1 Probing Coulomb stress triggering effects for a $M_w > 6.0$ earthquake sequence from
2 1997 to 2014 along the periphery of the Bayan Har block on the Tibetan Plateau

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22 **Abstract:**

23 Recently there have occurred the Manyi-Kangding earthquake sequence, including
24 the 1997 Manyi, 2001 Kokoxili, 2008 Yutian, 2008 Wenchuan, 2010 Yushu, 2013
25 Lushan, 2014 Yutian and 2014 Kangding earthquakes, along the periphery of the
26 Bayan Har block on the northern Tibetan Plateau. We employ the Coulomb failure
27 model to probe the stress triggering effects on this sequence in terms of coseismic,
28 postseismic and interseismic Coulomb stress changes. We examine the Coulomb
29 stress changes from both the Manyi-Kangding sequence and other large earthquakes
30 from 1411 to 2012 around the Bayan Har block and interseismic tectonic stressing.
31 We use a stratified spherical postseismic relaxation model to compute postseismic
32 Coulomb stress changes. We develop an explicit spherical least-squares collocation
33 model to calculate interseismic Coulomb stress changes. Our results indicate that
34 when merely considering triggering effects because of earthquakes from the
35 Manyi-Kangding sequence, the compounded Coulomb stress changes of the
36 coseismic and postseismic Coulomb stress changes are generally insignificant, except
37 for the 2013 Lushan earthquake (0.14 bars). This general insignificance of Coulomb
38 stress changes imparted by the Manyi-Kangding sequence agrees with previous
39 studies, although interseismic Coulomb stress changes always load each hypocenter.
40 On the other hand, when surrounding prior $M \geq 6.0$ earthquakes are considered, we
41 found that the compounded Coulomb stress changes become significant, ranging from
42 0.14 to 10.4 bars according to the constant apparent friction Coulomb failure model

with an intermediate coefficient of 0.4. Therefore, all eight earthquakes are well explained by Coulomb stress changes when thoroughly considering large earthquakes around the Bayan Har block. Our findings indicate the importance of considering a broader group of neighboring large earthquakes for Coulomb stress analysis.

Keywords: coseismic Coulomb stress; postseismic Coulomb stress; interseismic Coulomb stress; least-squares collocation; viscoelastic relaxation

1. Introduction

Since the occurrence of the 1997 Mw 7.6 Manyi earthquake to the southwest of the Kunlun fault in northern Tibet, multiple strong earthquakes have sequentially occurred along the periphery of the Bayan Har block on the northern Tibetan Plateau, such as the 2001 Mw 7.8 Kokoxili, 2008 Mw 7.1 Yutian, 2008 Mw 7.9 Wenhcuan, 2010 Mw 6.8 Yushu, 2013 Mw 6.6 Lushan, 2014 Mw 6.9 Yutian and 2014 Mw 6.1 Kangding earthquakes (Fig. 1), hereinafter termed the Manyi-Kangding sequence.

We study the Coulomb stress triggering effects for this earthquake sequence by using the Coulomb failure model. This model quantitatively delineates the Coulomb stress change on an earthquake fault plane (the so-called receiver fault) along a predefined slip direction as imparted by a seismogenic fault (the so-called source fault). The basic philosophy of the Coulomb failure model is that positive Coulomb stress change promotes an earthquake to occur, whereas negative Coulomb stress

64 change inhibits its occurrence (Harris et al., 1998; Stein, 1999; King et al., 1994, 2007;
65 Steacy et al., 2005; Freed et al., 2005).

66 Since the 1990s, the Coulomb failure model has been pervasively used to study
67 fault interactions, earthquake stress triggering and stress evolution in numerous
68 tectonic regions, such as the San Andreas fault system in California (e.g., King et al.,
69 1994; Freed and Lin, 2001; McCloskey et al., 2003; Toda and Stein, 2015), the
70 Anatolia fault system (Turkey) (e.g., Stein et al., 1997; Nalbant et al., 1998;
71 Hubert-Ferrari et al., 2000; Parsons et al., 2000), subduction zones along Costa Rica
72 (e.g., Bilek and Lithgow-Bertelloni, 2005), the Sunda Trench in Sumatra (e.g.,
73 McCloskey et al., 2005; Nalbant et al., 2005b, 2013; Fan and Shearer, 2016),
74 Hikurangi (New Zealand) (e.g., Hamling and Wallace, 2015), the West Philippine
75 Basin (e.g., Lin and Lin, 2015), northern Chile (e.g., Cortés-Aranda et al., 2015), the
76 Alaska-Aleutian arc (e.g., Macpherson and Ruppert, 2015), the North Qaidam thrust
77 system in Tibet (e.g., Elliott et al., 2011), and the fold-and-thrust belt of the
78 Longmenshan region along the northeastern margins of the Tibetan Plateau (e.g.,
79 Parsons et al., 2008; Toda et al., 2008; Shan et al., 2009; Luo and Liu, 2010; Wan and
80 Shen, 2010; Xu et al., 2010; Nalbant and McCloskey, 2011; Wang et al., 2014a; Shao
81 et al., 2016).

82 Investigations of Coulomb stress changes because of some portions of the
83 Manyi-Kangding sequence have also been conducted. For instance, the 2008 Mw 7.9
84 Wenchuan earthquake was extensively studied from the aspects of (1)

mainshock–aftershocks triggering (e.g., Xu et al., 2010; Wang et al., 2014b), (2) fault interactions (e.g., Parsons et al., 2008; Nalbant and McCloskey, 2011), (3) the likelihood of future earthquake hazards (e.g., Parsons et al., 2008; Toda et al., 2008; Nalbant and McCloskey, 2011; Shao et al., 2016), (4) reservoir-impoundment triggering (e.g., Tao et al., 2015), and (5) stress triggering among earthquakes with respect to coseismic and postseismic Coulomb stress changes (e.g., Nalbant and McCloskey, 2011; Parsons and Segou, 2014).

Specifically, Cheng et al. (2011) studied the coseismic and postseismic Coulomb stress changes for the 1997 Manyi, 2001 Kokoxili, 2008 Wenchuan and 2010 Yushu earthquakes. Jia et al. (2012) also explored these two types of Coulomb stress changes but focused on the 2001 Kokoxili, 2008 Yutian, 2008 Wenchuan and 2010 Yushu earthquakes. Neither of these studies examined the effects of Coulomb stress changes from surrounding earthquakes on the above hypocenters.

Similarly, except for a few case studies (e.g., Luo and Liu, 2010; Nalbant and McCloskey, 2011; Shan et al., 2013; Shao et al., 2016), almost all other previous studies on Coulomb stress changes in this tectonic region have ignored the influence of surrounding earthquakes on modifying the degree of Coulomb stress changes at each hypocenter of the Manyi-Kangding sequence. Instead, only a limited number of earthquakes were examined. However, ignoring nearby large earthquakes would lead to contrary conclusions regarding Coulomb stress triggering. For example, some researchers claimed that the 2008 Mw 7.9 Wenchuan earthquake co-seismically

loaded the southeastern segment of the neighboring Xianshuihe fault, thus increasing the likelihood of potential earthquakes there (e.g., Parsons et al., 2008; Toda et al., 2008). On the contrary, Luo and Liu (2010) argued that this segment still remained unloaded when considering the compounded contribution of Coulomb stress changes from six large earthquakes from 1893 to 1981 along that segment.

Another example involves the 2003 Mw 6.4 Bingol earthquake (Turkey). Milkereit et al. (2004) claimed that this earthquake was brought closer to failure because of prior events, whereas Nalbant et al. (2005a) argued that this earthquake was unlikely to have been triggered by previous events. This discrepancy is attributed to different treatments: The former study explored an earthquake sequence since 1874 and thus did not consider the nearby 1866 Ms 7.2 earthquake on the Bingol-Karlioiva segment of the East Anatolian Fault Zone (Turkey). In contrast, the latter study examined a longer earthquake sequence since 1822 including the 1866 Ms 7.2 earthquake. Coulomb stress calculations showed that this nearby earthquake cast a strong enough stress shadow at the 2003 earthquake hypocenter, thereby ultimately postponing rather than triggering the occurrence of the latter event. Accordingly, Considering large surrounding earthquakes is beneficial to comprehensively understand Coulomb stress changes both on major faults and at earthquake hypocenters.

Therefore, we study the overall Coulomb stress triggering effects for the longer recent Manyi-Kangding sequence with respect to coseismic, postseismic and

interseismic Coulomb stress changes. We explore the triggering effect on the earthquakes of this longer sequence from the earthquakes within the same sequence and examine the triggering effect from other surrounding prior large earthquakes. This systematical, longer earthquake sequence analysis, which differs from merely analyzing triggering effects for a few earthquakes, as previous studies have been done, should allow us to determine which recent earthquakes can be explained by compounded Coulomb stress changes from coseismic and postseismic Coulomb stress changes.

We use slip models of the Manyi-Kangding sequence to resolve changes in the earthquake stress tensors at each hypocenter and project these stress tensors onto the focal planes of the same sequence. We develop an explicit spherical least-squares collocation model to compute interseismic Coulomb stress changes. We employ a spherical stratified viscoelastic relaxation model to calculate postseismic Coulomb stress changes. We find that all eight earthquakes of the Manyi-Kangding sequence can be well explained by the compounded Coulomb stress changes when surrounding earthquakes are considered, rather than merely the Manyi-Kangding sequence.

2. Data: source faults and receiver faults

Both source faults and receiver faults must be predefined to compute Coulomb stress changes. Our focus is on the Coulomb stress changes in the Manyi-Kangding sequence, so we first choose each earthquake of this sequence as a receiver fault and its preceding earthquakes in the same sequence as source faults to explore triggering

effects among this strong earthquake sequence. We term the stress triggering within this earthquake sequence as internal stress triggering. For this internal stress triggering analysis, we adopt distributed-slip models of this earthquake sequence from various literature including Funning et al. (2007), Lasserre et al. (2005), Elliott et al. (2010), Hashimoto et al. (2010), Li et al. (2011), Jiang et al. (2014a), Zhang et al. (2014), and Jiang et al. (2015a). These slip models (Figures S1 to S8) are related to source faults and are inverted based on geodetic data, including Interferometric Synthetic Aperture Radar (InSAR) images, Global Navigation Satellite System (GNSS) crustal deformations and/or seismic waveforms. For the receiver faults, we use the focal planes that have the closest fault-plane orientations to these source faults from the global CMT catalog (Table 1).

Other earthquakes around the Bayan Har block may have also altered the stress states at each hypocenter of the earthquake sequence to some extent, so we also explore the Coulomb stress changes from these surrounding earthquakes at each hypocenter of the aforementioned earthquake sequence. We term the stress triggering from these large surrounding earthquakes at each hypocenter as external stress triggering. This external stress triggering has seldom been analyzed to our knowledge. For this analysis, we regard the surrounding earthquakes as source faults and each earthquake of the Manyi-Kangding sequence as a receiver fault. The receiver faults are the same as those for the internal stress triggering analysis. The source faults, on the other hand, should be specially treated.

We first analyze the global CMT (gCMT) catalog from 1976/1/1 to 2014/11/22 (Table S1) to examine which earthquake events more prominently affect the Coulomb stress changes at each hypocenter of the Manyi-Kangding sequence. We use the ‘MoPaD’ software (Krieger and Heimann, 2014) to determine the focal planes and seismic moments of the selected gCMT events. We then compute the amount of slip dislocation for each event by using the relationship between the scalar seismic moment and coseismic slip dislocation (Aki, 1966) and by assuming that the fault length and width of each event equal 1 km. Thus we can produce each source fault that is analogous to a point source. We then resolve the accumulated coseismic Coulomb stress changes onto a prescribed receiver plane to probe which events produce greater Coulomb stress changes and thereby possess larger effective triggering ranges (Figure 2).

Figure 2 indicates that only some events can create relatively large Coulomb stress changes within certain relatively large distances. The one-to-one Coulomb stress changes that are associated with these gCMT events are presented in Table S2. After quantitatively scrutinizing the Coulomb stress changes, some events other than those from the Manyi-Kangding sequence imparted no larger than 0.04 bars of Coulomb stress changes, although these relative significant events created large Coulomb stress changes compared to the other events. These relative significant events are the 1976 Mw 6.7, 1976 Mw 6.4, 1981 Mw 6.5, 1986 Mw 6.4, 1989 Mw 6.2, 1996 Mw 6.9, 2007 Mw 6.1 and 2012 Mw 6.3 earthquakes, which are marked by the

numbers 1, 3, 10, 17, 24, 36, 50, and 67 in Figure 2, respectively. Each of these events is close to one large earthquake from the Manyi-Kangding sequence. Although their coseismic triggering effects are still not quite significant, these events may have imparted certain pronounced postseismic Coulomb stress changes, so we incorporate these events into the input dataset of source faults for the external stress triggering analysis.

