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Behavior of Repeating Earthquake Sequences in Central California and the Implications for Subsurface Fault Creep

By

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Abstract

Repeating earthquakes (REs) are sequences of events that have nearly identical waveforms and are interpreted to represent fault asperities driven to failure by loading from aseismic creep on the surrounding fault surface at depth. We investigate the occurrence of these REs along faults in central California to determine which faults exhibit creep and the spatio-temporal distribution of this creep. At the juncture of the San Andreas and southern Calaveras-Paicines faults, both faults as well as a smaller secondary fault, the Quien Sabe fault, are observed to produce REs over the observation period of March 1984 – May 2005. REs in this area reflect a heterogeneous creep distribution along the fault plane with significant variations in time. Cumulative slip over the observation period at individual sequence locations is determined to range from 5.5 – 58.2 cm on the San Andreas fault, 4.8 – 14.1 cm on the southern Calaveras-Paicines fault, and 4.9 – 24.8 cm on the Quien Sabe fault. Creep at depth appears to mimic the behaviors seen of creep on the surface in that evidence of steady slip, triggered slip, and episodic slip phenomena are also observed in the RE sequences. For comparison, we investigate the occurrence of REs west of the San Andreas fault within the southern Coast Range. Events within these RE sequences only occurred minutes to weeks apart from each other and then did

not repeat again over the observation period, suggesting that REs in this area are not produced by steady aseismic creep of the surrounding fault surface.

Introduction

Repeating earthquakes (REs) are nearly identically repeating events that have similar magnitudes and hypocenters. They can be identified by their extremely similar waveforms and have either aperiodic or quasi-periodic recurrence intervals. To date, they have been observed in both transform and convergent plate boundaries (Vidale et al., 1994 ; Nadeau et al., 1995 ; Schaff et al., 1998 ; Igarashi et al., 2003 ; Uchida et al., 2003). Nadeau and McEvilly (1999) suggested that the congruent waveforms result from stuck patches in an otherwise creeping fault which repeatedly rupture the same asperity. Other proposed physical models for REs include weak asperities at the border between larger locked and creeping patches on the fault plane (Sammis and Rice, 2001), inner asperities embedded within a creeping patch within an otherwise locked fault plane (Anooshehpoor and Brune, 2001), or creeping patches that strain harden until they fail seismically (Beeler et al., 2001). In each of these proposed physical models, creep adjacent to the asperity plays an important role in cyclically loading the RE sequence location to failure. Thus, even the simple detection of a RE sequence along a fault plane would imply that the fault is creeping. Of course, the absence of REs along a fault plane does not necessarily mean that creep is not occurring. Recently, burst type REs, sequences of nearly identically repeating events which have extremely short recurrence intervals and are active only for a short period of time, have been identified in subduction zones, both on the plate boundary itself and off the actual subduction interface (Kimura et al., 2006 ; Igarashi et al., 2003). Kimura et al. (2006) hypothesized that they are triggered by a local increase in stress due to the occurrence of large nearby earthquakes and do not reflect the background creep rate of the fault.

Although the mechanism for creep is not known, several hypotheses have been proposed as to what may help initiate or facilitate aseismic fault creep. These include the presence of weak, velocity-strengthening material within the fault gouge, which could lower the frictional strength of the fault and promote stable slip, or high fluid pressures within the fault zone, which could lower the effective normal stress (Moore et al., 1997 ; Irwin and Barns, 1975). The geometry of the fault zone itself has also been suggested to influence aseismic creep (Moore and Byerlee, 1992). Furthermore, surface creep can be affected by non-tectonic environmental factors, such as rainfall and yearly seasonal variations (Roeloffs, 2001).

Faults that creep aseismically may also have stuck patches or asperities that can produce major earthquakes (Johanson and Bürgmann, 2005 ; Johanson et al., 2006). Identifying which areas of the fault are locked and accumulating strain to be released during a future earthquake and which areas are slowly releasing, at least a portion, of this strain through aseismic creep is essential when evaluating seismic potential and hazard. Determining the distribution of displacement over these actively creeping fault planes can be aided by the ability to calculate slip at specific points at depth on a fault from RE seismic data. This information can complement slip results from geodetic measurements of surface deformation (Schmidt et al., 2005). Additionally, since surface geodetic measurements can have difficulty resolving slip in the mid- to lower seismogenic zone (Bos and Spakmann, 2003), even areas with excellent surface geodetic data could benefit from RE data points which can extend down to the bottom of the seismogenic zone. Additionally, in areas where surface geodetic data is poor or non-existent, the identification of REs becomes crucial when investigating the occurrence, magnitude and distribution of fault creep.

In this study, we compare the occurrence and behavior of REs within and between two different areas in central California. In the first area, at the juncture of the San Andreas and southern Calaveras-Paicines faults, geodetic data has observed surface creep and inferred the distribution of creep at depth along sections of the faults (Breckenridge and Simpson, 1997 ; Johanson and Bürgmann, 2005). Few geodetic studies have investigated the second area, which includes a portion of the transpressive fault system west of the San Andreas fault, but one study inferred creep to have occurred postseismically after the Mw6.5 22 December 2003 San Simeon earthquake (Savage and Svarc, 2005). We investigate these two regions to independently determine which faults are slipping aseismically and the magnitude of this subsurface creep using seismological data and the method of Nadeau and McEvilly (1999).

Study Regions

The first study area focuses on the juncture between the San Andreas and southern Calaveras-Paicines faults (Box A, Figure 1). This juncture region marks a transition of the behavior of the Pacific-North American plate boundary fault system. North of the juncture region, the plate boundary forms an intricate network of parallel, predominately right-lateral strike-slip faults. To the south, it becomes a relatively simple single fault strand that accommodates the majority of the motion between the two plates. The juncture area also marks the transition between the creeping section of the San Andreas fault to the south and a locked portion of the fault that slipped in the Mw7.9 1906 San Francisco earthquake. The San Andreas fault in this region separates the granitic and metamorphic rocks of the Salinian block to the west from the Great Valley Sequence, Franciscan Complex, and Coast Range ophiolite to the east (Wallace, 1990).

Geodetic data has shown that surface creep within the juncture region appears to be influenced not only by larger earthquakes, such as the Mw6.9 1989 Loma

Prieta earthquake, which occurred north of our study area (Breckenridge and Simpson, 1997), and the Ml 5.5 1986 Tres Piños earthquake (Simpson et al., 1988), but also by slow earthquakes such as the 1992, 1996, and 1998 San Andreas fault slow earthquakes which had equivalent moments equal to M4.8, M4.9 and M5.0, respectively (Linde et al., 1996 ; Johnston et al., 1996 ; Gwyther et al., 2000). Additionally, an inversion of GPS and InSAR data has shown that between 1995 – 2000, the subsurface creep along the San Andreas fault in this juncture region generally increased from north to south but also included two asperities large enough to produce moderate sized earthquakes (Johanson and Bürgmann, 2005).

The second study area is located within the southern Coast Ranges, west of the creeping section of the San Andreas fault and directly to the south of the previously mentioned San Andreas-southern Calaveras fault juncture (Box B, Figure 1). Faults within the southern Coast Ranges are composed of both right-lateral strike slip faults, associated with the transform tectonic regime related to the San Andreas fault, and thrust faults, which are thought to accommodate a small component of fault-normal compression (Clark et al., 1994). As opposed to the juncture region previously described, this area is primarily composed of granitic and metamorphic rocks of the Salinian block. However, a narrow region of coastal Franciscan rocks is also present within the Coast Ranges consisting of relatively coherent, low P-T metamorphosed graywackes (Clark et al., 1994 ;

McLaughlin et al., 1982 ; Ernst, 1971 ; Platt, 1986). The Mw6.5 2003 San Simeon earthquake is thought to have occurred within this complex (Hauksson et al., 2004).

Data and Methodology

Sequence Identification

We identify RE sequences using a waveform similarity analysis that takes into account the unfiltered waveform cross-correlation coefficient, the phase coherency, and the amplitude coherency between events. These three similarity measures are included in the analysis to obtain the best average estimate of waveform similarity using different quantitative values that can be calculated from the waveform data.

To begin the analysis, we first cross-correlating local unfiltered waveform data collected by the Northern California Seismic Network (NCSN) and archived at the Northern California Earthquake Data Center (NCEDC). The cross correlation was performed over a 5 second window beginning with the P-phase arrival in the frequency domain for all pairs of events with epicenters within 10 km of each other. This distance is greater than twice the formal catalog-location uncertainties for more than 90% of the events studied.

Once the cross-correlations are performed, we identify RE sequences via a two-step process. The first step is to identify a pair of events, which we call a master-pair, that are nearly identical and thus repeating. The second step is to identify all earthquakes that are also nearly identical to at least one of the master-pair of events.

To determine if a particular master-pair of events are nearly identical, we first determine that its cross correlation coefficient averaged over all vertical component NCSN stations within 50 km is greater then 0.95. Next we calculate the coherence of their phase and amplitude spectra in the complex domain. To do this we compute the RMS amplitudes of the first 5 sec of the two events at a station and normalize the waveform amplitudes. We then compute the complex spectra of the normalized waveforms and determine the complex unit vectors, ν_1 and ν_2, from the spectra

$$\nu_1 = \frac{a_1(f) + ib_1(f)}{\sqrt{(a_1(f))^2 + (ib_1(f))^2}} \qquad (1)$$

$$\nu_2 = \frac{a_2(f) + ib_2(f)}{\sqrt{(a_2(f))^2 + (ib_2(f))^2}} \qquad (2)$$

between 8 – 20 Hz in 0.2 Hz increments. We then determine the angle θ between the vectors and use this to calculate the phase coherence, C_P,

$$C_P = \cos(\theta) \qquad (3)$$

for each frequency increment. The phase coherence between the two earthquakes is then determined by averaging the coherence over all frequency increments and stations. To find the maximum phase coherence between the master-pair, this process is then repeated after shifting the waveforms up to +/- 5 samples in increments of 1/25 of a sample. A phase coherence value of 1 would indicate an exact match between the two waveforms.

Next, we perform two tests to determine the coherence of the amplitude spectra of the events under consideration. First, we calculate the difference in the amplitude spectra, $\alpha_1 - \alpha_2$, of the normalized waveforms between 8 – 20 Hz in 0.2 Hz increments. We then determine the amplitude coherence, C_{A1}, between the two waveforms using

$$C_{A1} = 1 - \frac{\sum(|\alpha_1 - \alpha_2|)}{N_f} \qquad (4)$$

where N_f are the number of frequency increments. An amplitude coherence value of 1 would then indicate an exact match between the two spectra. The second amplitude coherence method we use involves cross-correlating the amplitude spectra between 8 – 20 Hz. A cross correlation value of 1 would indicate an exact match between the amplitude spectra using this method.

The master-pair under consideration is identified as a repeating earthquake if the average of the three above mentioned methods of determining the amplitude and phase coherence is greater than 0.85. If this is the case, the amplitude and phase spectra coherency is then also determined in the same manner for all other events that have cross correlation coefficients greater than 0.85 when compared to one of the original master-pair of events. These additional earthquakes are included within the repeating earthquake sequence if the average of the three amplitude and phase coherence measures is greater than 0.85. Lastly, we visually inspect the RE groups to assure quality. A previous study of RE sequences on the San Andreas fault using both surface and borehole seismometers suggested that nearby RE sites with average magnitudes less than ~M1.3, which were clearly separate using the borehole data, are not clearly separated when using only NCSN surface data (Nadeau and McEvilly, 2004). Therefore, we include only RE sequences with average magnitudes greater than this value in our analysis. An example of a RE sequence identified using the above methodology is shown in Figure .

We chose the above 0.85 amplitude and phase coherence criteria for the NCSN dataset based on comparisons between repeating earthquake catalogs derived independently using surface NCSN and borehole HRSN data sets in the Parkfield area (Nadeau and McEvilly, 1997 ; Nadeau and McEvilly, 2004). In these previous studies, the higher resolution borehole data was able to clearly demonstrate both the effective collocation and waveform coherence that is indicative of repeated patch rupture. These studies also showed a distinct drop in coherence values that distinguishes repeating events from nearby, nonoverlapping events which may have similar, but not nearly identical, waveforms. For the NCSN data, this drop in coherence was observed to typically occur between 0.80 and 0.90. Hence, in this study, we picked the mid-range value as our criteria for identifying repeating earthquakes.

This method of determining RE sequences was applied to the waveforms of the over 5,000 events occurring between 1 March 1984 and 1 May 2005 at the juncture of the San Andreas and southern Calaveras faults (Box A, Figure 1). This region also includes portions of the San Andreas fault that contained previously identified RE sequences (Nadeau and McEvilly, 2004). For these REs, we extended the time series of each sequence to include repeats occurring until 1 May 2005. Locations of RE sequences within this juncture region are plotted using a hypoDD-relocated earthquake catalog of northern California (Ellsworth *et al.*, 2000).

We also applied our RE sequence identification technique to the area west of the San Andreas fault within the southern Coast Ranges (Box B, Figure 1). Waveforms for over 7,000 events occurring between 1 March 1984 and 1 May 2005, which included the aftershock sequence of the Mw6.5 2003 San Simeon earthquake, were obtained from NCSN stations up to 50 km away and compared to identify RE sequences. Approximately 5,500 events in this study area are located within the San Simeon aftershock zone. RE sequences in this area are plotted using locations obtained from the NCSN catalog.

Slip Rates From REs

We use the method of Nadeau and McEvilly (1999) to determine the amount of slip at specific asperities along the fault plane. This approach assumes that a RE is a stuck patch in an otherwise creeping fault which “catches up” with the adjacent creeping fault when it fails seismically. The total amount of slip in centimeters, D_{tot}, at a RE location can be determined by the empirical relationship

$$D_{tot} = \left(10^{0.255(M-0.15)+0.377}\right) \times n \qquad (5)$$

where M is the average NCSN preferred catalog magnitude of the RE sequence and n the number of times the earthquake repeats. This empirical relationship, originally determined by calibrating geodetic creep and RE data along the creeping section of the San Andreas fault at Parkfield, estimates the amount of creep surrounding a RE location between each repeat within a sequence and multiplies it by the number of times the earthquake repeats over the observation period to compute the cumulative amount of slip at each sequence location. Incorporating additional assumptions, the empirical relationship can be used to infer the mechanical properties of rupture on these asperities, such as stress drop, but for the purposes of determining subsurface slip these additional assumptions are not required.

Although the empirical relation in Equation 5 was calibrated on the Parkfield segment of the San Andreas fault, it has also been employed in a subduction zone setting where the RE derived spatial and temporal distribution of slip along the plate boundary was shown to be consistent with independently determined geodetic interpretations of the plate coupling behavior (Igarashi et al., 2003 ; Uchida et al., 2003). Additionally, other studies on the Chihshang fault in Taiwan and on the Hayward fault in California have shown that creep rates determined from REs compare well with results from measurements taken at the surface (Chen et al., 2007 ; Bürgmann et al., 2000). This surprising observational result suggests that the strength of asperities that produce repeating earthquakes does not vary significantly between these locations and that these asperities rupture under essentially the same critical stress conditions in each of these diverse tectonic regimes.

Results

The range of ~22-year cumulative slip amounts calculated at individual patches along the fault plane using RE data on the San Andreas, southern Calaveras-Paicines, and Quien Sabe faults is determined to be between 5.5 – 58.2 cm, 4.8 – 14.1 cm, and 4.9 – 24.8 cm, respectively (Figure 3). This corresponds to a range of average slip rates between 2.5 – 26.7 mm/yr, 2.2 – 6.5 mm/yr, and 2.2 –

11.4 mm/yr, respectively, if we divide D_{tot}, by the time of the observation window, 21.83 yrs. Histogram distributions of the cumulative slip on these three faults can be seen in Figure 4 where the number of RE sequences with similar cumulative slip amounts are sorted into 6 cm bins. The repeating earthquake sequences in this dataset have average magnitudes between M1.3 and M3.2. In the electronic supplement, we document all RE event information and slip estimates determined in this study (Table S1).

Although we present slip rates for the San Andreas, southern Calaveras-Paicines and Quien Sabe faults, we will primarily focus on cumulative slip amounts when comparing the magnitude of slip between faults in this study since slip rates on two of our target faults are low and vary in time. This can be seen in the fact that the majority of RE sequences along the Quien Sabe and southern Calaveras-Paicines faults repeat only two or three times over the observation period. This is illustrated graphically in Figures 4 and 5 which show the occurrence and timing of events within individual sequences on these two faults throughout the observation period. Conversely, sequences on the San Andreas fault are seen to repeat up to 10 times (Figure 7). Here the repeat interval between events is short enough with respect to the observation window that a reasonably accurate estimate of the creep rate on the fault is possible since several cycles of loading and rupture are observed.

