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The 1999 M_w 7.1 Hector Mine, California, Earthquake: A Test of the Stress Shadow Hypothesis?

by Ruth A. Harris and Robert W. Simpson

Abstract We test the stress shadow hypothesis for large earthquake interactions by examining the relationship between two large earthquakes that occurred in the Mojave Desert of southern California, the 1992 M_w 7.3 Landers and 1999 M_w 7.1 Hector Mine earthquakes. We want to determine if the 1999 Hector Mine earthquake occurred at a location where the Coulomb stress was increased (earthquake advance, stress trigger) or decreased (earthquake delay, stress shadow) by the previous large earthquake. Using four models of the Landers rupture and a range of possible hypocentral planes for the Hector Mine earthquake, we discover that most scenarios yield a Landers-induced relaxation (stress shadow) on the Hector Mine hypocentral plane. Although this result would seem to weigh against the stress shadow hypothesis, the results become considerably more uncertain when the effects of a nearby Landers aftershock, the 1992 M_L 5.4 Pisgah earthquake, are taken into account. We calculate the combined static Coulomb stress changes due to the Landers and Pisgah earthquakes to range from -0.3 to $+0.3$ MPa (-3 to $+3$ bars) at the possible Hector Mine hypocenters, depending on choice of rupture model and hypocenter. These varied results imply that the Hector Mine earthquake does not provide a good test of the stress shadow hypothesis for large earthquake interactions. We use a simple approach, that of static dislocations in an elastic half-space, yet we still obtain a wide range of both negative and positive Coulomb stress changes. Our findings serve as a caution that more complex models purporting to explain the triggering or shadowing relationship between the 1992 Landers and 1999 Hector Mine earthquakes need to also consider the parametric and geometric uncertainties raised here.

Introduction

Earthquake-interaction models have been presented as a possible step toward understanding earthquake physics. One method that has gained popularity in recent years is the stress change approach, whereby Coulomb failure or another fracture criterion, such as rate-and-state friction or stress corrosion (e.g., Scholz, 1990), is used to determine if one earthquake advanced or delayed the occurrence time of subsequent events. The Coulomb failure formulation in particular employs simple equations and assumptions about the earth's response to earthquakes. The relative simplicity of this method has led to its widespread use over the past 30 years (see Harris, 1998, for a review).

One of the basic tenets of the Coulomb hypothesis is that earthquake-induced stress changes control the timing and locations of subsequent earthquakes. These stress changes may be static (permanent) or dynamic (transient; e.g., the result of seismic waves, or earth tides), but most of the analyses have been based on static stress changes, because these are easier to calculate. In the Coulomb hypothesis, if the static stress change on a specific fault (plane) is negative (a stress shadow), then that fault plane should not produce another earthquake until the stress shadow has been eroded by tectonic or other processes, such as pore-fluid flow. If the static stress change is positive, then the fault plane is deemed to have been advanced toward producing its next earthquake. Some have evaluated the correlation between static stress changes due to moderate and large mainshocks and the subsequent rate changes of small aftershocks (e.g., Reasenberg and Simpson, 1992; Toda *et al.*, 1998). The static stress change calculations for small aftershocks appear to explain the seismicity patterns in the majority of these tested cases, although there are some exceptions (e.g., Hardebeck *et al.*, 1998; Astiz *et al.*, 2000). There are also convincing correlations between static stress changes due to large earthquakes and their moderate-size (M >4–5) aftershocks (e.g., Harris and Simpson, 1992; Harris *et al.*, 1995; Deng and Sykes, 1997a,b, etc.).

The sample size is small, due to sparse data, but calculations have also been performed for the stress effect of great earthquakes on large aftershocks. This relationship is quite important both for the people living in the affected region and for enhancing our understanding of earthquake physics. Two great California earthquakes, the 1857 Ft. Tejon earthquake (Harris and Simpson, 1996; Deng and Sykes, 1997a) and the 1906 San Francisco earthquake (Simpson and Reasenberg, 1994; Jaumé and Sykes, 1996; Harris and Simpson, 1998) shut down large earthquakes on faults that were relaxed by these great events. In each case, the stress change effect has lasted for decades.

Although it appears that stress changes due to great earthquakes can affect subsequent large earthquakes and that stress changes due to large earthquakes can affect subsequent smaller earthquakes, we have limited detailed information about the potential impact of large earthquakes on equal or greater-size aftershocks (mainshocks). Great earthquakes are relatively rare, but numerous large earthquakes will occur within our lifetimes; it would therefore be quite helpful to understand the relationship between these large and potentially devastating events (e.g., Stein *et al.*, 1994, 1997). In the 1990s the eastern California shear zone (Mojave Desert) of southern California provided us with this study opportunity; two large earthquake occurred within 7 years and 30 km (Fig. 1).

In this article we continue the test of the static stress change hypothesis in an attempt to understand the relationship between the two large earthquakes in southern California. We explore two questions: (1) Did the hypocenter of the second large earthquake, the 1999 M_w 7.1 Hector Mine earthquake, occur in a calculated stress shadow of the first large event, the 1992 M_w 7.3 Landers earthquake? (as proposed by Scientists of the USGS *et al.*, [2000]), or (2) Did the hypocenter of the second large earthquake, the 1999 M_w 7.1 Hector Mine earthquake, not occur in a calculated stress shadow? (as proposed by Parsons and Dreger [2000]). If the Hector Mine earthquake did occur in a stress shadow, then we may need to refine or discard the stress shadow concept for large earthquake interactions.

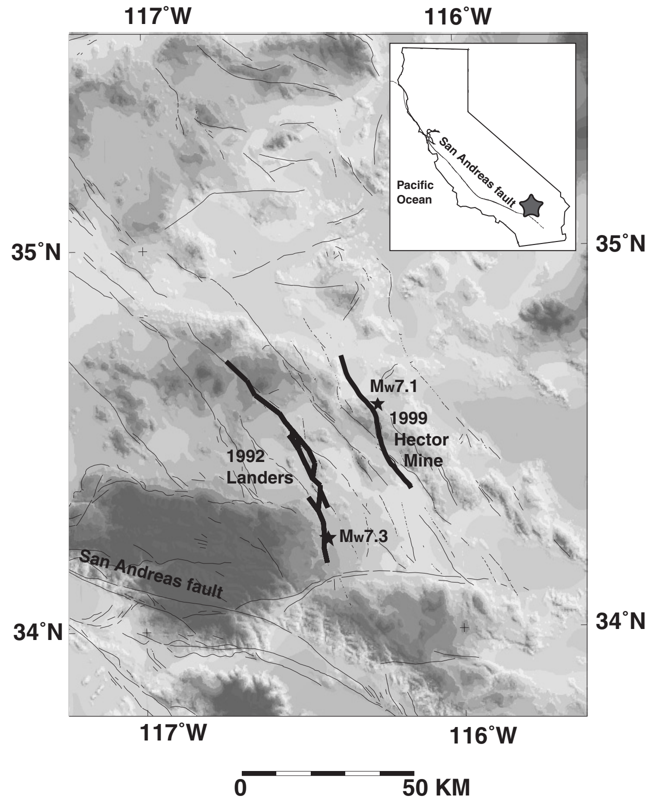

Figure 1. Setting of the 1992 M_w 7.3 Landers and 1999 M_w 7.1 Hector Mine earthquakes in southern California. Stars show the Hector Mine and Landers epicenters. The Hector Mine fault trace is from Treiman *et al.* (2002). The Landers fault trace is from Hudnut *et al.* (1994)

The Method

We employ the Coulomb failure stress change (ΔCFS) approach and evaluate the stress changes generated by the 1992 Landers earthquake on the hypocenter of the 1999 Hector Mine earthquake. The ΔCFS approach (see Harris, 1998, for a review) uses dislocation theory in an elastic half-space (Okada, 1992) and models the stress changes due to slip on one or more fault planes. We use the simple equation

$$\Delta\mathrm{CFS} = \Delta\tau + \mu(\Delta\sigma + \Delta p), \quad (1)$$

where ΔCFS is the change in Coulomb failure stress, $\Delta\tau$ is the change in shear stress resolved on the fault plane in the slip-direction of interest, μ is the coefficient of friction, $\Delta\sigma$ is the change in normal stress for that fault plane (positive for unclamping or tension), and Δp is the change in pore pressure. We assume, following Rice and Cleary (1976) and Roeloffs (1988), that

$$\Delta p = -B'(\Delta\sigma_{xx} + \Delta\sigma_{yy} + \Delta\sigma_{zz})/3, \quad (2)$$

where B', which is for rock, is similar to Skempton's (1954) coefficient for soils, and $\Delta\sigma_{xx}$, $\Delta\sigma_{yy}$, and $\Delta\sigma_{zz}$ are the diagonal elements of the stress tensor.

We take $B' = 1.0$, which is an upper bound that maximizes the pore-pressure effect. We use $\mu = 0.7$, which is an intermediate value between Byerlee's (1978) $\mu = 0.6$ for laboratory observations at low normal stress and $\mu = 0.85$ for observations at high normal stress. $\Delta\sigma$ is positive for relative tension. If ΔCFS is positive, the location on the fault plane is said to be advanced toward failure; if it is negative, the location is said to be delayed from failure, or in a stress shadow.

Immediately after an earthquake, with the pore fluids in an undrained state, pore pressures on nearby faults may be changing with time as the fluids flow. To evaluate this situation we include the Δp term in equation (1). It is possible that with passing time, the pore fluids re-equilibrate. We therefore also evaluate equation (1) with the other endmember value $\Delta p = 0$ for each of our earthquake interaction models.

The Earthquakes

1992 Landers

The 1992 M_w 7.3 Landers, California, earthquake ruptured at least five faults in the eastern California shear zone of southern California (Sieh *et al.*, 1993). We use dislocation models of the earthquake inferred from a combination of geodetic and seismological data (Wald and Heaton, 1994) and inferred from geodetic data (Hudnut and Larsen, 1993; Hudnut *et al.*, 1994; K. Hudnut, written comm., March 2000). Figure 2 shows the dislocation models in map view. The Wald and Heaton (1994) model consists of three fault planes with right-lateral strike-slip representing the Landers main rupture, and two additional planes representing slip during the 1992 M 6.2 Big Bear earthquake and slip on the Eureka Peak fault segment (Fig. 2a). The Wald and Heaton (1994) model has variable slip with depth. The Hudnut *et al.* (1994) model uses a more complex fault geometry but has slip extending uniformly down from the Earth's surface. Similar to the Wald and Heaton (1994) model, the Hudnut *et al.* model (1994) includes the 1992 Big Bear earthquake and Eureka Peak segments, but unlike the Wald and Heaton (1994) model, the Hudnut *et al.* (1994) model includes slip on a cross-fault extending west–east from the main Landers rupture (Fig. 2b). We examine the Parsons and Dreger (2000) model, which is a variation on the Wald and Heaton (1994) model and also includes a plane representing the 1992 M 6.1 Joshua Tree earthquake (Fig. 2c), and a slip model that is the same as the fault trace of Hudnut *et al.* (1994) (Fig. 2b) but has variable slip with depth (Hudnut and Larsen, 1993).

1999 Hector Mine

The 1999 M_w 7.1 Hector Mine, California earthquake occurred 30 km to the east of Landers and ruptured two known faults in the eastern California shear zone, the Lavic Lake and Bullion faults (Scientists of the USGS *et al.*, 2000). Seismological models of this earthquake show the event to have propagated bilaterally, but with slip primarily concentrated in the hypocentral region (Kaverina *et al.*, submitted). The centroid of moment release was much deeper (Ji *et al.*, 2000; Scientists of the USGS *et al.*, 2000), but the hypocentral depth from first motions was 4.5 ± 3 km (Hauksson *et al.*, 2002). From first motions, the hypocentral strike, dip, and rake of the Hector Mine earthquake were N6W, 81°, and 149°, respectively, at −116.27°W longitude, 34.60°N latitude (Hauksson et al., 2002).