In addition to the aforementioned events, we consider surrounding prior $M \geq 6.0$ earthquakes. The fault parameters of some of these earthquakes are from previous literature that examined Coulomb stress transfer along some major active faults in northeastern Tibet, while those of other source faults that are associated with fault geometries and slip senses are estimated by using empirical relationships of Wells and Coppersmith (1994) and Hanks and Kanamori (1979) (Table S3). After performing the above treatments, we collect 70 events that span from 1411 to 2012 with magnitudes $M \geq 6.0$ (Table S3), which are regarded as the source faults for the external stress triggering analysis (Figure 3).

3. Methodology

3.1 Spherical least-squares collocation strain rate model

We employ the spherical least-squares collocation strain rate model to compute the tectonic loading stress rate and to further calculate interseismic Coulomb stress changes by using the Coulomb failure criterion and by assuming the 1997 Mw 7.6 Manyi earthquake to be a zero-stress-baseline.

211 In essence, the key ingredient of least-squares collocation is how to determine
 212 the empirical covariance function. If this function is acquired, then the velocity at any
 213 point can be computed from the empirical covariance function, which relates the
 214 observation points to any other interpolated points. We here briefly introduce the
 215 basic formulae of least-squares collocation, with additional details in the
 216 supplementary material.

217 The observation equation of least-squares collocation is as follows (Jiang et al.,
 218 2010)

$$219 \quad V_{2N \times 1} = A_{2N \times 3} \Omega_{3 \times 1} + \begin{pmatrix} I_{2N \times 2N} & O_{2N \times 2M} \end{pmatrix} \begin{pmatrix} s_{2N \times 1} \\ s'_{2M \times 1} \end{pmatrix} + n_{2N \times 1} \quad (1)$$

220

221 where $V_{2N \times 1}$ is the crustal velocity and $V_{2N \times 1} = (V_e^1 \ V_n^1 \ V_e^2 \ V_n^2 \ \dots \ V_e^N \ V_n^N)^T$;

222 V_e^i and V_n^i are the eastern and northern velocities at the i^{th} observation station,

223 respectively; $A\Omega$ denotes the rigid Euler's motion of crust;

$$224 \quad A = (A_1 \ A_2 \ \dots \ A_N)^T ; \ A_i^T|_{i=1,2,\dots,N} = r \begin{pmatrix} -\sin \varphi_i \cos \lambda_i & -\sin \varphi_i \sin \lambda_i & \cos \varphi_i \\ \sin \lambda_i & -\cos \lambda_i & 0 \end{pmatrix}$$

225 (r is the Earth's radius and φ_i and λ_i are the latitude and longitude of the i^{th}

226 observation station on the Earth's surface); $\Omega = (\omega_x \ \omega_y \ \omega_z)^T$ is the Euler's

227 rotation vector; $I_{2N \times 2N}$ is the unitary matrix; $O_{2N \times 2M}$ is the zero-matrix; $s_{2N \times 1}$ is the

228 signal at the observation stations; $s'_{2M \times 1}$ is the signal at any other points; and $n_{2N \times 1}$ is

229 the observation error. The optimal estimation of the signal $s'_{2M \times 1}$ can be written as

230 follows (Jiang et al., 2010):

$$\begin{cases}
\begin{matrix} s' \\ 2M \times 1 \end{matrix} = \begin{matrix} C_{s's} \\ 2M \times 2N \end{matrix} \begin{matrix} C_{ll}^{-1} \\ 2N \times 2N \end{matrix} \begin{pmatrix} V - A \hat{\Omega} \\ 2N \times 1 \quad 2N \times 3 \quad 3 \times 1 \end{pmatrix} \\
\begin{matrix} \hat{\Omega} \\ 3 \times 1 \end{matrix} = \begin{pmatrix} A^T & C_{ll}^{-1} & A \\ 2N \times 3 & 2N \times 2N & 2N \times 3 \end{pmatrix}^{-1} \begin{pmatrix} A^T & C_{ll}^{-1} & V \\ 2N \times 3 & 2N \times 2N & 2N \times 1 \end{pmatrix} \\
\begin{matrix} C_{ll} \\ 2N \times 2N \end{matrix} = \begin{matrix} C_{ss} \\ 2N \times 2N \end{matrix} + \begin{matrix} C_{nn} \\ 2N \times 2N \end{matrix}
\end{cases} \quad (2)$$

232 where C_{ss} and C_{nn} are the covariance matrix of the signal and covariance
 233 matrix of noise, respectively; $C_{ss} = (C_{ij})$, where $C_{ij} = C_0 \exp(-b^2 d_{ij}^2)$; d_{ij} is the
 234 spherical distance between the i^{th} and j^{th} stations; and $C_{s's}$ is the covariance
 235 matrix that relates signal s' to signal s , both of which have the same form as
 236 $C_{ij} = C_0 \exp(-b^2 d_{ij}^2)$. We constrain these two unknowns using the 1999 to 2007 GPS
 237 velocity field in western China (Wu et al., 2015) after removing the rigid Euler's
 238 motion, which produces $C_0 = 26.601162 (mm/yr)^2$ and $b = 0.001837 km^{-1}$,
 239 respectively (Fig. S9).

240 After determining the signal s' at any interpolated points with equation (2),
 241 the strain rate tensor can be directly calculated by performing spatial partial
 242 derivatives for the signal s' with the following formulae:

$$\begin{cases}
\dot{\epsilon}_{\varphi\varphi} = \frac{u_r}{r} + \frac{1}{r} \frac{\partial u_\varphi}{\partial \varphi} \\
\dot{\epsilon}_{\varphi\lambda} = \frac{1}{2} \left(\frac{1}{r} \frac{\partial u_\lambda}{\partial \varphi} + \frac{1}{r \cos \varphi} \frac{\partial u_\varphi}{\partial \lambda} + \frac{u_\lambda}{r} \tan \varphi \right) \\
\dot{\epsilon}_{\lambda\lambda} = \frac{1}{r \cos \varphi} \frac{\partial u_\lambda}{\partial \lambda} - \frac{u_\varphi}{r} \tan \varphi + \frac{u_r}{r}
\end{cases} \quad (3)$$

244 where $\dot{\epsilon}_{\varphi\varphi}$, $\dot{\epsilon}_{\lambda\lambda}$ and $\dot{\epsilon}_{\varphi\lambda}$ are the northern and eastern normal strain rates and shear
 245 strain rate, respectively; u_r , u_λ and u_φ are the radial, eastern and northern
 246 velocity components, respectively; and r , φ , and λ are the Earth's radius,
 247 latitude and longitude for a point on the Earth's surface, respectively.

Although previous studies that computed interseismic Coulomb stress changes either used virtual-negative-slip models (e.g., Deng and Sykes, 1997; Papadimitriou et al., 2004; Paradisopoulou et al., 2007; Ali et al., 2008; Shao et al., 2016) or deep-slip models (e.g., Stein et al., 1997; Hubert-Ferrari et al., 2000; Shan et al., 2013), both models require either slip deficit rates on the shallower locked portions of a fault or secular slip rates on the deeper sliding portions of the fault. These parameters, however, are commonly constrained by using uniform segment-by-segment interseismic slip rates for major faults (e.g., Meade, 2007). Such uniform slip rates would smooth interseismic Coulomb stress changes in the vicinity of major faults, which probably confounds Coulomb stress triggering analysis for nearby major faults. In addition, additional uncertainties in fault geometries which are required to resolve interseismic Coulomb stress changes would make compounded Coulomb stress changes more uncertain.

Least-squares collocation, on the other hand, requires no slip rate or fault geometry information but merely the crustal deformation velocity field. Previous studies have presented the robustness and applicability of this method for resolving crustal strain rate fields compared to other interpolation methods (e.g., Jiang et al., 2010; Wu et al., 2011).

Least-squares collocation was first suggested by Krarup (1968) and then clarified and popularized by Moriz (1980) in the field of physical geodesy to study gravity fields in the 1960s. In the 1990s, this method was introduced into the field of tectonic geodesy to study crustal deformation (e.g., El-Fiky et al., 1997). Recently, Jiang et al. (2014b) estimated the tectonic stress rates of major active strike-slip faults on the Tibetan Plateau with this method. Wu et al. (2015) applied this method to study crustal deformation that was associated with the 2008 Mw 7.9 Wenchuan earthquake. Based on the rationale of this method, we develop an explicit spherical least-squares collocation model (supplementary material: part C) and then use this method to estimate the interseismic Coulomb stressing rate at each hypocenter of the Manyi-Kangding sequence.

3.2 Coulomb failure model

The Coulomb failure model delineates changes in the resultant stress that are associated with the shear stress and friction along a prescribed slip direction on a given receiver fault plane. The Coulomb failure model can be written as follows (King et al., 1994; Stein, 1999):

$$\Delta CFF = \Delta \tau + \mu(\Delta \sigma_n + \Delta P) \quad (4)$$

where $\Delta \tau$, $\Delta \sigma_n$ and ΔP are the changes in the shear stress (positive along slip direction), normal stress (positive for unclamping) and pore-pressure, respectively;

μ is the friction coefficient of the receiver fault plane; $\Delta P = -\frac{B}{3}tr(\Delta \sigma)$; B is the

286 Skempton's coefficient; and $tr(\Delta\sigma)$ is the trace of the change in the stress tensor
 287 induced by earthquake faulting or volcanic eruptions.

288 $tr(\Delta\sigma)$ is commonly assumed to be $tr(\Delta\sigma) = 3\Delta\sigma_n$ to implicitly incorporate
 289 the pore pressure into the Coulomb failure model (Cocco and Rice, 2002). Thus, a
 290 simplified Coulomb failure model is as follows:

$$291 \quad \Delta CFF = \Delta\tau + \mu'\Delta\sigma_n \quad (5)$$

292 where $\Delta\tau$ and $\Delta\sigma_n$ are the same as in equation (4); and μ' is the apparent
 293 friction coefficient, which is $\mu' = \mu(1 - B)$.

294 Equation (4) degenerates into equation (5) when setting the Skempton's
 295 coefficient B to be zero and when replacing the friction coefficient μ with the
 296 apparent friction coefficient μ' in equation (4), so we present the explicit form of
 297 the Coulomb failure model based on equation (4) as follows (Xu et al., 2010; Wang
 298 et al., 2014b):

$$\begin{aligned}
 \Delta CFF = & \sin \lambda \left[-\frac{1}{2} \sin^2 \phi \sin(2\delta) \sigma^{11} + \frac{1}{2} \sin(2\phi) \sin(2\delta) \sigma^{12} + \sin \phi \cos(2\delta) \sigma^{13} - \frac{1}{2} \cos^2 \phi \sin(2\delta) \sigma^{22} \right. \\
 & - \cos \phi \cos(2\delta) \sigma^{23} + \frac{1}{2} \sin(2\phi) \sin \delta \sigma^{33} \left. \right] + \cos \lambda \left[-\frac{1}{2} \sin(2\phi) \sin \delta \sigma^{11} + \cos(2\phi) \sin \delta \sigma^{12} \right. \\
 & + \cos \phi \cos \delta \sigma^{13} + \frac{1}{2} \sin(2\phi) \sin \delta \sigma^{22} + \sin \phi \cos \delta \sigma^{23} \left. \right] + \mu \left[\sin^2 \phi \sin^2 \delta \sigma^{11} - \sin(2\phi) \sin^2 \delta \sigma^{12} \right. \\
 & - \sin \phi \sin(2\delta) \sigma^{13} + \cos^2 \phi \sin^2 \delta \sigma^{22} + \cos \phi \sin(2\delta) \sigma^{23} + \cos^2 \delta \sigma^{33} - \frac{B}{3} (\sigma^{11} + \sigma^{22} + \sigma^{33}) \left. \right]
 \end{aligned}$$

300 (6)

301 where $\{\sigma^{ij} | i, j \in \{1, 2, 3\}\}$ are the six independent components of the second-order
 302 stress tensor in a local Cartesian coordinate system whose x, y and z axes correspond
 303 to the northern, eastern and upward directions, respectively; ϕ , λ and δ are the

strike, dip and rake angles of the receiver fault plane, respectively; μ is the friction coefficient; and B is the Skempton's coefficient. We choose $\mu' = 0.4$ to compute the Coulomb stress change, which is commonly used to minimize the uncertainty in the apparent friction coefficient (e.g., King et al., 1994; Avouac et al., 2014; Green et al., 2015).