San Andreas Fault REs

On the San Andreas fault, RE sequences occur on the fault throughout the seismogenic zone between approximately 1 – 15 km depths, sometimes on horizontal linear streaks of seismicity (Figure 8). As seen in previous studies (Breckenridge et al., 1997 ; Schaff et al., 1998 ; Nadeau and McEvilly, 2004), the Mw6.9 1989 Loma Prieta earthquake, which occurred approximately 30 km to the north of our study area, produced a strong increase in creep rate along the San Andreas fault. This increase in creep was strongest in the northwestern portion of the San Andreas fault studied and weaker in the southeastern portion. This can be seen in terms of RE inferred deep creep in Figure 7 by comparing the recurrence intervals and timing of events between Sections I and V before and after the Loma Prieta earthquake. In Section I, RE sequences were seen to start or to increase their frequency after the Loma Prieta earthquake while in Section V, sequences did not appear to be strongly influenced by the earthquake (Figure 7). Section II shows a disrupted creep zone, an area with significantly fewer REs, that had been previously identified by Nadeau and McEvilly (2004) to be a locked segment of the San Andreas fault which ruptured as the Mw5.1 12 August 1998 San Juan Bautista event. Consequently, directly after the Loma Prieta earthquake, an increase in the amount of creep was not observed in this area.

However, a clear and immediate effect on the San Andreas RE sequences in Section II occurred after the 1998 Mw5.1 San Juan Bautista event (Uhrhammer et al., 1999) (Figure 7). It increased the frequency of RE repeat times of sequences up to 3.5 km away.

The largest event to occur within our study area during the observation period was the Ml 5.5 Tres Piños earthquake that occurred on 26 January 1986 on the Quien Sabe fault zone. This event also had a M4.0 aftershock a few hours after the mainshock on the northeast segment of the Quien Sabe fault zone. Although this event produced up to ~5 mm of creep at the surface of the San Andreas fault (Simpson et al., 1988), there is no clear indication of a change in the rate of creep at depth on the San Andreas from the RE data.

Additionally, a M4.7 event occurred on 31 May 1986 just south of our study area on the San Andreas fault. This event appears to influence the timing of 5 RE sequences up to 1.5 km away (Section V of Figure 7). Another M4.7 event that occurred on 28 December 2001 on the study area's southern boundary on the San Andreas fault, did not produce a clear and consistent effect upon the timing of nearby RE sequences.

Calaveras-Paicines Fault REs

On the Calaveras-Paicines fault, RE sequences occur between 3 – 9 km depth sometimes on short subhorizontal linear streaks of seismicity (Figure S4). Several fault strands are seismically active in the general location of the Calaveras fault zone in this area (Figure 3A); nonetheless RE sequences can only confirm that one structure is actively creeping at depth throughout the observation period. Interestingly, RE sequences are not found in the transition zone between the southern Calaveras and Paicines faults, 5 km south of Hollister. The Paicines fault does not appear to merge with the San Andreas fault at depth as the repeating sequences delineate two creeping fault strands 1.6 km apart at 4.5 - 5 km depth (Figures 2A and S6). The background seismicity is extremely sparse along the Paicines fault, but it also appears to suggest that the Paicines and San Andreas faults are separate down to 11 km (Figure S6).

It is unclear if nearby larger events on other faults, such as the Mw6.9 Loma Prieta and the Mw5.1 San Juan Bautista earthquakes on the San Andreas fault, affect the timing of RE sequences on the southern Calaveras-Paicines fault (Figure 6). Additionally, two events larger than M4.0 occurred on the Calaveras fault during our observation period; however for both events, a M4.2 event in 1997 and a M4.3 event in 2003, it was unclear if they influenced the timing of RE sequences since an obvious response from nearby RE sequences was not observed (Figure 6).

Quien Sabe Fault REs

The smaller Quien Sabe fault zone is more structurally complex than the more mature San Andreas and southern Calaveras-Paicines faults and does not appear to have any linear streaks of seismicity, suggesting that streaks and a relatively simple fault geometry are not a requirement for deep fault creep or for the production of REs (Figures 2A and S1). RE sequences occur between 3 – 10 km depth and delineate two planar structures on the Quien Sabe fault zone. The northeast segment is a slightly west-dipping fault plane that is connected to an east dipping fault plane by a seismically active fault structure that was ruptured by the Ml 5.5 Tres Piños earthquake.

The timing of REs on the northeast segment of the Quien Sabe fault zone was clearly affected by the 26 January 1986 Tres Piños earthquake (Figure 5). Two repeating clusters on the northeast segment, sequences 5 and 7, just over 4.5 km away from the mainshock began within two weeks of this event and had repeat intervals that increased with time from the mainshock. The majority of the remaining sequences on the northeast segment produced an earthquake within a year or two of the mainshock, repeated before the mid-1990s, and have been aseismic since. Total slip at individual sequence locations on this segment was determined to be between 5.7 - 15.7 cm. During the observation period, the total slip averaged over all sequences on this segment was 11.0 cm. This is in contrast to RE sequences found on the southwest segment where the total slip at sequence locations was between 10.5 – 24.8 cm with an averaged total slip of 20.3 cm over all sequences on this segment. It is unclear if creep on the southwest segment was initiated or influenced by the Tres Piños mainshock since the pre-mainshock time period is very limited. Interestingly, these sequences occur with quasi-periodic recurrence intervals unlike the strikingly aperiodic recurrence intervals of the northeast segment, suggesting that this fault plane has been steadily creeping over the entire observation period (Figure 5).

Neither the Loma Prieta earthquake nor the San Juan Bautista earthquake produced a notable effect on the timing of RE sequences on the Quien Sabe fault zone. Additionally, two other earthquakes greater than M4.0, a 1987 M4.1 event and a 1988 M5.1 event, which also occurred on the Quien Sabe fault zone during our observation period, produced no obvious effect on the timing of events within RE sequences. This was surprising since the M4.1 event occurred a few kilometers below several of the RE sequences on the northeast segment and the closest RE sequence to the M5.1 event was just over 2.5 km away. However, it is important to note that any influence that these smaller events may have exerted on the RE sequences may be indistinguishable from the influence of the larger Tres Piños event.

Burst Type Repeaters

As described earlier, some repeating earthquake sequences involve events that recur within hours or days of each other. We refer to these as burst type REs. In the San Andreas fault juncture region, 24 burst type REs are identified to have occurred during the observation period. Of these, 3 burst type RE sequences (Sequences 1, 8, and 25) are located off the major fault planes that are inferred to creep and are composed only of two events each (Figure 3). Individual events within these 3 RE sequences occurred within 3 days of each other. Sequences 1 and 8 occurred near the northeast segment of the Quien Sabe fault zone and do not appear to be directly associated with the timing of nearby larger events (Figures 6 and S1). Sequence 1 occurred in 1986, a few months after the Ml 5.5 Tres Piños earthquake while Sequence 8 occurred in 1990, 4 years after the Tres Piños event and more than 2 years after the nearest event greater than M4.0. Sequence 25 is located between the Calaveras and San Andreas fault and occurred in 1998, several months before the nearby Mw5.1 San Juan Bautista event would occur on the San Andreas fault (Figures 5 and S3).

The remaining 21 burst sequences all occurred on the San Andreas fault and had between 2 and 4 individual events within each sequence. The shortest time interval between events within a sequence on the San Andreas fault was less than one minute. Interestingly, burst sequences containing 4 events typically had the first three events occur between minutes to days of one another while the last event often occurred between months to up to 1.5 years apart from the other sequence members. Of the 21 burst type events located here,14 occurred close in time and space to the Mw5.1 San Juan Bautista event and subsequent slow earthquake (Figures S9 and S10). The remaining 7 were located to the south of the San Juan Bautista segment and do not appear to be clustered in either time or space (Figures S9 and S10). All burst-type sequences are seen to be preferentially located along the lower edge of the areas in which RE sequences are identified.

Southern Coast Range REs

It has been suggested that one reason for the occurrence of creep on faults lies in the mineralogy of fault zone rocks. Along the San Andreas fault system, particular attention has been paid to the apparent correspondence of outcrops of serpentinite and the ability of the fault to creep (Irwin and Barnes, 1975). To investigate the occurrence of REs on fault planes not associated with the material contrasts across the primary San Andreas fault system, we examine the seismicity west of the creeping segment of the San Andreas fault (Box B in Figure 1). The southern Coast Ranges are dominantly made up of Salinian granites and associated sedimentary and metamorphic units. However, this area also includes the fault that produced the Mw6.5 22 December 2003 San Simeon earthquake and associated aftershock sequence, which appears to have occurred entirely within coastal Franciscan rocks (Hauksson et al., 2004). Our analysis shows that only 6 burst type REs occurred within this area between 1 March 1984 and 1 May 2005 (Figure 3B) and that no non-burst type sequences occurred. The burst sequences were only active for 1 – 42 days and seem to cluster to the north of the main rupture area of the San Simeon earthquake. A small M4.3 earthquake, which occurred in 1985, also appears to have occurred nearby. However, it is unclear if it affected the timing of the burst events. Since the last burst type RE observed in this area occurred in 2000, none were temporally associated with the aftershock sequence of the San Simeon earthquake, which produced ~5,500 of the events investigated in this study region, but not a single RE pair.

Discussion

Comparison with Geologic and Geodetic Data

Within the juncture study area, the San Andreas and southern Calaveras-Paicines faults are known to creep aseismically from surface data (Galehouse and Lienkaemper, 2003 ; Lisowski and Prescott, 1981). The identification of RE sequences along these faults identifies portions of the fault that are actively slipping at depth as well. No surface creep measurements have been taken across the Quien Sabe fault zone and space geodetic measurements have been inconclusive as well, possibly hampered by non-tectonic vertical deformation due to groundwater movement in this area (Johanson and Bürgmann, 2005). However, the RE seismological data clearly identify two major segments of the Quien Sabe fault that actively creeped, at least at depth, over the observation period.

A comparison between the 22 +/- 6 mm/yr overall long-term slip rate determined for the San Andreas fault segment north of the branch-off with the southern Calaveras-Paicines fault (Kelson et al., 1992) and slip rates determined in this study by non-burst type RE data at individual sequence locations shows that the majority of the RE slip patches are slipping at rates lower than the long-term slip. The average slip rate for the 99 non-burst type San Andreas fault RE sequences is 11.6 mm/yr, with a maximum slip rate observed at a RE location of 26.7 mm/yr. However, although the RE data are not consistent with the long-term rate, they are consistent with the geodetically determined creep rate of 11 +/- 3 mm/yr (Kelson et al., 1992). This geodetically determined rate is based on a compilation of published creep rates derived from modeling (Kelson et al., 1992).

Although slip on the southern Calaveras-Paicines and Quien Sabe fault zones can be highly variable in time, a similar comparison between long-term slip rates and ~22 year RE derived slip rates can be made as well. On the southern Calaveras fault, the 1999 Working Group on California Earthquake Probabilities

(WG99) inferred a long-term slip rate of 15 +/- 3 mm/yr (WG99, 1999) while the creep rate is thought to be approximately 12 +/- 6 mm/yr (Kelson et al., 1992). The average slip rates from non-burst type REs is 4.1 mm/yr with a range of 2.2 – 6.5 mm/yr. Thus, the calculated average RE slip rate is lower than either the long-term rate or the geodetic creep rate indicating that the portions of the fault which nucleate REs may have been accumulating strain over the past ~22 years. This could suggest that larger asperities on the fault plane retard creep and then fail in moderate earthquakes (Oppenheimer et al., 1990 ; Manaker et al., 2003). Alternatively, it is possible that our method, which was calibrated on the creeping section of the San Andreas fault, may not be appropriate for the Calaveras or Quien Sabe faults. However, good agreement between RE-derived slip rates and geodetic slip rates on other subduction and strike-slip faults suggest that this is not the case (Igarashi et al., 2003 ; Uchida et al., 2003 ; Bürgmann et al., 2000).

A probabilistic seismic hazard report assigned a slip rate of only 1 +/- 1 mm/yr for the Quien Sabe fault zone (Petersen et al., 1996). Nevertheless, one geologic investigation determined that the vertical slip rate ranged between 0.22 – 0.67 mm/yr, but was unable to determine the lateral component of displacement (Bryant, 1985). The Tres Pinos earthquake had a strike-slip to reverse sense of motion ratio of 6:1 (Hill et al., 1990). If the Tres Pinos earthquake is representative of the general horizontal to vertical displacement ratio of the fault, horizontal slip rates could be on the order of 1.32 – 4.02 mm/yr (Bryant, 1998).

The average slip rate from non-burst type REs is 5.0 mm/yr on the northeast segment, with a range of 2.6 – 7.2 mm/yr, and 9.3 mm/yr on the southeast segment, with a range of 4.8 – 11.4 mm/yr. Our ~22 year averaged values are significantly higher than either the assigned official slip rate or the inferred horizontal slip rate on the southeast segment. These RE-derived slip rates are more consistent with creep rates on the Calaveras fault than slip rates on the Quien Sabe fault. However, our averaged values for the northeast segment are only slightly higher than either the assigned or inferred slip rates on the Quien Sabe fault. On the northeast segment, the difference is likely due to a transient creep pulse induced by the Ml 5.5 Tres Piños earthquake. On the southwest segment, it is unclear if the higher RE-derived slip rates were induced by this larger event since the amount of pre-mainshock data is shorter than some of the recurrence intervals between REs and an immediate temporal triggering is not observed. Additionally, the quasi-periodic recurrence intervals indicate that creep on this segment has been occurring steadily over the observation period with no reduction in magnitude with time since the mainshock (Figure 5).

Effects of Larger Earthquakes

The influence of larger nearby earthquakes can be clearly seen in the timing of events on the San Andreas fault. For example, a clear relationship is seen between the increase in the frequency of RE occurrences within sequences along the San Andreas fault and the timing of the Loma Prieta earthquake (Section I in Figure 7). The same also holds true for the 1998 Mw5.1 San Juan Bautista earthquake (Section II in Figure 7). In contrast, the largest event to occur in our study area, the Ml 5.5 Tres Piños earthquake on the Quien Sabe fault zone, did not produce a clear effect on the timing of RE sequences on the San Andreas fault although it is known to have caused a small change in its surface creep (Simpson et al., 1988) and to have stimulated RE activity on the Quien Sabe fault. Additionally, although a 1986 M4.7 event just south of our study area on the San Andreas fault affected the timing of REs up to 1.5 km away (Section V in Figure 7), a 2001 M4.7 event near the same location did not produce a clear response from nearby sequences.

While some sequences could be immediately triggered by nearby larger earthquakes, other REs even closer to the hypocenter did not immediately recur. This indicates that the timing of rupture of a RE is not only influenced by the magnitude of the additional sudden stress increase induced by nearby larger earthquakes, but also by the state of stress at the sequence location and the temporally varying load increase due to the response of the creeping fault surrounding each RE location to the additional stress. Given all the different factors that could promote a RE recurrence, it is difficult to separate out these influences given the current dataset.

On the southern Calaveras-Paicines fault, it is unclear if larger nearby earthquakes affected RE sequence repeat intervals. On the surface, however, rapid slip pulses on the order of 12 – 14 mm, followed by a temporary but large decrease in creep rate along the southern Calaveras fault until mid-1993, were clearly observed after the 1989 Loma Prieta earthquake at creepmeters in Hollister (Galehouse and Lienkaemper, 2003). If present, a small change in creep at depth could have been masked by the lower background creep rate on this fault combined with the somewhat short pre-Loma Prieta time window. This could also explain why the timing of RE sequences did not appear to be effected by any nearby earthquakes larger than M4.0.

Larger earthquakes on the San Andreas fault did not influence the timing of RE sequences on the Quien Sabe fault. Additionally, although the Ml 5.5 1986 Tres Piños earthquake produced a clear effect on sequences on the northeastern Quien Sabe segment, a M5.1 1988 event also on the Quien Sabe fault zone did not appear to trigger any REs. However, a small effect could have been hidden by the stronger influence that the nearby Ml 5.5 Tres Piños earthquake previously exerted on these sequences.

Burst Type REs

We identify 24 burst type REs on or near all three active faults in the San Andreas fault juncture area. Three burst type REs, located near the creeping southern Calaveras and Quien Sabe faults (Figure 3A), do not appear to be associated with nearby larger earthquakes.

Most of the remaining burst type REs occurred on the San Andreas fault after the Mw5.1 San Juan Bautista event and subsequent slow earthquake (Figure 8). It is unclear if these burst type REs result from the static stress changes associated with the San Juan Bautista mainshock, from the immediate triggered aseismic slip due to the subsequent 1998 slow slip event, or from a different mechanism entirely.