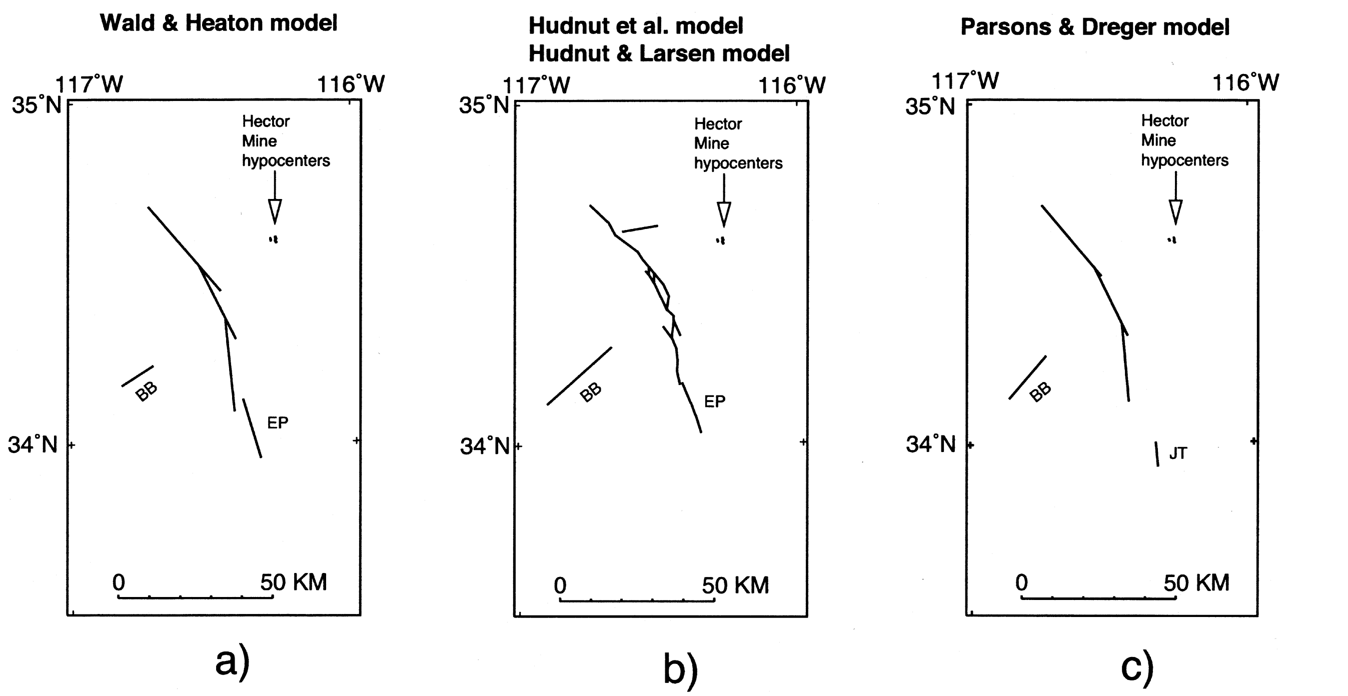

Figure 2. Map view of the four dislocation models (lines) and the 10 Hector Mine hypocenters (dots) used in our calculations. The hypocenters are described in Table 1 and in the text. The dislocation models are presented in tabular from in Appendix A. (a) The Wald and Heaton (1994) model; (b) Hudnut *et al.* (1994) model and Hudnut and Larsen (1993) model; (c) Parson and Dreger (2000) model. In each figure BB is the Big Bear earthquake dislocation and EP is the Eureka Peak fault segment; JT is the Joshua Tree earthquake dislocation.

We evaluate the stress changes generated by the 1992 Landers earthquake, resolved onto the possible hypocenters of the 1999 Hector Mine earthquake (Table 1). We calculate the stress changes at hypocentral depths of 1.5, 4.5, and 7.5 km and strike of 354° for the Hauksson *et al.* (2002) focal mechanism, at a hypocentral depth of 6.0 km and strikes of 325° and 345° for the mechanism proposed by Kaverina *et al.* (2002), at 5.0 and 13.5 km depth and 331° strike as proposed by Scientists of the USGS *et al.*, (2000) and for 6.0 km depth and 343° strike, which was the initial mechanism released on the Hector Mine website shortly after the earthquake. We also calculate the stress changes at the hypocenters described in Parsons and Dreger (2000), 6.0 km depth and strikes of 325° and 345°. The hypocenter information is detailed in Table 1. We now present the Coulomb stress change results. For the reader interested in the fine details of our models and findings, the Landers dislocation models that we used are in Appendix A and the resulting shear and normal stress components that we calculated are in Appendix B.

Results

Table 1 summarizes the Coulomb stress changes due to the four Landers models at the Hector Mine hypocenters. The details are as follows:

Wald and Heaton (1994) Model

Calculations using purely elastic assumptions about the earth's crust and upper mantle show the Wald and Heaton (1994) strike-slip model of the 1992 Landers earthquake (Fig. 2a) generating ΔCFS ranging from -0.085 to $+0.040$ MPa (-0.85 to $+0.40$ bars) at the possible hypocenters of the Hector Mine earthquake (Table 1). This range of values for ΔCFS seems to indicate that the Hector Mine hypocenter could have been delayed ($\Delta\text{CFS} < 0$) or advanced ($\Delta\text{CFS} > 0$) by the 1992 Landers earthquake, although the overall impression is that of a stress shadow ($\Delta\text{CFS} < 0$). For the Hauksson *et al.* (2002) mechanisms, rows 1, 2, and 3 in Table 1, the range for ΔCFS is -0.065 to $+0.011$ MPa (-0.65 to $+0.11$ bars).

Hudnut *et al.* (1994) Model

Calculations using the Hudnut *et al.* (1994) model (Fig. 2b) generate ΔCFS ranging from -0.176 to $+0.044$ MPa overall (Table 1). This range of ΔCFS once again indicates possible stress shadow or advance, although most values tend to be stress shadows. At the Hauksson *et al.* (2002) hypocenters, rows 1, 2, and 3 in Table 1, ΔCFS ranges from -0.176 to -0.056 MPa, indicating a stress shadow.

Parsons and Dreger (2000) Model

We determine ΔCFS at the Hector Mine hypocenter using the model described in Parsons and Dreger (2000) (Fig. 2c) and find -0.043 to $+0.041$ MPa overall, a stress shadow or advance, and -0.021 to $+0.029$ MPa for the Hauksson *et al.* (2002) hypocenters, rows 1, 2, and 3 in Table 1, indicating a stress shadow or advance. The calculations show a stress shadow ($\Delta\text{CFS} < 0$) of -0.005 to -0.027 MPa at the Parsons and Dreger (2000) hypocenters, which are hypocentral mechanisms 9 and 10 in Table 1. For comparison, Parsons and Dreger (2000) used $\mu = 0.8$, $\Delta p = 0$ in their publication, which leads to $\Delta\text{CFS} = -0.001$ and $+0.007$ MPa (not shown in Table 1, which uses $\mu = 0.7$ and $\Delta p = 0$ or $\mu = 0.7$ and Δp) at their hypocenters (mechanisms 9 and 10, respectively), a very small stress de-

Table 1
Effect of Landers Earthquakes on Hector Mine Hypocenter under Four Models

	Hector Mine Hypocenter					ΔCFS (MPa) due to Landers Model of							
						Wald and Heaton (1994)		Hudnut *et al.* (1994)		Parsons and Dreger (2000)		Hudnut and Larsen (1993)	
No.*	Lat., Long (°N, °W)	Depth (km)	Strike (°)	Dip (°E)	Rake (°)	$\mu = 0.7$, $\Delta p = 0$ (A)	$\mu = 0.7$, Δp (B)	$\mu = 0.7$, $\Delta p = 0$ (C)	$\mu = 0.7$, Δp (D)	$\mu = 0.7$, $\Delta p = 0$ (E)	$\mu = 0.7$, Δp (F)	$\mu = 0.7$, $\Delta p = 0$ (G)	$\mu = 0.7$, Δp (H)
1	34.5968, 116.2705	1.5	354	81	149	−0.030	−0.065	−0.065	−0.176	−0.004	−0.021	−0.139	−0.210
2	34.5968, 116.2705	4.5	354	81	149	−0.015	−0.048	−0.068	−0.171	0.010	−0.007	−0.125	−0.191
3	34.5968, 116.2705	7.5	354	81	149	0.011	−0.023	−0.056	−0.149	0.029	0.011	−0.100	−0.161
4	34.5900, 116.2700	6.0	345	77	180	−0.051	−0.077	−0.057	−0.147	−0.018	−0.029	−0.146	−0.202
5	34.5900, 116.2700	6.0	325	77	180	−0.042	−0.067	0.026	−0.064	−0.025	−0.035	−0.069	−0.125
6	34.5900, 116.2700	5.0	331	77	180	−0.059	−0.085	−0.007	−0.100	−0.033	−0.043	−0.109	−0.166
7	34.5900, 116.2700	13.5	331	77	180	0.040	0.012	0.028	−0.038	0.041	0.026	−0.022	−0.066
8	34.6000, 116.2700	6.0	343	70	175	−0.008	−0.045	−0.034	−0.134	0.013	−0.007	−0.104	−0.170
9	34.5955, 116.2879	6.0	345	77	180	−0.037	−0.079	−0.057	−0.172	−0.005	−0.027	−0.156	−0.232
10	34.5955, 116.2879	6.0	325	77	180	−0.012	−0.053	0.044	−0.071	0.001	−0.021	−0.067	−0.143

*1, First-motion solution from Hauksson *et al.* (2002); 2, first-motion solution from Hauksson *et al.* (2002); 3, first-motion solution from Hauksson *et al.* (2002); 4, from Kaverina *et al.* (2002); 5, from Kaverina *et al.* (2002); 6, preliminary mechanism published in Scientists of the USGS *et al.* (2000); 7, explores the effect near the preliminary centroid depth (Scientists of the USGS *et al.*, 2000); 8, mechanism originally released on the Hector Mine Website shortly after the earthquake; 9, hypocenter from Parsons and Dreger (2000); 10, hypocenter from Parsons and Dreger (2000).

Δp is defined by equation (2).

lay or advance. Our calculated Parsons and Dreger value using $\mu = 0.8$, $\Delta p = 0$ differs significantly from the $+0.05$ MPa result presented by Parsons and Dreger (2000), whereas one might expect our and their results to be the same. Both calculations used the same values for the shear modulus and the same computer program to calculate stress changes. The discrepancy occurs because Parsons and Dreger (2000) did not do the exact ΔCFS calculation at their Hector Mine hypocenters but instead estimated the value from their Figure 2 (Tom Parsons, personal comm., 9 May 2001).

Hudnut and Larsen (1993) Model

The Hudnut and Larsen (1993) model uses the same fault trace (Fig. 2b) but is more complex than the Hudnut *et al.* (1994) model in that slip is allowed to vary with depth. Calculations using purely elastic assumptions about the earth's crust and upper mantle show the Hudnut and Larsen (1993) strike-slip model of the 1992 Landers earthquake generating ΔCFS ranging from -0.022 to -0.232 MPa overall and -0.100 to -0.210 MPa for the Hauksson *et al.* (2002) hypocenters (Table 1). This range of values shows consistent $\Delta CFS < 0$ (stress shadow), or delay of the Hector Mine hypocenter by the Landers earthquake.

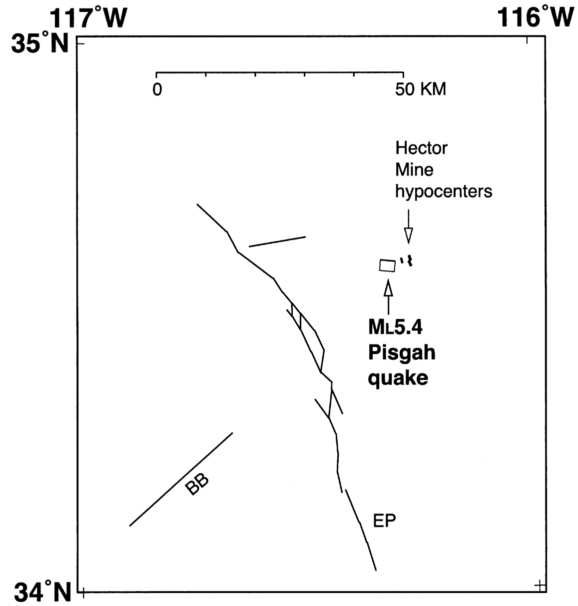

Figure 3. Map view of our dislocation model for the 1992 M_L 5.4 Pisgah earthquake (small square) and the 10 Hector Mine hypocenters (dots) used in our calculations. The Hudnut *et al.* (1994) fault model for Landers is shown for reference. The 1992 Pisgah earthquake, an aftershock of Landers (Harris and Simpson, 1992; Hauksson *et al.*, 1993), is described in the text. Note the close proximity of the 1992 Pisgah quake to the 1999 Hector Mine hypocenters.

Discussion

The 1992 Landers earthquake propelled the theory of static stress change calculations into the limelight when it was shown that elastic dislocation models of the earthquake predicted stress loading ($\Delta CFS > 0$) at the site of the subsequent 28 June 1992 *M* 6.2 Big Bear aftershock and on the San Bernardino segment of the San Andreas fault (Harris and Simpson, 1992; Jaumé and Sykes, 1992; Stein *et al.*, 1992). An encouraging aspect of these results is that three research groups using three models of the Landers earthquake and three slightly different methodologies arrived at the same conclusion about the magnitude of the Coulomb stress changes. In contrast, the story does not appear as straightforward for the Landers–Hector Mine relationship. There is also an additional complication which has not yet been considered.

1992 Pisgah Earthquake

The Earth's crust was not seismically inactive during the time between the large June 1992 and October 1999 earthquakes. In fact, one moderate aftershock of Landers occurred quite close to the eventual Hector Mine hypocenter, the M_L 5.4 5 July 1992 Pisgah fault earthquake (Harris and Simpson, 1992; Hauksson *et al.*, 1993) (Fig. 3). We therefore also need to calculate the stress change effect of this additional 1992 quake on the 1999 hypocenters, using the elastic calculations.