3.3 Stratified Earth model

A stratified Earth model that is associated with the rheological parameters for each of the Earth's layers must be predefined to compute postseismic Coulomb stress changes from viscoelastic relaxation in the lower crust and upper mantle after strong earthquakes. This model is created using equation (6) and the source code 'VISCO1D' (Pollitz, 1992). Some workers have investigated such parameters on the Tibetan Plateau and its margins. For instance, Ryder et al. (2007) interpreted a ~4-years postseismic deformation field from InSAR observations of the 1997 Mw 7.6 Manyi earthquake (Tibet) by using a two-layered half-space Earth model with a standard linear solid rheology beneath a 15-km-thick elastic layer. The standard linear solid consisted of an elastic element in series with a Kelvin element, which further consisted of an elastic element and a viscous element in parallel. Their optimal rheological parameters of the standard linear solid were 24 GPa and $4.0 \times 10^{18} \text{ Pa} \cdot \text{s}$ for the shear modulus and rheology of the Kelvin element, respectively, and 50 GPa for the shear modulus of the additional elastic element. Ryder et al. (2011) also modeled the postseismic deformation fields of the first-year

GPS time series and two to five subsequent InSAR datasets following the 2001 Kokoxili earthquake by using a rheological model with a Burgers rheological body beneath an uppermost pure elastic crustal layer. The Burgers rheological body consisted of a Kelvin element in series with a Maxwell element that further possessed an elastic element and a viscous element in series. Their preferred rheological parameters of the Burgers rheological body were $9.0 \times 10^{17} \text{ Pa} \cdot \text{s}$ for the transient rheology of the Kelvin element and $1.0 \times 10^{19} \text{ Pa} \cdot \text{s}$ for the long-term rheology of the Maxwell element. As the authors indicated, such a Burgers rheological body was also applicable to the postseismic deformation field following the 1997 Manyi earthquake after only modifying the transient rheology to $5.0 \times 10^{17} \text{ Pa} \cdot \text{s}$.

In terms of the crustal thickness associated with the Bayan Har block, Wang et al. (2007) inverted two profiles of deep seismic soundings through the eastern margin of the Tibetan Plateau and found that the crustal thicknesses of the western Sichuan plateau was 62 km. Xu et al. (2014) investigated a passive source seismic profile across the eastern Kunlun Mountain by using the techniques of receiver function imaging and H-k stacking and determined that the crustal thickness decreased from approximately 64 km in the Sonpan-Ganzi terrane to approximately 56 ~ 62 km in the Qaidam-Kunlun block and Qilian block.

By considering the aforementioned rheological model and crustal thickness, we constructed a stratified Earth model by using Crust 2.0 (Bassin et al., 2000) as follows. The Earth model consists of three layers: (1) a pure elastic upper crust with a

thickness of 28 km, which is thick enough to accommodate the deepest lower edges of most of the distributed-slip models of these strong earthquakes; (2) a viscous lower crust with a Burgers body with a thickness of 37 km; and (3) a viscous upper mantle with a Maxwell body. The transient and steady-state viscosities of the Burgers body are $7.0 \times 10^{17} \text{ Pa} \cdot \text{s}$ and $1.0 \times 10^{19} \text{ Pa} \cdot \text{s}$, respectively. The viscosity of the Maxwell body is $1.0 \times 10^{20} \text{ Pa} \cdot \text{s}$ (Nalbant and McCloskey, 2011). The shear modulus, bulk modulus and density for each layer are derived from Crust 2.0 by averaging the P and S wave velocities and density throughout the entire depth range that corresponds to each hypocenter of these strong earthquakes (Fig.4)

3.3 Coulomb stress analysis scheme

We first examine the internal triggering effects on each earthquake of the Manyi-Kangding sequence by preceding earthquakes from the same sequence in terms of coseismic, postseismic and interseismic Coulomb stress changes. Then, we probe the external triggering effects on the same earthquake sequence from large surrounding earthquakes. These methods allow us to better understand the stress transfer on each hypocenter of the earthquake sequence.

4. Results

4.1 Internal stress triggering

4.1.1 Coseismic Coulomb stress changes

Fig. 5 shows the coseismic Coulomb stress triggering effects on the Manyi-Kangding sequence. Five out of seven earthquakes lay in the stress triggering

zones, where the Coulomb stress changes are positive, which include the 2001 Kokoxili, 2008 Wenchuan, 2013 Lushan, 2014 Yutian and 2014 Kangding earthquakes. Thus, these five mainshocks were promoted by their corresponding preceding mainshocks through coseismic Coulomb stress transfer. On the contrary, the remaining two earthquakes, including the 2008 Yutian and 2010 Yushu earthquakes, were in stress shadows, where the Coulomb stress changes are negative, which indicates that these events were inhibited to failure. When scrutinizing each snapshot, only the 2013 Lushan earthquake was prominently promoted by the preceding earthquakes. This unique promotion characteristic can be explained by its closeness to the hypocenter of the 2008 Wenchuan earthquake, which predominantly controlled the occurrence of the 2013 Lushan earthquake, thus strongly influencing the nearby 2013 Lushan earthquake.

We calculated the coseismic Coulomb stress change at the hypocenter of each targeted mainshock as shown in Table 2 to quantitatively investigate the coseismic triggering effects among this strong earthquake sequence. The coseismic Coulomb stress change for each targeted mainshock ranged from -0.02 to 0.09 bars. The 2013 Lushan earthquake received the largest coseismic Coulomb stress change, approximately 0.088 bars from the 2008 Wenchuan earthquake. The overall coseismic Coulomb stress change that was imparted by previous strong earthquakes was merely 0.089 bars, which again quantitatively indicates that the 2008 Wenchuan earthquake played a much more important role in promoting the 2013 Lushan earthquake. In

addition, the 2014 Kangding earthquake was primarily influenced by the 2008 Wenchuan earthquake, with a coseismic Coulomb stress change of ~ 0.035 bars.

The coseismic stress changes from earthquakes in the Manyi-Kangding sequence at each hypocenter were generally insignificant (Table 2), primarily because of long separation distances for most pairs of hypocenters and the intrinsic fast decaying rates of coseismic Coulomb stress changes (Kilb et al., 2002; Toda et al., 2012).

Postseismic Coulomb stress changes from preceding earthquakes, on the other hand, perhaps contributed much more at the hypocenter of a subsequent mainshock. For instance, some studies of the classical earthquake pair of the 1992 Lander and 1999 Hector Mine earthquakes showed 1 to 2 bars of postseismic Coulomb stress change at the hypocenter of the latter (e.g., Freed and Lin, 2001; Zeng, 2001). In the following subsection, we test whether postseismic Coulomb stress changes from the Manyi-Kangding sequence were also significant.

4.1.2 Postseismic Coulomb stress change

Fig. 6 shows the postseismic Coulomb stress changes for each mainshock that was caused by its preceding mainshocks. Three out of seven mainshocks fell within stress shadows, including the 2001 Kokoxili, 2008 Yutian and 2010 Yushu earthquakes. Although the other mainshocks, including the 2008 Wenchuan, 2013 Lushan, 2014 Yutian and 2014 Kangding earthquakes, were in stress triggering zones, the magnitudes of the positive postseismic Coulomb stress changes at their hypocenters were too small to confidently claim that these mainshocks were brought

closer to failure because of postseismic relaxation of the lower crust and upper mantle from their preceding mainshocks. Similar to the case of the coseismic Coulomb stress changes, the 2013 Lushan earthquake received the largest accumulated postseismic Coulomb stress change, approximately 0.05 bars; The 2008 Wenchuan earthquake contributed the most to the postseismic Coulomb stress accumulation (Table 3). On the other hand, the postseismic Coulomb stress changes at the other hypocenters were one order of magnitude smaller than that at the 2013 Lushan earthquake.

4.1.3 Interseismic Coulomb stress change

Fig. 7 shows the interseismic Coulomb stress changes due to tectonic loading. Compared to the spatial patterns of the coseismic and postseismic Coulomb stress changes (Figs. 5 and 6), the interseismic Coulomb stress changes were much more intensive and all the mainshocks lay in stress triggering zones. The interseismic Coulomb stress changes were linearly proportional to the interseismic stress-loading rate, so the interseismic Coulomb stress changes linearly increased with time from the zero-stress-baseline. Thus, the spatial pattern of the interseismic Coulomb stress changes for each snapshot in Fig. 7 should be further intensified when the increment of time is not presumed to be relative to the 1997 Manyi earthquake but rather to a certain time before this earthquake. Accordingly, Fig.7 merely presents conservative patterns of the interseismic Coulomb stress changes. Nevertheless, all these mainshocks were encouraged by interseismic Coulomb stress changes; notably, the 2010 Yushu and 2014 Kangding earthquakes were both brought much closer to failure

(Table 4).

4.1.4 Net Coulomb stress change

We also computed the overall Coulomb stress changes to explore the combined effect of the coseismic, postseismic and interseismic Coulomb stress changes (Fig. 8). When comparing Fig. 8 and Fig. 7, the general patterns for each corresponding snapshots are similar, except for those regions where strong earthquakes occurred. In these local regions, the coseismic and postseismic Coulomb stress changes altered the spatial pattern of the interseismic Coulomb stress changes. Nevertheless, all the strong earthquakes lay in stress triggering zones, which agrees with the quantitative results (Table 4) of the compounded Coulomb stress changes that were associated with coseismic, postseismic and interseismic Coulomb stress changes for the earthquake sequence.

Except for the 2013 Lushan earthquake for which the combined coseismic and postseismic Coulomb stress changes were double those of the interseismic Coulomb stress changes, the other remaining earthquakes exhibited larger interseismic Coulomb stress changes than the combined coseismic and postseismic Coulomb stress changes (Table 4). In addition, four earthquakes, namely, the 2010 Yushu, 2013 Lushan, 2014 Yutian and 2014 Kangding earthquakes, increased by more than 0.11 bars, while the 2001 Kokoxili and 2008 Yutian and 2008 Wenchuan earthquakes exhibited positive Coulomb stress changes that were larger than 0.03 bars.

4.2 External stress triggering

In this subsection, we investigate the coseismic and postseismic stress triggering effects on the Manyi-Kangding sequence from surrounding earthquakes from 1411 to 2012. This investigation is very important because both prior large earthquakes from the Manyi-Kangding sequence and large surrounding earthquakes may have modified the stress states at each hypocenter.

Fig. 9 shows the coseismic Coulomb stress changes that were resolved on the fault plane of each earthquake from prior large surrounding earthquakes. All eight earthquakes lay in stress triggering zones with positive Coulomb stress changes, which indicates that these events were promoted to some extent. Comparing Fig. 9 and Fig. 5 shows that the spatial patterns of the Coulomb stress changes have become much more heterogeneous and intensive. These significant differences indicate that the coseismic Coulomb stress changes from large surrounding earthquakes could have been both intensified and canceled out in various regions, creating quite different values of Coulomb stress changes than those from the Manyi-Kangding with a few earthquakes.

Fig. 10 shows the accumulative postseismic Coulomb stress changes from large surrounding earthquakes. The postseismic Coulomb stress changes were also significant compared to the snapshots in Fig. 6. In this case, all the earthquakes lay in stress triggering zones with positive Coulomb stress changes, except for the 2008 Wenchuan earthquake. This earthquake exhibited a postseismic Coulomb stress

change of -0.03 bars, while all the other earthquakes exhibited changes from 0.02 to 2.83 bars (Table 5).

Fig. 11 shows the combined coseismic and postseismic Coulomb stress changes. All the earthquakes fell within stress triggering zones and were thus likely brought closer to failure. This observation can be quantitatively examined as follows. The large coseismic Coulomb stress change of ~ 0.34 bars at the hypocenter of the 2008 Wenchuan earthquake caused this event (which exhibited -0.03 bars of postseismic Coulomb stress change) to still lie in the stress triggering zone with a compounded Coulomb stress change of 0.31 bars (Table 5). The 2014 Kangding earthquake exhibited the largest change (10.38 bars) and the 2001 Kokoxili earthquake exhibited the smallest change (0.14 bars) (Table 5).