These San Juan Bautista RE bursts appear to be unique in that neither the Mw6.9 Loma Prieta nor the Ml5.5 Tres Piños earthquakes triggered any bursts. However, it is important to note that the Loma Prieta earthquake occurred 30km to the north of our study area, perhaps too far away for bursts to be triggered within our study area, and that the Tres Piños earthquake occurred on a fault structure separate from those which nucleated the REs on the Quien Sabe fault zone. Moreover, a previous 1996 slow earthquake, which also occurred within our study area on the San Andreas fault and was of comparable moment with the 1998 slow earthquake, did not appear to trigger any bursts. However, at the time of the 1996 slow slip event the San Juan Bautista asperity still had not ruptured and was known to be partially shielding this area from creep (Nadeau and McEvilly, 2004). Therefore, perhaps not enough creep was occurring in this area to nucleate a burst type RE. Slow slip events have also been observed along other portions of the San Andreas fault (Linde et al., 1996), however, studies specifically looking for burst type REs have not yet been conducted near these events.

It is unclear as to why burst type REs south of the San Juan Bautista mainshock do not appear to be temporally correlated with larger events, or in fact with each other. The only common attribute between bursts in the northern and southern ends of the San Andreas fault studied are that most of these bursts occur on the lowermost boundary of the area where REs are seen to nucleate, (Figure S9), suggesting perhaps a change in fault zone lithology, rheology, physical conditions, and/or a change between locked and creeping behavior on the fault as influences on the occurrence of burst type REs seen on the San Andreas fault.

Southern Coast Ranges REs

In the southern Coast Ranges fault system west of the San Andreas fault, only burst type REs occurred (Figure 3B). The Mw6.5 San Simeon event and associated aftershock sequence also occurred within this region within the coastal Franciscan complex. Considering the theory that fault zone lithology may influence fault creep, if one type of rock possibly found within the Franciscan mélange is promoting fault creep, the lack of REs within this complex does not rule out fault zone lithology as an important factor in the ability of faults to nucleate REs. The Franciscan complex is composed of many different types of rocks of different origins, thus the exact composition of the mélange present within the Franciscan complex in the juncture region may be different from that found within the coast Franciscan complex. Within the granitic and metamorphic Salinian block, only burst type REs are seen to occur, suggesting that granitic rocks may not promote active fault creep and cyclic loading of asperities associated with REs. However, the number of earthquakes outside of the San Simeon aftershock zone is rather small (~1,500 events) and we cannot rule out small, slowly creeping faults in this region based on the small sample of events.

Conclusions

We identify portions of the San Andreas, southern Calaveras-Paicines, and Quien Sabe fault zones as actively slipping at depth between 1 March 1984 and 1 May 2005 based on the identification of 150 RE sequences (Figure 3A). Of these three faults, only the San Andreas and southern Calaveras-Paicines faults are known to be also actively creeping at the surface. Although several fault structures are seismically active in the general location of the southern Calaveras fault zone, RE sequences clearly delineate one actively creeping fault plane (Figure 3A). Since REs did not occur in the center of our study area over the transition between the southern Calaveras and Paicines faults, it is unclear if this portion of the fault is locked, creeping at a slower rate than can be imaged, or if this portion is simply unable to nucleate RE sequences.

The recurrence intervals of REs are seen to be both quasi-periodic and aperiodic, indicating that portions of the fault were creeping steadily over the observation period while other portions had a variable creep rate, possibly influenced by stress changes induced by nearby larger earthquakes. Quasi-periodic recurrence intervals are observed for RE sequences on the southwestern segment of the Quien Sabe fault zone as well as on portions of the San Andreas and southern Calaveras-Paicines faults, suggesting that creep surrounding these RE sequences is occurring steadily at depth. Evidence of triggered creep is seen on the northwestern segment of the Quien Sabe fault zone, after the Mw5.5 1986 Tres Piños earthquake (Sequences 1-7 in Figure 5), and on the San Andreas fault after both the Mw6.9 1989 Loma Prieta earthquake (Section 1 in Figure 7) and the Mw5.1 San Juan Bautista event (Section II in Figure 7). Discrete episodic creep events, not caused by larger nearby earthquakes, are also identified on the San Andreas and southern Calaveras-Paicines faults from an increase in frequency of events within certain RE sequences (for example Sequence 23 in Figure 6).

Of the sequences identified, 24 were burst type REs and occurred both near the southern Calaveras and Quien Sabe fault zones and also along portions of the San Andreas fault. Interestingly, the majority of these bursts occurred around the time of the Mw5.1 1998 San Juan Bautista event and subsequent slow earthquake. Further research into this intriguing phenomenon is necessary to better illuminate the mechanism causing these burst REs.

We compare the spatial and temporal behavior of REs identified on the San Andreas and southern Calaveras-Paicines fault juncture area (Box A in Figure 1) with the behavior of REs identified on the southern Coast Ranges fault system west of the creeping section of the San Andreas fault (Box B in Figure 1). Only six burst type REs are identified within the granitic and metamorphic Salinian block (Figure 3B). Non-burst type REs were not found in this area, even within the sliver of the coastal Franciscan which is thought to have nucleated the Mw6.5 2003 San Simeon earthquake and aftershock sequence (Hauksson et al., 2004).

The reason why some faults creep aseismically while others do not is an area of active scientific interest. The identification of RE sequences and the determination of the amount of slip at individual sequence locations have been shown to be a convenient proxy to the location and magnitude of fault creep. Two caveats must be added. The first being that burst type REs have been identified both on and off major fault planes, but may not be indicative of a general background creep rate. The second caveat is that the lack of REs along a fault plane does not necessarily indicate that creep is not occurring. Additionally, the identification of RE sequences along the Quien Sabe fault zone shows that faults do not need to be mature or have streaks of seismicity for creep to occur on them. The lack of non-burst type REs on the fault structures within the Salinian block of the southern Coast Ranges west of the creeping section of the San Andreas fault, suggests that perhaps the production of REs, and thus creep, is hindered in environments where granitic rocks occur on both sides of the fault zone.

Data Sources

The Northern California Seismic Network (NCSN) phase and waveform data used in this study was collected by the U.S. Geological Survey, Menlo Park and is freely available from the Northern California Earthquake Data Center (www.ncedc.org).

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Figure Captions

Figure 1. Map of central California. Box A delineates the San Andreas-southern Calaveras fault juncture study area while Box B delineates the southern Coast Ranges study area. Seismicity as small grey dots and faults as black lines. Fault labels are SAF = San Andreas fault, CPF = Southern Calaveras-Paicines fault, SF = Sargent fault, RF = Rinconada Fault, and SGHF = San Gregorio-Hosgri fault. Triangles are locations of large earthquakes considered in the discussion: SJB = Mw 5.1 1998 San Juan Bautista earthquake, TP = Ml 5.5 1986 Tres Piños earthquake, SS = Mw6.5 2003 San Simeon earthquake, and P = Mw6.0 2004 Parkfield earthquake. Inset map is of California with box representing zoomed in area.

Figure 2. Raw waveforms for Sequence 13 on the Quien Sabe fault zone at station OBPI. Event A occurred on 1988.113 (YYYY.JDY), Event B on 1994.035, and Event C on 2000.344. Y axis is in digital counts and X axis is in seconds.

Figure 3. A) Map of the juncture of the San Andreas and Calaveras faults. Extent of study area indicated by black box. Blue boxes indicate subsections I – V on the San Andreas fault discussed within the text. RE locations as large colored circles, burst type REs as colored diamonds, and fault traces as thick grey lines. Background seismicity relocated by Ellsworth et al. (2000) as small grey dots, earthquakes larger than M4.0 as green triangles, green triangles with grey outline indicate catalog locations of earthquakes greater than M4.0 that were not included in the relocated catalog. Two largest earthquakes to occur in the study area are indicated by large red triangles labeled TPeq, for the Ml 5.5 1986 Tres Piños earthquake, and SJBeq, for the Mw 5.1 1989 San Juan Bautista earthquake. Creepmeters are indicated by inverted grey triangles and strainmeter by the inverted black triangle. Cities are indicated by black stars and labeled SJB, for the city of San Juan Bautista, and Hollister, for the city of Hollister.

Figure 4. Histogram plots showing the number of RE sequences on each of the three faults in the San Andreas-southern Calaveras study area sorted into 6 cm cumulative slip bins. X label indicates the median slip value of the bins.

Figure 5. Occurrence of REs though time for all RE sequences located on the Quien Sabe fault zone. Cumulative total slip at a sequence location over the observation period is shown in centimeters. Time is in years. Thick grey

horizontal line separates sequences found on the northeastern segment of the fault (top) from those found on the southwestern segment (bottom). Dashed vertical line indicates the time of the Mw6.9 1989 Loma Prieta earthquake. Solid vertical black lines indicate the time of nearby earthquakes larger than M4.7. Magnitudes of the large nearby earthquakes indicated at top of plot.

Figure 6. Occurrence of REs though time for all RE sequences located on the Calaveras-Paicines fault. Cumulative total slip at a sequence location over the observation period is shown in centimeters and time is in years. Thick grey horizontal line separates sequences found on the southern Calaveras fault from those found on the Paicines fault. Dashed vertical line indicates the time of the Mw6.9 1989 Loma Prieta earthquake. Solid vertical black lines indicate the time of nearby earthquakes larger than M4.7. Magnitudes of the large nearby earthquakes indicated at top of plot.

Figure 7. Occurrence of REs though time for a subset of RE sequences located on the San Andreas fault. Cumulative total slip at a sequence location over the observation period is shown in centimeters. Time is in years. Thick grey horizontal lines separate four different subsections of the fault with Section I as the northernmost section within the study area and Section V as the southernmost. Sequence numbers are the numerical label names associated with each RE sequence. Dashed vertical line indicates the time of the Mw6.9

1989 Loma Prieta earthquake. Solid vertical black lines indicate the time of nearby earthquakes larger than M4.7. Magnitudes of the large nearby earthquakes indicated at top of plot.

Figure 8. Cross-section map of northern portion of San Andreas Fault studied. REs as colored circles and labels are individual sequence names for reference. Sequence label numbers increase from northwest to southeast. Burst type REs are colored triangles and labels are individual sequence names for reference. Burst type RE sequence label numbers increase from northwest to southeast. Color indicates the cumulative amount of slip at each sequence location over the observation period. Small dots are background seismicity from the hypoDD-relocated catalog of Ellsworth et al. (2000). Triangles indicate earthquakes larger than M4.0 and green triangles with grey outline indicate catalog locations of earthquakes greater than M4.0 that were not included in the relocated catalog. Red triangle labeled SJB is the Mw5.1 1998 San Juan Bautista event.

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Figure 1.

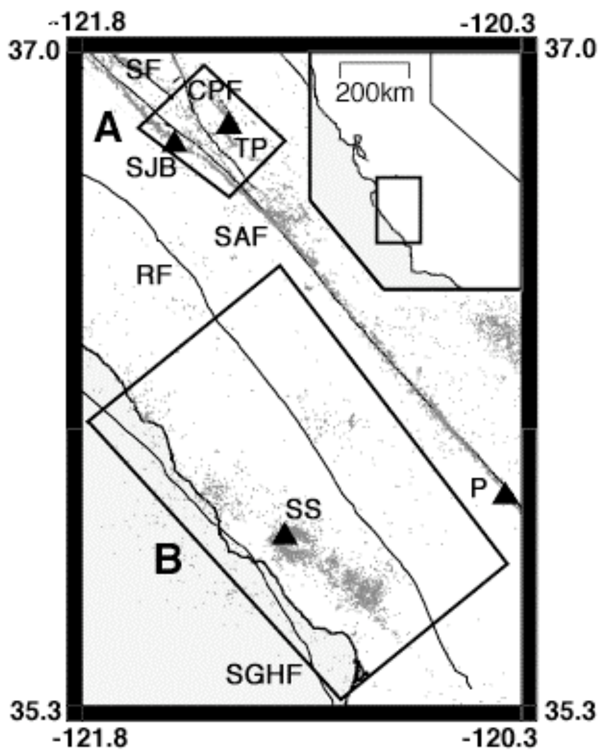

-121.8
-120.3
37.0
37.0
SF
CPF
A
SJB
TP
200km
SAF
RF
P
SS
B
SGHF
35.3
35.3
-121.8
-120.3

Figure 2.

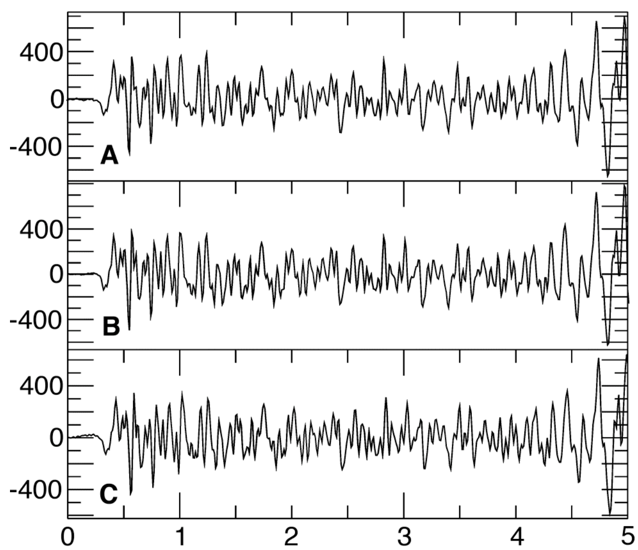


Figure 3.

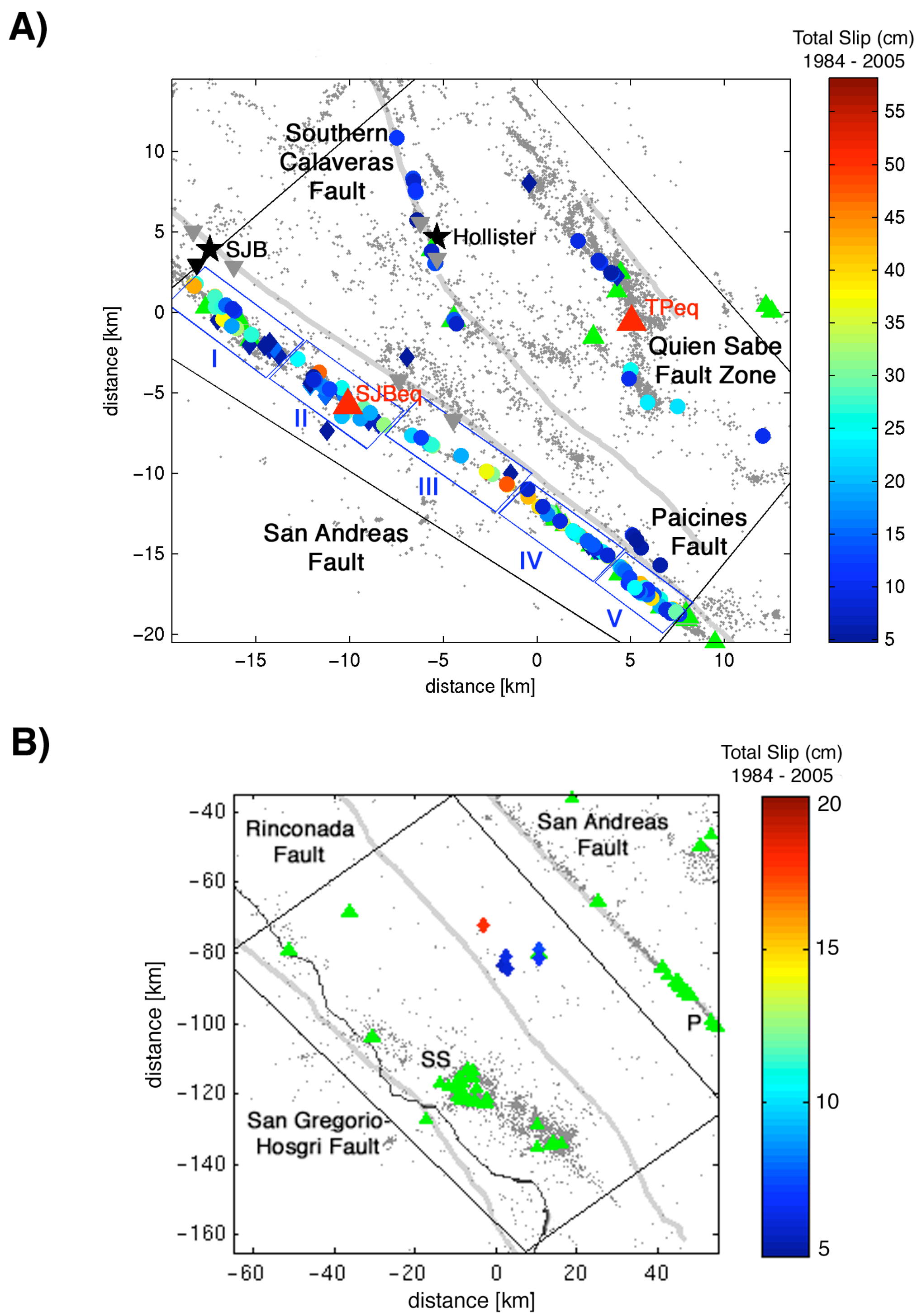
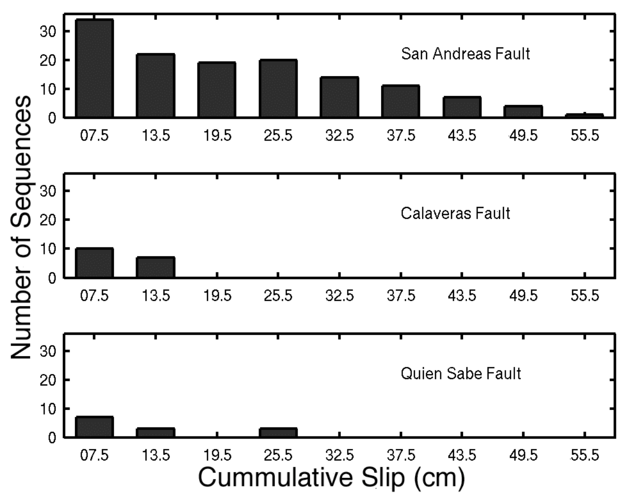
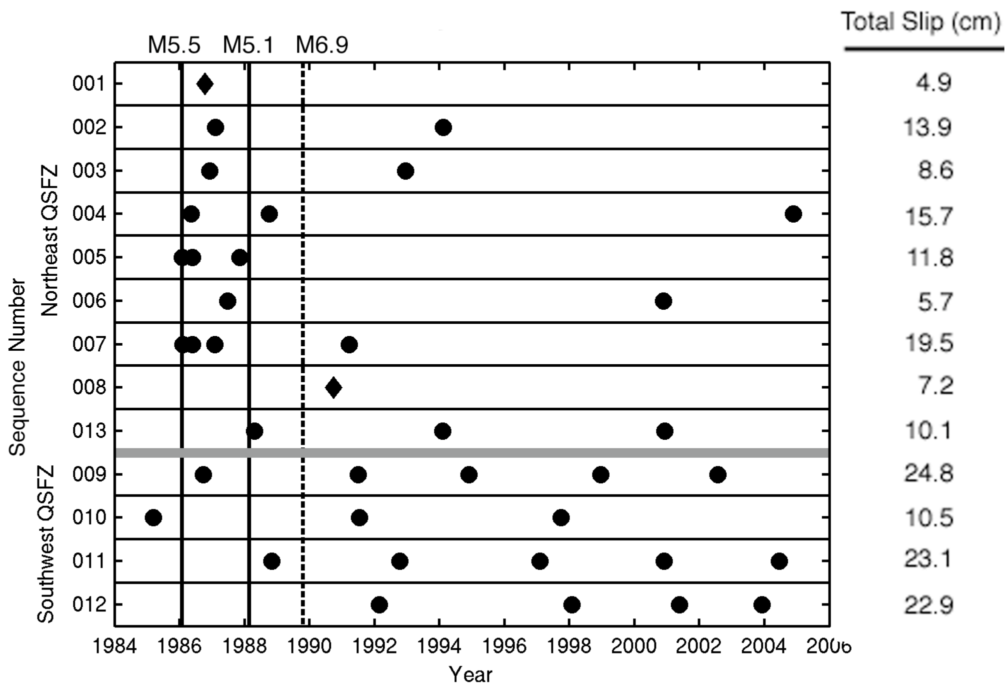