Our model of the moderate 1992 Pisgah earthquake is not well constrained, but hypocentral information is attainable. We determined the Pisgah earthquake's epicentral location, and strike, dip, rake, and depth values by relocating the earthquake using the phase-data catalog (Southern California Earthquake Data Center). The data allow two possible focal mechanisms, and each focal mechanism allows two possible fault plane solutions. Fortunately, this earthquake did generate aftershocks, and therefore it is possible to discover which fault plane was the active one. This exercise, which was performed earlier by Hauksson et al. (1993), allows us to choose the east–west striking fault plane (Table 2). Our fault plane solution is unable to constrain the depth of the hypocenter, but Hauksson *et al.* (1993) found 7.5 km, so we use their depth. The dislocation slip magnitude is assigned based on the Pisgah earthquake's rake, magnitude (M_L 5.4), and the moment–magnitude relationship (Hanks and Kanamori, 1979)

$$\text{magnitude} = (\log_{10}\text{moment} - 16)/1.5 \qquad (3)$$

We now calculate the ΔCFS values for the 1992 Pisgah earthquake at the hypocenter of the 1999 Hector Mine earthquake (Table 3). We find that the Pisgah earthquake influenced the ΔCFS stress changes at Hector Mine by -0.211 to $+0.282$ MPa overall and -0.035 to $+0.282$ MPa at the Hauksson *et al.* (2002) hypocenters (numbers 1 to 3 in Table 3), leading to either a stress shadow or stress advance. The magnitudes

Table 2
Pisgah Earthquake Fault Plan Information

Latitude (°N)	Longitude (°W)	Depth (km)	Strike (°)	Dip (°)	Rake (°)
34.5863	116.3202	7.5	95	45	40

of these stress changes are at least as large as those produced by the 1992 Landers earthquake.

1992 Landers Earthquake + 1992 Pisgah Earthquake

When we include the effects of the significant Pisgah earthquake we are reminded about the sensitivity of the Coulomb stress changes (ΔCFS) at the Hector Mine hypocenter to the as yet unknown fine details of the Landers earthquake, the Pisgah earthquake, the Hector Mine hypocenter, and the pore-pressure change, Δp. At the Hector Mine hypocenter the summed effects of Landers and Pisgah (Table 3; Fig. 4) range from ΔCFS = −0.348 to +0.311 MPa (−3.48 to +3.11 bars).

For each Landers model and the individual hypocenters the specific results are: ΔCFS = −0.271 to +0.293 MPa for the Wald and Heaton (1994) Landers model, −0.282 to +0.226 MPa for the Hudnut *et al.* (1994) Landers model, −0.244 to +0.311 MPa for the Parsons and Dreger (2000) Landers model, and −0.348 to +0.182 MPa for the Hudnut and Larsen (1993) Landers model. If we examine only the Hauksson *et al.* (2002) hypocenters (rows 1 to 3 in Table 3), the range over all of the slip models is −0.240 to +0.311 MPa. All of these cases show the Hector Mine earthquake occurring in either a stress shadow or a stress advanced region, with static stress changes thought to be of significantly high value (±0.3 MPa) relative to the few hundredths of a megapascal thought to affect seismicity patterns (Reasenberg and Simpson, 1992; Anderson and Johnson, 1999).

Implications for Other Types of Modeling

We have just shown that the hypocenter of the 1999 Hector Mine earthquake may have occurred in a location advanced toward failure (ΔCFS > 0) by its largest recent predecessors or may have occurred in a location delayed from failure (stress shadow; ΔCFS < 0) by its predecessors. Since the Lavic Lake and Bullion faults, on which the Hector Mine earthquake occurred, appear to have very slow long-term slip rates on the order of 0.1 to 1 mm/year (M. Rymer, personal comm., October 2000), the magnitude of our calculated stress changes, up to 0.3 MPa of positive or negative stress increment, should have significantly affected the timing of the Hector Mine earthquake. (For example, a very simple calculation assuming 1 mm/yr of pure strike-slip motion on a deep extension of the Hector Mine fault plane results in only 0.001 MPa stress change over a 7-year period, at a 7.5-km-deep hypocenter.). The ambiguity in our results, whereby we calculate significantly large values of both positive and negative ΔCFS values, is therefore troubling. Our findings are even more troubling when we consider that the calculations were very simple and included only the possible static elastic effects for a homogeneous medium, whereas we know that in the real Earth there are numerous complexities that we have not accounted for. Included among these are that the area between Landers and Hector Mine is not homogeneous rock (e.g., Langenheim and Jachens, 2002), and, over the time period of 7 years, such as that which elapsed between the two large earthquakes, other earth processes such as viscoelasticity in the region (e.g., Deng *et al.*, 1998; Pollitz *et al.*, 2000), must be important. However, unless the magnitudes of these other earth processes are shown to be much greater than the uncertainty range for the elastic ΔCFS static stress calculations provided here (e.g., >0.3

Table 3
Effect of the Pisgah Earthquake and of the Pisgah and Landers Earthquakes Combined on the Hector Mine Hypocenter

	Hector Mine Hypocenter					ΔCFS (Mpa) due to Pisgah Earthquake		ΔCFS (Mpa) due to Pisgah and Landers Earthquakes under Landers Model of							
								Wald and Heaton (1994)		Hudnut et al. (1994)		Parsons and Dreger (2000)		Hudnut and Larsen (1993)	
No.	Lat., Long (°N, °W)	Depth (km)	Strike (°)	Dip (°E)	Rake (°)	μ = 0.7, Δp = 0	μ = 0.7, Δp	μ = 0.7, Δp = 0 (A)	μ = 0.7, Δp (B)	μ = 0.7, Δp = 0 (C)	μ = 0.7, Δp (D)	μ = 0.7, Δp = 0 (E)	μ = 0.7, Δp (F)	μ = 0.7, Δp = 0 (G)	μ = 0.7, Δp (H)
1	34.5968, 116.2705	1.5	354	81	149	−0.023	−0.030	−0.053	−0.095	−0.088	−0.206	−0.027	−0.051	−0.163	−0.240
2	34.5968, 116.2705	4.5	354	81	149	−0.035	−0.019	−0.050	−0.067	−0.104	−0.190	−0.025	−0.026	−0.161	−0.210
3	34.5968, 116.2705	7.5	354	81	149	0.282	0.217	0.293	0.193	0.226	0.068	0.311	0.228	0.182	0.056
4	34.5900, 116.2700	6.0	345	77	180	−0.035	−0.021	−0.086	−0.098	−0.092	−0.168	−0.053	−0.050	−0.181	−0.223
5	34.5900, 116.2700	6.0	325	77	180	−0.132	−0.119	−0.174	−0.186	−0.106	−0.183	−0.157	−0.154	−0.202	−0.244
6	34.5900, 116.2700	5.0	331	77	180	−0.211	−0.181	−0.271	−0.266	−0.219	−0.282	−0.244	−0.224	−0.320	−0.348
7	34.5900, 116.2700	13.5	331	77	180	−0.000	−0.007	+0.040	0.006	0.027	−0.045	+0.041	0.019	−0.022	−0.073
8	34.6000, 116.2700	6.0	343	70	175	0.170	0.148	0.162	0.103	0.136	0.013	0.183	0.141	0.066	−0.023
9	34.5955, 116.2879	6.0	345	77	180	0.153	0.182	0.115	0.103	0.096	0.010	0.148	0.155	−0.003	−0.050
10	34.5955, 116.2879	6.0	325	77	180	−0.174	−0.145	−0.186	−0.198	−0.130	−0.216	−0.173	−0.166	−0.241	−0.288

For reference notes on 1 to 10, see Table 1.

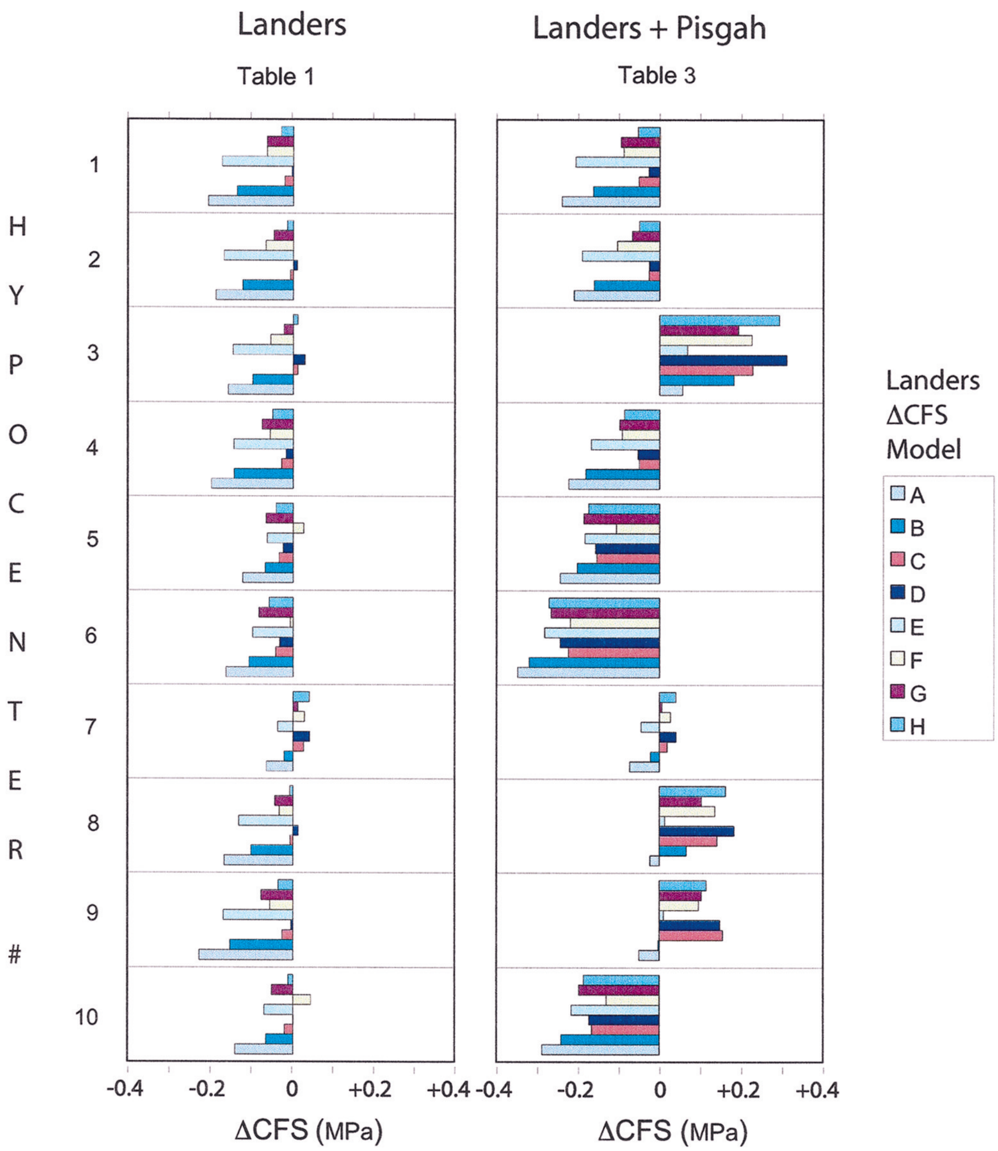

Figure 4. Coulomb stress changes due to the Landers (left) and both Landers and Pisgah (right) earthquakes at the 10 possible Hector Mine hypocenters. The Landers models (A–H) are the same as those described in the text (and labeled A to H in Tables 1 and 3). Models A, C, E, and G are for ΔCFS calculations using $\mu = 0.7$, $\Delta p = 0$; models B, D, F, and H are for ΔCFS calculations using $\mu = 0.7$, Δp. The hypocenters (1–10) are the same as those mentioned throughout the text and tables. The left figure presents the same results as those written in Table 1, but in histogram format; the right figure presents the same results as those written in Table 3, but in histogram format.

MPa), it will be difficult to prove which effect was most critical for the occurrence of the Hector Mine earthquake. For example, three publications proposed that viscoelastic stress changes during the postseismic period after the Landers earthquake helped trigger the Hector Mine earthquake (Freed and Lin, 2001; Pollitz and Sacks, 2002; Zeng, 2001). Freed and Lin (2001) arrived at 0.1 to 0.2 MPa viscoelastic stress transfer and both Pollitz and Sacks (2002) and Zeng (2001) calculated approximately 0.1 MPa of viscoelastic stress transfer between Landers and Hector Mine. None of these publications presented a value of postseismic stress transfer that comes close to the 0.3 MPa of uncertainty that we demonstrate in the coseismic stress change; therefore, the calculated postseismic stress change is difficult to defend as a triggering agent. To summarize, due to the uncertainties in essential parameters, it does not appear possible to determine if the Hector Mine hypocenter occurred in a stress-enhanced or stress-shadowed location. We have been limited by our lack of precise knowledge about the Hector Mine earthquake itself, and the appropriate model for the Landers earthquake. Therefore, unless more precise information about the Hector Mine hypocenter and the Landers and Pisgah earthquakes' slip becomes available, which seems unlikely, the 1999 M_w 7.1 Hector Mine earthquake cannot provide a good test of the stress shadow hypothesis for large earthquake interactions.

Conclusions

Calculations using Coulomb stress changes and simple elastic models of the 1992 Landers earthquake do not produce consistent results at the hypocenter of the 1999 Hector Mine earthquake. Instead the results depend on the Landers model, the exact (unknown) hypocentral location and focal mechanism of Hector Mine, and whether or not pore-pressure changes are included in the calculations. In addition to these complications, a 1992 moderate aftershock of Landers occurred quite close to the Hector Mine hypocenter and produced stress changes comparable to or larger than those produced by Landers. These findings demonstrate that the Hector Mine earthquake is a poor test of the stress shadow hypothesis for large earthquake interactions. These results also show that more comprehensive (e.g., viscoelastic, rate-and-state friction, etc.) studies that propose to explain the 7-year interevent timing may be difficult to defend unless more precise information becomes available for the Landers earthquake, its aftershocks, and the Hector Mine hypocenter.

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References

Anderson, G., and H. Johnson (1999). A new statistical test for static stress triggering: application to the 1987 Superstition Hills earthquake sequence, *J. Geophys. Res.* **104,** 20,153–20,168.