5. Discussion

Coseismic, postseismic and interseismic Coulomb stress changes are three typical types of Coulomb stress changes that have been pervasively linked to earthquake occurrence (e.g., King et al., 1994; Deng and Sykes, 1997; Nalbant et al., 2013), seismicity burst and quietness (e.g., Stein, 1999; Parsons, 2002; Green et al., 2015) and stress transfer among major faults (e.g., Parsons et al., 2008; Nalbant and McCloskey, 2011). Quantitatively computing these three types of Coulomb stress changes allowed us to systematically investigate the triggering effects of a recent large earthquake sequence along the periphery of the Bayan Har block.

Although some studies (e.g., Parson et al., 2008; Toda et al., 2008; Shan et al.,

2009, 2013; Luo and Liu, 2010; Cheng et al., 2011; Nalbant and McCloskey, 2011; Jia et al., 2012; Fang et al., 2015) have examined Coulomb stress changes from some large earthquakes of the Manyi-Kangding sequence, we expanded on these previous studies by considering more recent earthquakes, and we computed the interseismic Coulomb stress changes at each hypocenter of the earthquake sequence by using our developed explicit least-squares collocation method. Additionally, we considered triggering effects on the earthquake sequence from large surrounding earthquakes from 1411 to 2012, which were rarely comprehensively considered in previous studies. Our understanding on the causal linkages between the recent earthquake sequences and Coulomb stress transfer has been deepened through these improvements.

5.1 Importance of considering large surrounding earthquakes

Considering large surrounding earthquakes is very important. When only examining the triggering effects from earthquakes within the Manyi-Kangding sequence, we recognize that the compounded coseismic and postseismic Coulomb stress changes were insignificant, except for the 2013 Lushan earthquake, for which the compounded Coulomb stress change was approximately 0.14 bars (Table 4). This result is consistent with the measured Coulomb stress changes from previous studies, which ranged from approximately 0.04 bars to 0.5 bars (Table S4). However, when considering large surrounding earthquakes as well, all the earthquakes in the Manyi-Kangding sequence exhibited positive coseismic Coulomb stress changes

ranging from 0.04 bars to 7.55 bars; Six out of the eight earthquakes are influenced by coseismic Coulomb stress changes that were significantly larger than 0.1 bars, one by a change of approximately 0.1 bars and the remaining event by a change of 0.04 bars (Table 5). Coulomb stress change as small as 0.1 bars are commonly assumed to be related to the earthquake stress triggering (Harris, 1998; Stein, 1999), so the much larger coseismic Coulomb stress changes from the surrounding earthquakes in this study increased the likelihood of bringing most of the earthquakes in the Manyi-Kangding sequence closer to failure.

The situations of the aforementioned coseismic Coulomb stress changes alters slightly when further considering postseismic Coulomb stress changes from surrounding earthquakes. The 2008 Wenchuan earthquake was imposed by a negative postseismic Coulomb stress change of -0.03 bars (Table 5), which agrees with the value of approximately -0.05 bars by Nalbant and McCloskey (2011). On the other hand, their compounded Coulomb stress change of coseismic and postseismic Coulomb stress changes ranged from -0.009 bars to -0.052 bars, which was smaller than the absolute values by Shan et al. (2013) (-0.13 to -0.2 bars). Nonetheless, our measured result was 0.31 bars (Table 5), which was plausibly attributed to the effects by all the surrounding earthquakes.

When summing the coseismic and postseismic Coulomb stress changes from both the internal earthquakes of the Manyi-Kangding sequence and other surrounding earthquakes, the net Coulomb stress changes are all positive, ranging from 0.14 bars

to 10.4 bars (Table 5), which was primarily influenced by coseismic and postseismic changes from surrounding earthquakes. The internal triggering effects were generally insignificant, except for the 2013 Lushan earthquake. This earthquake exhibited compounded coseismic and postseismic Coulomb stress changes of 0.13 bars from the 2008 Wenchuan earthquake, which was comparable to the value of 0.25 bars from the surrounding earthquakes in terms of its order of magnitude.

The above results indicate the necessity of performing comprehensive Coulomb stress analyses by considering a large group of earthquakes, especially when assessing the likelihood of potential hazardous earthquakes in the vicinity of major active faults. Otherwise, spurious warnings for potential earthquakes would mislead policy makers and communities during the preparation of prevention and mitigation of future earthquake hazards when using Coulomb stress maps with incomplete Coulomb stress changes.

5.2 Role of distance in Coulomb stress triggering

Significant coseismic Coulomb stress changes depend on three factors: (1) the magnitude of the source fault, (2) the distance between the source fault and receiver fault, and (3) the appropriate alignment between the source and receiver faults.

Significant postseismic Coulomb stress changes, on the other hand, also depend on the viscoelastic structure of the Earth. For a certain event magnitude of a source fault in a given study region, the distance within which Coulomb stress changes are still significant generally plays a much more important role, especially for coseismic Coulomb stress changes (Figs. 12 and 13).

Fig. 12 shows that four out of the eight earthquakes in the Manyi-Kangding sequence exhibited the largest Coulomb stress changes from their nearby earthquakes (snapshots (a), (d), (f), and (h)). The other four earthquakes were predominantly influenced by very large surrounding earthquakes (snapshots (b), (c), (e), and (g)), mainly because earthquakes with very large magnitude can transmit coseismic Coulomb stress changes much farther and accordingly compensate for the fast decaying of coseismic Coulomb stress changes. In contrast, only two earthquakes in Fig. 13 were imposed heavily by neighboring earthquakes (snapshots (a) and (h)). The other six earthquakes were intensively influenced by very large surrounding earthquakes (snapshots (b) to (g)). Nonetheless, some additional surrounding earthquakes also induced postseismic Coulomb stress changes that were no smaller than 0.01 bars.

The common feature of Fig. 12 and Fig. 13 is that relatively significant earthquakes swarmed in the vicinity of each earthquake from the Manyi-Kangding sequence, which indicates the importance of separation distance in determining pronounced triggering effects among pairs of earthquakes, although whether the receiver fault is optimally-oriented relative to the source fault is also important (King et al., 1994; Mallman and Zoback, 2007; Xu et al., 2010).

Some previous studies also verified the essential role of separation distance between pairs of earthquake events. For instance, Chery et al. (2001) found significant postseismic Coulomb stress change from 0.1 to 0.9 bars for a separation distance of

approximately 400 km in Mongolia because of the viscoelastic relaxation of lower crust and upper mantle, which contrasted the negligible coseismic Coulomb stress change of ~ 0.001 bars from prior earthquakes. Pollitz et al. (2003) also found that the postseismic Coulomb stress change was predominant for a longer earthquake sequence with a separation distance from 100 to 400 km in the same tectonic region, whereas the coseismic Coulomb stress change was negligible.

On the other hand, coseismic and postseismic Coulomb stress changes can be comparable to each other over shorter distance. For example, Parsons and Dreger (2001) studied the stress triggering between the 1992 Landers and 2001 Hector Mine earthquakes, which were separated by only 20 km, and identified that the latter earthquake exhibited 0.5 bars of coseismic Coulomb stress change. Meanwhile, Freed and Lin (2001) found positive postseismic Coulomb stress changes from 1 to 2 bars at this location and Zeng (2001) resolved postseismic Coulomb stress increases that exceeded 1 bars.

Whether a mainshock induces significant triggering effects on other earthquakes depends upon complex factors, but considering large surrounding mainshocks is vital for Coulomb stress analysis.

5.3 Possible triggering effects of afterslip, poroelastic rebound and dynamic stress

5.3.1 Afterslip and poroelastic rebound

We modeled the coseismic and postseismic Coulomb stress changes by using a coseismic dislocation model and a postseismic viscoelastic relaxation model,

598 respectively. Both models require coseismic slip distributions of seismogenic source
599 faults. Most of the coseismic slip distributions that we used here were inverted by
600 using modern geodetic data spanning before and after each strong earthquakes with
601 certain time intervals from previous literatures, so we cannot rule out the possibility
602 that some postseismic slip dislocations from afterslip and poroelastic rebound would
603 have somewhat contaminated the coseismic slip distributions.

604 Nonetheless, such contamination, if it exists, may not significantly modify the
605 amount of Coulomb stress change. This is not only because earlier postseismic stress
606 redistributions from afterslip and poroelastic rebound are transient and localized (e.g.,
607 Peltzer et al., 1998; Jónsson et al., 2003), but Coulomb stress changes imparted by
608 afterslip and poroelastic rebound can be computed by using the same dislocation
609 theory (e.g. Okada, 1992; Wang et al., 2006). Therefore, the accommodation of a
610 certain amount of afterslip in coseismic slip models would be feasible.

611 Recently, Huang et al. (2014) showed that the effect of poroelastic rebound was
612 negligible and that the geodetic moment of the afterslip represented a tiny proportion
613 of approximately 5.4%, of that of the mainshock for the 2008 Wenchuan earthquake.
614 The postseismic deformations of some other large earthquakes from the studied
615 earthquake sequence were also reported to be small and localized compared to
616 coseismic deformations from mainshocks (e.g., Wang et al., 2011; Qu et al., 2013).
617 Hence, we do not need to consider the contribution to the ultimate Coulomb stress
618 change from afterslip or poroelastic rebound.

5.3.2 *Dynamic stress triggering*

Dynamic Coulomb stress changes would have altered the stress state at each hypocenter of the strong earthquake sequence along the periphery of the Bayan Har block. Although dynamic Coulomb stress changes can result in both near-field and remote earthquake triggering after the passage of seismic surface waves (e.g., Kilb et al., 2002; Peng et al., 2011; Pollitz et al., 2012; Johnson and Burgmann, 2016), this process is transient and would be substantial in a time scale from seconds to days. Therefore, this type of Coulomb stress change is not likely to be responsible for the occurrence of the strong earthquake sequence that we studied, of which the earthquakes generally occupied time intervals of years.

5.4 *Sensitivity of Coulomb stress changes to the empirical coefficients*

The more complex equation (4) is referred to as the isotropic poroelastic model, while the simpler equation (5) is the constant apparent friction model (Feuillet et al., 2004; Feuillet, 2013). Their difference is that the former depends on two empirical coefficients, namely, the friction coefficient and Skempton's coefficient, whereas the latter nominally depends on one apparent friction coefficient by incorporating both aforementioned coefficients.

The constant apparent friction model is pervasively employed in the realm of Coulomb stress analysis (e.g., King et al., 1994; Harris et al. 1998; McCloskey et al., 2003; Toda et al., 2005; Steacy et al., 2005; Freed et al., 2007; Parsons et al., 2008; Toda et al., 2008; Feuillet et al., 2011; Feuillet, 2013; Sumy et al., 2014; Cattania et

al., 2014, 2015; Green et al., 2015; Verdecchia and Carena, 2015, 2016). Nevertheless, some previous studies claimed that the discrepancy in Coulomb stress changes from the two aforementioned models was significant (e.g., Beeler et al., 2000; Cocco and Rice, 2002). Therefore, we also tested the sensitivity of the Coulomb stress changes to both the empirical coefficients and the two models. We tested the variations in the Coulomb stress changes with the apparent friction coefficients from 0.2 to 0.8 and a friction coefficient and the Skempton's coefficient of both 0.7 following Nalbant and McCloskey (2011).

Fig. 14 shows that the coseismic and postseismic Coulomb stress changes at the hypocenters of the 2010 Yushu and 2014 Kangding earthquakes were relatively more sensitive to the apparent friction coefficient and to the choice of the isotropic poroelastic model. At the 2010 Yushu hypocenter, both the coseismic and postseismic Coulomb stress changes varied by approximately 0.8 bars. At the 2014 Kangding hypocenter, the coseismic Coulomb stress changes fluctuated by 5.5 bars and postseismic Coulomb stress changes varied by 2.5 bars. Nonetheless, these variations in the Coulomb stress changes merely reflect the lack of current knowledge regarding the frictional distribution on the ruptured fault planes and the porosity of the underlying host rocks that surround the fault planes, rather than the actual uncertainties in these parameters. Thus, these two parameters are usually predefined empirically (e.g., King et al., 1994; Toda et al., 2008; Parsons et al., 2008; Steacy et al., 2014; Avouac et al., 2014; Green et al., 2015).