A)
Total Slip (cm)
1984 - 2005
Southern
Calaveras
Fault
SJB
Hollister
TPeq
Quien Sabe
Fault Zone
SJBeq
I
II
III
IV
V
San Andreas
Fault
Paicines
Fault
distance [km]
distance [km]
B)
Total Slip (cm)
1984 - 2005
Rinconada
Fault
San Andreas
Fault
P
SS
San Gregorio-
Hosgri Fault
distance [km]
distance [km]

Figure 4.



Number of Sequences
San Andreas Fault
Calaveras Fault
Quien Sabe Fault
0
10
20
30
07.5
13.5
19.5
25.5
32.5
37.5
43.5
49.5
55.5
Cummulative Slip (cm)

Figure 5.



Total Slip (cm)
M5.5
M5.1
M6.9
001
002
003
004
005
006
007
008
013
009
010
011
012
4.9
13.9
8.6
15.7
11.8
5.7
19.5
7.2
10.1
24.8
10.5
23.1
22.9
Sequence Number
Northeast QSFZ
Southwest QSFZ
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

Figure 6.

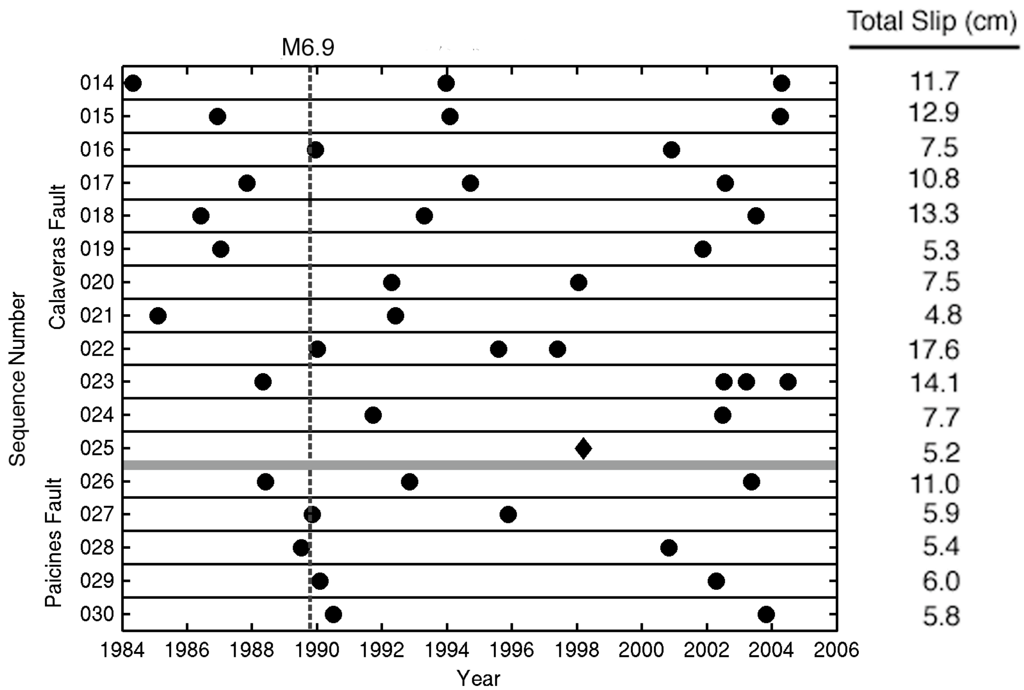

Total Slip (cm)
M6.9
014
015
016
017
018
019
020
021
022
023
024
025
026
027
028
029
030
Sequence Number
Calaveras Fault
Paicines Fault
11.7
12.9
7.5
10.8
13.3
5.3
7.5
4.8
17.6
14.1
7.7
5.2
11.0
5.9
5.4
6.0
5.8
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year

Figure 7.

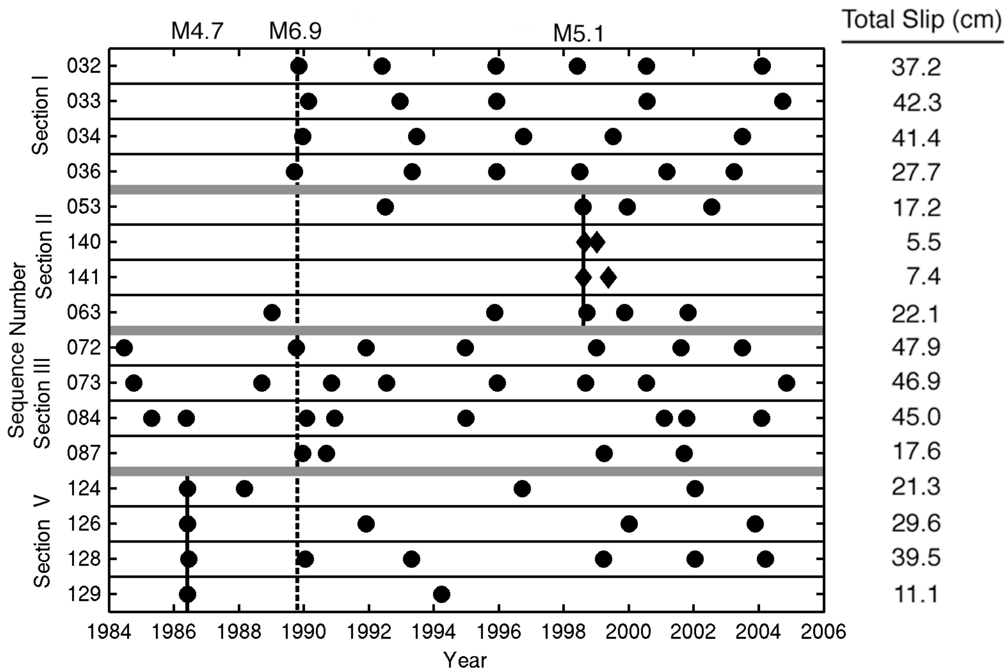
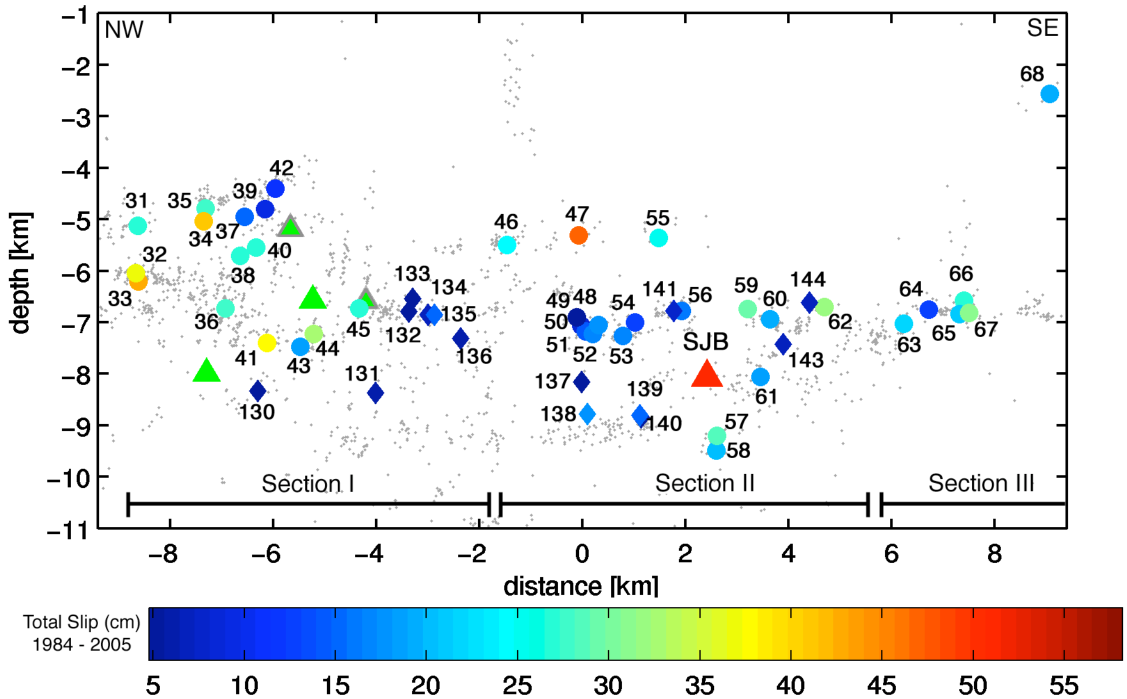

M4.7
M6.9
M5.1
Total Slip (cm)
Sequence Number
Section I
Section II
Section III
Section V
032
033
034
036
053
140
141
063
072
073
084
087
124
126
128
129
37.2
42.3
41.4
27.7
17.2
5.5
7.4
22.1
47.9
46.9
45.0
17.6
21.3
29.6
39.5
11.1
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

Figure 8.



NW
SE
Section I
Section II
Section III
SJB
depth [km]
distance [km]
Total Slip (cm)
1984 - 2005

Figure S1.

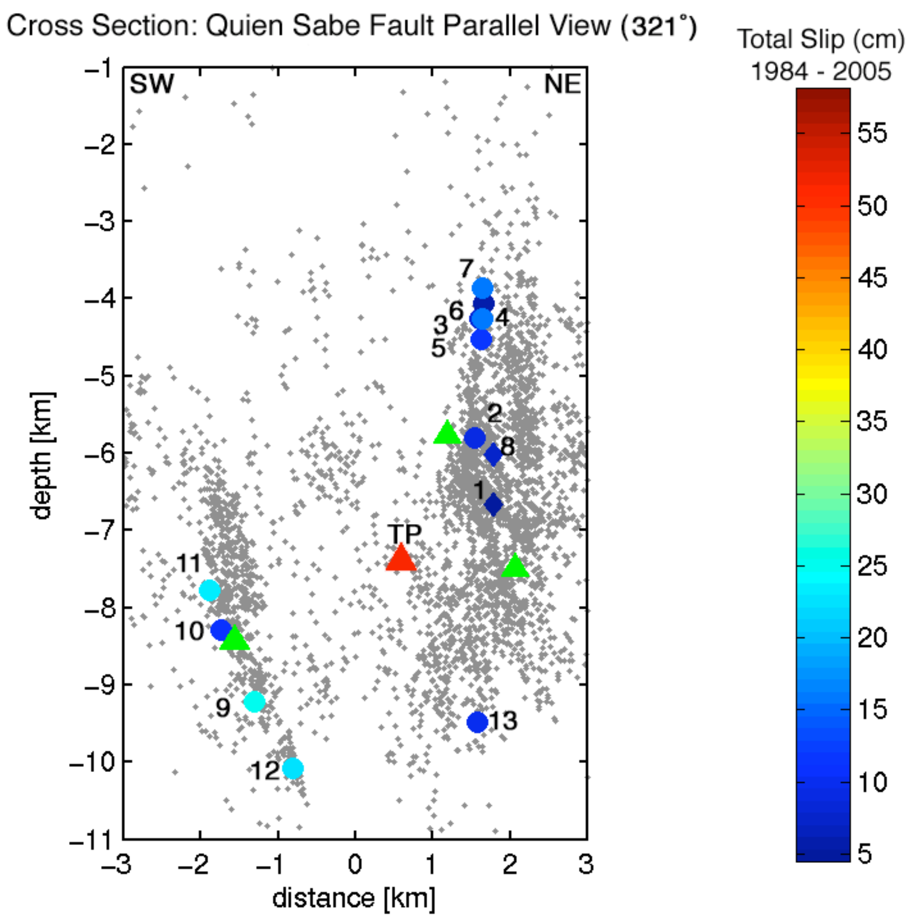

Cross Section: Quien Sabe Fault Parallel View (321˚)
SW
NE
depth [km]
distance [km]
TP
Total Slip (cm)
1984 - 2005

Figure S2.

