* 1996; Xu and Zhao 2006; Yin 2010). Among them, the India–Eurasia collision and continuous northward movement of the Indian plate play a dominant role in controlling the tectonic movement and present-day tectonic stress environment of Chinese Mainland (e.g., Tapponnier and Molnar 1977; Deng *et al.* 1979; Tapponnier *et al.* 1982; Yin 2010). Tapponnier *et al.* (1982) modelled the India–Eurasia collision with plasticine layers (Eurasia) and steel piston (India) and proposed the ‘Extrusion Model’ for the tectonics of Asia (figure 8). Generally, the present study results and GPS velocities in the Chinese Mainland (figure 9) support and agree with Tapponnier’s model, which may provide new insights into the tectonic models.

The Tibetan plateau underwent substantial internal shortening with an average ~ 40 mm/yr convergence rate in the direction of about $NE20^\circ$ (figure 9). The southern Tibet region was characterized by a series of $\sim N-S$ -trending normal faults and grabens in a NF regime (figure 4; Tapponnier and Molnar 1977; Yin 2010). GPS measurements indicated that the extensional rate across southern Tibet was about 20 mm/yr (Wang *et al.* 2001; Zhao 2015). Regions in the eastern Tibetan plateau showed a prominent clockwise rotation around the Eastern Himalayan Syntaxis (figure 9; Holt *et al.* 2000; Wang *et al.* 2001; Yin 2010). In general,

it was $\sim E-W$ -trending in western Sichuan, $\sim SE-NW$ -trending in northern Yunnan, $\sim SSE-NNW$ -trending in southern Yunnan and $\sim N-S$ -trending in western Yunnan (figure 9). In the northwestern Chinese Mainland, widespread active tectonics and high seismicity attested to rapid crustal shortening. In this region, the total shortening rate in the western part was higher (~ 20 mm/yr in the west and ~ 2 mm/yr in the east), which was consistent with the conclusion of eastward decreases of crustal shortening based on geological investigations and theoretical modelling (Wang *et al.* 2001). In the North China region, the GPS measurements indicated a $\sim SEE-NWW$ -trending movement at rates of $2\sim 8$ mm/yr. The majority of active faults in the North China region were in the $NNE-SSW$ direction, which intersected with the south-southeastward movement would probably produce right-lateral strike-slip components. These components resulted in major earthquakes (Wang *et al.* 2001). In South China, an average velocity of $6\sim 11$ mm/yr with respect to stable Eurasia oriented toward near the eastern direction (figure 9). In addition, the South China was generally considered as a rigid block with rare internal deformations (Holt *et al.* 2000) and earthquakes.

5.3 Driving forces

According to the present analysis and previous studies (e.g., Deng *et al.* 1979; Xu and Zhao 2006), the driving forces for the present-day tectonic stress field in the Chinese Mainland can be divided into two parts on the basis of plate tectonics.

Figure 8. Hand drawings of faults observed in experiments (after Tapponnier *et al.* 1982).

In the western Chinese Mainland, the collision between Indo-Australian plate and the Eurasian plate caused the stress field and dominated the movements from the Himalayas to Tianshan Mountains. Thrust-type strong earthquakes occurred frequently along the edges of the Qinghai–Tibet Plateau and in the Tianshan region, and a $\sim$ E–W-trending extensional motion with a NF regime apparently occurred in the southern Tibet region (Tapponnier and Molnar 1977; Tapponnier *et al.* 1986; Xie *et al.* 1999, 2004; Wang *et al.* 2001; Xu and Zhao 2006; figure 4). The average σ_1 orientation was $\sim$ N–S-trending in the southern Tibet region, and $\sim$ NNW–SSE-trending in the Yunnan region due to the resistance of Sichuan Basin and the existing of strike-slip fault nearby. In addition, in the Xinjiang region, remote effects of the collision between India and Eurasian plate caused the σ_1 orientation varied from $\sim$ NNW–SSE-trending to $\sim$ NNE–SSW-trending (figure 4).

In the eastern Chinese Mainland, the present-day stress field was produced by a joint action from the subduction of Pacific plate and the collision between India and Eurasian plate (Deng *et al.* 1979; Yin and Nie 1993; Xie *et al.* 1999, 2004).

In addition, the present-day tectonic stress field in the eastern Chinese Mainland started in the Late Miocene, while in the western part, it began at the end of Early Pleistocene. The time difference was determined by the tectonic evolution and geological surroundings (Xie and Liu 1989; Xie *et al.* 1999; Zhang 1999).

6. Conclusions

In this study, the present-day tectonic stress field and stress pattern in the Chinese Mainland were analyzed with 421 earthquake focal mechanism data, and the tectonic regimes and driving forces were also discussed.

The σ_1 orientation varied greatly across the Chinese Mainland. Because of the collision between the Indian and Eurasian plate, the σ_1 orientation in the western Chinese Mainland varied between NW–SE-trending and NE–SW-trending, whereas in the eastern part, joint actions of the Pacific plate subduction and the collision between the Indian and Eurasian plate caused the $\sim$ E–W-trending σ_1 orientation. In addition, the present study results combined with GPS velocities in the

Figure 9. GPS velocity vectors (mm/yr) with respect to the stable Eurasia plotted on a relief map of the Asia topography (after Zhao 2015).

Chinese Mainland supported and provided new insights into previous tectonic models (e.g., the Tapponnier's extrusion model).

The tectonic stress regime showed variations in different regions of Chinese Mainland. In the eastern Chinese Mainland, the dominant was a SS stress regime, whereas the western part was relatively complex. It was a NF regime in the southern Tibet, SS regime in the northern Tibet, western Xinjiang and Yunnan regions, and TF regime in the majority of Xinjiang, Qinghai and Gansu regions.

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Appendix

Table A1. Compiled data base of focal mechanisms used in this study grouped in 23 boxes.