Summing the coseismic and postseismic Coulomb stress changes from the Manyi-Kangding sequence and large surrounding earthquakes, indicated that the compounded Coulomb stress changes at the hypocenter of each earthquake event from the Manyi-Kangding sequence ranged from 0.1 bars to 15 bars. This result indicates that each earthquake event was brought closer to failure regardless of the choice of the apparent coefficient for the constant apparent friction model. Additionally, the isotropic poroelastic model produced compounded Coulomb stress changes from 0.1 to 11.7 bars, except for the 1997 Manyi earthquake which exhibited -0.08 bars (Table 6). Table 6 shows that the compounded Coulomb stress changes when using an apparent friction coefficient of 0.4, averaging the compounded Coulomb stress changes and employing the isotropic poroelastic model. Generally, the compounded Coulomb stress change at each hypocenter did not vary significantly. Therefore, applying the constant apparent friction model to our case study was also feasible.

Some previous studies suggested an apparent friction coefficient as low as 0.2 for matured and repeatedly ruptured faults with more cumulative slips and a coefficient as high as 0.8 for young minor faults (e.g., Parsons et al., 1999; Nalbant et al., 2006). Nonetheless, such suggestions are based on conventional recognition rather than rigorous field experiments because of the paucity of the current comprehensive knowledge on this parameter. Therefore, this coefficient is one of the most empirical parameter of the Coulomb failure model (Wang et al., 2014b). An intermediate value

of 0.4, which was proposed by King et al. (1994) and many others, could indeed minimize our knowledge gap for this parameter. Alternatively, considering failure criteria other than the Coulomb failure criterion could allow us to bypass the choice of this parameter and the Skempton's coefficient for future earthquake stress triggering analysis.

6. Conclusions

Eight strong earthquakes sequentially occurred along the periphery of the Bayan Har block on the northern Tibetan Plateau from 1997 to 2014. This sequence influenced us to probe the triggering effects on this Manyi-Kangding sequence. A systematical investigation on the coseismic, postseismic and interseismic Coulomb stress changes that were induced by this strong earthquake sequence, showed that the triggering effects within the Manyi-Kangding sequence were insignificant, except for the 2013 Lushan earthquake. This exception is primarily attributed to its proximity to the 2008 Wenchuan earthquake, which imparted up to 0.13 bars at the hypocenter of the 2013 Lushan earthquake. Interseismic Coulomb stress changes always continue loading each hypocenter. On the other hand, all eight earthquakes in this sequence were imposed by significant compounded positive Coulomb stress changes when further considering the effects of surrounding prior large earthquakes on the Manyi-Kangding sequence, ranging from a minimum increment of 0.14 bars for the 2001 Kokoxili earthquake to a maximum increment of 10.43 bars for the 2014 Kangding earthquake. Thus, all these events can be well explained by coseismic and

postseismic Coulomb stress transfer primarily from surrounding earthquakes. Our findings indicate that the necessity of performing comprehensive Coulomb stress change analysis by considering a broader group of neighboring large earthquakes.

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724 **References**

- 725 Aki, K., 1966. Generation and propagation of G waves from the Niigata earthquake of
 726 June 16, 1964. Part 2. Estimation of earthquake moment, released energy, and
 727 stress-strain drop from the G wave spectrum. *Bull. Earthquake Res. Inst.* 44, 73–88.
- 728 Ali, S.T., Freed, A.M., Calais, E., Manaker, D.M., McCann, W.R., 2008. Coulomb
 729 stress evolution in Northeastern Caribbean over the past 250 years due to coseismic,
 730 postseismic and interseismic deformation. *Geophys. J. Int.* 174, 904–918.
 731 doi:10.1111/j.1365-246X.2008.03634.x.
- 732 Avouac, J.P., Ayoub, F., Wei, S.J., Ampuero, J.P., Meng, L.S., Leprince, S., Jolivet,
 733 R., Duputel, Z., Helmberger, D., 2014. The 2013, Mw 7.7 Balochistan earthquake,
 734 energetic strike-slip reactivation of a thrust fault. *Earth Planet. Sci. Lett.* 391, 128–134.
 735 <http://dx.doi.org/10.1016/j.epsl.2014.01.036>.
- 736 Bassin, C., Laske, G., Masters, G., 2000. The current limits of resolution for surface
 737 wave tomography in North America. *EOS Trans AGU*, 81, F897.
- 738 Beeler, N.M., Simpson, R.W., Hickman, S.H., Lockner, D.A., 2000. Pore fluid
 739 pressure, apparent friction, and Coulomb failure. *J. Geophys. Res.* 105 (B11),
 740 25533–25542. doi:10.1029/2000JB900119.
- 741 Bilek, S.L., Lithgow-Bertelloni, C., 2005. Stress changes in the Costa Rica subduction
 742 zone due to the 1999 Mw=6.9 Quepos earthquake. *Earth Planet. Sci. Lett.* 230, 97–112.
 743 doi:10.1016/j.epsl.2004.11.020.

744 Cattania, C., Hainzl, S., Wang, L., Enescu, B., Roth, F., 2015. Aftershock triggering by
 745 postseismic stresses: A study based on Coulomb rate-and-state models. *J. Geophys. Res.*
 746 120, 2388–2407. doi:10.1002/2014JB011500.

747 Cattania, C., Hainzl, S., Wang, L., Roth, F., Enescu, B., 2014. Propagation of Coulomb
 748 stress uncertainties in physics-based aftershock models. *J. Geophys. Res.* 119,
 749 7846–7864. doi:10.1002/2014JB011183.

750 Cheng, J., Liu, J., Gan, W.J., et al., 2011. Coulomb stress interaction among strong
 751 earthquakes around the Bayan Har block since the Manyi earthquake in 1997 (*in*
 752 *Chinese with English abstract*). *Chinese J. Geophys.* 54 (8), 1997–2010.
 753 doi:10.3969/j.issn.0001-5733.

754 Chery, J., Carretier, S., Ritz, J.-F., 2001. Postseismic stress transfer explains
 755 timeclustering of large earthquakes in Mongolia. *Earth Planet. Sci. Lett.* 194,
 756 277–286.

757 Cocco, M., Rice, J.R., 2002. Pore pressure and poroelasticity effects in Coulomb
 758 stress analysis of earthquake interactions. *J. Geophys. Res.* 107 (B2).
 759 doi:10.1029/2000JB000138.

760 Cortés-Aranda, J., González, G., Rémy, D., Martinod, J., 2015. Normal upper plate
 761 fault reactivation in northern Chile and the subduction earthquake cycle: From
 762 geological observations and static Coulomb Failure Stress (CFS) change.
 763 *Tectonophys.* 639, 118–131. <http://dx.doi.org/10.1016/j.tecto.2014.11.019>.

764 Deng, J.S., Sykes, L.R., 1997. Evolution of the stress field in southern California and
 765 triggering of moderate-size earthquakes: A 200-year perspective. *J. Geophys. Res.*
 766 102 (B5), 9859–9886.

767 El-Fiky, G.S., Kato, T., Fujii, Y., 1997. Distribution of vertical crustal movement
 768 rates in the Tohoku district, Japan, predicted by least-squares collocation. *J. Geod.* 71,
 769 432–442.

770 Elliott, J.R., Parsons, B., Jackson, J.A., Shan, X., Sloan, R.A., Walker, R.T., 2011.
 771 Depth segmentation of the seismogenic continental crust: The 2008 and 2009 Qaidam
 772 earthquakes. *Geophys. Res. Lett.* 38, L06305. doi:10.1029/2011GL046897.

773 Elliott, J.R., Walters, R.J., England, P.C., Jackson, J.A., Li, Z., Parsons, B., 2010.
 774 Extension on the Tibetan plateau: recent normal faulting measured by InSAR and
 775 body wave seismology. *Geophys. J. Int.* 183, 503–535. doi:
 776 10.1111/j.1365-246X.2010.04754.x.

777 Fan, W.Y., Shearer, P.M., 2016. Fault interactions and triggering during the
 778 10 January 2012 Mw 7.2 Sumatra earthquake. *Geophys. Res. Lett.* 43, 1934–1942.
 779 doi:10.1002/2016GL067785.

780 Fang, L.H., Wu, J.P., Liu, J., Cheng, J., Jiang, C.S., Han, L.B., Wang, Y.S., Chen, K.,
 781 Zhao, X., Wu, Z.L., 2015. Preliminary report on the 22 November 2014 Mw 6.1/Ms
 782 6.3 Kangding earthquake, western Sichuan, China. *Seismol. Res. Lett.* 86 (6), 1–11.
 783 doi:10.1785/0220150006.

784 Feuillet, N., 2013. The 2011-2012 unrest at Santorini rift: Stress interaction between
 785 active faulting and volcanism. *Geophys. Res. Lett.* 40, 3532–3537.
 786 doi:10.1002/grl.50516.

787 Feuillet, N., Beauducel, F., Jacques, E., Tapponnier, P., Delouis, B. Bazin, S., Vallee,
 788 M., King, G.C.P., 2011. The Mw = 6.3, November 21, 2004, Les Saintes earthquake
 789 (Guadeloupe): Tectonic setting, slip model and static stress changes. *J. Geophys. Res.*
 790 116 (B10301), 1–25. doi:10.1029/2011JB008310.

791 Feuillet, N. Nostro, C., Chiarabba, C., Cocco, M., 2004. Coupling between earthquake
 792 swarms and volcanic unrest at the Alban Hills Volcano (central Italy) modeled
 793 through elastic stress transfer. *J. Geophys. Res.* 109(B02308), 1–16.
 794 doi:10.1029/2003JB002419.

795 Freed, A.M., 2005. Earthquake triggering by static, dynamic and postseismic stress
 796 transfer. *Annu. Rev. Earth Planet. Sci.* 33, 335–367.
 797 doi:10.1146/annurev.earth.33.092203.122505.

798 Freed, A.M., Ali S.T., Burgmann, R., 2007. Evolution of stress in Southern California
 799 for the past 200 years from coseismic, postseismic and interseismic stress changes.
 800 *Geophys. J. Int.* 169, 1164–1179. doi:10.1111/j.1365-246X.2007.03391.x.

801 Freed, A.M., Lin, J., 2001. Delayed triggering of the 1999 Hector Mine earthquake by
 802 viscoelastic stress transfer. *Nature* 411, 180–183. doi:10.1038/35075548.

803 Funning, G.J., Parsons, B., Wright, T.J., 2007. Fault slip in the 1997 Manyi, Tibet
 804 earthquake from linear elastic modelling of InSAR displacements. *Geophys. J. Int.* 169,
 805 988–1008. doi: 10.1111/j.1365-246X.2006.03318.x.

806 Green, R.G., Greenfield, T., White, R.S., 2015. Triggered earthquakes suppressed by an
 807 evolving stress shadow from a propagating dyke. *Nature Geosci.* 8, 629–632.
 808 doi:10.1038/ngeo2491.

809 Hamling, I.J., Wallace, L.M., 2015. Silent triggering: Aseismic crustal faulting induced
 810 by a subduction slow slip event. *Earth Planet. Sci. Lett.* 421, 13–19.
 811 <http://dx.doi.org/10.1016/j.epsl.2015.03.046>.

812 Hanks, T.C., Kanamori, H., 1979. A moment magnitude scale. *J. Geophys. Res.* 84
 813 (B5), 2348–2350.

814 Harris, R.A., 1998. Introduction to special section: Stress triggers, stress shadows, and
 815 implications for seismic hazard. *J. Geophys. Res.* 103 (B10), 24,347–24,358.
 816 doi:10.1029/98JB01576.

817 Hashimoto, M., Enomoto, M., Fukushima, Y., 2010. Coseismic deformation from the
 818 2008 Wenchuan, China, earthquake derived from ALOS/PALSAR images.
 819 *Tectonophys.* 491 (1–4), 59–71. doi:10.1016/j.tecto.2009.08.034.

820 Huang, M.-H., Burgmann, R., Freed, A.M., 2014. Probing the lithospheric rheology
 821 across the eastern margin of the Tibetan Plateau. *Earth Planet. Sci. Lett.* 396, 88–96.
 822 doi:10.1016/j.epsl.2014.04.003.

823 Hubert-Ferrari, A., Barka, A., Jacques, E., Nalbant, S.S., Meyer, B., Armijo, R.,
 824 Tapponnier, P., King, G.C.P., 2000. Seismic hazard in the Marmara Sea region
 825 following the 17 August 1999 Izmit earthquake. *Nature* 404 (6775), 269–273.

 826 Jia, K., Zhou, S.Y., Wang, R., 2012. Stress interactions within the strong earthquake
 827 sequence from 2001 to 2010 in the Bayankala block of eastern Tibet. *Bull. Seismol.*
 828 *Soc. Am.* 102 (5), 2157–2164. doi:10.1785/0120110333.