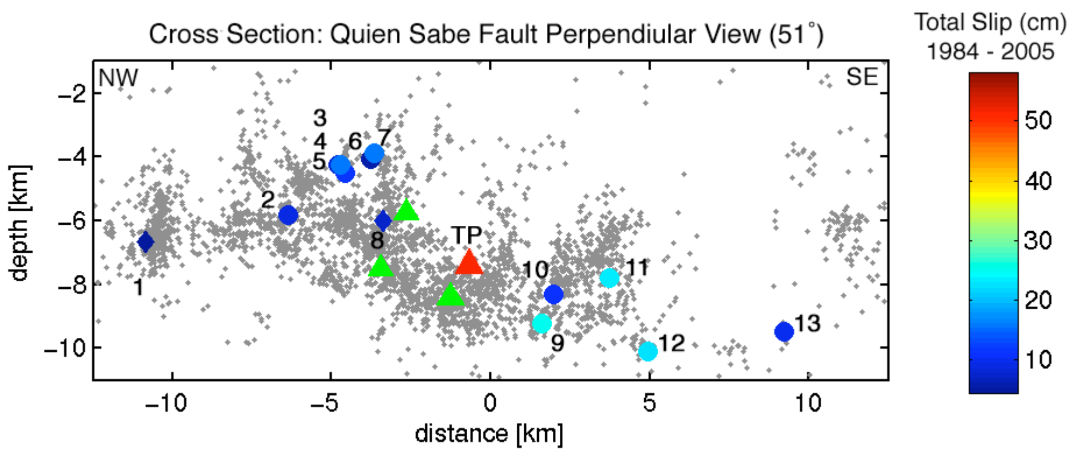
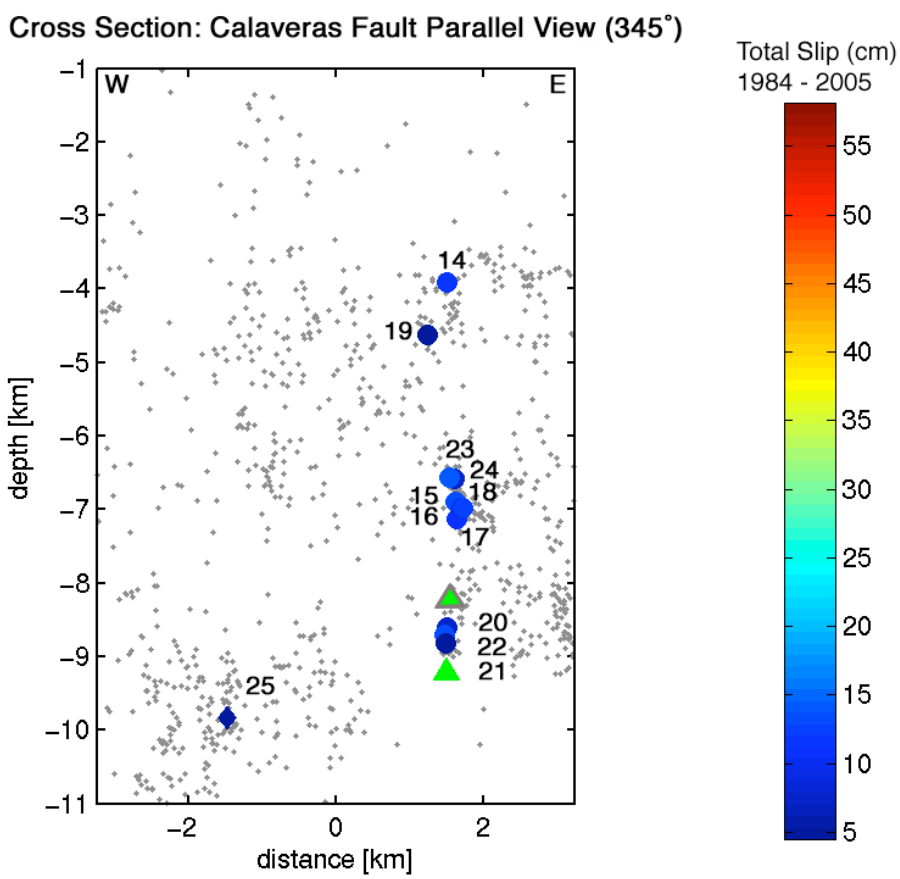

Cross Section: Quien Sabe Fault Perpendiular View (51°)
Total Slip (cm)
1984 - 2005
NW
SE
depth [km]
distance [km]
TP
−2
−4
−6
−8
−10
−10
−5
0
5
10
10
20
30
40
50
1
2
3
4
5
6
7
8
9
10
11
12
13

Figure S3.



Cross Section: Calaveras Fault Parallel View (345˚)
W
E
14
19
23
24
15
18
16
17
20
22
21
25
depth [km]
distance [km]
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−2
0
2
Total Slip (cm)
1984 - 2005
55
50
45
40
35
30
25
20
15
10
5

Figure S4.

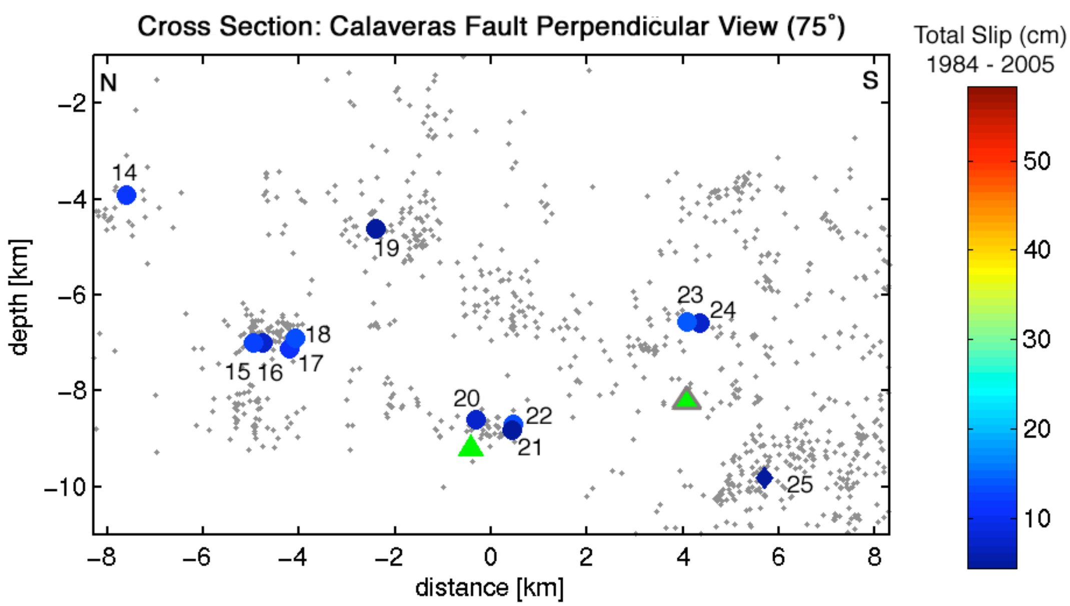

Cross Section: Calaveras Fault Perpendicular View (75˚)
N
S
depth [km]
distance [km]
−2
−4
−6
−8
−10
−8
−6
−4
−2
0
2
4
6
8
14
15
16
17
18
19
20
21
22
23
24
25
Total Slip (cm)
1984 - 2005
10
20
30
40
50

Figure S5.

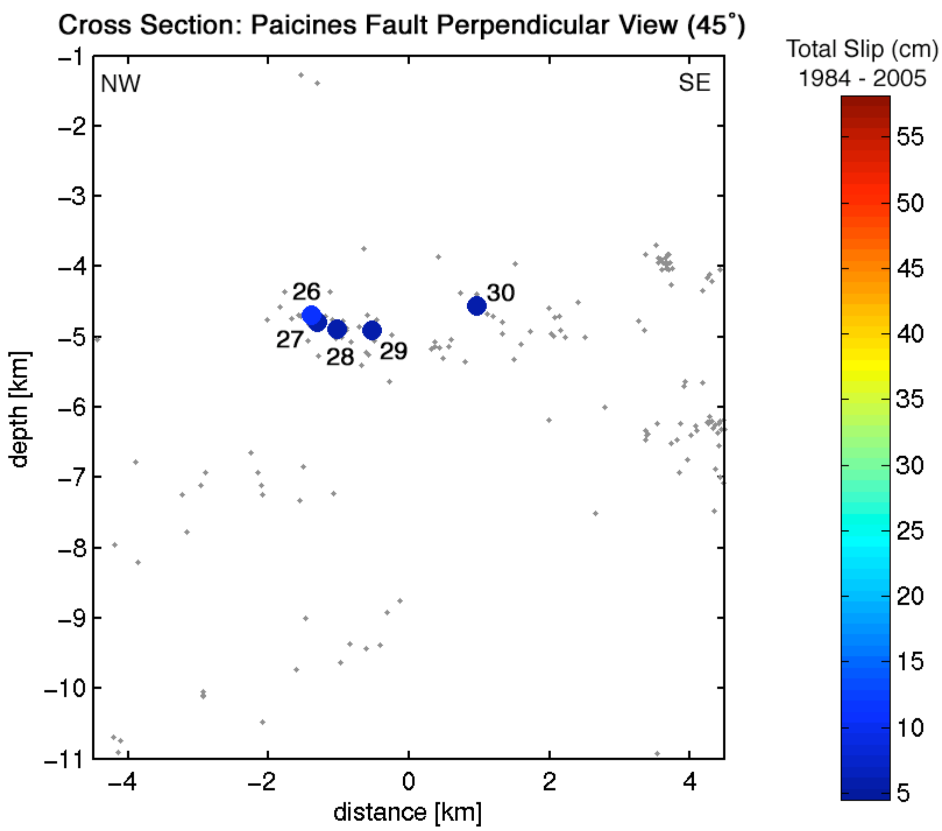

Cross Section: Paicines Fault Perpendicular View (45˚)
NW
SE
26
27
28
29
30
depth [km]
distance [km]
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−4
−2
0
2
4
Total Slip (cm)
1984 - 2005
55
50
45
40
35
30
25
20
15
10
5

Figure S6.

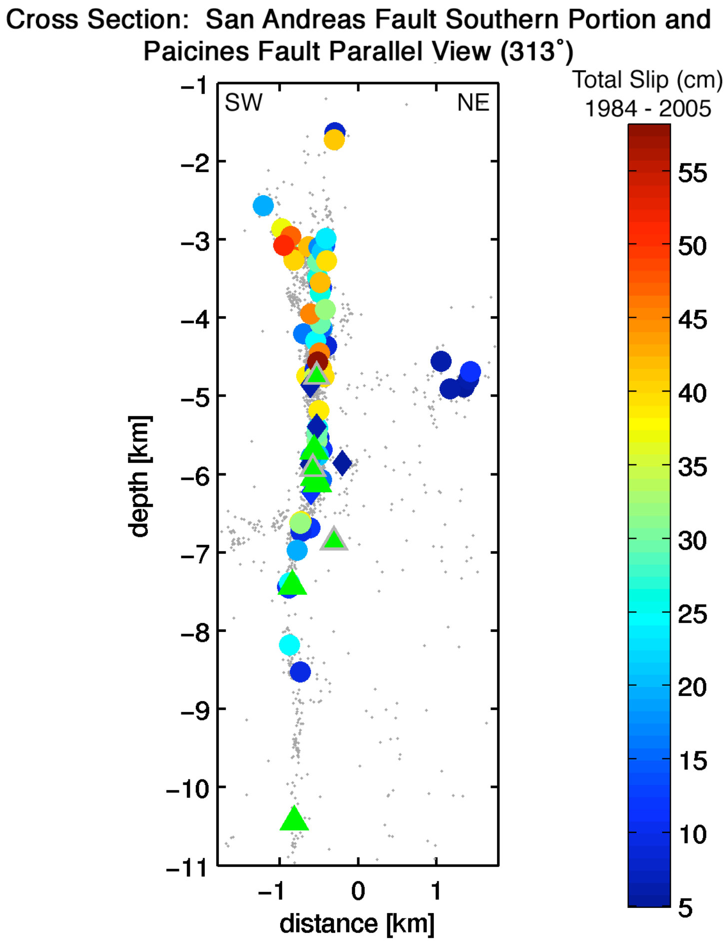
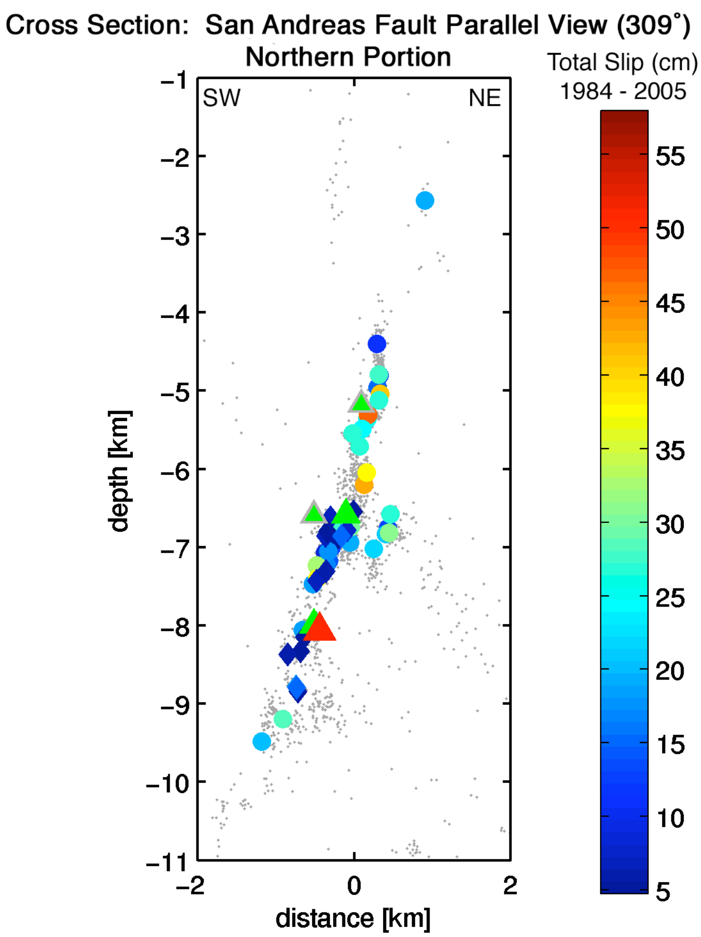

Cross Section: San Andreas Fault Southern Portion and
Paicines Fault Parallel View (313˚)
SW
NE
Total Slip (cm)
1984 - 2005
depth [km]
distance [km]
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−1
0
1
55
50
45
40
35
30
25
20
15
10
5

Figure S7.



Cross Section: San Andreas Fault Parallel View (309˚)
Northern Portion
Total Slip (cm)
1984 - 2005
SW
NE
depth [km]
distance [km]
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−2
0
2
55
50
45
40
35
30
25
20
15
10
5

Figure S8.

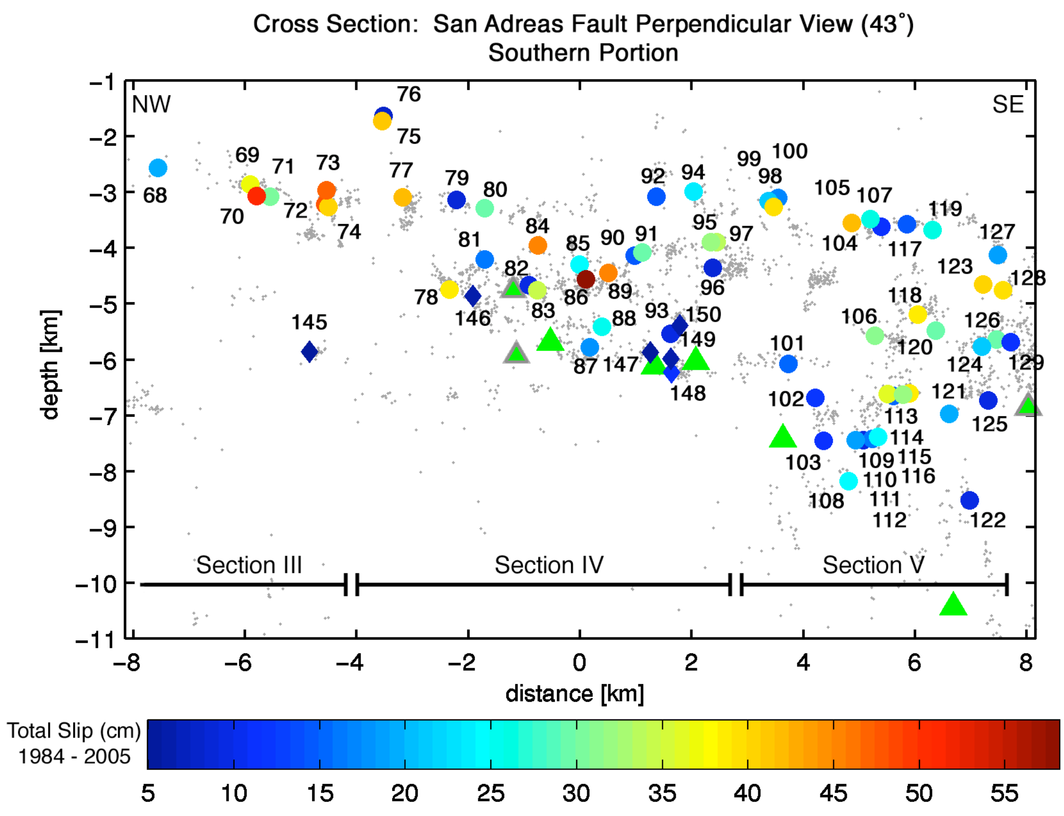

Cross Section: San Adreas Fault Perpendicular View (43˚)
Southern Portion
NW
SE
depth [km]
distance [km]
Section III
Section IV
Section V
Total Slip (cm)
1984 - 2005

Figure S9.