Astiz, L., P. M. Shearer, and D. C. Agnew (2000). Precise relocations and stress-change calculations for the Upland earthquake sequence in southern California, *J. Geophys. Res.* **105,** 2937–2954.

Byerlee, J. D. (1978). Friction of rocks, *Pure Appl. Geophysics* **116,** 615–626.

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

Deng, J., and L. R. Sykes (1997b). Stress evolution in southern California and triggering of moderate-, small-, and micro-size earthquakes, *J. Geophys. Res.* **102,** 24,411–24,435.

Deng, J., M. Gurnis, H. Kanamori, and E. Hauksson (1998). Viscoelastic flow in the lower crust after the 1992 Landers, California, earthquake, *Science* **282,** 1689–1692.

Freed, A. M., and J. Lin (2001). Delayed triggering of the 1999 Hector Mine earthquake by viscoelastic stress transfer, *Nature* **411,** 180–183.

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

Hardebeck, J. L., J. J. Nazareth, and E. Hauksson (1998). The static stress change triggering model: constraints from two southern California aftershock sequences, *J. Geophys. Res.* **103,** 24,427–24,437.

Harris, R. A. (1998). Stress triggers, stress shadows, and implications for seismic hazard, introduction to the special issue, *J. Geophys. Res.* **103,** 24,347–24,358.

Harris, R. A., and R. W. Simpson (1992). Changes in static stress on southern California faults after the 1992 Landers earthquake, *Nature* **360,** 251–254.

Harris, R. A., and R. W. Simpson (1996). In the shadow of 1857: effect of the Great Ft. Tejon earthquake on subsequent earthquakes in southern California, *Geophys. Res. Lett.* **23,** 229–232.

Harris, R. A., and R. W. Simpson (1998). Suppression of large earthquakes by stress shadows: a comparison of Coulomb and rate-and-state failure, *J. Geophys. Res.* **103,** 24,439–24,451.

Harris, R. A., R. W. Simpson, and P. A. Reasenberg (1995). Influence of static stress changes on earthquake locations in southern California, *Nature* **375,** 221–224.

Hauksson, E., L. M. Jones, and K. Hutton (2002). The 1999 M_w 7.1 Hector Mine, California earthquake sequence: complex conjugate strike-slip faulting, *Bull. Seism. Soc. Am.* **92,** 1154–1170 (this issue).

Hauksson, E., L. M. Jones, K. Hutton, and D. Eberhart-Phillips (1993). The 1992 Landers earthquake sequence: seismological observations, *J. Geophys. Res.* **98,** 19,835–19,858.

Hudnut, K. W., and S. C. Larsen (1993). Slip distribution in the 1992 Landers, California earthquake sequence determined from geodetic data, *EOS Trans. Am. Geophys. Union* **74,** 183.

Hudnut, K. W., Y. Bock, M. Cline, P. Fang, Y. Feng, J. Freymueller, X. Ge, K. Gross, D. Jackson, M. Kim, N. King, J. Langbein, S. Larsen, M. Lisowski, Z. Shen, J. Svarc, and J. Zhang (1994). Co-seismic displacements of the 1992 Landers earthquake sequence, *Bull. Seism. Soc. Am.* **84,** 625–645.

Jaumé, S. C., and L. R. Sykes (1992). Change in the state of stress on the southern San Andreas fault resulting from the California earthquake sequence of April to June 1992, *Science* **258,** 1325–1328.

Jaumé, S. C., and L. R. Sykes (1996). Evolution of moderate seismicity in the San Francisco Bay region, 1850 to 1993: seismicity changes related to the occurrence of large and great earthquakes, *J. Geophys. Res.* **101,** 765–789.

Ji, C., D. J. Wald, and D. V. Helmberger (2000). Slip history of the 1999 Hector Mine, California earthquake, *Seism. Res. Lett.* **71,** 224.

Kaverina, A., D. Dreger, and E. Price (2002). The combined inversion of seismic and geodetic data for the source process of the 16 October 1999 M_w 7.1 Hector Mine, California, earthquake, *Bull. Seism. Soc. Am.* **92,** 1266–1280 (this issue).

Langenheim, V. E., and R. C. Jachens (2002). The Emerson Lake body: a link between the Landers and Hector Mine earthquakes, southern California, as inferred from gravity and magnetic anomalies, *Bull. Seism. Soc. Am.* **92,** 1606–1620 (this issue).

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

Parsons, T., and D. S. Dreger (2000). Static-stress impact of the 1992 Landers earthquake sequence on nucleation and slip at the site of the 1999 $M = 7.1$ Hector Mine earthquake, southern California, *Geophys. Res. Lett.* **27,** 1949–1952.

Pollitz, F. F., and I. S. Sacks (2002). Stress triggering of the 1999 Hector Mine earthquake by transient deformation following the 1992 Landers earthquake, *Bull. Seism. Soc. Am.* **92,** 1487–1496 (this issue).

Pollitz, F. F., G. Peltzer, and R. Bürgmann (2000). Mobility of continental mantle: evidence from postseismic geodetic observations following the 1992 Landers earthquake, *J. Geophys. Res.* **105,** 8035–8054.

Reasenberg, P. A., and R. W. Simpson (1992). Response of regional seismicity to the static stress change produced by the Loma Prieta earthquake, *Science* **255,** 1687–1690.

Rice, J. R., and M. P. Cleary (1976). Some basic stress diffusion solutions for fluid-saturated elastic porous media with compressible constituents, *Rev. Geophys. Space Phys.* **14,** 227–241.

Roeloffs, E. A. (1988). Fault stability changes induced beneath a reservoir with cyclic variations in water level, *J. Geophys. Res.* **93,** 2107–2124.

Scholz, C. H. (1990). *The Mechanics of Earthquakes and Faulting*, Cambridge Univ. Press, New York, 439 pp.

Scientists of the U. S. Geological Survey, Southern California Earthquake Center, and California Division of Mines and Geology (2000). Preliminary report on the 16 October 1999 *M* 7.1 Hector Mine, California, earthquake, *Seism. Res. Lett.* **71,** 11–23.

Sieh, K. E., L. M. Jones, E. Hauksson, K. W. Hudnut, D. Eberhart-Phillips, T. H. Heaton, S. E. Hough, L. K. Hutton, H. Kanamori, A. Lilje, S. C. Lindvall, S. F. McGill, J. J. Mori, C. M. Rubin, J. A. Spotila, J. M. Stock, H. K. Thio, J. A. Treiman, B. P. Wernicke, and J. Zachariasen (1993). Near-field investigations of the Landers earthquake sequence, April to July 1992, *Science* **260,** 171–176.

Simpson, R. W., and P. A. Reasenberg (1994). Earthquake-induced static stress changes on central California faults, in *The Loma Prieta, California, Earthquake of October 17, 1989: Tectonic Processes and Models*, R. W. Simpson (Editor), *U.S. Geological Survey Profess. Pap. 1550-F*.

Skempton, A. W. (1954). The pore-pressure coefficients *A* and *B*, *Geotechnique* **4,** 143–147.

Stein, R. S., A. A. Barka, and J. H. Dieterich (1997). Progressive failure on the North Anatolian fault since 1939 by earthquake stress triggering, *Geophys. J. Int.* **128,** 594–604.

Stein, R. S., G. C. P. King, and J. Lin (1992). Change in failure stress on the southern San Andreas fault system caused by the 1992 magnitude $= 7.4$ Landers earthquake, *Science* **258,** 1328–1332.

Stein, R. S., G. C. P. King, and J. Lin (1994). Stress triggering of the 1994 $M = 6.7$ Northridge, California, earthquake by its predecessors, *Science* **265,** 1432–1435.

Toda, S., R. S. Stein, P. A. Reasenberg, J. H. Dieterich, and A. Yoshida (1998). Stress transferred by the 1995 $M_w = 6.9$ Kobe, Japan, shock: effect on aftershocks and future earthquake probabilities, *J. Geophys. Res.* **103,** 24,543–24,565.

Treiman, J. A., K. J. Kendrick, W. A. Bryant, T. K. Rockwell, and S. F. McGill (2002). Primary surface rupture associated with the M_w 7.1 16 October 1999 Hector Mine earthquake, San Bernadino County, California, *Bull. Seism. Soc. Am.* **92,** 1171–1191 (this issue).

Wald, D. J., and T. H. Heaton (1994). Spatial and temporal distribution of slip for the 1992 Landers, California, earthquake, *Bull. Seism. Soc. Am.* **84,** 668–691.

Zeng, Y. (2001). Viscoelastic stress triggering of the 1999 Hector Mine earthquake by the 1992 Landers earthquake, *Geophys. Res. Lett.* **28,** 3007–3010.

Appendix A

Table A1
Landers Dislocation Models

Wald and Heaton (1994) Landers Dislocation Model (see Fig. 2a for map view)											
TYP	LONCEN	LATCEN	DCEN	STR	DIP	HORLEN	DIPLEN	SS(m)	DS(m)	OP(m)	RAKE
−2	−116.7111	34.6862	1.2500	320.0000	90.000	3.0000	2.5000	−0.82	0.	0.	180.
−2	−116.6899	34.6654	1.2500	320.0000	90.000	3.0000	2.5000	−1.1	0.	0.	180.
−2	−116.6688	34.6447	1.2500	320.0000	90.000	3.0000	2.5000	−0.82	0.	0.	180.
−2	−116.6477	34.6239	1.2500	320.0000	90.000	3.0000	2.5000	−1.83	0.	0.	180.
−2	−116.6266	34.6031	1.2500	320.0000	90.000	3.0000	2.5000	−4.12	0.	0.	180.
−2	−116.6055	34.5824	1.2500	320.0000	90.000	3.0000	2.5000	−5.12	0.	0.	180.
−2	−116.5845	34.5616	1.2500	320.0000	90.000	3.0000	2.5000	−4.76	0.	0.	180.
−2	−116.5634	34.5408	1.2500	320.0000	90.000	3.0000	2.5000	−6.31	0.	0.	180.
−2	−116.5424	34.5201	1.2500	320.0000	90.000	3.0000	2.5000	−5.67	0.	0.	180.
−2	−116.5213	34.4993	1.2500	320.0000	90.000	3.0000	2.5000	−3.94	0.	0.	180.
−2	−116.5003	34.4785	1.2500	320.0000	90.000	3.0000	2.5000	−0.55	0.	0.	180.
−2	−116.4793	34.4577	1.2500	320.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.7111	34.6862	3.7500	320.0000	90.000	3.0000	2.5000	−0.43	0.	0.	180.
−2	−116.6899	34.6654	3.7500	320.0000	90.000	3.0000	2.5000	−3.94	0.	0.	180.
−2	−116.6688	34.6447	3.7500	320.0000	90.000	3.0000	2.5000	−1.77	0.	0.	180.
−2	−116.6477	34.6239	3.7500	320.0000	90.000	3.0000	2.5000	−1.47	0.	0.	180.
−2	−116.6266	34.6031	3.7500	320.0000	90.000	3.0000	2.5000	−1.9	0.	0.	180.
−2	−116.6055	34.5824	3.7500	320.0000	90.000	3.0000	2.5000	−3.37	0.	0.	180.
−2	−116.5845	34.5616	3.7500	320.0000	90.000	3.0000	2.5000	−5.25	0.	0.	180.
−2	−116.5634	34.5408	3.7500	320.0000	90.000	3.0000	2.5000	−6.57	0.	0.	180.
−2	−116.5424	34.5201	3.7500	320.0000	90.000	3.0000	2.5000	−2.8	0.	0.	180.
−2	−116.5213	34.4993	3.7500	320.0000	90.000	3.0000	2.5000	−0.45	0.	0.	180.
−2	−116.5003	34.4785	3.7500	320.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4793	34.4577	3.7500	320.0000	90.000	3.0000	2.5000	−0.33	0.	0.	180.
−2	−116.7111	34.6862	6.2500	320.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.6899	34.6654	6.2500	320.0000	90.000	3.0000	2.5000	−0.37	0.	0.	180.
−2	−116.6688	34.6447	6.2500	320.0000	90.000	3.0000	2.5000	−0.85	0.	0.	180.
−2	−116.6477	34.6239	6.2500	320.0000	90.000	3.0000	2.5000	−1.41	0.	0.	180.
−2	−116.6266	34.6031	6.2500	320.0000	90.000	3.0000	2.5000	−1.91	0.	0.	180.
−2	−116.6055	34.5824	6.2500	320.0000	90.000	3.0000	2.5000	−2.65	0.	0.	180.
−2	−116.5845	34.5616	6.2500	320.0000	90.000	3.0000	2.5000	−4.1	0.	0.	180.
−2	−116.5634	34.5408	6.2500	320.0000	90.000	3.0000	2.5000	−4.3	0.	0.	180.
−2	−116.5424	34.5201	6.2500	320.0000	90.000	3.0000	2.5000	−1.49	0.	0.	180.
−2	−116.5213	34.4993	6.2500	320.0000	90.000	3.0000	2.5000	−0.31	0.	0.	180.