Data-time group Event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
<i>Northeastern China region (Box-1)</i>	7									
CM19800210-04:46:10	120.97	48.66	15.0	5.1	130	54	006	083	173	UF
CM19860815-20:20:39	126.09	48.61	15.0	5.0	116	63	-012	074	164	SS
CM19990129-05:44:25	116.37	44.67	15.0	5.0	130	64	-002	085	175	SS
CM20020915-08:39:36	130.04	44.77	589.4	6.4	098	19	163	152	062	UF
CM20030816-10:58:46	119.47	43.80	30.0	5.4	317	57	010	093	003	TF
CM20040324-01:53:51	118.15	45.38	13.0	5.3	167	28	086	079	169	TF
CM20050725-15:43:38	124.88	46.86	12.0	5.0	355	45	093	070	160	TF
<i>Northern China region (Box-2)</i>	15									
CM19760727-19:42:11	118.03	39.52	15.0	7.6	229	43	-163	075	165	UF
CM19760728-10:45:46	118.78	39.75	15.0	7.0	072	44	-110	086	176	NF
CM19761115-13:53:07	117.71	39.45	15.0	6.4	318	56	-009	097	007	SS
CM19770512-11:17:54	118.00	39.56	22.0	5.7	322	52	008	102	012	UF
CM19780518-12:33:34	122.56	40.79	15.0	5.5	023	60	-177	067	157	SS
CM19790619-04:15:09	111.50	36.83	33.0	5.0	278	30	-063	084	174	NF
CM19811108-18:01:08	115.09	37.08	15.0	5.6	031	72	162	079	169	SS
CM19891018-14:57:27	113.61	39.83	15.0	5.4	204	76	-176	068	158	SS
CM19891018-17:01:39	113.49	39.77	15.0	5.6	200	75	-175	065	155	SS
CM19891018-18:20:50	113.84	39.63	15.0	5.4	092	44	-039	062	152	NF
CM19910325-18:02:44	113.34	40.10	15.0	5.4	106	82	007	060	150	SS
CM19980110-03:50:46	114.34	41.34	15.0	5.7	207	54	135	086	176	TF
CM19990311-13:18:13	114.64	41.73	15.0	5.1	295	65	-009	074	164	SS
CM19991101-13:25:19	113.74	39.85	15.0	5.2	122	72	-007	078	168	SS
CM20000111-23:43:58	123.11	40.36	15.0	5.1	027	43	-178	071	161	UF
<i>Eastern China region (Box-3)</i>	5									
CM19790709-10:57:25	118.99	31.11	15.0	5.4	138	66	022	089	179	SS
CM19831106-21:09:51	115.17	35.21	21.0	5.5	142	44	071	065	155	TF
CM19840521-15:39:01	121.37	32.56	24.3	6.0	202	85	178	066	156	SS
CM19950920-03:14:34	118.07	34.87	33.0	5.1	308	69	-007	084	174	SS
CM20051126-00:49:38	115.71	29.66	17.8	5.2	324	57	023	099	009	UF
<i>Southwestern Junggar Basin (Box-4)</i>	11									
CM19780422-15:04:25	086.54	42.26	15.0	5.3	336	38	135	040	130	TF
CM19801106-01:34:31	086.22	43.89	20.0	5.7	082	18	066	003	093	TF
CM19830303-03:32:19	086.91	43.97	65.6	5.3	148	38	128	036	126	TF
CM19831215-10:52:60	087.64	43.10	56.3	5.1	165	44	132	049	139	TF
CM19901024-23:38:15	083.99	43.79	15.0	5.2	106	48	141	164	074	TF
CM19950502-11:48:13	084.54	43.49	18.0	5.5	098	57	170	146	056	SS
CM19960109-06:27:59	085.47	44.01	33.0	5.4	108	23	118	005	095	TF
CM20030213-17:34:28	085.41	44.04	45.2	5.3	073	32	064	177	087	TF
CM20061123-11:04:47	083.47	44.26	30.4	5.1	231	39	052	162	072	TF

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress Regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
<i>Southwestern Junggar Basin (Box-4)</i>										
CM20070720-10:06:56	082.38	42.93	25.3	5.6	324	66	175	011	101	SS
CM20080830-12:46:50	083.96	42.79	12.8	5.3	265	39	118	159	069	TF
<i>Aksu region (Box-5)</i>										
	15									
CM19770723-06:57:09	083.59	42.20	33.0	5.4	299	19	118	016	106	TF
CM19780312-08:29:26	079.97	41.92	15.0	5.4	300	27	131	014	104	TF
CM19790329-02:01:35	083.69	41.93	15.0	5.6	279	29	107	001	091	TF
CM19801206-02:45:32	078.56	40.37	15.0	5.2	256	20	126	142	052	TF
CM19870105-22:52:51	081.48	41.77	15.0	5.7	226	21	047	142	052	TF
CM19870124-08:09:24	079.31	41.26	15.0	6.1	268	45	107	167	077	TF
CM19870303-09:41:33	079.52	41.30	33.0	5.0	042	21	096	131	041	TF
CM19910225-14:30:35	079.20	40.34	15.0	6.0	242	40	085	156	066	TF
CM19940509-09:14:13	079.02	40.25	33.0	5.0	068	45	102	150	060	TF
CM19940823-14:18:37	079.37	40.37	15.0	5.2	085	35	134	151	061	TF
CM19950926-04:39:11	081.40	42.02	43.0	5.1	246	38	077	163	073	TF
CM19980625-06:39:20	080.44	41.16	15.1	5.1	262	27	129	152	062	TF
CM19980728-04:51:47	081.58	41.93	46.9	5.1	260	42	088	173	083	TF
CM19990315-10:43:01	082.38	41.98	17.0	5.4	279	19	135	163	073	TF
CM20090220-10:02:32	078.63	40.74	16.6	5.3	262	36	091	171	081	TF
<i>Eastern Kaxgar region (Box-6)</i>										
	29									
CM19771218-16:47:22	077.44	39.92	15.0	5.9	286	27	125	041	131	TF
CM19850823-08:33:05	076.46	39.31	15.0	5.0	308	85	175	173	083	SS
CM19931130-20:37:27	076.50	39.73	19.0	5.6	219	74	004	173	083	SS
CM19940112-10:22:58	076.53	39.15	32.0	5.5	298	60	151	170	080	SS
CM19960319-15:00:36	076.80	39.93	22.2	6.3	273	26	109	174	084	TF
CM19961123-01:59:52	076.84	39.00	33.0	5.0	345	19	117	062	152	TF
CM19970121-01:48:29	077.26	39.51	33.0	5.9	315	75	−177	180	090	SS
CM19970129-08:20:18	077.42	38.97	33.0	5.2	042	43	010	173	083	UF
CM19970301-06:04:19	076.89	39.40	22.0	5.6	180	80	−173	044	134	SS
CM19970405-23:46:23	076.93	39.41	33.0	5.9	161	78	179	026	116	SS
CM19970406-04:36:38	077.03	39.52	15.0	5.9	253	42	−036	045	135	NF
CM19970406-12:58:21	076.99	39.48	33.0	5.3	227	36	−061	037	127	NF
CM19970411-05:34:50	076.93	39.61	15.0	6.1	240	37	−045	040	130	NF
CM19970412-21:09:15	077.20	39.64	16.0	5.3	243	48	−065	046	136	NF
CM19970415-18:19:16	076.99	39.69	23.0	5.8	170	66	−162	031	121	SS
CM19970624-09:24:51	077.18	39.80	33.8	5.1	345	72	−167	029	119	SS
CM19971017-17:35:18	077.07	39.59	33.0	5.3	339	81	178	024	114	SS
CM19980319-13:51:39	076.88	39.94	32.7	5.6	243	23	079	156	066	TF
CM19980802-04:40:47	077.13	39.67	15.0	5.6	231	30	−056	028	118	NF
CM19980827-09:03:41	077.22	39.51	32.0	6.3	240	78	000	015	105	SS
CM20030104-11:07:24	077.11	39.73	33.0	5.2	341	71	−162	025	115	SS
CM20030224-02:03:54	077.24	39.37	24.0	6.3	239	33	062	164	074	TF
CM20030224-21:18:49	077.04	39.35	15.0	5.2	289	33	126	178	088	TF
CM20030225-03:52:48	077.62	39.52	15.0	5.3	110	77	166	157	067	SS
CM20030312-04:47:60	077.32	39.29	15.0	5.7	245	33	073	165	075	TF
CM20030315-22:59:32	077.47	39.74	15.0	5.0	330	57	178	016	106	SS
CM20030330-23:15:51	077.46	39.02	41.6	5.2	273	34	089	004	094	TF
CM20030504-15:44:36	077.39	38.86	15.0	5.8	308	53	−179	178	088	UF
CM20030604-16:28:47	077.69	39.66	15.0	5.2	090	36	087	003	093	TF