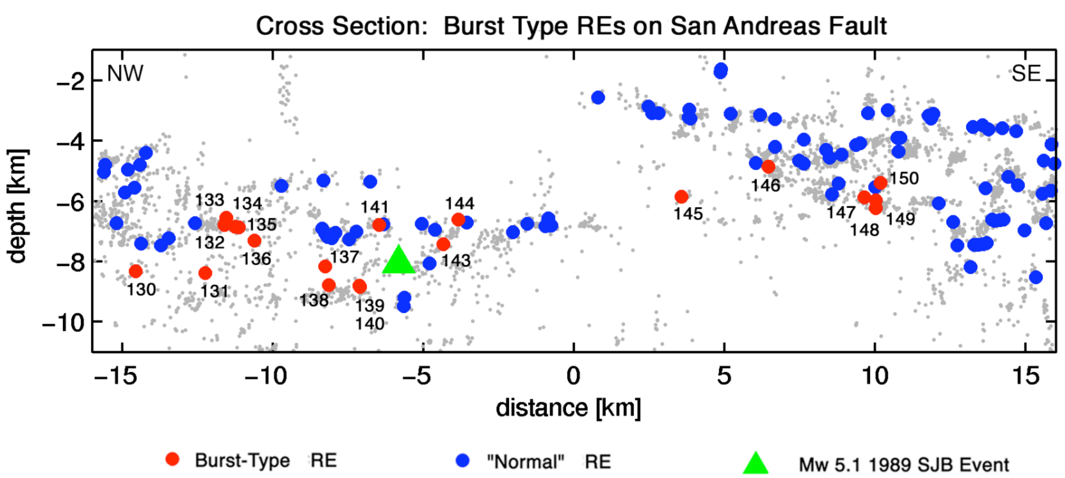
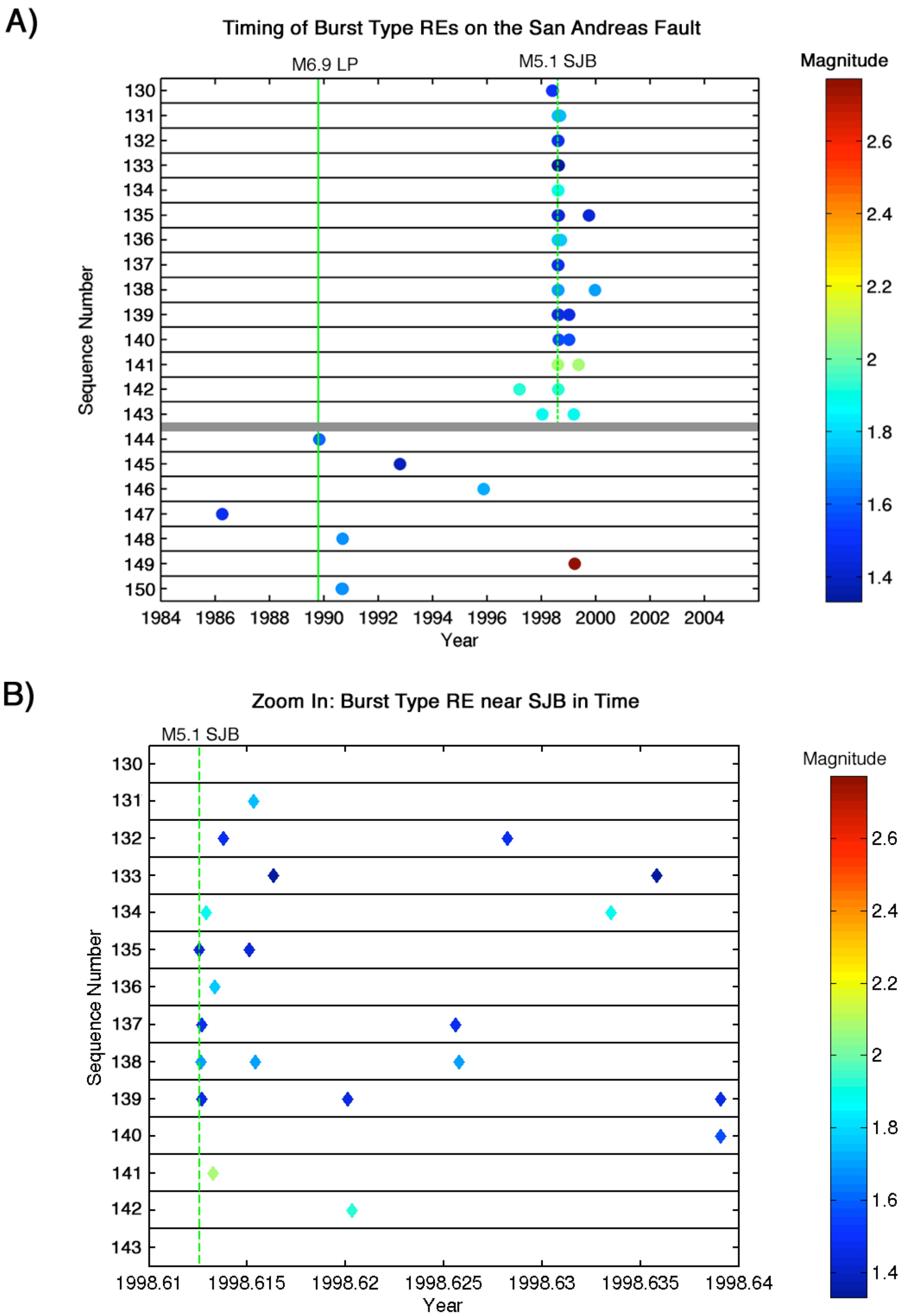

Cross Section: Burst Type REs on San Andreas Fault
NW
SE
depth [km]
distance [km]
130
131
132
133
134
135
136
137
138
139
140
141
143
144
145
146
147
148
149
150
Burst-Type RE
"Normal" RE
Mw 5.1 1989 SJB Event

Figure S10



A)
Timing of Burst Type REs on the San Andreas Fault
M6.9 LP
M5.1 SJB
Magnitude
Sequence Number
Year
B)
Zoom In: Burst Type RE near SJB in Time
M5.1 SJB
Magnitude
Sequence Number
Year

Figure S11.

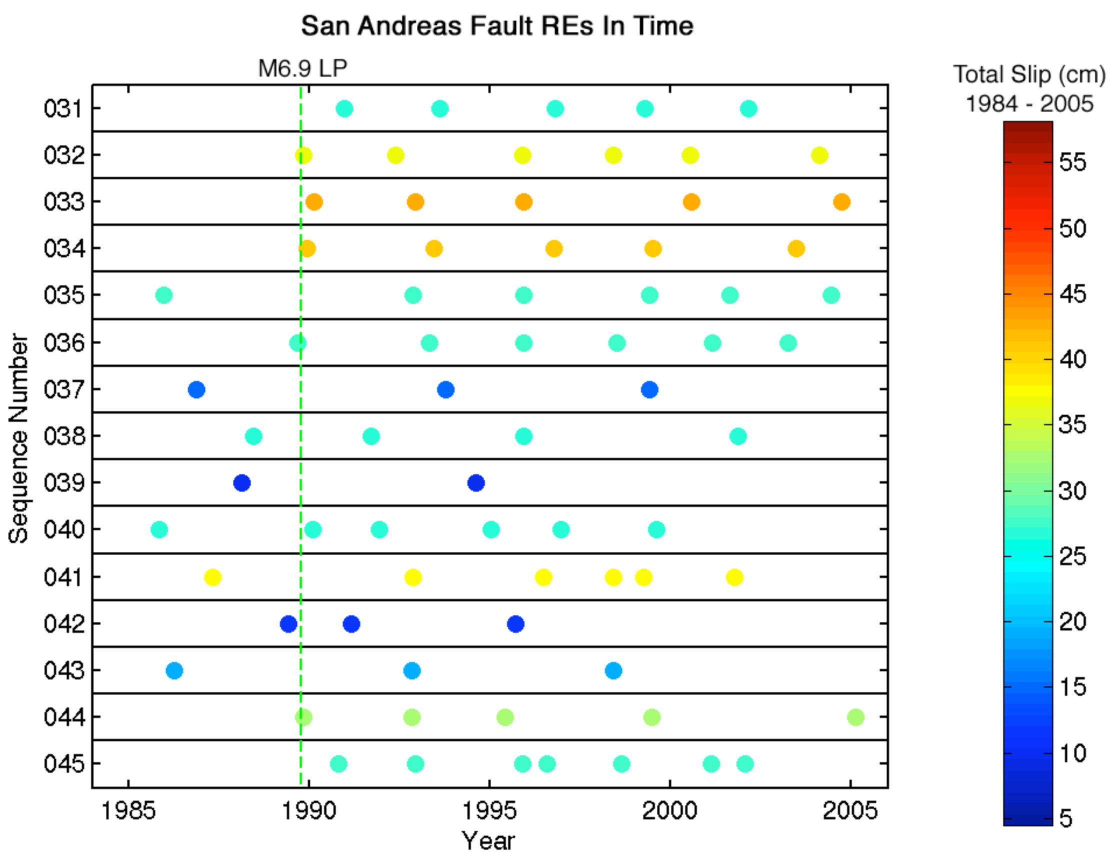

San Andreas Fault REs In Time
M6.9 LP
031
032
033
034
035
036
037
038
039
040
041
042
043
044
045
Sequence Number
1985
1990
1995
2000
2005
Year
Total Slip (cm)
1984 - 2005
55
50
45
40
35
30
25
20
15
10
5

Figure S12.

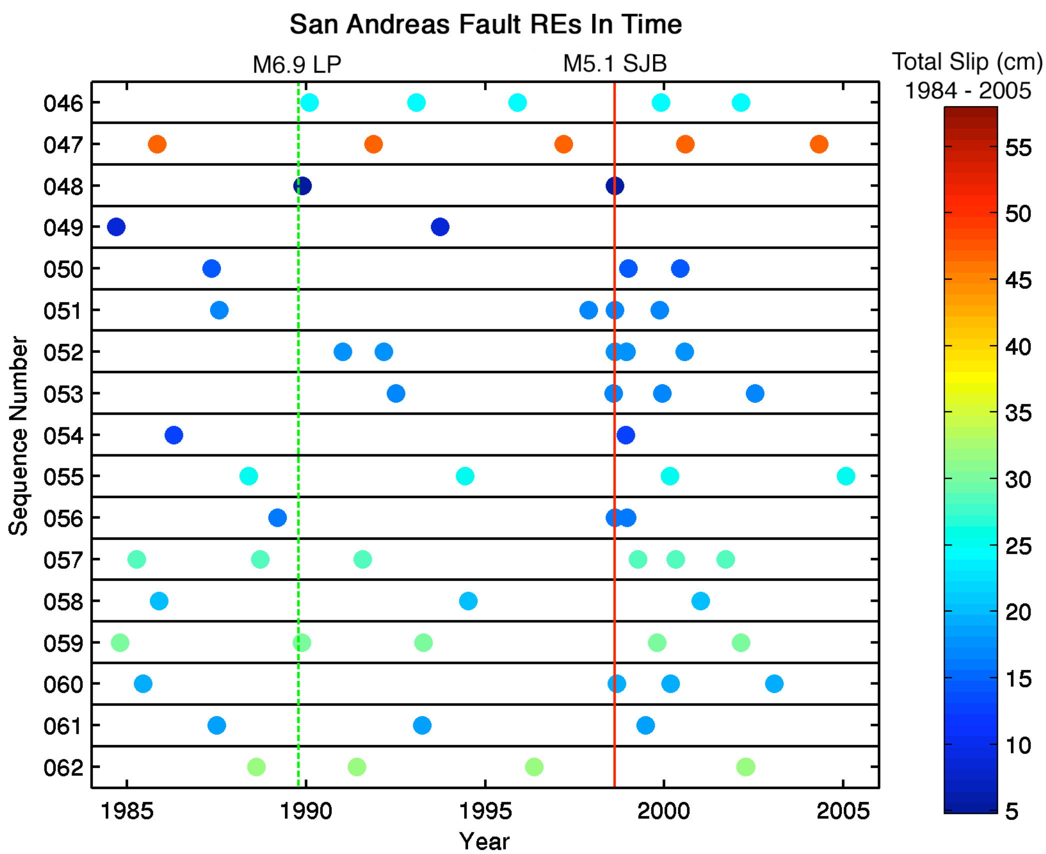

San Andreas Fault REs In Time
M6.9 LP
M5.1 SJB
Total Slip (cm)
1984 - 2005
55
50
45
40
35
30
25
20
15
10
5
Sequence Number
046
047
048
049
050
051
052
053
054
055
056
057
058
059
060
061
062
1985
1990
1995
2000
2005
Year

Figure S13.

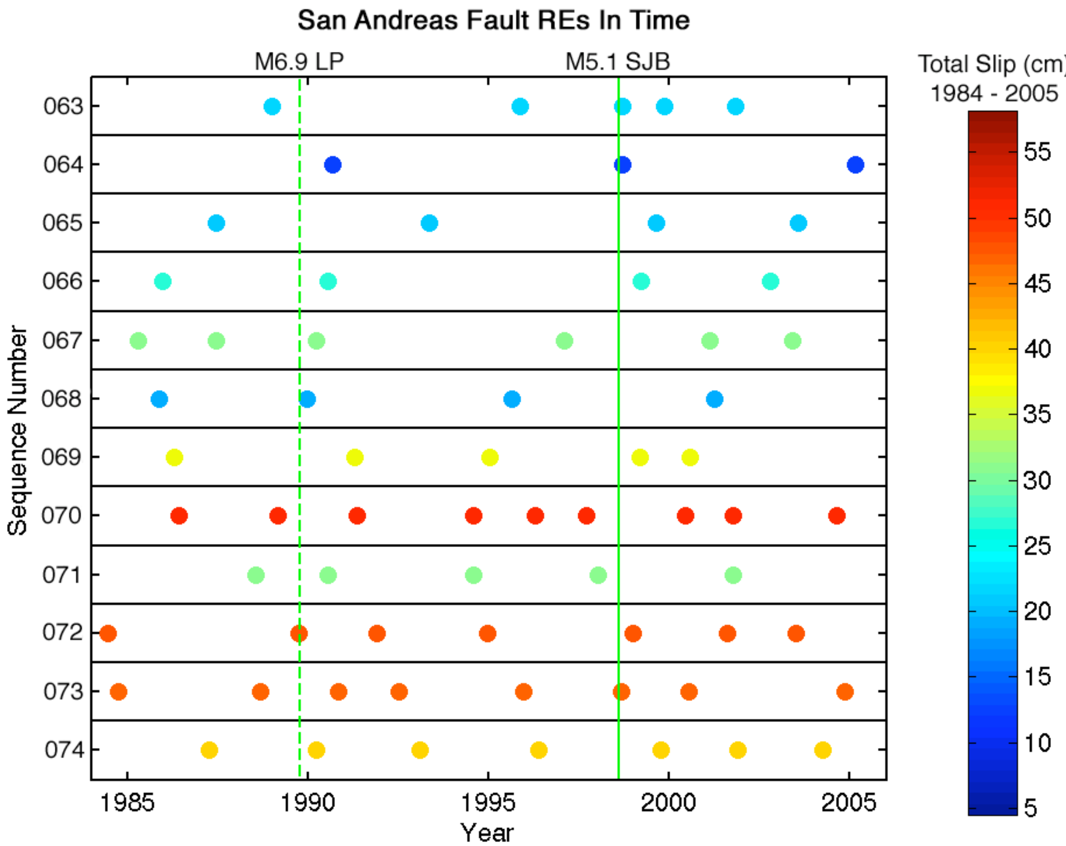

San Andreas Fault REs In Time
M6.9 LP
M5.1 SJB
Sequence Number
063
064
065
066
067
068
069
070
071
072
073
074
1985
1990
1995
2000
2005
Year
Total Slip (cm)
1984 - 2005
55
50
45
40
35
30
25
20
15
10
5

Figure S14.