−2	−116.5003	34.4785	6.2500	320.0000	90.000	3.0000	2.5000	−0.02	0.	0.	180.
−2	−116.4793	34.4577	6.2500	320.0000	90.000	3.0000	2.5000	−1.03	0.	0.	180.
−2	−116.7111	34.6862	8.7500	320.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.6899	34.6654	8.7500	320.0000	90.000	3.0000	2.5000	−0.12	0.	0.	180.
−2	−116.6688	34.6447	8.7500	320.0000	90.000	3.0000	2.5000	−0.47	0.	0.	180.
−2	−116.6477	34.6239	8.7500	320.0000	90.000	3.0000	2.5000	−0.98	0.	0.	180.
−2	−116.6266	34.6031	8.7500	320.0000	90.000	3.0000	2.5000	−1.44	0.	0.	180.
−2	−116.6055	34.5824	8.7500	320.0000	90.000	3.0000	2.5000	−1.9	0.	0.	180.
−2	−116.5845	34.5616	8.7500	320.0000	90.000	3.0000	2.5000	−2.93	0.	0.	180.
−2	−116.5634	34.5408	8.7500	320.0000	90.000	3.0000	2.5000	−2.65	0.	0.	180.
−2	−116.5424	34.5201	8.7500	320.0000	90.000	3.0000	2.5000	−0.63	0.	0.	180.
−2	−116.5213	34.4993	8.7500	320.0000	90.000	3.0000	2.5000	−0.19	0.	0.	180.
−2	−116.5003	34.4785	8.7500	320.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4793	34.4577	8.7500	320.0000	90.000	3.0000	2.5000	−1.18	0.	0.	180.
−2	−116.7111	34.6862	11.2500	320.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.6899	34.6654	11.2500	320.0000	90.000	3.0000	2.5000	−0.06	0.	0.	180.
−2	−116.6688	34.6447	11.2500	320.0000	90.000	3.0000	2.5000	−0.17	0.	0.	180.
−2	−116.6477	34.6239	11.2500	320.0000	90.000	3.0000	2.5000	−0.48	0.	0.	180.
−2	−116.6266	34.6031	11.2500	320.0000	90.000	3.0000	2.5000	−0.85	0.	0.	180.
−2	−116.6055	34.5824	11.2500	320.0000	90.000	3.0000	2.5000	−1.25	0.	0.	180.
−2	−116.5845	34.5616	11.2500	320.0000	90.000	3.0000	2.5000	−2.18	0.	0.	180.
−2	−116.5634	34.5408	11.2500	320.0000	90.000	3.0000	2.5000	−1.95	0.	0.	180.
−2	−116.5424	34.5201	11.2500	320.0000	90.000	3.0000	2.5000	−0.55	0.	0.	180.
−2	−116.5213	34.4993	11.2500	320.0000	90.000	3.0000	2.5000	−0.07	0.	0.	180.
−2	−116.5003	34.4785	11.2500	320.0000	90.000	3.0000	2.5000	−0.01	0.	0.	180.
−2	−116.4793	34.4577	11.2500	320.0000	90.000	3.0000	2.5000	−1.29	0.	0.	180.
−2	−116.7111	34.6862	13.7500	320.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.6899	34.6654	13.7500	320.0000	90.000	3.0000	2.5000	−0.03	0.	0.	180.
−2	−116.6688	34.6447	13.7500	320.0000	90.000	3.0000	2.5000	−0.04	0.	0.	180.
−2	−116.6477	34.6239	13.7500	320.0000	90.000	3.0000	2.5000	−0.18	0.	0.	180.
−2	−116.6266	34.6031	13.7500	320.0000	90.000	3.0000	2.5000	−0.39	0.	0.	180.
−2	−116.6055	34.5824	13.7500	320.0000	90.000	3.0000	2.5000	−1.04	0.	0.	180.
−2	−116.5845	34.5616	13.7500	320.0000	90.000	3.0000	2.5000	−1.85	0.	0.	180.
−2	−116.5634	34.5408	13.7500	320.0000	90.000	3.0000	2.5000	−1.71	0.	0.	180.
−2	−116.5424	34.5201	13.7500	320.0000	90.000	3.0000	2.5000	−0.91	0.	0.	180.
−2	−116.5213	34.4993	13.7500	320.0000	90.000	3.0000	2.5000	−0.29	0.	0.	180.
−2	−116.5003	34.4785	13.7500	320.0000	90.000	3.0000	2.5000	−0.42	0.	0.	180.
−2	−116.4793	34.4577	13.7500	320.0000	90.000	3.0000	2.5000	−0.65	0.	0.	180.
−2	−116.5394	34.5124	1.2500	334.0000	90.000	3.0000	2.5000	−0.48	0.	0.	180.
−2	−116.5251	34.4881	1.2500	334.0000	90.000	3.0000	2.5000	−2.6	0.	0.	180.
−2	−116.5107	34.4637	1.2500	334.0000	90.000	3.0000	2.5000	−3.61	0.	0.	180.
−2	−116.4964	34.4394	1.2500	334.0000	90.000	3.0000	2.5000	−3.73	0.	0.	180.
−2	−116.4820	34.4150	1.2500	334.0000	90.000	3.0000	2.5000	−3.61	0.	0.	180.
−2	−116.4677	34.3906	1.2500	334.0000	90.000	3.0000	2.5000	−3.49	0.	0.	180.
−2	−116.4533	34.3663	1.2500	334.0000	90.000	3.0000	2.5000	−3.85	0.	0.	180.
−2	−116.4390	34.3419	1.2500	334.0000	90.000	3.0000	2.5000	−1.08	0.	0.	180.
−2	−116.4247	34.3176	1.2500	334.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.5394	34.5124	3.7500	334.0000	90.000	3.0000	2.5000	−3.2	0.	0.	180.
−2	−116.5251	34.4881	3.7500	334.0000	90.000	3.0000	2.5000	−4.76	0.	0.	180.
−2	−116.5107	34.4637	3.7500	334.0000	90.000	3.0000	2.5000	−7.05	0.	0.	180.
−2	−116.4964	34.4394	3.7500	334.0000	90.000	3.0000	2.5000	−3.05	0.	0.	180.
−2	−116.4820	34.4150	3.7500	334.0000	90.000	3.0000	2.5000	−2.32	0.	0.	180.
−2	−116.4677	34.3906	3.7500	334.0000	90.000	3.0000	2.5000	−7.87	0.	0.	180.
−2	−116.4533	34.3663	3.7500	334.0000	90.000	3.0000	2.5000	−0.84	0.	0.	180.
−2	−116.4390	34.3419	3.7500	334.0000	90.000	3.0000	2.5000	−0.86	0.	0.	180.
−2	−116.4247	34.3176	3.7500	334.0000	90.000	3.0000	2.5000	−3.23	0.	0.	180.
−2	−116.5394	34.5124	6.2500	334.0000	90.000	3.0000	2.5000	−5.02	0.	0.	180.
−2	−116.5251	34.4881	6.2500	334.0000	90.000	3.0000	2.5000	−5.14	0.	0.	180.
−2	−116.5107	34.4637	6.2500	334.0000	90.000	3.0000	2.5000	−6.92	0.	0.	180.
−2	−116.4964	34.4394	6.2500	334.0000	90.000	3.0000	2.5000	−4.66	0.	0.	180.
−2	−116.4820	34.4150	6.2500	334.0000	90.000	3.0000	2.5000	−1.91	0.	0.	180.
−2	−116.4677	34.3906	6.2500	334.0000	90.000	3.0000	2.5000	−1.8	0.	0.	180.
−2	−116.4533	34.3663	6.2500	334.0000	90.000	3.0000	2.5000	−0.79	0.	0.	180.
−2	−116.4390	34.3419	6.2500	334.0000	90.000	3.0000	2.5000	−0.89	0.	0.	180.
−2	−116.4247	34.3176	6.2500	334.0000	90.000	3.0000	2.5000	−1.97	0.	0.	180.
−2	−116.5394	34.5124	8.7500	334.0000	90.000	3.0000	2.5000	−5.31	0.	0.	180.
−2	−116.5251	34.4881	8.7500	334.0000	90.000	3.0000	2.5000	−5.54	0.	0.	180.
−2	−116.5107	34.4637	8.7500	334.0000	90.000	3.0000	2.5000	−6.36	0.	0.	180.

−2	−116.4964	34.4394	8.7500	334.0000	90.000	3.0000	2.5000	−5.14	0.	0.	180.
−2	−116.4820	34.4150	8.7500	334.0000	90.000	3.0000	2.5000	−2.58	0.	0.	180.
−2	−116.4677	34.3906	8.7500	334.0000	90.000	3.0000	2.5000	−0.95	0.	0.	180.
−2	−116.4533	34.3663	8.7500	334.0000	90.000	3.0000	2.5000	−0.8	0.	0.	180.
−2	−116.4390	34.3419	8.7500	334.0000	90.000	3.0000	2.5000	−0.82	0.	0.	180.
−2	−116.4247	34.3176	8.7500	334.0000	90.000	3.0000	2.5000	−1.21	0.	0.	180.
−2	−116.5394	34.5124	11.2500	334.0000	90.000	3.0000	2.5000	−5.4	0.	0.	180.
−2	−116.5251	34.4881	11.2500	334.0000	90.000	3.0000	2.5000	−5.1	0.	0.	180.
−2	−116.5107	34.4637	11.2500	334.0000	90.000	3.0000	2.5000	−4.98	0.	0.	180.
−2	−116.4964	34.4394	11.2500	334.0000	90.000	3.0000	2.5000	−4.65	0.	0.	180.
−2	−116.4820	34.4150	11.2500	334.0000	90.000	3.0000	2.5000	−3.2	0.	0.	180.
−2	−116.4677	34.3906	11.2500	334.0000	90.000	3.0000	2.5000	−1.69	0.	0.	180.
−2	−116.4533	34.3663	11.2500	334.0000	90.000	3.0000	2.5000	−1.1	0.	0.	180.
−2	−116.4390	34.3419	11.2500	334.0000	90.000	3.0000	2.5000	−0.88	0.	0.	180.
−2	−116.4247	34.3176	11.2500	334.0000	90.000	3.0000	2.5000	−1.	0.	0.	180.
−2	−116.5394	34.5124	13.7500	334.0000	90.000	3.0000	2.5000	−1.53	0.	0.	180.
−2	−116.5251	34.4881	13.7500	334.0000	90.000	3.0000	2.5000	−5.23	0.	0.	180.
−2	−116.5107	34.4637	13.7500	334.0000	90.000	3.0000	2.5000	−4.8	0.	0.	180.
−2	−116.4964	34.4394	13.7500	334.0000	90.000	3.0000	2.5000	−4.83	0.	0.	180.
−2	−116.4820	34.4150	13.7500	334.0000	90.000	3.0000	2.5000	−3.96	0.	0.	180.
−2	−116.4677	34.3906	13.7500	334.0000	90.000	3.0000	2.5000	−2.76	0.	0.	180.
−2	−116.4533	34.3663	13.7500	334.0000	90.000	3.0000	2.5000	−2.03	0.	0.	180.
−2	−116.4390	34.3419	13.7500	334.0000	90.000	3.0000	2.5000	−1.63	0.	0.	180.
−2	−116.4247	34.3176	13.7500	334.0000	90.000	3.0000	2.5000	−1.57	0.	0.	180.
−2	−116.4528	34.3495	1.2500	355.0000	90.000	3.0000	2.5000	−3.38	0.	0.	180.
−2	−116.4500	34.3225	1.2500	355.0000	90.000	3.0000	2.5000	−2.18	0.	0.	180.
−2	−116.4471	34.2955	1.2500	355.0000	90.000	3.0000	2.5000	−3.38	0.	0.	180.
−2	−116.4443	34.2685	1.2500	355.0000	90.000	3.0000	2.5000	−2.4	0.	0.	180.
−2	−116.4414	34.2415	1.2500	355.0000	90.000	3.0000	2.5000	−2.51	0.	0.	180.
−2	−116.4386	34.2145	1.2500	355.0000	90.000	3.0000	2.5000	−2.18	0.	0.	180.
−2	−116.4357	34.1875	1.2500	355.0000	90.000	3.0000	2.5000	−0.87	0.	0.	180.
−2	−116.4329	34.1605	1.2500	355.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4301	34.1335	1.2500	355.0000	90.000	3.0000	2.5000	−0.54	0.	0.	180.
−2	−116.4272	34.1065	1.2500	355.0000	90.000	3.0000	2.5000	−0.32	0.	0.	180.
−2	−116.4528	34.3495	3.7500	355.0000	90.000	3.0000	2.5000	−5.89	0.	0.	180.
−2	−116.4500	34.3225	3.7500	355.0000	90.000	3.0000	2.5000	−3.4	0.	0.	180.
−2	−116.4471	34.2955	3.7500	355.0000	90.000	3.0000	2.5000	−1.33	0.	0.	180.
−2	−116.4443	34.2685	3.7500	355.0000	90.000	3.0000	2.5000	−0.25	0.	0.	180.
−2	−116.4414	34.2415	3.7500	355.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4386	34.2145	3.7500	355.0000	90.000	3.0000	2.5000	−2.3	0.	0.	180.
−2	−116.4357	34.1875	3.7500	355.0000	90.000	3.0000	2.5000	−5.78	0.	0.	180.
−2	−116.4329	34.1605	3.7500	355.0000	90.000	3.0000	2.5000	−3.89	0.	0.	180.
−2	−116.4301	34.1335	3.7500	355.0000	90.000	3.0000	2.5000	−0.4	0.	0.	180.
−2	−116.4272	34.1065	3.7500	355.0000	90.000	3.0000	2.5000	−0.01	0.	0.	180.
−2	−116.4528	34.3495	6.2500	355.0000	90.000	3.0000	2.5000	−4.72	0.	0.	180.
−2	−116.4500	34.3225	6.2500	355.0000	90.000	3.0000	2.5000	−3.21	0.	0.	180.
−2	−116.4471	34.2955	6.2500	355.0000	90.000	3.0000	2.5000	−2.04	0.	0.	180.
−2	−116.4443	34.2685	6.2500	355.0000	90.000	3.0000	2.5000	−1.64	0.	0.	180.
−2	−116.4414	34.2415	6.2500	355.0000	90.000	3.0000	2.5000	−1.29	0.	0.	180.
−2	−116.4386	34.2145	6.2500	355.0000	90.000	3.0000	2.5000	−2.15	0.	0.	180.
−2	−116.4357	34.1875	6.2500	355.0000	90.000	3.0000	2.5000	−3.21	0.	0.	180.
−2	−116.4329	34.1605	6.2500	355.0000	90.000	3.0000	2.5000	−1.19	0.	0.	180.
−2	−116.4301	34.1335	6.2500	355.0000	90.000	3.0000	2.5000	−0.1	0.	0.	180.
−2	−116.4272	34.1065	6.2500	355.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4528	34.3495	8.7500	355.0000	90.000	3.0000	2.5000	−3.22	0.	0.	180.
−2	−116.4500	34.3225	8.7500	355.0000	90.000	3.0000	2.5000	−2.72	0.	0.	180.
−2	−116.4471	34.2955	8.7500	355.0000	90.000	3.0000	2.5000	−1.94	0.	0.	180.
−2	−116.4443	34.2685	8.7500	355.0000	90.000	3.0000	2.5000	−1.81	0.	0.	180.
−2	−116.4414	34.2415	8.7500	355.0000	90.000	3.0000	2.5000	−1.66	0.	0.	180.
−2	−116.4386	34.2145	8.7500	355.0000	90.000	3.0000	2.5000	−1.44	0.	0.	180.
−2	−116.4357	34.1875	8.7500	355.0000	90.000	3.0000	2.5000	−1.06	0.	0.	180.
−2	−116.4329	34.1605	8.7500	355.0000	90.000	3.0000	2.5000	−0.49	0.	0.	180.
−2	−116.4301	34.1335	8.7500	355.0000	90.000	3.0000	2.5000	−0.08	0.	0.	180.
−2	−116.4272	34.1065	8.7500	355.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4528	34.3495	11.2500	355.0000	90.000	3.0000	2.5000	−2.93	0.	0.	180.
−2	−116.4500	34.3225	11.2500	355.0000	90.000	3.0000	2.5000	−2.46	0.	0.	180.
−2	−116.4471	34.2955	11.2500	355.0000	90.000	3.0000	2.5000	−1.53	0.	0.	180.
−2	−116.4443	34.2685	11.2500	355.0000	90.000	3.0000	2.5000	−1.52	0.	0.	180.