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
<i>Western Karagar region (Box-7)</i>	17									
CM19770729-09:14:17	075.45	38.54	131.7	5.2	158	05	021	103	013	UF
CM19781008-14:20:08	074.29	39.48	10.0	5.9	246	36	027	006	096	UF
CM19800731-19:03:09	074.31	39.41	10.0	5.2	261	37	082	174	084	TF
CM19830213-01:40:17	075.11	39.94	15.0	6.2	230	60	−007	161	071	NF
CM19830825-11:05:34	073.87	39.09	15.0	5.1	212	52	005	160	070	UF
CM19850823-12:42:13	075.09	39.54	15.4	6.9	315	29	159	022	112	UF
CM19850829-23:39:55	075.14	39.25	10.0	5.2	081	27	057	007	097	TF
CM19850911-20:45:01	075.32	39.50	10.0	6.1	090	44	068	016	106	TF
CM19870430-05:17:43	074.67	39.67	15.0	5.6	113	44	086	026	116	TF
CM19870608-13:30:36	075.30	39.64	15.0	5.1	298	27	091	029	119	TF
CM19880106-15:31:16	075.50	39.01	36.7	5.3	248	30	069	169	079	TF
CM19880923-04:46:44	074.47	39.66	15.0	5.1	106	23	064	030	120	TF
CM19900417-01:59:35	074.78	39.29	15.0	6.0	118	68	156	167	077	SS
CM20021525-12:57:03	074.90	38.95	15.0	5.6	325	36	160	020	110	UF
CM20030901-23:16:41	075.32	38.71	15.0	5.7	107	47	−153	142	052	NS
CM20061224-02:58:34	074.56	39.83	17.3	5.0	299	51	130	001	091	TF
CM20080410-07:17:21	075.05	39.48	12.7	5.0	302	45	119	013	103	TF
<i>Hotan region (Box-8)</i>	5									
CM19951224-09:36:12	078.16	37.72	33.0	5.1	138	23	114	036	126	TF
CM19970530-17:54:54	078.06	37.18	33.0	5.0	117	23	091	026	116	TF
CM19980528-21:11:44	079.06	37.55	29.3	5.6	095	09	063	018	108	UF
CM19990417-07:20:55	075.45	37.61	149.6	5.1	232	55	151	113	023	TF
CM20050825-21:08:18	079.35	37.13	15.0	5.4	089	23	068	012	102	TF
<i>Gansu region (Box-9)</i>	14									
CM19800601-06:19:02	095.90	38.98	15.0	5.4	334	34	093	058	148	TF
CM19860826-09:43:07	101.72	37.80	15.0	5.9	125	37	055	056	146	TF
CM19901020-08:07:33	103.54	37.06	15.0	5.7	098	85	−003	053	143	SS
CM19950721-22:44:10	103.03	36.26	15.0	5.6	104	41	091	012	102	TF
CM19960601-12:49:17	102.80	37.36	15.0	5.2	278	79	−011	054	144	SS
CM19961120-18:09:22	096.23	40.23	15.0	5.7	101	46	059	033	123	TF
CM20000606-10:59:13	103.91	37.02	15.0	5.5	096	68	−006	052	142	SS
CM20021214-13:27:35	097.23	39.85	15.0	5.5	098	34	097	005	095	TF
CM20031025-12:41:42	101.02	38.30	15.0	5.8	108	40	055	039	129	TF
CM20031025-12:48:03	100.84	38.15	15.0	5.8	085	54	021	034	124	SS
CM20040504-05:05:00	096.65	37.60	18.6	5.3	145	83	175	011	101	SS
CM20070722-09:34:34	101.37	38.42	24.1	5.0	159	85	176	024	114	SS
CM20080330-08:32:28	101.94	37.91	18.8	5.1	064	75	001	018	108	SS
CM20091002-13:49:11	096.12	39.62	20.3	5.0	194	82	180	058	148	SS
<i>Sichuan region (Box-10a)</i>	10									
CM19810123-21:13:56	101.35	30.86	10.0	6.5	319	73	−004	095	005	SS
CM19820615-23:24:38	100.55	31.90	10.0	5.6	105	72	−003	061	151	SS
CM19890118-18:22:54	100.13	29.88	15.0	5.2	120	50	−020	082	172	SS
CM19890415-20:34:21	099.37	29.92	15.0	6.4	273	29	−073	085	175	NF
CM19890425-02:13:31	099.41	29.90	15.0	6.1	245	40	−114	079	169	NF
CM19890503-05:53:12	099.69	30.00	15.0	6.2	240	44	−117	078	168	NF
CM19890503-15:41:41	099.43	29.83	15.0	5.8	271	45	−090	091	001	NF