 829 Jiang, Z.S., Liu, J.N., 2010. The method in establishing strain field and velocity field
 830 of crustal movement using least squares collocation (*in Chinese with English*
 831 *abstract*). *Chinese J. Geophy.* 53 (5), 1109–1117.
 832 doi:10.3969/j.issn.0001-5733.2010.05.011.

 833 Jiang, Z., Wang, M., Wang, Y., Wu, Y., Che, S., Shen, Z.K., Burgmann, R., Sun, J.,
 834 Yang, Y., Liao, H., Li, Q., 2014a. GPS constrained coseismic source and slip
 835 distribution of the 2013 Mw6.6 Lushan, China, earthquake and its tectonic
 836 implications. *Geophys. Res. Lett.* 41, 407–413. doi:10.1002/2013GL058812.

 837 Jiang, G., Wen, Y., Liu, Y., Xu, X., Fang, L., Chen, G., Gong, M., Xu, C., 2015a.
 838 Joint analysis of the 2014 Kangding, southwest China, earthquake sequence with
 839 seismicity relocation and InSAR inversion. *Geophys. Res. Lett.* 42, 3273–3281.
 840 doi:10.1002/2015GL063750.

 841 Jiang, G., Xu, X., Chen, G., Liu, Y., Fukahata, Y., Wang, H., Yu, G., Tan, X., Xu, C.,
 842 2015b. Geodetic imaging of potential seismogenic asperities on the

843 Xianshuihe-Anninghe-Zemuhe fault system, southwest China, with a new 3-D
844 viscoelastic interseismic coupling model. *J. Geophys. Res.* 120, 1855–1873.
845 doi:10.1002/2014JB011492.

846 Jiang, G.Y., Xu, C.J., Wen, Y.M., Xu, X.W. Ding, K.H., Wang, J.J., 2014b.
847 Contemporary tectonic stressing rates of major strike-slip faults in the Tibetan Plateau
848 from GPS observations using Least-Squares Collocation. *Tectonophys.* 615–616,
849 85–95. <http://dx.doi.org/10.1016/j.tecto.2013.12.022>.

850 Johnson, C.W., Burgmann, R., 2016. Delayed dynamic triggering: Local seismicity
851 leading up to three remote $M \geq 6$ aftershocks of the 11 April 2012 M8.6 Indian Ocean
852 earthquake. *J. Geophys. Res.* 121, 134–151. doi:10.1002/2015JB012243.

853 Jónsson, S., Segall, P., Pedersen, R., Björnsson, G., 2003. Post-earthquake ground
854 movements correlated to pore-pressure transients. *Nature* 424,
855 179–183. doi:10.1038/nature01776.

856 Kilb, D., Gomberg, J., Bodin, P., 2002. Aftershock triggering by complete Coulomb
857 stress changes. *J. Geophys. Res.* 107 (B4) 1–8. doi:10.1029/2001JB000202.

858 King, G.C.P., 2007. Fault interaction, earthquake stress changes and the evolution of
859 seismicity. *Treatise Geophys.* 4, 225–255.

860 King, G.C.P., Stein, R.S., Lin, J., 1994. Static stress changes and the triggering of
861 earthquakes. *Bull. Seismol. Soc. Am.* 84 (3), 935–953.

862 Krarup, T., 1968. A Framework for Least Squares Determination of the Potential of
863 the Earth, A preliminary report. Letter to IAG SSG 5.31.

864 Krieger, L., Heimann, S., 2012. MoPaD-moment tensor plotting and decomposition:
865 A tool for graphical and numerical analysis of seismic moment tensors. *Seismol. Res.*
866 *Lett.* 83 (3), 589–595.

867 Lasserre, C. , Peltzer, G., Crampe, F., Klinger, Y., Woerd, J. Van der, Tapponnier, P.,
868 2005. Coseismic deformation of the 2001 Mw = 7.8 Kokoxili earthquake in Tibet,
869 measured by synthetic aperture radar interferometry. *J. Geophys. Res.* 110, B12408,
870 1–17. doi:10.1029/2004JB003500.

871 Li Z., Elliott, J.R., Feng, W., Jackson, J.A., Parsons, B.E., Walters, R.J., 2011. The
872 2010 Mw 6.8 Yushu (Qinghai,China) earthquake: Constraints provided by InSAR and
873 body wave seismology. *J. Geophys. Res.* 116 (B10302), 1–16.
874 doi:10.1029/2011JB008358.

875 Lin, Y.C., Lin, J.Y., 2015. Source mechanism of the 1998 Mw 7.4 intraplate
876 strike-slip earthquake in the West Philippine Basin revealed by Coulomb stress
877 changes. *Tectonophys.* <http://dx.doi.org/10.1016/j.tecto.2015.11.029>.

878 Luo, G., Liu, M., 2010. Stress evolution and fault interactions before and after the
879 2008 Great Wenchuan earthquake. *Tectonophys.* 491 (1–4), 127–140.
880 doi:10.1016/j.tecto.2009.12.019.

881 Macpherson, K.A., Ruppert, N.A., 2015. Evidence of Wadati-Benioff zone triggering
 882 following the Mw 7.9 Little Sitkin, Alaska intermediate depth earthquake of 23 June
 883 2014. *Geophys. Res. Lett.* 42, 6269–6277. doi:10.1002/2015GL065023.

884 Mallman, E.P., Zoback, M.D., 2007. Assessing elastic Coulomb stress transfer models
 885 using seismicity rates in southern California and southwestern Japan. *J. Geophys. Res.*
 886 112, B03304. doi:10.1029/2005JB004076.

887 McCloskey, J., Nalbant, S.S., Steacy, S., 2005. Indonesian earthquake: Earthquake
 888 risk from co-seismic stress. *Nature* 434, 291. doi:10.1038/434291a.

889 McCloskey, J., Nalbant, S.S., Steacy, S., Nostro, C., Scotti, O., Baumont, D., 2003.
 890 Structural constraints on the spatial distribution of aftershocks. *Geophys. Res. Lett.* 30
 891 (12), 1610. doi:10.1029/2003GL017225.

892 Meade, B.J., 2007. Present-day kinematics at the India-Asia collision zone. *Geology*
 893 35 (1), 81–84. doi:10.1130/G22924A.1.

894 Milkereit, C., Grosser, H., Wang, R., Wetzel, H.-U., Woith, H., Karakisa, S., Zünbül,
 895 S., Zschau, J., 2004. Implications of the 2003 Bingöl earthquake for the interaction
 896 between the North and East Anatolian faults. *Bull. Seismol. Soc. Am.* 94 (6),
 897 2400–2406. doi:10.1785/0120030194.

898 Moritz, H., 1980. *Advanced physical geodesy*. Wichmann: Abacus Press, Karlsruhe:
 899 Tunbridge, Eng.

900 Nalbant, S.S., Hubert, A., King, G.C.P., 1998. Stress coupling between earthquakes in
 901 northwest Turkey and the north Aegean Sea. *J. Geophys. Res.* 103 (B10), 24,
 902 469–24,486. doi:10.1029/98JB01491.

903 Nalbant, S.S., McCloskey, J., 2011. Stress evolution before and after the 2008
 904 Wenchuan, China earthquake. *Earth Planet. Sci. Lett.* 307, 222–232.
 905 doi:10.1016/j.epsl.2011.04.039.

906 Nalbant, S.S., McCloskey, J., Steacy, S., 2005a. Lessons on the calculation of static
 907 stress loading from the 2003 Bingol, Turkey earthquake. *Earth Planet. Sci. Lett.* 235,
 908 632–640. doi:10.1016/j.epsl.2005.04.036.

909 Nalbant, S.S., McCloskey, J. , Steacy, S. , NicBhloscaidh, M., Murphy, S., 2013.
 910 Interseismic coupling, stress evolution, and earthquake slip on the Sunda megathrust.
 911 *Geophys. Res. Lett.* 40, 4204–4208. doi:10.1002/grl.50776.

912 Nalbant, S.S., Steacy, S., McCloskey, J., 2006. Stress transfer relations among the
 913 earthquakes that occurred in Kerman province, southern Iran since 1981. *Geophys. J.*
 914 *Int.*, 167 (1), 309–318. doi:10.1111/j.1365-246X.2006.03119.x.

915 Nalbant, S.S., Steacy, S., Sieh, K., Natawidjaja, D., McCloskey, J., 2005b.
 916 Seismology: Earthquake risk on the Sunda trench. *Nature* 435, 756–757.
 917 doi:10.1038/nature435756a.

918 Okada, Y., 1992. Internal deformation due to shear and tensile faults in a half-space.
 919 *Bull. Seismol. Soc. Am.* 82 (2), 1018–1040.

920 Papadimitriou, E., Wen, X.Z., Karakostas, V., Jin, X.S., 2004. Earthquake triggering
 921 along the Xianshuihe fault zone of western Sichuan, China. *Pure Appl. Geophys.* 161,
 922 1683–1707. doi:10.1007/s00024-003-2471-4.

923 Paradisopoulou, P., Garlaoui, C.G., Jin, X.S., Papadimitriou, E.E., Karakostas, V.G.,
 924 Yang, J.L., 2007. Application of the stress evolutionary model along the Xiaojiang
 925 fault zone in Yunnan Province, Southeast China. *Acta Geophys.* 55 (4), 577–593.
 926 doi:10.2478/s11600-007-0028-0.

927 Parsons, T., 2002. Post-1906 stress recovery of the San Andreas fault system
 928 calculated from three-dimensional finite element analysis. *J. Geophys. Res.* 107 (B8),
 929 1–13. doi:10.1029/2001JB001051.

930 Parsons, T., Dreger, D.S., 2000. Static-stress impact of the 1992 Landers earthquake
 931 sequence on nucleation and slip at the site of the 1999 M=7.1 Hector Mine earthquake,
 932 southern California. *Geophys. Res. Lett.* 27 (13), 1949–1952. doi:
 933 10.1029/1999GL011272.

934 Parsons, T., Ji, C., Kirby, E., 2008. Stress changes from the 2008 Wenchuan
 935 earthquake and increased hazard in the Sichuan basin. *Nature* 454, 509–510.
 936 doi:10.1038/nature07177.

937 Parsons, T., Segou, M., 2014. Stress, distance, magnitude, and clustering influences
 938 on the success or failure of an aftershock forecast: The 2013 M 6.6 Lushan earthquake
 939 and other examples. *Seismol. Res. Lett.* 85 (1), 44–51. doi: 10.1785/0220130100.

940 Parsons, T., Stein, R.S., Simpson, R.W., Reasenber, P.A., 1999. Stress sensitivity of
 941 fault seismicity: A comparison between limited-offset oblique and major strike-slip
 942 faults. *J. Geophys. Res.* 104 (B9), 20183–20202.

943 Parsons, T., Toda, S., Stein, R.S., Barka, A., Dietrich, J.H., 2000. Heightened odds of
 944 large earthquakes near Istanbul: An interaction-based probability calculation. *Science*
 945 288, 661–665.

946 Peltzer, G., Rosen, P., Rogez, F., Hudnut, K., 1998. Poroelastic rebound along the
 947 Landers 1992 earthquake surface rupture. *J. Geophys. Res.* 103 (B12),
 948 30,131–30,145.

949 Peng, Z.G., Wu C.Q., Aiken, C., 2011. Delayed triggering of microearthquakes by
 950 multiple surface waves circling the Earth. *Geophys. Res. Lett.* 38 (L04306), 1–5.
 951 doi:10.1029/2010GL046373.

952 Pollitz, F.F., 1992. Postseismic relaxation theory on the spherical earth. *Bull. Seismol.*
 953 *Soc. Am.* 82 (1), 422–453.

954 Pollitz, F.F., Stein, R.S., Sevilgen, V., Burgmann, R., 2012. The 11 April 2012 east
 955 Indian Ocean earthquake triggered large aftershocks worldwide. *Nature* 490, 250–253.
 956 doi:10.1038/nature11504.

957 Pollitz, F., Vergnolle, M., Calais, E., 2003. Fault interaction and stress triggering of
 958 twentieth century earthquakes in Mongolia. *J. Geophys. Res.*, 108 (B10), 2503, 1–14.
 959 doi:10.1029/2002JB002375.

960 Qu, C.Y., Zhang, G.F., Shan, X.J., Zhang, G.H., Liu, Y.H., Song, X.G., 2013.
 961 Coseismic and postseismic deformation fields of the 2010 Yushu, Qinghai Ms7.1
 962 earthquake and their evolution processes (*in Chinese with English abstract*). Chinese
 963 J. Geophys. 56 (7), 2280–2291. doi:10.6038/cjg20130715.