−2	−116.4414	34.2415	11.2500	355.0000	90.000	3.0000	2.5000	−1.22	0.	0.	180.
−2	−116.4386	34.2145	11.2500	355.0000	90.000	3.0000	2.5000	−0.53	0.	0.	180.
−2	−116.4357	34.1875	11.2500	355.0000	90.000	3.0000	2.5000	−0.23	0.	0.	180.
−2	−116.4329	34.1605	11.2500	355.0000	90.000	3.0000	2.5000	−0.14	0.	0.	180.
−2	−116.4301	34.1335	11.2500	355.0000	90.000	3.0000	2.5000	−0.01	0.	0.	180.
−2	−116.4272	34.1065	11.2500	355.0000	90.000	3.0000	2.5000	−0.09	0.	0.	180.
−2	−116.4528	34.3495	13.7500	355.0000	90.000	3.0000	2.5000	−1.42	0.	0.	180.
−2	−116.4500	34.3225	13.7500	355.0000	90.000	3.0000	2.5000	−2.89	0.	0.	180.
−2	−116.4471	34.2955	13.7500	355.0000	90.000	3.0000	2.5000	−1.64	0.	0.	180.
−2	−116.4443	34.2685	13.7500	355.0000	90.000	3.0000	2.5000	−1.23	0.	0.	180.
−2	−116.4414	34.2415	13.7500	355.0000	90.000	3.0000	2.5000	−0.82	0.	0.	180.
−2	−116.4386	34.2145	13.7500	355.0000	90.000	3.0000	2.5000	−0.19	0.	0.	180.
−2	−116.4357	34.1875	13.7500	355.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4329	34.1605	13.7500	355.0000	90.000	3.0000	2.5000	0.	0.	0.	180.
−2	−116.4301	34.1335	13.7500	355.0000	90.000	3.0000	2.5000	−0.13	0.	0.	180.
−2	−116.4272	34.1065	13.7500	355.0000	90.000	3.0000	2.5000	−0.6	0.	0.	180.
−2	−116.7661	34.2004	8.7500	57.0000	90.000	12.0000	12.5000	1.15	0.	0.	0.*
−2	−116.3649	34.0416	2.0000	343.0000	90.000	20.0000	4.0000	−0.3	0.	0.	−180.†
−2	−116.3649	34.0416	8.0000	343.0000	90.000	20.0000	8.0000	−0.6	0.	0.	−180.‡

Hudnut *et al.* (1994) Landers dislocation model (see Fig. 2b)

TYP	LONCEN	LATCEN	DCEN	STR	DIP	HORLEN	DIPLEN	SS(m)	DS(m)	OP(m)	RAKE
−2	−116.7070	34.6791	5.0000	133.2800	90.000	8.1400	10.0000	0.	0.	0.	180.
−2	−116.6619	34.6344	5.0000	152.0400	90.000	4.9630	10.0000	−2.	0.	0.	180.
−2	−116.6114	34.5913	5.0000	126.9200	90.000	8.6710	10.0000	−2.7	0.	0.	180.
−2	−116.5634	34.5549	5.0000	147.4000	90.000	3.4390	10.0000	−6.4	0.	0.	180.
−2	−116.5432	34.5319	5.0000	140.1100	90.000	2.8870	10.0000	−5.8	0.	0.	180.
−2	−116.5240	34.5126	5.0000	141.4700	90.000	2.6800	10.0000	−2.55	0.	0.	180.
−2	−116.4996	34.4873	5.0000	141.2800	90.000	4.5120	10.0000	−4.8	0.	0.	180.
−2	−116.4741	34.4538	5.0000	154.8300	90.000	4.3700	10.0000	−3.6	0.	0.	180.
−2	−116.5331	34.5099	5.0000	179.6500	90.000	2.6980	10.0000	−3.75	0.	0.	180.
−2	−116.5148	34.4881	5.0000	179.6900	90.000	3.3590	10.0000	−1.3	0.	0.	180.
−2	−116.4677	34.4157	5.0000	188.7600	90.000	4.5810	10.0000	−3.45	0.	0.	180.
−2	−116.5389	34.5037	5.0000	140.7200	90.000	1.7300	10.0000	−1.5	0.	0.	180.
−2	−116.5239	34.4853	5.0000	148.7700	90.000	3.2250	10.0000	−2.4	0.	0.	180.
−2	−116.5032	34.4521	5.0000	155.3400	90.000	4.7610	10.0000	−2.25	0.	0.	180.
−2	−116.4816	34.4133	5.0000	155.3500	90.000	4.7500	10.0000	−6.15	0.	0.	180.
−2	−116.4597	34.3864	5.0000	132.4300	90.000	2.9450	10.0000	−0.9	0.	0.	180.
−2	−116.4483	34.3704	5.0000	182.6100	90.000	1.5760	10.0000	−1.4	0.	0.	180.
−2	−116.4369	34.3412	5.0000	156.2900	90.000	5.3830	10.0000	−3.8	0.	0.	180.
−2	−116.4521	34.3375	5.0000	186.2500	90.000	5.7960	10.0000	−3.2	0.	0.	180.
−2	−116.4707	34.3288	5.0000	143.8900	90.000	4.7530	10.0000	0.	0.	0.	180.
−2	−116.4481	34.2973	5.0000	156.9700	90.000	3.4650	10.0000	−4.1	0.	0.	180.
−2	−116.4389	34.2654	5.0000	174.8500	90.000	3.9180	10.0000	−2.8	0.	0.	180.
−2	−116.4380	34.2299	5.0000	182.7600	90.000	4.0110	10.0000	−1.9	0.	0.	180.
−2	−116.4341	34.1937	5.0000	167.3200	90.000	4.1410	10.0000	−3.1	0.	0.	180.
−2	−116.4076	34.1506	5.0000	157.5800	90.000	7.1560	10.0000	−1.3	0.	0.	180.
−2	−116.3849	34.1027	5.0000	160.3100	90.000	4.2820	10.0000	0.	0.	0.	180.
−2	−116.3673	34.0587	5.0000	162.5200	90.000	6.0500	10.0000	−0.1	0.	0.	180.
−2	−116.7833	34.2042	5.0000	48.0000	90.000	28.0000	10.0000	0.436	0.	0.	180.
−2	−116.5625	34.6337	5.0000	80.3400	90.000	11.6140	10.0000	0.23	0.	0.	180.

Parsons and Dreger (2000) Landers dislocation model (see Fig. 2c)

TYP	LONCEN	LATCEN	DCEN	STR	DIP	HORLEN	DIPLEN	SS(m)	DS(m)	OP(m)	RAKE
−2	−116.7215	34.6844	2.5000	139.8060	90.000	4.9820	5.0000	−0.5	0.	0.	180.
−2	−116.6869	34.6496	2.5000	139.8408	90.000	4.9923	5.0000	−1.	0.	0.	180.
−2	−116.6524	34.6146	2.5000	139.8927	90.000	4.9887	5.0000	−2.	0.	0.	180.
−2	−116.6179	34.5797	2.5000	139.8626	90.000	4.9882	5.0000	−4.	0.	0.	180.
−2	−116.5834	34.5448	2.5000	139.8121	90.000	4.9893	5.0000	−5.	0.	0.	180.
−2	−116.5489	34.5100	2.5000	139.7970	90.000	4.9904	5.0000	−3.5	0.	0.	180.
−2	−116.6524	34.6146	7.5000	139.8927	90.000	4.9887	5.0000	−1.	0.	0.	180.
−2	−116.6179	34.5797	7.5000	139.8626	90.000	4.9882	5.0000	−2.	0.	0.	180.
−2	−116.5834	34.5448	7.5000	139.8121	90.000	4.9893	5.0000	−2.5	0.	0.	180.
−2	−116.6179	34.5797	12.5000	139.8626	90.000	4.9882	5.0000	−1	0.	0.	180.
−2	−116.5834	34.5448	12.5000	139.8121	90.000	4.9893	5.000	−1.	0.	0.	180
−2	−116.4589	34.3257	2.5000	174.7975	90.000	4.9825	5.0000	−3.5	0.	0.	180.
−2	−116.4549	34.2807	2.5000	174.8183	90.000	4.9959	5.0000	−2.	0.	0.	180.

−2	−116.4510	34.2357	2.5000	174.8975	90.000	4.9935	5.0000	−1.5	0.	0.	180.
−2	−116.4470	34.1908	2.5000	174.7845	90.000	4.9844	5.0000	−2.	0.	0.	180.
−2	−116.4430	34.1458	2.5000	174.7888	90.000	4.9963	5.0000	−1.	0.	0.	180.
−2	−116.4589	34.3257	7.5000	174.7975	90.000	4.9825	5.0000	−3.5	0.	0.	180.
−2	−116.4549	34.2807	7.5000	174.8183	90.000	4.9959	5.0000	−2.5	0.	0.	180.
−2	−116.4510	34.2357	7.5000	174.8975	90.000	4.9935	5.000	−1.	0.	0.	180.
−2	−116.4470	34.1908	7.5000	174.7845	90.000	4.9844	5.0000	−1.5	0.	0.	180.
−2	−116.4430	34.1458	7.5000	174.7888	90.000	4.9963	5.0000	−0.7	0.	0.	180.
−2	−116.4589	34.3257	12.5000	174.7975	90.000	4.9825	5.0000	−2.	0.	0.	180.
−2	−116.4549	34.2807	12.5000	174.8183	90.000	4.9959	5.0000	−1.5	0.	0.	180.
−2	−116.4510	34.2357	12.5000	174.8975	90.000	4.9935	5.0000	−0.7	0.	0.	180.
−2	−116.5455	34.5002	2.5000	153.7326	90.000	4.984?	5.0000	−2.5	0.	0.	180.
−2	−116.5223	34.4594	2.5000	153.8450	90.000	4.9927	5.0000	−3.	0.	0.	180.
−2	−116.4991	34.4186	2.5000	153.8184	90.000	4.9905	5.0000	−3.	0.	0.	180.
−2	−116.4759	34.3778	2.5000	153.8992	90.000	4.9903	5.0000	−2.5	0.	0.	180.
−2	−116.4528	34.3370	2.5000	153.7722	90.000	4.9925	5.0000	−1.	0.	0.	180.
−2	−116.5455	34.5002	7.5000	153.7326	90.000	4.9844	5.0000	−4.5	0.	0.	180.
−2	−116.5223	34.4594	7.5000	153.8450	90.000	4.9927	5.0000	−6.	0.	0.	180.
−2	−116.4991	34.4186	7.5000	153.8184	90.000	4.9905	5.0000	−3.	0.	0.	180.
−2	−116.4759	34.3778	7.5000	153.8992	90.000	4.9903	5.0000	−1.	0.	0.	180.
−2	−116.4528	34.3370	7.5000	153.7722	90.000	4.9925	5.0000	−0.5	0.	0.	180.
−2	−116.5455	34.5002	12.5000	153.7326	90.000	4.9844	5.0000	−3.5	0.	0.	180.
−2	−116.5223	34.4594	12.5000	153.8450	90.000	4.9927	5.0000	−5.	0.	0.	180.
−2	−116.4991	34.4186	12.5000	153.8184	90.000	4.9905	5.0000	−3.5	0.	0.	180.
−2	−116.4759	34.3778	12.5000	153.8992	90.000	4.9903	5.0000	−1.5	0.	0.	180.
−2	−116.4528	34.3370	12.5000	153.7722	90.000	4.9925	5.000	−1.	0.	0.	180.
−2	−116.7956	34.1973	7.2500	220.4655	90.000	18.3980	10.5000	0.83	0.	0.	0.
−2	−116.3455	33.9671	7.2500	174.8002	90.000	8.0174	10.5000	−0.5	0.	0.	180.