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
CM19890721-03:09:23	099.54	29.79	15.0	5.6	059	38	−127	082	172	NF
CM19961221-08:39:49	099.90	30.67	15.0	5.4	028	71	−167	071	161	SS
CM20020808-11:42:11	099.95	30.69	55.1	5.3	092	41	−086	089	179	NF
<i>Sichuan region (Box-10b)</i>	30									
CM19760816-14:06:55	104.42	32.63	15.0	6.7	029	48	122	098	008	TF
CM19760821-21:49:58	104.29	32.37	15.3	6.3	198	40	113	072	162	TF
CM19760823-03:30:12	104.21	32.11	19.6	6.4	172	45	072	102	012	TF
CM19860806-19:55:20	101.20	29.15	15.0	5.3	040	41	−162	078	168	UF
CM19890922-02:25:57	102.83	30.87	15.0	6.1	352	18	061	095	005	TF
CM20010223-00:09:28	101.32	29.44	33.0	5.6	092	34	−073	080	170	NF
CM20080226-17:50:05	101.96	30.03	29.2	5.1	340	78	−007	115	025	SS
CM20080512-06:28:40	104.10	31.44	12.8	7.9	231	35	138	139	049	TF
CM20080512-11:11:05	103.62	31.31	14.9	6.1	204	71	−169	066	156	SS
CM20080512-20:08:53	104.11	31.37	28.4	5.6	227	41	132	129	039	TF
CM20080512-23:46:21	103.61	31.30	15.6	5.2	116	59	−007	073	163	SS
CM20080512-23:54:49	103.58	31.30	20.7	5.1	063	37	−099	068	158	NF
CM20080513-07:07:13	103.42	30.90	14.3	5.8	213	42	109	125	035	TF
CM20080514-02:54:40	103.59	31.28	12.0	5.4	215	80	−177	079	169	SS
CM20080514-09:26:47	104.08	31.30	20.7	5.1	029	42	108	107	017	TF
CM20080516-05:25:51	103.33	31.25	24.0	5.6	235	71	−170	098	008	SS
CM20080516-20:16:54	103.55	31.30	17.9	5.0	360	69	174	046	136	SS
CM20080517-17:08:30	105.08	32.21	16.1	5.8	038	45	077	137	047	TF
CM20080519-06:06:56	105.38	32.56	16.2	5.2	316	60	028	086	176	TF
CM20080525-08:21:52	105.45	32.57	27.0	6.1	059	84	178	103	013	SS
CM20080527-08:03:24	105.65	32.71	25.5	5.2	335	73	002	110	020	SS
CM20080527-08:37:54	105.66	32.74	24.1	5.5	089	73	−164	132	042	SS
CM20080723-19:54:47	105.61	32.71	12.0	5.5	010	44	115	084	174	TF
CM20080724-07:09:32	105.55	32.82	13.4	5.6	110	75	012	063	153	SS
CM20080801-08:32:48	104.72	32.04	21.0	5.7	354	29	054	107	017	TF
CM20080805-09:49:20	105.57	32.69	12.0	6.0	348	44	103	068	158	TF
CM20080911-17:39:02	105.65	32.98	12.0	5.1	339	41	093	064	154	TF
CM20081115-22:59:52	104.74	32.14	29.2	5.0	077	83	003	032	122	SS
CM20081209-18:53:10	105.65	32.66	15.7	5.1	024	38	034	144	054	TF
CM20090629-18:03:55	104.15	31.31	12.0	5.3	212	29	054	142	052	TF
<i>Northwestern Yunnan region (Box-11)</i>	15									
CM19761106-18:04:16	101.40	27.50	22.7	6.3	019	66	−006	155	065	SS
CM19780831-03:26:54	101.04	27.41	10.0	5.3	005	58	−026	147	057	SS
CM19800202-12:29:20	101.38	27.60	10.0	5.5	213	74	−006	168	078	NF
CM19820703-08:13:38	100.27	26.59	10.0	5.3	347	26	−090	173	083	NF
CM19930717-09:46:39	099.82	27.42	15.0	5.4	140	33	−055	120	030	NF
CM19960203-11:14:32	100.28	27.15	15.0	6.6	000	36	−068	164	074	NF
CM19960204-16:58:14	100.38	26.84	15.0	5.5	358	33	−086	007	097	NF
CM19960206-07:36:22	100.12	27.52	15.0	5.4	132	57	−141	164	074	NS
CM19960924-19:24:55	100.70	27.18	15.0	5.5	321	41	−098	145	055	NF
CM19971023-12:28:38	100.55	27.14	15.0	5.1	153	20	−110	162	072	NF
CM19981002-12:49:38	101.52	27.45	15.0	5.3	332	16	−089	154	064	NF
CM19981119-11:38:18	101.47	27.25	15.0	5.6	031	79	−009	168	078	SS
CM20010523-21:10:46	101.11	27.53	33.0	5.4	008	87	−002	143	053	SS
CM20011027-05:35:46	101.01	26.36	15.0	5.5	035	69	001	170	080	SS
CM20030721-15:16:38	101.32	25.98	15.0	5.9	200	80	−006	156	066	SS