964 Ryder, I., Burgmann, R., Pollitz, F., 2011. Lower crustal relaxation beneath the
 965 Tibetan Plateau and Qaidam Basin following the 2001 Kokoxili earthquake. Geophys.
 966 J. Int. 187 (2), 613–630. doi: 10.1111/j.1365-246X.2011.05179.x.

967 Ryder, I., Parsons, B., Wright, T., Funning, G.J., 2007. Post-seismic motion following
 968 the 1997 Manyi (Tibet) earthquake: InSAR observations and modelling. Geophys. J.
 969 Int. 169, 1009–1027. doi: 10.1111/j.1365-246X.2006.03312.x.

970 Shan, B., Xiong, X., Wang, R.J., Zheng, Y., Yang, S., 2013. Coulomb stress evolution
 971 along Xianshuihe–Xiaojiang Fault System since 1713 and its interaction with
 972 Wenchuan earthquake, May 12, 2008. Earth Planet. Sci. Lett. 377–378, 199–210.
 973 doi:10.1016/j.epsl.2013.06.044.

974 Shan, B., Xiong, X., Zheng, Y., Diao, F.Q., 2009. Stress changes on major faults
 975 caused by Mw 7.9 Wenchuan earthquake, May 12, 2008. Sci. China Ser. D: Earth Sci.
 976 52 (5), 593–601. doi:10.1007/s11430-009-0060-9.

977 Shao, Z.G., Xu, J. Ma, H.S., Zhang, L.P., 2016. Coulomb stress evolution over the
 978 past 200 years and seismic hazard along the Xianshuihe fault zone of Sichuan, China.
 979 Tectonophys. 670, 48–65. <http://dx.doi.org/10.1016/j.tecto.2015.12.018>.

980 Steacy, S., Gomberg, J., Cocco, M., 2005. Introduction to special section: Stress
 981 transfer, earthquake triggering, and time-dependent seismic hazard. *J. Geophys. Res.*
 982 110, B05S01. doi:10.1029/2005JB003692.

983 Steacy, S., Jimenez, A., Holden, C., 2014. Stress triggering and the Canterbury
 984 earthquake sequence. *Geophys. J. Int.* 196 (1), 473–480. doi:10.1093/gji/ggt380.

985 Stein, R.S., 1999. The role of stress transfer in earthquake occurrence. *Nature* 402,
 986 605–609. doi:10.1038/45144.

987 Stein, R.S., Barka, A.A., Dieterich, J.H., 1997. Progressive failure on the North
 988 Anatolian fault since 1939 by earthquake stress triggering. *Geophys. J. Int.* 128,
 989 594–604. doi:10.1111/j.1365-246X.1997.tb05321.x.

990 Styron, R., Taylor, M., Okoronkwo, K., 2010. HimaTibetMap-1.0: new ‘web-2.0’
 991 online database of active structures from the Indo-Asian collision. *Eos* 91 (20),
 992 181–182. doi:10.1029/2010EO200001.

993 Sumy, D.F., Cochran, E.S., Keranen, K.M., Wei, M., Abers, G.A., 2014. Observations
 994 of static Coulomb stress triggering of the November 2011 M5.7 Oklahoma earthquake
 995 sequence. *J. Geophys. Res.* 119, 1904–1923. doi:10.1002/2013JB010612.

996 Tao, W., Masterlark, T., Shen Z.-K., Ronchin, E., 2015. Impoundment of the
 997 Zipingpu reservoir and triggering of the 2008 Mw 7.9 Wenchuan earthquake. *China. J.*
 998 *Geophys. Res.* 120, 7033–7047. doi:10.1002/2014JB011766.

999 Taylor, M.H., Yin, A., 2009. Active structures of the Himalayan-Tibetan orogen and
 1000 their relationships to earthquake distribution, contemporary strain field, and Cenozoic
 1001 volcanism. *Geosphere* 5 (3), 199–214. doi: 10.1130/GES00217.1.

1002 Toda, S., Lin, J., Meghraoui, M., Stein, R.S., 2008. 12 May 2008 $M = 7.9$ Wenchuan,
 1003 China, earthquake calculated to increase failure stress and seismicity rate on three
 1004 major fault systems. *Geophys. Res. Lett.* 35, L17305. doi:10.1029/2008GL034903.

1005 Toda, S., Stein, R.S., 2015. 2014 M_w 6.0 south Napa earthquake triggered exotic
 1006 seismic clusters near several major faults. *Seismol. Res. Lett.* 86 (6), 1593–1602.
 1007 doi:10.1785/0220150102.

1008 Toda, S., Stein, R.S., Beroza, G.C., Marsan, D., 2012. Aftershocks halted by static
 1009 stress shadows. *Nature Geosci.* 5, 410–413. doi:10.1038/NGEO1465.

1010 Toda, S., Stein, R.S., Richards-Dinger, K., Bozkurt, S.B., 2005. Forecasting the
 1011 evolution of seismicity in southern California: Animations built on earthquake stress
 1012 transfer. *J. Geophys. Res.* 110, B05S16. doi:10.1029/2004JB003415.

1013 Verdecchia, A., Carena, S., 2015. One hundred and fifty years of Coulomb stress
 1014 history along the California-Nevada border, USA. *Tectonics* 34, 213–231.
 1015 doi:10.1002/2014TC003746.

1016 Verdecchia, A., Carena, S., 2016. Coulomb stress evolution in a diffuse plate
 1017 boundary: 1400 years of earthquakes in eastern California and western Nevada, USA.
 1018 *Tectonics* 35, 1793–1811. doi:10.1002/2015TC004091.

1019 Wan, Y., Shen, Z.-K., 2010. Static Coulomb stress changes on faults caused by the
 1020 2008 Mw 7.9 Wenchuan, China earthquake. *Tectonophys.* 491, 105–118.
 1021 doi:10.1016/j.tecto.2010.03.017.

1022 Wang, C.-Y., Han W.-B., Wu J.-P., Lou, H., Chan, W.W., 2007. Crustal structure
 1023 beneath the eastern margin of the Tibetan Plateau and its tectonic implications. *J.*
 1024 *Geophys. Res.* 112, B07307. doi:10.1029/2005JB003873.

1025 Wang, F., Chen, W.T., Wang, M., Shen, Z.K., Wang, Y.Z., Wan, Y.G., 2011.
 1026 Coseismic and postseismic deformation of Ms7.3 Yutian earthquake derived from
 1027 GPS data (*in Chinese with English abstract*). *Chinese J. Geophys.* 54 (9), 2250–2255.
 1028 doi:10.3969/j.issn.0001-5733.2011.09.007.

1029 Wang, R.J., Lorenzo-Martín, F., Frank, R., 2006. PSGRN/PSCMP—a new code for
 1030 calculating co- and post-seismic deformation, geoid and gravity changes based on the
 1031 viscoelastic-gravitational dislocation theory. *Comput. Geosci.* 32 (4), 527–541.
 1032 doi:10.1016/j.cageo.2005.08.006.

1033 Wang, Y.Z., Wang, F., Wang, M., Shen, Z.-K., Wan, Y.G., 2014a. Coulomb stress
 1034 change and evolution induced by the 2008 Wenchuan earthquake and its delayed
 1035 triggering of the 2013 Mw 6.6 Lushan earthquake. *Seismol. Res. Lett.* 85 (1), 52–59.
 1036 doi:10.1785/0220130111.

1037 Wang, J.J., Xu, C.J., Freymueller, J.T., Li, Z.H., Shen, W.B., 2014b. Sensitivity of
 1038 Coulomb stress change to the parameters of the Coulomb failure model: A case study

1039 using the 2008 Mw 7.9 Wenchuan earthquake. J. Geophys. Res. 119, 3371–3392.
 1040 doi:10.1002/2012JB009860.

1041 Wells, D.L., Coppersmith, K.J., 1994. New empirical relationships among magnitude,
 1042 rupture length, rupture width, rupture area, and surface displacement. Bull. Seismol.
 1043 Soc. Am. 84 (4), 974–1002.

1044 Wessel, P., Smith, W.H.F., 1998. New improved version of generic mapping tools
 1045 released, Eos Trans. AGU 79 (47), 579–579. doi:10.1029/98EO00426.

1046 Wu, Y.Q., Jiang, Z.S., Yang, G., Wei, W., Liu, X., 2011. Comparison of GPS strain
 1047 rate computing methods and their reliability. Geophys. J. Int. 185, 703–717.
 1048 doi:10.1111/j.1365-246X.2011.04976.x.

1049 Wu, Y.Q., Jiang, Z.S., Zhao, J., Liu, X., Wei, W., Liu, Q., Li, Q., Zou, Z.Y., Zhang,
 1050 L., 2015. Crustal deformation before the 2008 Wenchuan Ms8.0 earthquake studied
 1051 using GPS data. J. Geodyn. 85, 11–23. <http://dx.doi.org/10.1016/j.jog.2014.12.002>.

1052 Wu, C.Y., Zhang, Z.Q., Zhao, C.P., Wu, G.D., Liu, J.M., Chen, J.B., Hu, W.H., Song,
 1053 H.P., Yao, Y., 2014. 2014 Yutian Ms7.3 earthquake: Structural response of the
 1054 Bayankala tectonic-block to eastward extrusion (*in Chinese with English abstract*).
 1055 Chinese J. Geophys. 57 (10), 3226–3237. doi:10.6038/cjg20141011.

1056 Xu, C.J., Wang, J.J., Li, Z.H., Drummond, J., 2010. Applying the Coulomb failure
 1057 function with an optimally oriented plane to the 2008 Mw 7.9 Wenchuan earthquake
 1058 triggering. Tectonophys. 491, 119–126. doi:10.1016/j.tecto.2009.09.019.

1059 Xu, T., Wu, Z.B., Zhang, Z.J., Tian, X.B., Deng, Y.F., Wu, C.L., Teng, J.W., 2014.
 1060 Crustal structure across the Kunlun fault from passive source seismic profiling in East
 1061 Tibet. *Tectonophys.* 627, 98–107. <http://dx.doi.org/10.1016/j.tecto.2013.11.010>.
 1062 Zeng, Y.H., 2001. Viscoelastic stress-triggering of the 1999 Hector Mine earthquake
 1063 by the 1992 Landers earthquake. *Geophys. Res. Lett.* 28 (15), 3007–3010. doi:
 1064 10.1029/2000GL012806.
 1065 Zhang, Y., Xu, L.S., Chen, Y.T., Wang, R.J., 2014. Fast inversion for the rupture
 1066 process of the 12 February 2014 Yutian Mw6.9 earthquake: Discussion on the
 1067 impacts of focal mechanisms on rupture process inversions (*in Chinese with English*
 1068 *abstract*). *Acta Seismol. Sin.* 36 (2),
 1069 159–164. doi:10.3969/j.issn.0253-3782.2014.02.001.
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Table 1 Occurrence times, hypocenters and focal mechanisms of the eight strong earthquakes.

Event time	Epicenter		Depth (km)	Focal mechanism		Seismic moment (N·m)
	Lat.	Lon.		Plane1 φ	Plane 2	
	(°)	(°)		(°)	(°)	
1997/11/08	35.33	86.96	16.4	79/69/2	348/88/159	2.23e+20
2001/11/14	35.80	92.91	15.0	94/61/-12	190/80/-150	5.90e+20
2008/03/20	35.43	81.37	12.0	203/52/-74	358/41/-110	5.43e+19
2008/05/12	31.44	104.10	12.8	231/35/138	357/68/63	8.97e+20
2010/04/13	33.05	96.79	15.7	300/88/23	210/67/178	2.53e+19
2013/04/20	30.22	103.12	21.9	212/42/100	19/49/81	1.02e+19
2014/02/12	36.22	82.57	18.3	242/86/-5	332/85/-176	2.87e+19
2014/11/22	30.24	101.78	24.6	143/85/-1	233/89/-175	1.90e+18

φ) Nodal plane 1 is considered to be a receiver fault, and all data are from the Global CMT webpage (<http://www.globalcmt.org>).

Table 2 Coseismic Coulomb stress changes induced by preceding earthquakes at the hypocenter of each subsequent earthquake for the Manyi-Kangding sequence^a (unit: bars).