Hudnut and Larsen (1993) Landers dislocation model (see Fig. 2b)

TYP	LONCEN	LATCEN	DCEN	STR	DIP	HORLEN	DIPLEN	SS(m)	DS(m)	OP(m)	RAKE
−2	−116.7063	34.6777	1.2500	133.3000	90.000	8.1400	2.5000	−0.4774	0.	0.	180.
−2	−116.7063	34.6777	3.7500	133.3000	90.000	8.1400	2.5000	0.0851	0.	0.	180.
−2	−116.7063	34.6777	6.2500	133.3000	90.000	8.1400	2.5000	0.1441	0.	0.	180.
−2	−116.7063	34.6777	8.7500	133.3000	90.000	8.1400	2.5000	−0.0322	0.	0.	180.
−2	−116.7063	34.6777	11.2500	133.3000	90.000	8.1400	2.5000	−0.1955	0.	0.	180.
−2	−116.7063	34.6777	13.7500	133.3000	90.000	8.1400	2.5000	−0.2104	0.	0.	180.
−2	−116.6612	34.6330	1.2500	152.0000	90.000	4.9600	2.5000	−1.1031	0.	0.	180.
−2	−116.6612	34.6330	3.7500	152.0000	90.000	4.9600	2.5000	−0.9753	0.	0.	180.
−2	−116.6612	34.6330	6.2500	152.0000	90.000	4.9600	2.5000	−0.9169	0.	0.	180.
−2	−116.6612	34.6330	8.7500	152.0000	90.000	4.9600	2.5000	−0.8678	0.	0.	180.
−2	−116.6612	34.6330	11.2500	152.0000	90.000	4.9600	2.5000	−0.7544	0.	0.	180.
−2	−116.6612	34.6330	13.7500	152.0000	90.000	4.9600	2.5000	−0.496	0.	0.	180.
−2	−116.6107	34.5899	1.2500	126.9000	90.000	8.6700	2.5000	−2.3741	0.	0.	180.
−2	−116.6107	34.5899	3.7500	126.9000	90.000	8.6700	2.5000	−3.7113	0.	0.	180.
−2	−116.6107	34.5899	6.2500	126.9000	90.000	8.6700	2.5000	−3.9517	0.	0.	180.
−2	−116.6107	34.5899	8.7500	126.9000	90.000	8.6700	2.5000	−3.4985	0.	0.	180.
−2	−116.6107	34.5899	11.2500	126.9000	90.000	8.6700	2.5000	−2.7157	0.	0.	180.
−2	−116.6107	34.5899	13.7500	126.9000	90.000	8.6700	2.5000	−1.6219	0.	0.	180.
−2	−116.5627	34.5535	1.2500	147.4000	90.000	3.4400	2.5000	−7.5656	0.	0.	180.
−2	−116.5627	34.5535	3.7500	147.4000	90.000	3.4400	2.5000	−6.1131	0.	0.	180.
−2	−116.5627	34.5535	6.2500	147.4000	90.000	3.4400	2.5000	−4.4975	0.	0.	180.
−2	−116.5627	34.5535	8.7500	147.4000	90.000	3.4400	2.5000	−3.1524	0.	0.	180.
−2	−116.5627	34.5535	11.2500	147.4000	90.000	3.4400	2.5000	−2.0773	0.	0.	180.
−2	−116.5627	34.5535	13.7500	147.4000	90.000	3.4400	2.5000	−1.1095	0.	0.	180.
−2	−116.5425	34.5305	1.2500	140.1000	90.000	2.8900	2.5000	−8.234	0.	0.	180.
−2	−116.5425	34.5305	3.7500	140.1000	90.000	2.8900	2.5000	−6.3043	0.	0.	180.
−2	−116.5425	34.5305	6.2500	140.1000	90.000	2.8900	2.5000	−4.4012	0.	0.	180.
−2	−116.5425	34.5305	8.7500	140.1000	90.000	2.8900	2.5000	−2.9227	0.	0.	180.
−2	−116.5425	34.5305	11.2500	140.1000	90.000	2.8900	2.5000	−1.8308	0.	0.	180.
−2	−116.5425	34.5305	13.7500	140.1000	90.000	2.8900	2.5000	−0.9432	0.	0.	180.
−2	−116.5233	34.5112	1.2500	141.5000	90.000	2.6800	2.5000	−3.0986	0.	0.	180.
−2	−116.5233	34.5112	3.7500	141.5000	90.000	2.6800	2.5000	−3.8394	0.	0.	180.
−2	−116.5233	34.5112	6.2500	141.5000	90.000	2.6800	2.5000	−3.3182	0.	0.	180.
−2	−116.5233	34.5112	8.7500	141.5000	90.000	2.6800	2.5000	−2.3561	0.	0.	180.
−2	−116.5233	34.5112	11.2500	141.5000	90.000	2.6800	2.5000	−1.4966	0.	0.	180.
−2	−116.5233	34.5112	13.7500	141.5000	90.000	2.6800	2.5000	−0.7594	0.	0.	180.
−2	−116.4989	34.4859	1.2500	141.3000	90.000	4.5100	2.5000	−1.2774	0.	0.	180.

−2	−116.4989	34.4859	3.7500	141.3000	90.000	4.5100	2.5000	−3.7183	0.	0.	180.
−2	−116.4989	34.4859	6.2500	141.3000	90.000	4.5100	2.5000	−3.5982	0.	0.	180.
−2	−116.4989	34.4859	8.7500	141.3000	90.000	4.5100	2.5000	−2.6279	0.	0.	180.
−2	−116.4989	34.4859	11.2500	141.3000	90.000	4.5100	2.5000	−1.6841	0.	0.	180.
−2	−116.4989	34.4859	13.7500	141.3000	90.000	4.5100	2.5000	−0.8756	0.	0.	180.
−2	−116.4734	34.4524	1.2500	154.8000	90.000	4.3700	2.5000	−0.0117	0.	0.	180.
−2	−116.4734	34.4524	3.7500	154.8000	90.000	4.3700	2.5000	−3.8366	0.	0.	180.
−2	−116.4734	34.4524	6.2500	154.8000	90.000	4.3700	2.5000	−4.0525	0.	0.	180.
−2	−116.4734	34.4524	8.7500	154.8000	90.000	4.3700	2.5000	−2.9561	0.	0.	180.
−2	−116.4734	34.4524	11.2500	154.8000	90.000	4.3700	2.5000	−1.8531	0.	0.	180.
−2	−116.4734	34.4524	13.7500	154.8000	90.000	4.3700	2.5000	−0.9358	0.	0.	180.
−2	−116.5324	34.5085	1.2500	179.7000	90.000	2.7000	2.5000	−2.2101	0.	0.	180.
−2	−116.5324	34.5085	3.7500	179.7000	90.000	2.7000	2.5000	−1.5719	0.	0.	180.
−2	−116.5324	34.5085	6.2500	179.7000	90.000	2.7000	2.5000	−0.9099	0.	0.	180.
−2	−116.5324	34.5085	8.7500	179.7000	90.000	2.7000	2.5000	−0.4755	0.	0.	180.
−2	−116.5324	34.5085	11.2500	179.7000	90.000	2.7000	2.5000	−0.2408	0.	0.	180.
−2	−116.5324	34.5085	13.7500	179.7000	90.000	2.7000	2.5000	−0.1054	0.	0.	180.
−2	−116.5141	34.4867	1.2500	179.7000	90.000	3.3600	2.5000	−0.6222	0.	0.	180.
−2	−116.5141	34.4867	3.7500	179.7000	90.000	3.3600	2.5000	−0.3308	0.	0.	180.
−2	−116.5141	34.4867	6.2500	179.7000	90.000	3.3600	2.5000	−0.1367	0.	0.	180.
−2	−116.5141	34.4867	8.7500	179.7000	90.000	3.3600	2.5000	−0.0816	0.	0.	180.
−2	−116.5141	34.4867	11.2500	179.7000	90.000	3.3600	2.5000	0.0725	0.	0.	180.
−2	−116.5141	34.4867	13.7500	179.7000	90.000	3.3600	2.5000	−0.0581	0.	0.	180.
−2	−116.4670	34.4143	1.2500	188.8000	90.000	4.5800	2.5000	−2.6676	0.	0.	180.
−2	−116.4670	34.4143	3.7500	188.8000	90.000	4.5800	2.5000	−2.427	0.	0.	180.
−2	−116.4670	34.4143	6.2500	188.8000	90.000	4.5800	2.5000	−1.8653	0.	0.	180.
−2	−116.4670	34.4143	8.7500	188.8000	90.000	4.5800	2.5000	−1.2885	0.	0.	180.
−2	−116.4670	34.4143	11.2500	188.8000	90.000	4.5800	2.5000	−0.8159	0.	0.	180.
−2	−116.4670	34.4143	13.7500	188.8000	90.000	4.5800	2.5000	−0.4193	0.	0.	180.
−2	−116.5382	34.5023	1.2500	140.7000	90.000	1.7300	2.5000	−1.5896	0.	0.	180.
−2	−116.5382	34.5023	3.7500	140.7000	90.000	1.7300	2.5000	−2.071	0.	0.	180.
−2	−116.5382	34.5023	6.2500	140.7000	90.000	1.7300	2.5000	−1.8713	0.	0.	180.
−2	−116.5382	34.5023	8.7500	140.7000	90.000	1.7300	2.5000	−1.3888	0.	0.	180.
−2	−116.5382	34.5023	11.2500	140.7000	90.000	1.7300	2.5000	−0.9089	0.	0.	180.
−2	−116.5382	34.5023	13.7500	140.7000	90.000	1.7300	2.5000	−0.4721	0.	0.	180.
−2	−116.5232	34.4839	1.2500	148.8000	90.000	3.2300	2.5000	−5.5687	0.	0.	180.
−2	−116.5232	34.4839	3.7500	148.8000	90.000	3.2300	2.5000	−4.4303	0.	0.	180.
−2	−116.5232	34.4839	6.2500	148.8000	90.000	3.2300	2.5000	−3.0993	0.	0.	180.
−2	−116.5232	34.4839	8.7500	148.8000	90.000	3.2300	2.5000	−2.0223	0.	0.	180.
−2	−116.5232	34.4839	11.2500	148.8000	90.000	3.2300	2.5000	−1.2458	0.	0.	180.
−2	−116.5232	34.4839	13.7500	148.8000	90.000	3.2300	2.5000	−0.6426	0.	0.	180.
−2	−116.5032	34.4521	1.2500	155.3000	90.000	4.7600	2.5000	−4.3486	0.	0.	180.
−2	−116.5032	34.4521	3.7500	155.3000	90.000	4.7600	2.5000	−3.972	0.	0.	180.
−2	−116.5032	34.4521	6.2500	155.3000	90.000	4.7600	2.5000	−3.2553	0.	0.	180.
−2	−116.5032	34.4521	8.7500	155.3000	90.000	4.7600	2.5000	−2.3797	0.	0.	180.
−2	−116.5032	34.4521	11.2500	155.3000	90.000	4.7600	2.5000	−1.5807	0.	0.	180.
−2	−116.5032	34.4521	13.7500	155.3000	90.000	4.7600	2.5000	−0.8404	0.	0.	180.
−2	−116.4816	34.4133	1.2500	155.3000	90.000	4.7500	2.5000	−5.169	0.	0.	180.
−2	−116.4816	34.4133	3.7500	155.3000	90.000	4.7500	2.5000	−6.3143	0.	0.	180.
−2	−116.4816	34.4133	6.2500	155.3000	90.000	4.7500	2.5000	−5.6675	0.	0.	180.
−2	−116.4816	34.4133	8.7500	155.3000	90.000	4.7500	2.5000	−4.1784	0.	0.	180.
−2	−116.4816	34.4133	11.2500	155.3000	90.000	4.7500	2.5000	−2.7072	0.	0.	180.
−2	−116.4816	34.4133	13.7500	155.3000	90.000	4.7500	2.5000	−1.3993	0.	0.	180.
−2	−116.4590	34.3850	1.2500	132.4000	90.000	2.9400	2.5000	−0.3699	0.	0.	180.
−2	−116.4590	34.3850	3.7500	132.4000	90.000	2.9400	2.5000	−1.8561	0.	0.	180.
−2	−116.4590	34.3850	6.2500	132.4000	90.000	2.9400	2.5000	−2.2612	0.	0.	180.
−2	−116.4590	34.3850	8.7500	132.4000	90.000	2.9400	2.5000	−1.9582	0.	0.	180.
−2	−116.4590	34.3850	11.2500	132.4000	90.000	2.9400	2.5000	−1.4134	0.	0.	180.
−2	−116.4590	34.3850	13.7500	132.4000	90.000	2.9400	2.5000	−0.7819	0.	0.	180.
−2	−116.4476	34.3690	1.2500	182.6000	90.000	1.5800	2.5000	−0.5221	0.	0.	180.
−2	−116.4476	34.3690	3.7500	182.6000	90.000	1.5800	2.5000	−0.8722	0.	0.	180.
−2	−116.4476	34.3690	6.2500	182.6000	90.000	1.5800	2.5000	−0.7708	0.	0.	180.
−2	−116.4476	34.3690	8.7500	182.6000	90.000	1.5800	2.5000	−0.5428	0.	0.	180.
−2	−116.4476	34.3690	11.2500	182.6000	90.000	1.5800	2.5000	−0.3403	0.	0.	180.
−2	−116.4476	34.3690	13.7500	182.6000	90.000	1.5800	2.5000	−0.1723	0.	0.	180.
−2	−116.4362	34.3398	1.2500	156.3000	90.000	5.3800	2.5000	−1.643	0.	0.	180.
−2	−116.4362	34.3398	3.7500	156.3000	90.000	5.3800	2.5000	−3.6146	0.	0.	180.
−2	−116.4362	34.3398	6.2500	156.3000	90.000	5.3800	2.5000	−4.0275	0.	0.	180.