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
<i>Northern Yunnan region (Box-12)</i>	13									
CM19850418-05:52:56	102.64	25.39	10.0	5.7	100	57	−170	142	052	SS
CM19860313-08:41:22	101.02	25.45	15.0	5.3	330	25	−104	165	075	NF
CM19930814-14:30:08	101.80	25.63	33.0	5.2	209	76	015	162	072	SS
CM19951023-22:46:58	102.54	25.87	15.0	6.2	013	75	−009	148	058	SS
CM20000114-22:09:06	101.28	25.34	33.0	5.5	025	77	−002	160	070	SS
CM20000114-23:37:11	101.40	25.39	33.0	5.9	027	78	−006	162	072	SS
CM20010709-23:51:35	101.25	24.89	33.0	5.1	233	50	002	000	090	UF
CM20031016-12:28:12	101.52	25.89	33.0	5.6	018	88	−001	153	063	SS
CM20050805-14:14:47	103.19	26.46	27.0	5.2	252	73	−178	118	028	SS
CM20080830-08:30:57	102.04	26.19	24.1	6.0	100	86	180	145	055	SS
CM20080831-08:31:14	102.01	26.16	24.6	5.6	011	77	−007	146	056	SS
CM20090709-11:19:20	101.17	25.52	15.1	5.7	204	84	−003	160	070	SS
CM20090710-09:02:04	101.10	25.54	14.9	5.2	021	83	004	156	066	SS
<i>Southwestern Yunnan region (Box-13)</i>	19									
CM19760529-12:23:30	098.65	24.39	15.0	6.7	323	80	−172	007	097	SS
CM19760529-14:00:33	098.58	24.29	15.0	6.6	242	88	000	018	108	SS
CM19760531-05:08:35	098.60	24.26	15.0	6.1	342	72	−169	027	117	SS
CM19760721-15:10:52	098.57	24.74	15.0	6.1	338	88	−178	024	114	SS
CM19780909-23:11:15	101.03	23.20	10.0	5.3	223	69	007	176	086	SS
CM19790315-12:52:30	101.61	23.24	10.0	6.0	033	62	−003	168	078	SS
CM19810814-06:09:40	098.51	25.61	10.0	5.2	153	46	−141	003	093	NF
CM19810919-06:51:02	101.54	22.84	10.0	5.3	143	71	−172	006	096	SS
CM19821008-13:34:59	099.61	25.69	10.0	5.2	146	22	−112	158	068	NF
CM19850905-18:30:26	098.23	25.29	60.7	5.5	014	65	177	060	150	SS
CM19881106-13:03:31	099.68	23.00	15.0	7.0	333	78	174	019	109	SS
CM19881107-02:40:03	099.42	23.38	15.0	5.2	122	55	040	064	154	TS
CM19881127-04:17:59	100.17	22.70	15.0	5.5	071	61	014	022	112	SS
CM19881130-08:13:29	099.54	22.15	15.0	6.0	167	75	−177	032	122	SS
CM19890507-00:38:20	099.65	23.46	15.0	5.6	335	76	169	021	111	SS
CM19930126-20:32:09	100.88	22.86	24.4	5.6	050	82	−005	006	096	SS
CM19950424-16:13:14	103.16	22.88	33.0	5.2	102	80	−173	147	057	SS
CM20010412-10:47:09	098.81	24.77	15.0	5.6	057	63	−028	019	109	SS
CM20070602-21:35:01	101.13	23.02	12.0	6.1	146	63	156	016	106	SS
<i>Northwestern Qinghai region (Box-14)</i>	9									
CM19770101-21:39:46	090.67	38.22	10.0	6.0	322	37	127	030	120	TF
CM19790928-07:46:51	090.45	37.81	15.0	5.1	129	23	042	065	155	TF
CM19791202-01:37:16	090.09	38.55	12.0	5.5	255	67	020	025	115	SS
CM19870225-19:56:45	091.08	38.30	15.0	5.8	127	36	124	018	108	TF
CM19900114-03:03:31	092.10	37.60	15.0	6.0	072	45	041	012	102	TF
CM19931002-08:42:39	088.82	38.16	15.0	6.1	326	42	146	026	116	UF
CM19940907-13:56:24	090.19	38.42	33.0	5.2	238	58	−006	021	111	NF
CM20000131-07:26:02	088.75	38.00	33.0	5.4	347	76	167	033	123	SS
CM20070202-22:32:24	091.85	37.87	20.2	5.4	111	45	114	004	094	TF
<i>Central Qinghai region (Box-15)</i>	19									
CM19770119-00:46:22	094.81	37.08	10.0	5.8	289	35	068	032	122	TF
CM19850811-16:06:05	095.88	36.41	10.0	5.3	200	33	123	078	168	TF
CM19951218-04:57:12	097.63	34.74	33.0	5.7	046	81	176	091	001	SS
CM19970209-11:28:22	095.82	35.70	15.0	5.5	001	70	−172	044	134	SS
CM20021026-20:28:51	096.14	35.18	33.0	5.3	011	78	176	057	147	SS
CM20030417-00:48:46	096.45	37.53	16.0	6.3	294	29	088	026	116	TF

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
CM20040224-20:21:52	096.61	37.66	23.0	5.0	141	87	−179	006	096	SS
CM20040316-21:23:24	096.56	37.60	13.0	5.1	127	42	116	021	111	TF
CM20040504-11:36:05	096.62	37.61	21.6	5.2	140	87	−178	005	095	SS
CM20040510-23:27:30	096.58	37.55	12.0	5.5	272	33	069	015	105	TF
CM20060329-23:38:55	095.62	35.53	24.3	5.3	297	73	011	072	162	TF
CM20081110-01:22:10	095.75	37.51	27.2	6.3	252	28	057	010	100	TF
CM20081111-21:56:05	095.82	37.52	23.9	5.1	357	41	158	050	140	UF
CM20090828-01:52:13	095.76	37.64	12.0	6.3	295	31	102	018	108	TF
CM20090828-16:28:44	095.76	37.75	17.0	5.0	056	80	−003	012	102	SS
CM20090830-17:15:53	095.57	37.66	16.8	5.4	272	45	118	164	074	TF
CM20090831-10:15:34	095.86	37.59	12.0	5.8	277	33	090	007	097	TF
CM20091104-21:56:14	095.83	37.65	14.5	5.1	313	52	151	010	100	TS
CM20091221-05:15:14	096.68	37.57	22.1	5.0	122	43	112	017	107	TF
<i>Eastern Qinghai region (Box-16)</i>										
	11									
CM19900426-09:37:23	100.27	36.01	15.0	6.2	090	40	019	038	128	UF
CM19900426-09:37:28	100.57	36.25	15.0	6.4	101	46	041	042	132	TF
CM19900507-05:17:44	100.74	35.30	15.0	5.3	156	37	122	047	137	TF
CM19900515-22:30:13	100.26	36.65	15.0	5.3	271	17	047	022	112	TF
CM19940103-05:52:36	100.51	35.71	15.0	5.7	156	35	123	047	137	TF
CM19940904-14:50:44	100.15	36.08	15.0	5.2	165	26	094	072	162	TF
CM19940923-19:15:51	100.05	36.07	15.0	5.3	123	31	071	044	134	TF
CM19941010-14:08:05	100.18	36.13	33.0	5.1	327	45	109	043	133	TF
CM19950709-15:56:29	100.35	35.55	33.0	5.1	100	33	077	017	107	TF
CM20000912-00:28:05	099.48	35.50	15.0	6.1	343	80	−170	027	117	SS
CM20000920-19:21:18	099.61	35.32	15.0	5.0	354	59	−177	038	128	SS
<i>Southern Qinghai region (Box-17)</i>										
	8									
CM19790329-07:07:25	097.75	32.61	12.0	5.8	358	75	−174	042	132	SS
CM20000415-09:32:39	095.65	32.85	33.0	5.2	090	68	−004	046	136	SS
CM20000913-15:11:23	095.12	33.94	15.0	5.0	084	77	001	039	129	SS
CM20010725-16:02:58	095.85	33.27	33.0	5.5	350	53	−164	033	123	NF
CM20020629-06:54:48	094.28	34.06	33.0	5.6	090	87	003	045	135	SS
CM20060717-20:41:56	096.40	33.07	22.1	5.2	297	70	−001	074	164	SS
CM20060719-09:53:08	096.27	33.06	24.6	5.5	302	64	004	079	169	TF
CM20070507-11:59:53	097.95	31.44	14.5	5.5	210	73	−173	073	163	SS
<i>Southwestern Qinghai region (Box-18)</i>										
	20									
CM19800306-21:00:19	091.93	36.37	10.0	5.4	285	59	029	052	142	TF
CM19810609-22:08:27	091.28	34.21	10.0	6.0	076	81	−003	031	121	SS
CM19860820-21:24:03	091.96	34.58	15.0	6.4	253	69	−018	031	121	SS
CM19881105-02:14:40	091.70	34.17	15.0	6.2	158	67	171	026	116	SS
CM19881125-22:29:44	091.77	34.29	15.0	5.5	262	60	007	035	125	SS
CM19890513-23:19:48	091.65	35.69	15.0	5.3	248	66	002	022	112	SS
CM19941228-03:56:23	090.57	35.75	33.0	5.1	031	25	−116	043	133	NF
CM20000212-00:04:29	090.88	34.05	33.0	5.1	257	79	006	032	122	SS
CM20011114-09:27:16	092.91	35.80	15.0	7.8	094	61	−012	052	142	SS
CM20011118-21:59:60	093.51	35.94	15.0	5.6	282	40	112	178	088	TF
CM20011119-17:45:30	093.52	35.83	15.0	5.3	100	44	090	010	100	TF
CM20011130-10:43:22	091.11	36.07	15.0	5.2	187	34	−149	040	130	UF