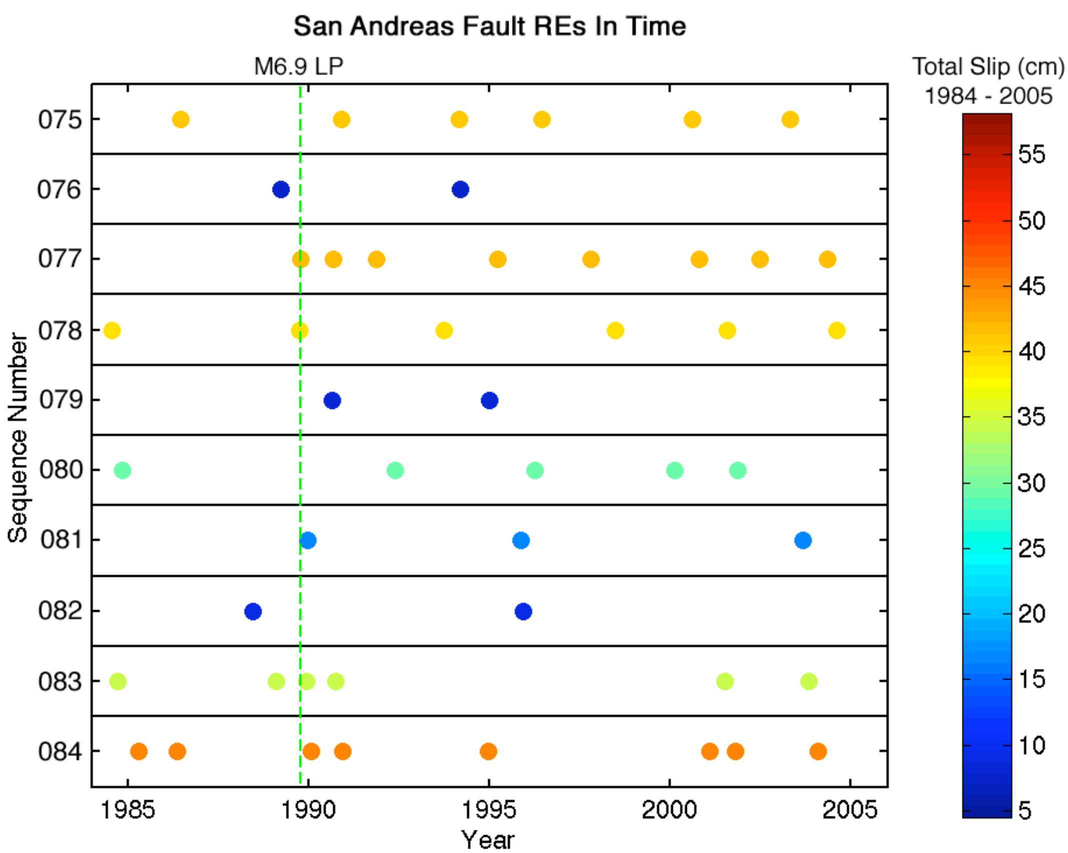
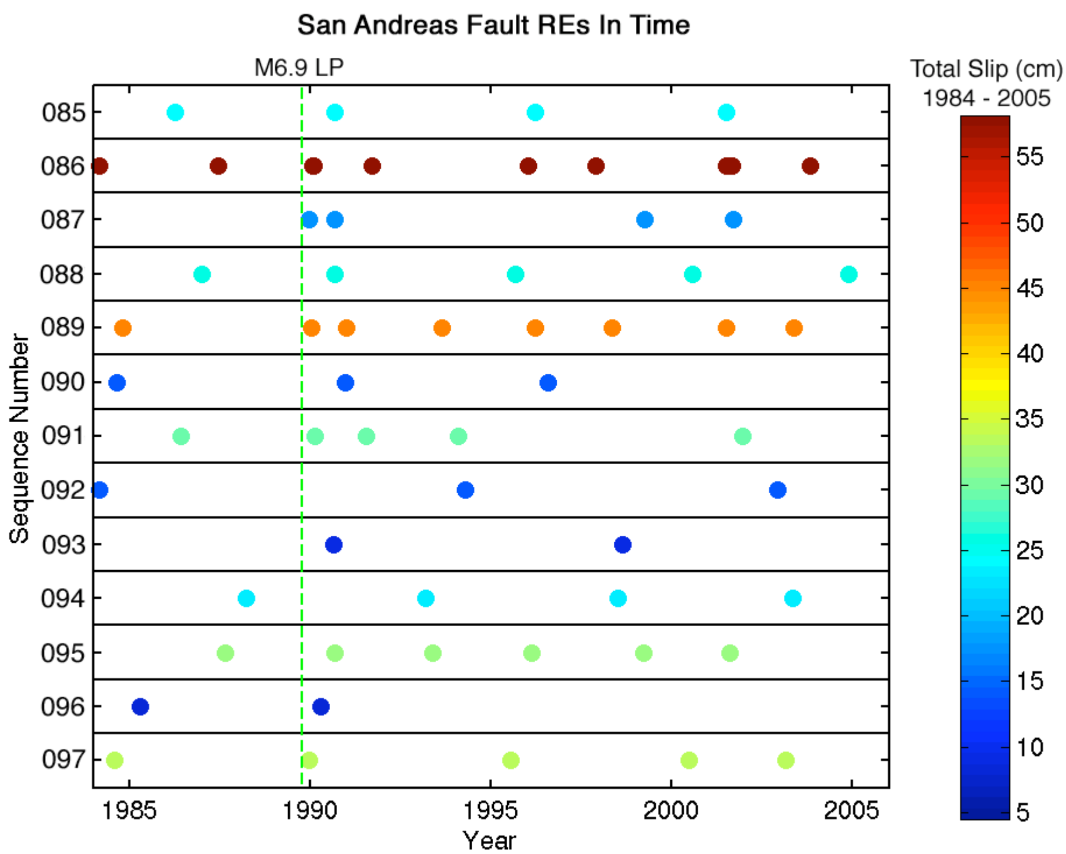

San Andreas Fault REs In Time
M6.9 LP
Total Slip (cm)
1984 - 2005
075
076
077
078
079
080
081
082
083
084
Sequence Number
1985
1990
1995
2000
2005
Year
55
50
45
40
35
30
25
20
15
10
5

Figure S15.



San Andreas Fault REs In Time
M6.9 LP
Total Slip (cm)
1984 - 2005
Sequence Number
085
086
087
088
089
090
091
092
093
094
095
096
097
1985
1990
1995
2000
2005
Year
55
50
45
40
35
30
25
20
15
10
5

Figure S16.

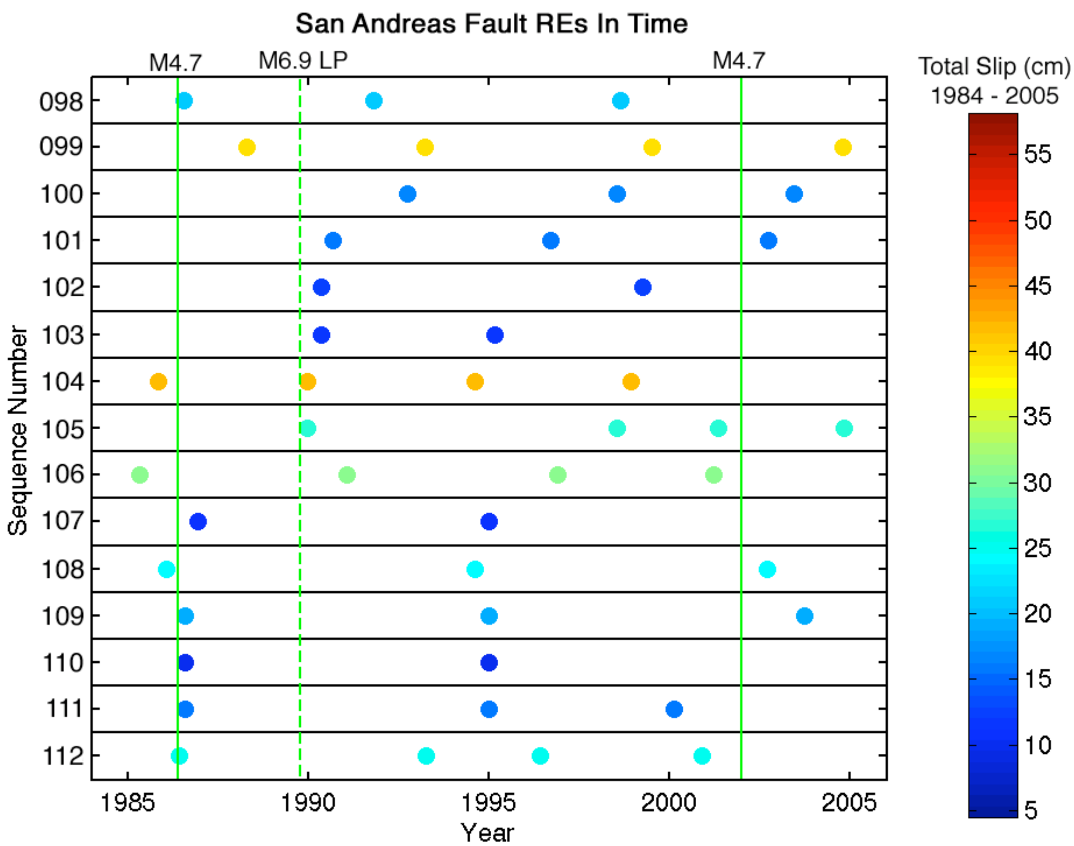
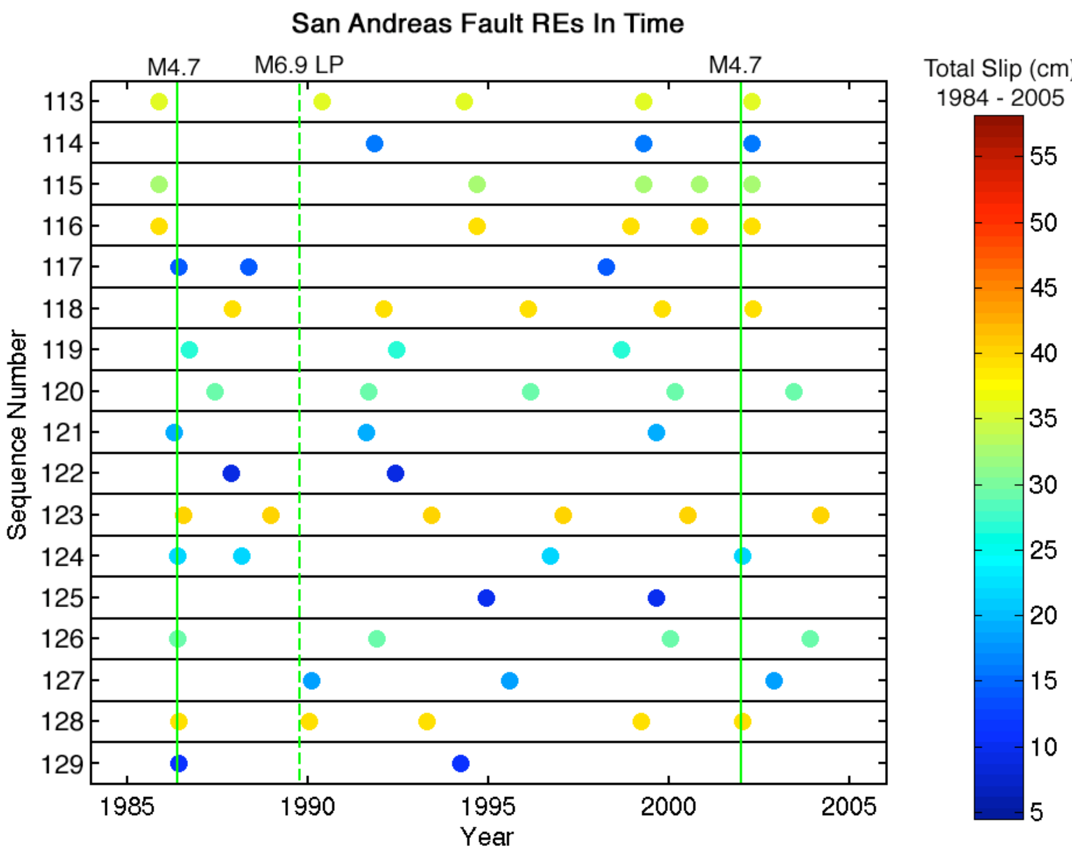

San Andreas Fault REs In Time
M4.7
M6.9 LP
M4.7
Sequence Number
098
099
100
101
102
103
104
105
106
107
108
109
110
111
112
1985
1990
1995
2000
2005
Year
Total Slip (cm)
1984 - 2005
55
50
45
40
35
30
25
20
15
10
5

Figure S17.



San Andreas Fault REs In Time
M4.7
M6.9 LP
M4.7
Total Slip (cm)
1984 - 2005
Sequence Number
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
1985
1990
1995
2000
2005
Year
55
50
45
40
35
30
25
20
15
10
5

Figure S18.

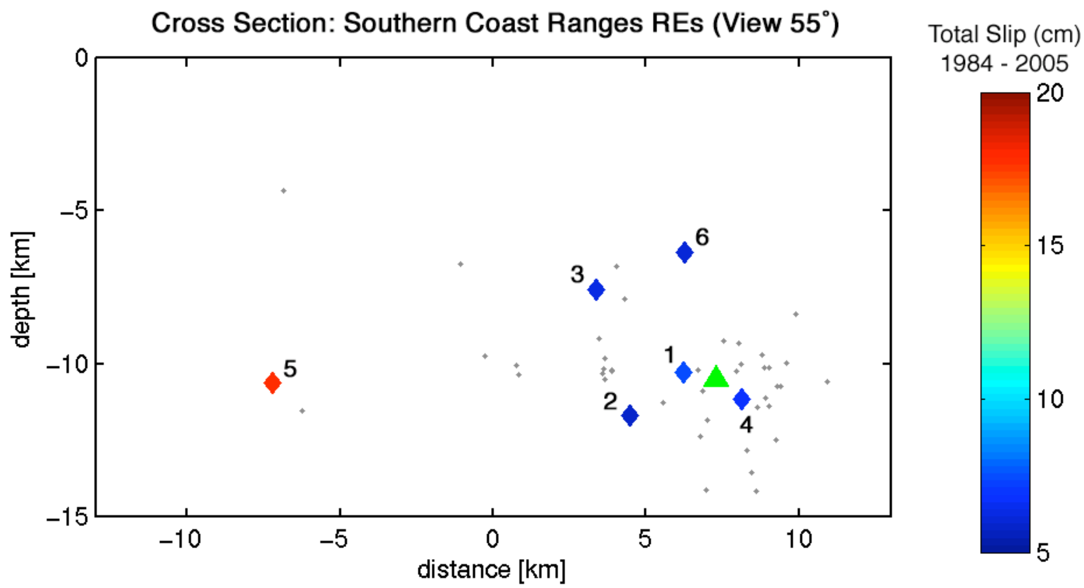

Cross Section: Southern Coast Ranges REs (View 55˚)
depth [km]
distance [km]
0
−5
−10
−15
−10
−5
0
5
10
1
2
3
4
5
6
Total Slip (cm)
1984 - 2005
20
15
10
5

Figure S19.