−2	−116.4362	34.3398	8.7500	156.3000	90.000	5.3800	2.5000	−3.5103	0.	0.	180.
−2	−116.4362	34.3398	11.2500	156.3000	90.000	5.3800	2.5000	−2.6281	0.	0.	180.
−2	−116.4362	34.3398	13.7500	156.3000	90.000	5.3800	2.5000	−1.5105	0.	0.	180.
−2	−116.4514	34.3361	1.2500	186.2000	90.000	5.8000	2.5000	−5.4623	0.	0.	180.
−2	−116.4514	34.3361	3.7500	186.2000	90.000	5.8000	2.5000	−4.173	0.	0.	180.
−2	−116.4514	34.3361	6.2500	186.2000	90.000	5.8000	2.5000	−2.7194	0.	0.	180.
−2	−116.4514	34.3361	8.7500	186.2000	90.000	5.8000	2.5000	−1.6188	0.	0.	180.
−2	−116.4514	34.3361	11.2500	186.2000	90.000	5.8000	2.5000	−0.896	0.	0.	180.
−2	−116.4514	34.3361	13.7500	186.2000	90.000	5.8000	2.5000	−0.4108	0.	0.	180.
−2	−116.4700	34.3274	1.2500	143.9000	90.000	4.7500	2.5000	−0.2162	0.	0.	180.
−2	−116.4700	34.3274	3.7500	143.9000	90.000	4.7500	2.5000	−2.5349	0.	0.	180.
−2	−116.4700	34.3274	6.2500	143.9000	90.000	4.7500	2.5000	−3.1317	0.	0.	180.
−2	−116.4700	34.3274	8.7500	143.9000	90.000	4.7500	2.5000	−2.8342	0.	0.	180.
−2	−116.4700	34.3274	11.2500	143.9000	90.000	4.7500	2.5000	−2.1899	0.	0.	180.
−2	−116.4700	34.3274	13.7500	143.9000	90.000	4.7500	2.5000	−1.2933	0.	0.	180.
−2	−116.4474	34.2960	1.2500	157.000	90.000	3.4600	2.5000	−3.3692	0.	0.	180.
−2	−116.4474	34.2960	3.7500	157.000	90.000	3.4600	2.5000	−3.3542	0.	0.	180.
−2	−116.4474	34.2960	6.2500	157.000	90.000	3.4600	2.5000	−2.8719	0.	0.	180.
−2	−116.4474	34.2960	8.7500	157.000	90.000	3.4600	2.5000	−2.2354	0.	0.	180.
−2	−116.4474	34.2960	11.2500	157.000	90.000	3.4600	2.5000	−1.5943	0.	0.	180.
−2	−116.4474	34.2960	13.7500	157.000	90.000	3.4600	2.5000	−0.9016	0.	0.	180.
−2	−116.4382	34.2641	1.2500	174.8000	90.000	3.9200	2.5000	−2.6882	0.	0.	180.
−2	−116.4382	34.2641	3.7500	174.8000	90.000	3.9200	2.5000	−2.5633	0.	0.	180.
−2	−116.4382	34.2641	6.2500	174.8000	90.000	3.9200	2.5000	−2.1182	0.	0.	180.
−2	−116.4382	34.2641	8.7500	174.8000	90.000	3.9200	2.5000	−1.576	0.	0.	180.
−2	−116.4382	34.2641	11.2500	174.8000	90.000	3.9200	2.5000	−1.0636	0.	0.	180.
−2	−116.4382	34.2641	13.7500	174.8000	90.000	3.9200	2.5000	−0.5709	0.	0.	180.
−2	−116.4373	34.2286	1.2500	182.8000	90.000	4.0100	2.5000	−1.5572	0.	0.	180.
−2	−116.4373	34.2286	3.7500	182.8000	90.000	4.0100	2.5000	−1.6155	0.	0.	180.
−2	−116.4373	34.2286	6.2500	182.8000	90.000	4.0100	2.5000	−1.3827	0.	0.	180.
−2	−116.4373	34.2286	8.7500	182.8000	90.000	4.0100	2.5000	−1.0416	0.	0.	180.
−2	−116.4373	34.2286	11.2500	182.8000	90.000	4.0100	2.5000	−0.7029	0.	0.	180.
−2	−116.4373	34.2286	13.7500	182.8000	90.000	4.0100	2.5000	−0.3741	0.	0.	180.
−2	−116.4334	34.1924	1.2500	167.3000	90.000	4.1400	2.5000	−4.48	0.	0.	180.
−2	−116.4334	34.1924	3.7500	167.3000	90.000	4.1400	2.5000	−3.5128	0.	0.	180.
−2	−116.4334	34.1924	6.2500	167.3000	90.000	4.1400	2.5000	−2.4564	0.	0.	180.
−2	−116.4334	34.1924	8.7500	167.3000	90.000	4.1400	2.5000	−1.6644	0.	0.	180.
−2	−116.4334	34.1924	11.2500	167.3000	90.000	4.1400	2.5000	−1.0931	0.	0.	180.
−2	−116.4334	34.1924	13.7500	167.3000	90.000	4.1400	2.5000	−0.5929	0.	0.	180.
−2	−116.4069	34.1493	1.2500	157.6000	90.000	7.1600	2.5000	−0.7781	0.	0.	180.
−2	−116.4069	34.1493	3.7500	157.6000	90.000	7.1600	2.5000	−1.7555	0.	0.	180.
−2	−116.4069	34.1493	6.2500	157.6000	90.000	7.1600	2.5000	−1.8585	0.	0.	180.
−2	−116.4069	34.1493	8.7500	157.6000	90.000	7.1600	2.5000	−1.5541	0.	0.	180.
−2	−116.4069	34.1493	11.2500	157.6000	90.000	7.1600	2.5000	−1.1437	0.	0.	180.
−2	−116.4069	34.1493	13.7500	157.6000	90.000	7.1600	2.5000	−0.6601	0.	0.	180.
−2	−116.3842	34.1014	1.2500	160.3000	90.000	4.2800	2.5000	−0.086	0.	0.	180.
−2	−116.3842	34.1014	3.7500	160.3000	90.000	4.2800	2.5000	−0.6315	0.	0.	180.
−2	−116.3842	34.1014	6.2500	160.3000	90.000	4.2800	2.5000	−0.6113	0.	0.	180.
−2	−116.3842	34.1014	8.7500	160.3000	90.000	4.2800	2.5000	−0.4533	0.	0.	180.
−2	−116.3842	34.1014	11.2500	160.3000	90.000	4.2800	2.5000	−0.3156	0.	0.	180.
−2	−116.3842	34.1014	13.7500	160.3000	90.000	4.2800	2.5000	−0.1837	0.	0.	180.
−2	−116.3666	34.0574	1.2500	162.5000	90.000	6.0500	2.5000	−0.2047	0.	0.	180.
−2	−116.3666	34.0574	3.7500	162.5000	90.000	6.0500	2.5000	−0.7401	0.	0.	180.
−2	−116.3666	34.0574	6.2500	162.5000	90.000	6.0500	2.5000	−0.8127	0.	0.	180.
−2	−116.3666	34.0574	8.7500	162.5000	90.000	6.0500	2.5000	−0.5505	0.	0.	180.
−2	−116.3666	34.0574	11.2500	162.5000	90.000	6.0500	2.5000	−0.2771	0.	0.	180.
−2	−116.3666	34.0574	13.7500	162.5000	90.000	6.0500	2.5000	−0.0909	0.	0.	180.
−2	−116.7826	34.2029	7.5000	48.0000	90.000	28.0000	15.0000	0.4515	0.	0.	180.
−2	−116.5618	34.6323	7.5000	80.3000	90.000	11.6100	15.0000	0.249	0.	0.	180.

*Wald and Heaton (1994) Big Bear model

†Wald and Heaton (1994) Eureka Peak fault shallower part

‡Wald and Heaton (1994) Eureka Peak fault deeper part

TYP, Type −2 = center point of dislocation is given in degrees; LONCEN, Longitude (degrees east) of the center point; LATCEN, Latitude (degrees north) of the center point; DCEN, Vertical depth to center point of dislocation (km); STR, Strike of the dislocation (°N); DIP, Dip of the dislocation (°); HORLEN, Full horizontal length of the dislocation (km); DIPLEN, Full vertical length of the dislocation (km); SS, Strike-slip Burger's vector (m) + is left lateral; DS, Dip-slip Burger's vector (m) + is normal faulting for positive dips; OP, Opening mode Burger's vector (m) + is expansion; RAKE, Rake angle for slip on the dislocation (not relevant if SS, DS given).

Appendix B

Table B1
Stress Change Results: Shear and Normal Stress Components

Effect of Landers Earthquake on Hector Mine Hypocenter

	Stress Changes (MPa) Due to:							
	Wald and Heaton (1994) Landers Model		Hudnut *et al.* (1994) Landers Model		Parsons and Dreger (2000) Landers Model		Hudnut and Larsen (1993) Landers Model	
No.*	$\Delta\tau$	$\Delta\sigma$	$\Delta\tau$	$\Delta\sigma$	$\Delta\tau$	$\Delta\sigma$	$\Delta\tau$	$\Delta\sigma$
1	−0.050	0.009	−0.175	0.149	−0.015	0.005	−0.173	0.016
2	−0.046	0.011	−0.152	0.127	−0.012	0.007	−0.151	0.009
3	−0.038	0.031	−0.119	0.109	−0.009	0.025	−0.124	0.012
4	−0.057	0.008	−0.146	0.127	−0.018	0.000	−0.168	0.031
5	−0.083	0.058	−0.132	0.226	−0.039	0.021	−0.177	0.154
6	−0.085	0.037	−0.156	0.213	−0.038	0.008	−0.196	0.123
7	−0.006	0.066	−0.037	0.092	0.011	0.043	−0.073	0.074
8	−0.050	0.058	−0.127	0.146	−0.016	0.039	−0.147	0.066
9	−0.075	0.053	−0.174	0.167	−0.030	0.035	−0.196	0.057
10	−0.090	0.112	−0.155	0.284	−0.041	0.061	−0.207	0.200

Effect of Pisgah and Landers Earthquake on Hector Mine Hypocenter

	Stress Changes (MPa) Due to Pisgah and Landers Earthquakes under Landers Model:							
	Wald and Heaton (1994)		Hudnut *et al.* (1994)		Parsons and Dreger (2000)		Hudnut and Larsen (1993)	
No.*	$\Delta\tau$	$\Delta\sigma$	$\Delta\tau$	$\Delta\sigma$	$\Delta\tau$	$\Delta\sigma$	$\Delta\tau$	$\Delta\sigma$
1	−0.017	−0.022	−0.142	0.118	0.018	−0.027	−0.140	−0.015
2	0.043	−0.137	−0.064	−0.020	0.076	−0.141	−0.063	−0.139
3	−0.006	0.380	−0.087	0.458	0.023	0.373	−0.093	0.361
4	0.021	−0.153	−0.068	−0.034	0.060	−0.161	−0.090	−0.130
5	−0.083	−0.130	−0.133	0.038	−0.040	−0.167	−0.178	−0.034
6	−0.122	−0.213	−0.192	−0.037	−0.075	−0.242	−0.232	−0.127
7	0.005	0.050	−0.026	0.076	0.022	0.027	−0.063	0.058
8	0.043	0.157	−0.034	0.244	0.077	0.137	−0.054	0.164
9	0.299	−0.262	0.200	−0.148	0.344	−0.280	0.177	−0.259
10	0.094	−0.400	0.029	−0.228	0.143	−0.452	−0.022	−0.312

*1, First-motion solution from Hauksson *et al.* (2002); 2, first-motion solution from Hauksson *et al.* (2002); 3, first-motion solution from Hauksson *et al.* (2002); 4, from Kaverina *et al.* (submitted); 5, from Kaverina *et al.* (submitted); 6, preliminary mechanism published in Scientists of the USGS *et al.*, (2000); 7, explores the effect near the preliminary centroid depth (Scientists of the USGS *et al.*, 2000); 8, mechanism originally released on the Hector Mine Website shortly after the earthquake; 9, hypocenter from Parsons and Dreger (2000); 10, hypocenter from Parsons and Dreger (2000).

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