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
CM20011201-12:25:29	093.93	35.58	15.0	5.1	254	36	−141	081	171	NF
CM20011208-04:12:56	093.13	36.07	15.0	5.2	089	30	−040	062	152	NF
CM20021019-07:24:41	092.87	35.72	33.0	5.1	186	76	−166	050	140	SS
CM20040629-08:11:32	092.54	35.75	17.1	5.3	093	63	−015	051	141	SS
CM20041210-03:44:05	093.35	35.83	19.4	5.0	341	48	133	043	133	TF
CM20080618-05:23:35	091.33	35.31	22.5	5.4	252	88	000	027	117	SS
CM20080818-14:11:10	091.93	33.65	23.2	5.3	170	84	−178	036	126	SS
CM20081020-14:26:35	091.32	35.26	22.9	5.0	341	86	−177	026	116	SS
<i>Eastern Tibet region (Box-19)</i>										
	20									
CM19900602-00:32:43	093.28	32.20	15.0	5.2	043	44	−044	016	106	NF
CM19940629-18:22:45	093.68	32.57	15.0	5.9	009	40	−105	023	113	NF
CM19940630-00:48:38	093.76	32.53	15.0	5.0	346	38	−118	019	109	NF
CM19990529-20:10:51	093.77	32.81	33.0	5.3	261	80	−003	037	127	SS
CM20000105-09:45:30	092.29	32.03	33.0	5.4	225	36	−020	178	088	UF
CM20000710-04:25:23	092.55	32.74	15.0	5.3	006	38	−113	026	116	NF
CM20030211-10:36:31	093.67	32.55	46.1	5.1	017	35	−062	000	090	NF
CM20030520-18:34:44	093.23	32.53	33.0	5.1	040	31	−038	012	102	NF
CM20030524-11:28:02	092.29	32.16	33.0	5.0	349	17	−080	164	074	NF
CM20030524-19:32:43	092.36	32.59	33.0	5.0	352	28	−103	006	096	NF
CM20040824-10:05:40	092.28	32.50	12.0	5.5	052	49	−030	018	108	NS
CM20020927-17:14:44	093.49	32.95	33.0	5.1	172	81	−171	037	127	SS
CM20040306-11:54:44	092.13	33.26	12.0	5.0	195	46	−131	040	130	NF
CM20080608-17:56:24	092.19	33.08	18.5	5.2	154	63	−155	014	104	SS
CM20080610-10:05:04	092.25	33.13	16.5	5.4	160	57	−146	015	105	NS
CM20080610-11:04:18	092.22	33.04	14.3	5.1	168	49	−142	019	109	NF
CM20080610-14:15:44	092.22	33.07	13.0	5.3	170	47	−131	016	106	NF
CM20080618-08:12:18	092.21	33.09	18.7	5.2	154	62	−156	013	103	SS
CM20080716-22:58:24	092.24	33.15	16.6	5.3	159	68	−160	020	110	SS
CM20080805-21:59:50	092.22	33.13	15.3	5.0	049	60	−027	011	101	SS
<i>Southern Tibet region (Box-20a)</i>										
	11									
CM19820122-04:30:05	089.75	30.87	10.0	5.5	139	36	−132	163	073	NF
CM19870925-23:16:34	090.34	29.47	15.0	5.0	201	45	−090	022	112	NF
CM19890203-17:50:10	090.13	29.74	15.0	5.4	221	77	−009	176	086	SS
CM19890409-02:31:43	089.94	28.74	15.0	5.1	330	43	−119	157	067	NF
CM19920730-08:25:00	090.30	29.46	15.0	6.1	010	42	−094	022	112	NF
CM19930118-12:42:13	090.28	30.34	15.0	5.9	025	48	−057	002	092	NF
CM20040307-13:29:49	091.33	31.60	20.7	5.6	326	80	−173	011	101	SS
CM20060419-21:05:44	090.67	31.61	23.2	5.7	325	80	−179	010	100	SS
CM20081006-08:30:52	090.50	29.66	12.0	6.3	044	48	−055	022	112	NF
CM20081006-12:10:38	090.53	29.56	13.6	5.2	173	43	−121	014	104	NF
CM20081008-14:07:22	090.57	29.76	14.7	5.5	069	62	−025	030	120	SS
<i>Southern Tibet region (Box-20b)</i>										
	19									
CM19800222-03:02:58	089.16	30.69	10.0	6.3	007	39	−084	012	102	NF
CM19860110-03:46:44	087.09	28.60	81.4	5.1	140	46	−163	178	088	UF
CM19860620-17:12:52	086.77	30.82	15.0	6.0	051	78	−004	006	096	SS
CM19860719-20:12:59	086.88	30.88	15.0	5.1	051	78	004	006	096	SS
CM19930320-14:52:11	087.64	28.87	15.0	6.2	161	46	121	049	139	TF
CM19930320-21:26:49	087.35	29.03	26.6	5.1	160	16	−106	169	079	NF
CM19940723-20:58:10	086.51	31.04	17.0	5.4	142	67	171	010	100	SS