Event	1997	2001	2008Y	2008W	2010	2013	2014Y	Total
2001	0.002632							0.002632
2008Y	-0.007921	0.001390						-0.006531
2008W	0.000140	0.000733	0.000013					0.000886
2010	0.000528	-0.010542	0.000031	-0.004276				-0.014259
2013	0.000177	0.001062	0.000012	0.088132	-0.000038			0.089345
2014Y	-0.020325	0.001480	0.034482	0.000411	0.000029	-0.000008		0.016069
2014K	0.000184	0.001239	0.000019	0.035304	0.000091	0.004555	0.000012	0.041404

a) The earthquake sequence consists of the 1997 Manyi, 2001 Kokoxili, 2008 Yutian, 2008 Wenchuan, 2010 Yushu, 2013 Lushan, 2014 Yutian and 2014 Kangding earthquakes, which are abbreviated as 1997, 2001, 2008Y, 2008W, 2010, 2013, 2014Y, and 2014K, respectively. Hereinafter, all abbreviations of the event names are the same as adopted here.

1104 **Table 3** Postseismic Coulomb stress changes that were induced by preceding
 1105 earthquakes at the hypocenter of each subsequent earthquake for the earthquake
 1106 sequence (unit: bars).

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Event	1997	2001	2008Y	2008W	2010	2013	2014Y	Total
2001	-0.001145							-0.001145
2008Y	-0.001854	-0.000211						-0.002065
2008W	0.000183	0.000250	0.000005					0.000438
2010	-0.000820	-0.008734	0.000006	0.001069				-0.008479
2013	0.001481	0.005095	-0.000057	0.042004	-0.000018			0.048505
2014Y	-0.001189	-0.002268	0.011702	-0.000532	-0.000002	0.000019		0.007730
2014K	0.000205	-0.000959	-0.000028	0.006909	-0.000041	0.002215	-0.000037	0.008264

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Table 4 Net Coulomb stress changes of the combined coseismic, postseismic and
interseismic Coulomb stress changes^a (unit: bars).

Event	Co-CFS	Post-CFS	Co+Post-CFS	Inter-CFS	Net-CFS
2001	0.002632	-0.001145	0.001487	0.059224	0.060711
2008Y	-0.006531	-0.002065	-0.008596	0.041254	0.032658
2008W	0.000886	0.000438	0.001324	0.028958	0.030282
2010	-0.014259	-0.008479	-0.022738	0.134855	0.112117
2013	0.089345	0.048505	0.137850	0.060677	0.198527
2014Y	0.016069	0.007730	0.023799	0.098518	0.122317
2014K	0.041404	0.008264	0.049668	0.289172	0.338840

a) Co-CFS, Post-CFS and Inter-CFS denote the coseismic, postseismic and
interseismic Coulomb stress changes, respectively. Co+Post-CFS represents the
combined coseismic and postseismic Coulomb stress changes. Net-CFS indicates
the combined coseismic, postseismic and interseismic Coulomb stress changes.

Table 5. Statistics of the Coulomb stress changes at each hypocenter of the earthquake sequence.

ΔCFS^a	1997	2001	2008Y	2008W	2010	2013	2014Y	2014K
ΔCFS_{prior}^{co}	0.162735	0.041590	0.121135	0.337166	0.624948	0.091838	0.311260	7.554943
$\Delta CFS_{prior}^{post}$	0.024195	0.095592	0.160526	-0.027922	0.096224	0.158268	0.145464	2.827521
$\Delta CFS_{prior}^{comb}$	0.186930	0.137182	0.281661	0.309244	0.721172	0.250106	0.456724	10.382464
$\Delta CFS_{seque}^{comb}$	0	0.001487	-0.008596	0.001324	-0.022738	0.137850	0.023799	0.049668
$\Delta CFS_{prseq}^{comb}$	0.186930	0.138669	0.273065	0.310568	0.698434	0.387956	0.480523	10.432132

a) ΔCFS_{prior}^{co} indicates the accumulated coseismic Coulomb stress changes imparted by prior earthquakes as shown in Figure 3. $\Delta CFS_{prior}^{post}$ indicates the accumulated postseismic Coulomb stress changes imparted by prior earthquakes as shown in Figure 3. $\Delta CFS_{prior}^{comb}$ is the summation of ΔCFS_{prior}^{co} and $\Delta CFS_{prior}^{post}$. $\Delta CFS_{seque}^{comb}$ indicates the compounded coseismic and postseismic Coulomb stress changes aroused by each earthquake of the Manyi-Kangding sequence as shown in Figure 3. $\Delta CFS_{prseq}^{comb}$ is the summation of $\Delta CFS_{prior}^{comb}$ and $\Delta CFS_{seque}^{comb}$. For $\Delta CFS_{seque}^{comb}$, the starting time of the 1997 ~ 2014 Manyi-Kangding sequence was the occurrence time of the 1997 Manyi earthquake, so no Coulomb stress changes were received from other earthquakes in the sequence at this time.

Table 6. Compounded coseismic and postsesimic Coulomb stress changes (unit: bars) from surrounding earthquakes based on the constant apparent friction model, with the apparent friction coefficients of 0.4 and 0.5 (the latter corresponds to averaging the constant apparent friction model), and on the isotropic poroelastic model, with the friction and Skempton's coefficients both equaling 0.7 following Nalbant and McCloskey (2011). The abbreviations in the first row of this table are the same as in Table 2.

Coefficients	1997	2001	2008Y	2008W	2010	2013	2014Y	2014K
$\mu' = 0.4$	0.186930	0.137182	0.281661	0.309244	0.721172	0.250106	0.456724	10.382464
$\mu' = 0.5$	0.211518	0.156146	0.307560	0.326473	0.991866	0.254875	0.547730	11.573719
$\mu = 0.7 \ B = 0.7$	-0.081134	0.108239	0.216540	0.262051	0.852313	0.132030	0.565165	11.746167

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1169 **Fig. 1.** Seismogenic tectonic region that is associated with eight recent strong
1170 earthquakes. The red beachballs are the eight typical Mw > 6.0 strong mainshocks
1171 from 1997 to 2014 along the periphery of the Bayan Har block. The cyan beachballs
1172 are other focal mechanisms from 1976/1/1 to 2014/11/22 (Table S1). All the focal
1173 mechanisms are from the global CMT webpage (<http://www.globalcmt.org/>). The
1174 pink stars represent large earthquakes from 1411 to 2012 (Table S3). The thick black
1175 lines delineate the major active faults on the Tibetan Plateau (Wu et al., 2014; Jiang et
1176 al., 2015b). The thin black lines are also active faults, and the thick dashed lines are
1177 geological sutures from the ‘HimaTibetMap’ database (Taylor and Yin, 2009; Styron
1178 et al., 2010). The bold black arrows denote plate and block velocities (Wu et al.,
1179 2014). The small red rectangles indicate some cities and counties.

Fig. 2. Coseismic Coulomb stress changes induced by earthquake events from 1976/1/1 to 2014/11/22 with magnitudes $M \geq 6$ and hypocenter depths shallower than 50 km from gCMT. These events are assumed to be point sources. The Coulomb stress changes are resolved on the average focal plane of these earthquake events, with the strike, dip and rake angles being 180° , 58° and 7° , respectively, at an average depth of 17.5 km. The red beachballs are the focal mechanisms of the recent typical large earthquake sequence along the periphery of the Bayan Har block. The small black open circles delineate epicenters of the gCMT events. Each number next to the open circles is the sequential number of each gCMT event (Table S1). The green contours indicate Coulomb stress changes of -0.1 bars and 0.1 bars. These contours depict the effective range of the Coulomb stress changes, beyond which the Coulomb stress change is assumed to be too small to trigger other earthquakes. The black solid

1193 and dashed lines are major faults and sutures (Taylor and Yin, 2009; Styron et al.,
1194 2010).

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1196 **Fig. 3.** Prior $M \geq 6$ large earthquakes (blue stars) around the Manyi-Kangding
1197 sequence (red stars). Above each star is the occurrence time of the corresponding
1198 earthquake event with the magnitude inside brackets. The gray solid and dashed lines
1199 are major faults and sutures (Taylor and Yin, 2009; Styron et al., 2010).

Fig. 4. Earth's velocity and density models from Crust 2.0. (a) Vertical profile of the P and S wave velocities at each epicenter of these strong earthquakes. The bold blue dashed and red lines denote the average S and P wave velocities, respectively. (b) Vertical profile of the density at each hypocenter of these strong earthquakes. The bold spring green line shows the average density.

Fig. 5. Spatial pattern of coseismic Coulomb stress changes from preceding mainshocks on the fault plane of each subsequent mainshock for the Manyi-Kangding sequence. Coulomb stress changes induced by the preceding earthquakes on the receiver fault of (a) the 2001 Kokoxili earthquake, (b) the 2008 Yutian earthquake, (c) the 2008 Wenchuan earthquake, (d) the 2010 Yushu earthquakes, (e) the 2013 Lushan earthquake, (f) the 2014 Lushan earthquake, and (g) the 2014 Kangding earthquake. The red beachballs are the preceding mainshocks, and the blue beachballs are the targeted receiver fault planes to each earthquake for each snapshot. The Coulomb stress changes in each snapshot are resolved onto these receiver faults at their hypocenter depths of 15.0 km, 12.0 km, 12.8 km, 15.7 km, 21.9 km, 18.3 km and 24.6 km (Table 1), respectively. If no special illustrations are shown, hereinafter, receiver faults and sampling depths are the same as used here.

Fig. 6. Same as Figure 5, but for postseismic Coulomb stress changes.

Fig. 7. Same as Figure 5, but for interseismic Coulomb stress changes. (a) This snapshot shows the stress loading from 1997 to 2001, which was resolved on the

receiver fault of the 2001 Kokoxili earthquake; (b) from 1997 to 2008 on the 2008 Yutian earthquake; (c) from 1997 to 2008 on the 2008 Wenchuan earthquake; (d) from 1997 to 2010 on the 2010 Yushu earthquake; (e) from 1997 to 2013 on the 2013 Lushan earthquake; (f) from 1997 to 2014 on the 2014 Yutian earthquake; and (g) from 1997 to 2014 on the 2014 Kangding earthquake.

Fig. 8. Same as Figure 5, but for the net Coulomb stress changes. These Coulomb stress changes are the summation of the coseismic (Figure 5), postseismic (Figure 6), and interseismic (Figure 7) Coulomb stress changes.

Fig. 9. Same as Figure 5, but for the coseismic Coulomb stress changes that were imparted by large surrounding earthquakes, which are shown in Figure 3.

Fig. 10. Same as Figure 9, but for the postseismic Coulomb stress changes.

Fig. 11. Same as Figure 9, but for the combined coseismic and postseismic Coulomb stress changes.

Fig. 12. Spatial patterns of the hypocenters (blue stars) of surrounding earthquakes that imparted coseismic Coulomb stress changes, of which the absolute values are not smaller than 0.01 bars at the hypocenter (red stars) of each earthquake from the Manyi-Kangding earthquake. The gray stars delineate the surrounding earthquakes that induced coseismic Coulomb stress changes that were less than 0.01 bars. a) The text of '1973(7.0,0.15)' marks the 1973 M 7.0 earthquake (the blue star edged in green), which caused the largest coseismic Coulomb stress change (0.15 bars) at the hypocenter of the 1997 Manyi earthquake; b) '1950(8.6,0.02)' marks the 2001 Kokoxili earthquakes; c) '1902(8.6, 0.08)' marks the 2008 Yutian earthquake; d) '1933(7.5,0.35)' marks the 2008 Wenchuan earthquake; e) '1950(8.6,0.63)' marks the 2010 Yushu earthquake; f) '1786(7.7,0.18)' marks the 2013 Lushan earthquake; g) '1902(8.6,0.16)' marks the 2014 Yutian earthquake; and h) '1955(7.5,2.82)' marks the 2014 Kangding earthquake.

Fig. 13. Same as Figure 12, but for the postseismic Coulomb stress changes.

Fig. 14. Sensitivity of (a) coseismic and (b) postseismic Coulomb stress changes to the apparent friction coefficient μ' for the constant apparent friction model

1260 (equation (5)) and to the friction coefficient μ and the Skempton's coefficient B
1261 for the isotropic poroelastic model (equation (6)). For clarity, the coseismic and
1262 postseismic Coulomb stress changes at the hypocenter of the 2014 Kangding
1263 earthquake (deep-green hexagons) were subtracted by 8 bars and 3.4 bars,
1264 respectively. The upper and lower horizontal dashed lines represent Coulomb stress
1265 change of 0.1 bars and -0.1 bars, respectively.
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