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
CM19960703-06:44:52	088.32	29.77	15.0	5.6	172	45	−102	015	105	NF
CM19960703-10:10:42	088.19	29.92	33.0	5.0	175	27	−083	170	080	NF
CM19960731-08:00:34	088.67	29.74	15.0	5.4	023	32	−041	176	086	NF
CM19971103-02:29:57	085.39	28.60	33.0	5.5	021	31	−070	009	099	NF
CM19980720-01:06:07	088.47	29.83	15.0	5.7	016	32	−083	012	102	NF
CM19980721-14:40:54	088.50	29.93	15.7	5.0	034	43	−090	033	123	NF
CM19980825-07:41:53	088.31	29.86	15.0	5.8	014	46	−067	008	098	NF
CM19980828-22:02:02	088.41	30.08	15.0	5.0	199	45	−090	023	113	NF
CM19980930-02:29:59	088.25	29.64	33.0	5.1	139	32	−112	152	062	NF
CM19981005-10:24:57	088.60	29.89	33.0	5.2	026	29	−077	019	109	NF
CM20090724-03:12:03	086.10	31.05	28.1	5.8	318	74	−172	002	092	SS
CM20091107-20:08:54	086.28	29.31	18.8	5.5	178	43	−092	161	071	NF
<i>Southwestern Tibet region (Box-21)</i>	21									
CM19970321-21:04:58	085.02	33.15	15.0	5.3	035	26	−043	011	101	NF
CM20040711-23:08:51	083.78	30.56	13.0	6.2	359	45	−074	167	077	NF
CM20040728-22:22:16	083.63	30.35	13.7	5.0	009	47	−064	170	080	NF
CM20050407-20:04:47	083.77	30.24	12.0	6.3	170	43	−091	160	070	NF
CM20050407-21:41:42	083.72	30.54	19.1	5.4	189	34	−054	161	071	NF
CM20050408-19:51:41	083.76	30.25	19.6	5.0	177	45	−084	153	063	NF
CM20080109-08:26:53	085.32	32.30	13.3	6.4	206	46	−075	030	120	NF
CM20080116-11:54:51	085.29	32.35	12.0	5.9	023	44	−087	021	111	NF
CM20080122-18:43:38	085.22	32.31	12.6	5.5	045	35	−060	027	117	NF
CM20080425-12:03:56	085.42	32.65	26.6	5.0	328	60	−173	015	105	NF
CM20080608-18:24:49	085.32	32.40	20.6	5.1	354	41	−114	023	113	NF
CM20080825-13:22:09	083.51	30.61	17.3	6.7	030	48	−048	004	094	NF
CM20080825-19:13:57	083.48	30.41	19.2	5.1	158	41	−114	172	082	NF
CM20080825-20:40:49	083.72	30.85	23.7	5.0	225	68	−019	003	093	NF
CM20080830-21:31:17	083.67	30.73	22.2	5.0	209	74	−015	166	076	NF
CM20080910-01:14:38	083.71	30.79	20.3	5.3	206	77	−012	163	073	NF
CM20080910-01:28:12	083.64	30.69	19.6	5.4	317	68	−163	179	089	NF
CM20080925-01:47:18	083.69	30.66	21.2	6.0	208	75	−013	164	074	NF
CM20090218-10:11:43	083.95	30.43	20.0	5.1	206	68	003	158	068	SS
CM20090929-06:01:19	083.55	30.56	21.1	5.0	036	56	−031	000	090	NS
CM20091120-07:17:02	083.71	30.60	18.9	5.0	115	46	−136	143	053	NF
<i>Western Tibet region (Box-22)</i>	24									
CM19780404-00:40:35	082.03	33.03	10.0	5.9	223	59	−008	176	086	NF
CM19780731-11:55:46	081.78	35.68	10.0	5.5	219	28	−032	020	110	NF
CM19801007-09:32:16	082.06	35.76	15.0	5.8	192	39	−053	160	070	NF
CM19820123-17:37:37	082.24	31.71	10.0	6.3	017	38	−058	178	088	NF
CM19821031-18:40:58	082.36	36.07	10.0	5.4	215	45	−015	172	082	UF
CM19850615-15:17:47	083.37	34.55	10.0	5.3	040	61	−030	003	093	NS
CM19860706-19:24:30	080.15	34.24	15.0	5.9	263	74	−015	040	130	SS
CM19920627-13:21:27	081.12	35.18	33.0	5.0	012	30	−090	011	101	NF
CM20020604-14:36:09	081.25	30.13	15.0	5.6	159	49	−130	005	095	NF
CM20041026-02:11:37	080.97	30.88	12.0	5.6	112	73	−165	156	066	SS
CM20070505-08:51:48	081.97	34.33	23.9	6.1	220	88	002	175	085	SS
CM20071230-09:55:31	084.51	36.44	24.4	5.0	236	64	000	012	102	SS
CM20080320-22:33:12	081.37	35.43	12.0	7.1	358	41	−110	024	114	NF

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
CM20080321-06:16:08	081.65	35.89	29.9	5.2	199	40	−062	024	114	NF
CM20080321-12:03:00	081.43	35.39	19.5	5.2	200	40	−073	037	127	NF
CM20080321-20:52:18	081.16	35.09	27.8	5.0	222	56	−021	174	084	NF
CM20080323-20:56:19	081.65	35.86	16.1	5.1	206	47	−046	167	077	NF
CM20080324-07:58:37	081.64	35.80	27.5	5.1	224	67	007	177	087	SS
CM20080326-10:39:32	081.66	35.85	17.7	5.2	141	80	172	007	097	SS
CM20080418-03:01:56	081.29	35.28	35.3	5.0	128	73	177	173	083	SS
CM20090401-02:34:42	082.47	33.73	20.9	5.0	342	46	−119	177	087	NF
CM20090604-02:54:55	081.82	32.79	26.6	5.0	211	70	−013	167	077	NF
CM20090809-04:02:11	081.58	35.76	18.3	5.1	226	43	−008	004	094	UF
CM20091025-11:40:52	080.25	34.94	17.6	5.0	353	62	178	038	128	SS
<i>Northeastern Tibet region (Box-23)</i>										
	29									
CM19771118-05:20:18	088.14	33.00	10.0	6.4	191	19	−088	011	101	NF
CM19800624-07:35:58	088.77	33.09	15.0	5.7	156	73	−165	019	109	SS
CM19831105-19:48:31	090.06	33.97	10.0	5.6	250	73	−007	026	116	SS
CM19850421-13:21:33	087.18	35.72	10.0	5.6	246	50	000	037	127	UF
CM19850520-15:11:47	087.16	35.58	10.0	5.8	156	79	175	021	111	SS
CM19921222-16:42:44	088.03	34.67	15.0	5.2	152	41	−139	000	090	NF
CM19940814-07:38:35	089.18	34.97	33.0	5.2	061	68	005	015	105	SS
CM19971108-10:03:03	086.96	35.33	16.4	7.5	079	69	002	034	124	SS
CM19971109-00:25:01	088.56	33.58	33.0	5.3	046	32	−060	030	120	NF
CM20001126-02:01:54	089.71	36.23	29.5	5.3	298	38	014	080	170	UF
CM20010305-15:50:14	086.76	34.47	15.0	5.9	170	64	−170	033	123	SS
CM20030707-06:55:54	089.59	34.67	33.0	5.8	060	81	−006	015	105	SS
CM20040327-18:47:35	089.35	34.00	12.0	6.0	187	44	−105	016	106	NF
CM20040327-20:05:57	089.19	33.87	18.4	5.0	044	36	−049	021	111	NF
CM20040328-22:05:47	089.37	34.07	17.7	5.2	051	62	−030	013	103	SS
CM20040328-22:27:31	089.28	33.91	16.9	5.1	046	50	−039	015	105	NF
CM20040406-10:30:37	089.25	33.83	12.0	5.1	174	49	−123	016	106	NF
CM20040422-10:02:22	089.33	33.88	17.7	5.2	036	49	−050	010	100	NF
CM20040523-07:38:13	089.42	34.04	12.0	5.3	152	65	−160	012	102	SS
CM20040703-14:10:50	089.41	34.09	13.6	5.2	055	65	−024	016	106	SS
CM20060226-02:13:58	089.67	35.36	12.0	5.4	158	61	−150	016	106	NS
CM20060301-09:36:47	089.67	35.40	18.6	5.1	060	50	−031	026	116	NS
CM20060414-09:27:47	089.74	35.46	17.7	5.6	353	49	−137	024	114	NF
CM20070315-18:30:09	089.49	35.50	18.6	5.0	041	46	−051	018	108	NF
CM20070316-21:51:22	089.50	35.56	16.5	5.0	041	45	−047	014	104	NF
CM20070505-17:38:21	090.03	34.67	24.5	5.0	347	74	179	032	122	SS
CM20080629-08:41:60	088.20	35.73	34.3	5.0	341	76	177	028	118	SS
CM20080629-12:47:31	088.44	35.76	18.1	5.5	259	82	−004	035	125	SS
CM20080702-20:22:60	088.36	35.72	17.5	5.2	250	82	−008	025	115	SS
<i>Others</i>										
	25									
CM19790824-16:59:32	108.24	40.83	15.0	5.7	111	44	−065	094	004	NF
CM19800712-20:39:42	094.08	37.03	15.0	5.2	161	09	106	060	150	UF
CM19801215-22:11:51	090.31	45.85	10.0	5.5	273	44	113	168	078	TF
CM19810209-23:13:15	086.98	36.53	10.0	5.3	222	30	−053	005	095	NF
CM19821027-15:36:35	105.85	23.97	10.0	5.2	033	74	006	167	077	SS
CM19860424-00:22:17	089.54	47.33	33.0	5.0	345	70	161	034	124	SS
CM19870107-18:19:11	103.86	34.23	15.0	5.4	170	65	028	118	028	SS

Table A1. (Continued.)

Data-time group event	Location			Focal mechanism data				SH		Stress regime
	Longitude	Latitude	Depth	Mw	Strike	Dip	Slip	Max	Min	
CM19870810-12:12:20	105.63	37.57	21.3	5.3	336	25	−075	148	058	NF
CM19871222-00:16:43	089.75	41.27	19.0	5.5	186	49	128	065	155	TF
CM19880103-21:32:31	106.86	38.13	15.0	5.2	110	57	005	064	154	SS
CM19880125-01:12:27	094.87	29.80	33.0	5.2	037	69	159	085	175	SS
CM19910819-06:05:43	085.41	46.03	54.8	5.2	068	36	051	000	090	TF
CM19941229-18:58:34	103.59	28.80	33.0	5.1	038	55	147	092	002	TS
CM19941231-02:57:20	109.43	20.56	32.1	5.3	008	68	017	140	050	SS
CM19950110-10:09:50	109.33	20.57	15.0	5.5	264	64	−173	130	040	SS
CM19960503-03:32:50	109.69	40.72	25.0	6.0	308	75	−012	084	174	SS
CM19970809-04:48:08	097.46	30.16	33.0	5.2	073	27	−090	074	164	NF
CM19990130-03:51:10	088.70	41.67	23.3	5.4	116	36	099	022	112	TF
CM20000126-21:38:02	095.72	30.79	33.0	5.1	095	70	011	048	138	SS
CM20031113-02:35:15	104.10	34.61	15.0	5.1	347	42	053	109	019	TF
CM20031114-18:49:46	103.21	27.68	15.0	5.6	250	36	−170	119	029	UF
CM20040810-10:26:18	103.78	27.16	15.1	5.3	156	85	001	111	021	SS
CM20050824-22:32:48	079.66	39.88	46.4	5.0	048	56	024	176	086	UF
CM20060825-05:51:47	104.31	28.00	17.4	5.0	355	50	045	114	024	TF
CM20070225-01:49:42	090.63	33.10	20.5	5.4	066	67	−019	025	115	SS

Note: Date-time group: CM (China Mainland) followed by date (year-month-day), time (hour-minute-second); Depth (estimated depth in km); Focal mechanism data: Mw (moment magnitude); Strike, Dip and Slip of focal plane; Horizontal stress orientations: SH, max-S_{Hmax}, min-S_{Hmin}.

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