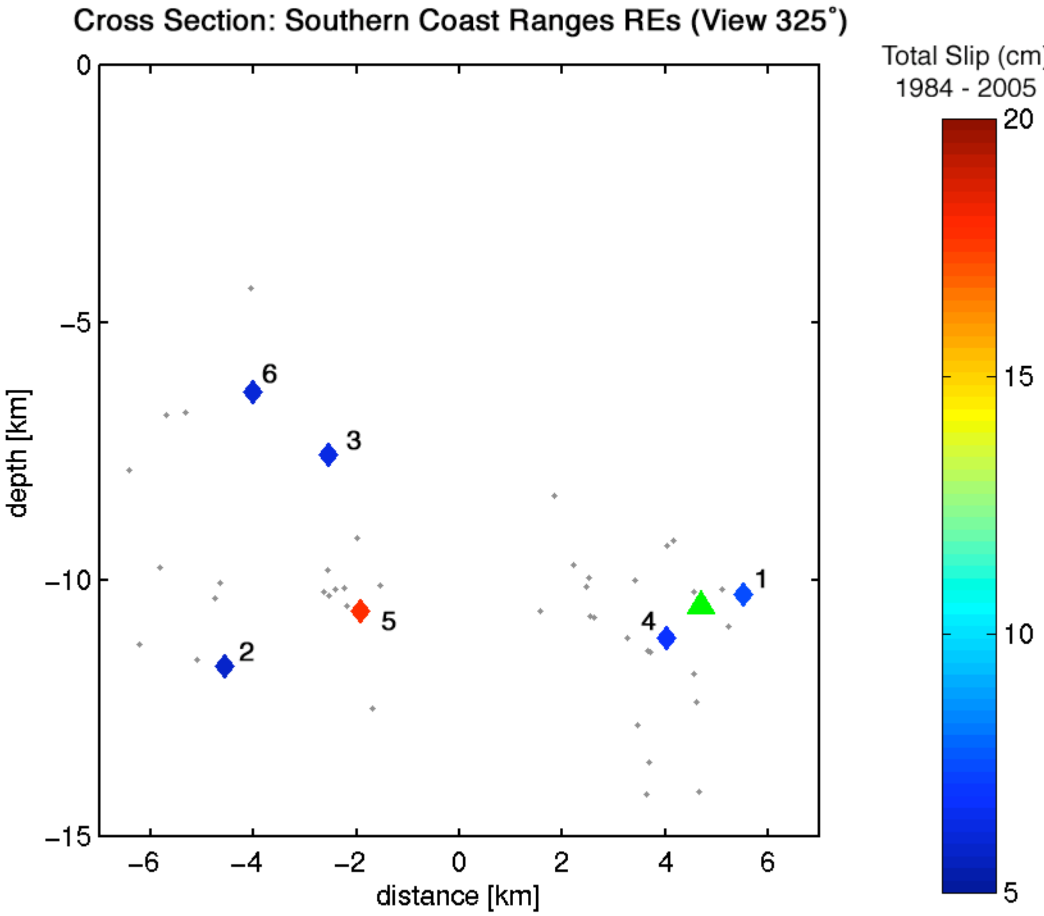
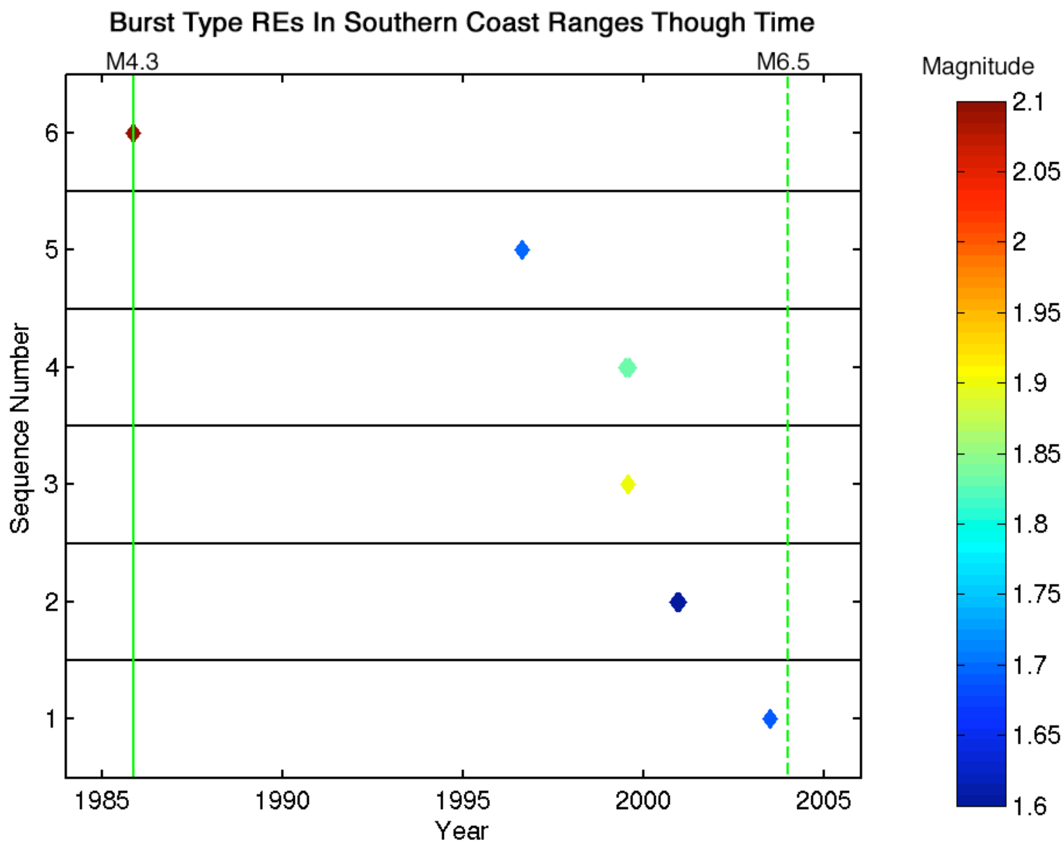

Cross Section: Southern Coast Ranges REs (View 325˚)
depth [km]
distance [km]
0
−5
−10
−15
−6
−4
−2
0
2
4
6
1
2
3
4
5
6
Total Slip (cm)
1984 - 2005
20
15
10
5

Figure S20.



Burst Type REs In Southern Coast Ranges Though Time
M4.3
M6.5
Sequence Number
Year
1985
1990
1995
2000
2005
1
2
3
4
5
6
Magnitude
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6

README.txt

The supplemental table is in the form sequence label number, average sequence latitude, average sequence longitude, average sequence depth, average sequence magnitude, total amount of slip (cm) at sequence location, and slip rate (mm/yr) at sequence location. The following indented lines indicate earthquake time (YYY.JDY.HHMMSS), earthquake latitude, earthquake longitude, earthquake depth, and earthquake magnitude for each individual event within a repeating earthquake sequence.

Table S1.

1	36.8822	-121.3462	6.21	1.39	4.9	0.23	
	1986.287.012625	36.8820	-121.3432	6.58	1.36		
	1986.290.150349	36.8825	-121.3493	5.85	1.42		
2	36.8508	-121.3144	5.67	1.95	9.2	0.42	
	1987.041.081555	36.8505	-121.3152	5.57	2.08		
	1994.043.163835	36.8508	-121.3148	5.71	1.80		
	2005.214.165507	36.8512	-121.3132	5.72	1.96		
3	36.8401	-121.3019	4.29	2.33	8.6	0.39	
	1986.336.023245	36.8400	-121.3015	4.32	2.34		
	1992.351.062630	36.8402	-121.3023	4.25	2.32		
4	36.8396	-121.3014	4.32	2.15	15.7	0.72	
	1986.126.234806	36.8382	-121.3017	4.03	1.84		
	1988.279.230916	36.8392	-121.3017	4.41	2.33		
	2004.322.164418	36.8413	-121.3010	4.51	2.27		
5	36.8375	-121.3014	4.09	1.69	11.8	0.54	

1986.031.024320 36.8378 -121.3013 4.15 1.71

1986.141.133948 36.8373 -121.3008 4.08 1.73

1987.312.130323 36.8373 -121.3020 4.03 1.63

6 36.8336 -121.2963 4.09 1.62 5.7 0.26

1987.175.092323 36.8328 -121.2962 3.98 1.50

2000.327.023425 36.8343 -121.2963 4.21 1.70

7 36.8327 -121.2949 3.65 1.38 15.6 0.72

1986.038.053103 36.8323 -121.2948 3.68 1.37

1986.147.020422 36.8347 -121.2947 3.73 1.45

1987.033.231814 36.8320 -121.2953 3.44 1.25

1991.079.123647 36.8318 -121.2942 3.64 1.39

2005.325.131528 36.8328 -121.2953 3.76 1.46

8 36.8310 -121.2903 6.03 2.03 7.2 0.33

1990.274.151720 36.8310 -121.2903 5.95 2.13

1990.276.162009 36.8310 -121.2903 6.11 1.88

9 36.7770 -121.2855 9.24 1.78 24.8 1.14

1986.268.110034 36.7757 -121.2860 9.11 1.70

1991.181.225923 36.7772 -121.2860 9.42 1.84

1994.333.051017 36.7765 -121.2857 9.13 1.74

1998.352.043752 36.7777 -121.2852 9.33 1.80

2002.207.114807 36.7780 -121.2848 9.23 1.78

10 36.7715 -121.2859 8.05 1.39 10.5 0.48

1985.068.092002 36.7710 -121.2865 7.88 1.24

1991.197.114701 36.7715 -121.2850 8.09 1.37

1997.269.091506 36.7720 -121.2862 8.17 1.57

11 36.7598 -121.2732 7.88 1.66 23.1 1.06

1988.303.160739 36.7585 -121.2755 8.11 1.61

1992.281.065555 36.7582 -121.2740 7.97 1.67

1997.034.171328 36.7610 -121.2697 7.75 1.62

2000.331.162358 36.7615 -121.2742 7.70 1.71

2004.168.060645 36.7598 -121.2728 7.87 1.67

12 36.7552 -121.2575 9.95 1.64 22.9 1.05

1992.050.161728 36.7538 -121.2560 9.45 1.60

1998.023.220648 36.7557 -121.2570 9.96 1.59

2001.137.090320 36.7552 -121.2573 10.18 1.47

2001.137.091621 36.7562 -121.2587 10.32 1.26

2003.336.085237 36.7550 -121.2585 9.86 1.87

13	36.7390	-121.2042	9.57	1.43	10.1	0.46
	1988.113.011141	36.7388	-121.2048	9.78	1.32	
	1994.035.101918	36.7370	-121.2050	9.22	1.44	
	2000.344.024753	36.7412	-121.2028	9.72	1.49	
14	36.9054	-121.4226	3.88	1.68	11.7	0.54
	1984.118.024658	36.9075	-121.4223	3.68	1.81	
	1993.354.034334	36.9043	-121.4227	3.71	1.60	
	2004.108.042349	36.9043	-121.4228	4.26	1.56	
15	36.8848	-121.4156	7.36	1.81	12.8	0.59
	1986.335.233040	36.8842	-121.4157	6.75	1.63	
	1994.032.023608	36.8847	-121.4155	7.84	1.82	
	2004.093.012458	36.8855	-121.4155	7.49	1.97	
16	36.8837	-121.4144	7.71	2.10	7.5	0.34
	1989.348.214135	36.8828	-121.4168	7.08	1.95	
	2000.329.123504	36.8845	-121.4120	8.35	2.19	
17	36.8777	-121.4142	7.90	1.54	10.8	0.49
	1987.307.123255	36.8767	-121.4150	7.44	1.42	

	1994.261.114157	36.8777	-121.4135	8.04	1.69		
	2002.207.125728	36.8788	-121.4142	8.21	1.42		
18	36.8768	-121.4137	7.11	1.89	13.3	0.61	
	1986.149.192036	36.8762	-121.4137	7.14	1.83		
	1993.106.171630	36.8767	-121.4140	7.24	1.96		
	2003.187.104403	36.8777	-121.4135	6.95	1.88		
19	36.8580	-121.4168	4.29	1.52	5.3	0.24	
	1987.011.083259	36.8570	-121.4158	3.96	1.40		
	2001.319.100445	36.8590	-121.4178	4.63	1.61		
20	36.8372	-121.4093	8.44	2.09	7.4	0.34	
	1992.104.113535	36.8363	-121.4082	8.45	2.12		
	1998.015.065327	36.8380	-121.4105	8.43	2.05		
21	36.8301	-121.4082	8.23	1.34	4.8	0.22	
	1985.034.151654	36.8302	-121.4088	7.92	1.24		
	1992.150.143602	36.8300	-121.4075	8.54	1.43		
22	36.8305	-121.4078	8.51	1.57	13.2	0.60	
	1990.002.160818	36.8313	-121.4107	7.73	1.43		

	1995.212.230230	36.8287	-121.4052	8.84	1.28	
	1997.142.065559	36.8310	-121.4083	8.47	1.91	
	2005.284.003258	36.8310	-121.4072	9.01	1.67	
23	36.8042	-121.3900	6.14	1.32	14.1	0.65
	1988.117.162731	36.8043	-121.3900	5.97	1.28	
	2002.189.095808	36.8050	-121.3897	6.77	1.41	
	2003.080.105655	36.8038	-121.3907	5.85	1.22	
	2004.180.075313	36.8038	-121.3895	5.97	1.29	
24	36.8010	-121.3882	6.76	2.15	7.7	0.35
	1991.262.220820	36.8012	-121.3877	6.34	2.22	
	2002.176.211023	36.8008	-121.3888	7.18	2.06	
25	36.7858	-121.4076	8.67	1.46	5.1	0.24
	1998.075.010646	36.7900	-121.4143	9.05	1.46	
	1998.075.025955	36.7815	-121.4008	8.29	1.46	
26	36.6894	-121.2828	4.66	1.57	11.0	0.51
	1988.148.150832	36.6893	-121.2823	4.43	1.53	
	1992.307.032239	36.6890	-121.2847	4.65	1.52	
	2003.134.111235	36.6900	-121.2815	4.90	1.67	

27		36.6872	-121.2814	4.55	1.69	5.9	0.27
	1989.307.075612	36.6882	-121.2813	4.78	1.81		
	1995.318.195757	36.6863	-121.2815	4.33	1.48		
28		36.6863	-121.2803	5.14	1.54	5.4	0.25
	1989.183.203342	36.6862	-121.2798	5.06	1.61		
	2000.299.183005	36.6865	-121.2808	5.23	1.44		
29		36.6812	-121.2764	5.17	1.72	6.0	0.27
	1990.030.100609	36.6807	-121.2760	5.25	1.70		
	2002.102.074911	36.6818	-121.2768	5.09	1.73		
30		36.6706	-121.2633	4.33	1.67	5.8	0.27
	1990.180.015856	36.6708	-121.2640	4.42	1.76		
	2003.304.112334	36.6703	-121.2627	4.25	1.54		
31		36.8248	-121.5437	4.30	1.91	26.8	1.23
	1990.357.105918	36.8258	-121.5415	4.54	2.01		
	1993.222.023809	36.8247	-121.5428	4.58	1.91		
	1996.290.082711	36.8247	-121.5438	4.56	1.89		
	1999.101.092944	36.8255	-121.5440	4.22	1.86		

	2002.055.013356	36.8232	-121.5462	3.58	1.95		
32	36.8238	-121.5462	5.88	2.09	37.2	1.70	
	1989.305.145200	36.8233	-121.5463	5.69	2.03		
	1992.148.151316	36.8248	-121.5482	6.03	2.08		
	1995.335.033532	36.8235	-121.5462	6.17	2.13		
	1998.152.122936	36.8243	-121.5458	5.61	1.99		
	2000.198.083816	36.8240	-121.5467	6.22	2.11		
	2004.037.193757	36.8232	-121.5440	5.54	2.10		
33	36.8242	-121.5483	6.30	2.69	42.3	1.94	
	1990.048.184836	36.8237	-121.5463	6.17	2.70		
	1992.347.170455	36.8245	-121.5487	6.50	2.69		
	1995.336.065633	36.8237	-121.5478	6.15	2.64		
	2000.206.183004	36.8232	-121.5455	6.17	2.69		
	2004.264.144029	36.8260	-121.5530	6.51	2.72		
34	36.8194	-121.5362	5.23	2.65	41.4	1.89	
	1989.349.083832	36.8203	-121.5380	5.66	2.65		
	1993.169.233628	36.8173	-121.5332	4.78	2.56		
	1996.277.135708	36.8178	-121.5335	4.66	2.68		
	1999.190.032220	36.8202	-121.5375	5.74	2.42		

	2003.176.090818	36.8213	-121.5388	5.30	2.72		
35	36.8192	-121.5338	4.48	1.58	27.6	1.26	
	1985.354.225323	36.8192	-121.5310	4.66	1.53		
	1992.325.075643	36.8185	-121.5347	4.47	1.56		
	1995.337.123023	36.8198	-121.5368	5.00	1.65		
	1999.153.182841	36.8190	-121.5315	4.12	1.62		
	2001.238.084333	36.8187	-121.5312	4.37	1.60		
	2004.162.023924	36.8197	-121.5377	4.23	1.31		
36	36.8119	-121.5311	6.59	1.59	27.7	1.27	
	1989.256.024054	36.8122	-121.5307	6.53	1.54		
	1993.116.202008	36.8132	-121.5318	6.71	1.53		
	1995.337.093550	36.8125	-121.5345	7.20	1.67		
	1998.181.153430	36.8117	-121.5302	6.46	1.60		
	2001.060.123957	36.8113	-121.5293	6.51	1.59		
	2003.087.065914	36.8107	-121.5302	6.12	1.61		
37	36.8125	-121.5285	5.15	2.14	15.3	0.70	
	1986.326.112338	36.8118	-121.5295	4.58	2.24		
	1993.289.161909	36.8113	-121.5272	5.05	2.14		
	1999.148.083539	36.8145	-121.5288	5.82	2.09		

38	36.8112	-121.5286	5.57	2.39	26.6	1.22	
	1988.168.203227	36.8115	-121.5275	5.23	2.42		
	1991.265.021843	36.8112	-121.5288	5.83	2.36		
	1995.345.211440	36.8112	-121.5298	5.50	2.56		
	2001.319.185806	36.8108	-121.5285	5.71	2.37		
39	36.8117	-121.5229	4.93	2.55	9.8	0.45	
	1988.046.162841	36.8098	-121.5195	4.21	2.49		
	1994.228.210154	36.8135	-121.5262	5.65	2.59		
40	36.8102	-121.5265	5.31	1.51	26.5	1.21	
	1985.306.072639	36.8118	-121.5262	5.07	1.49		
	1990.041.104339	36.8103	-121.5257	5.24	1.53		
	1991.349.171640	36.8097	-121.5270	5.35	1.51		
	1995.013.220048	36.8102	-121.5267	5.54	1.52		
	1996.352.114632	36.8090	-121.5263	5.27	1.46		
	1999.226.035627	36.8100	-121.5270	5.40	1.56		
41	36.8041	-121.5264	7.35	2.12	37.9	1.73	
	1987.123.161225	36.8033	-121.5277	7.54	2.20		
	1992.316.090153	36.8045	-121.5265	7.51	2.14		

	1996.180.015453	36.8035	-121.5257	6.94	2.10	
	1998.152.142450	36.8033	-121.5260	7.31	2.19	
	1999.087.132726	36.8052	-121.5268	7.46	2.06	
	2001.281.014139	36.8050	-121.5258	7.33	1.97	
42	36.8074	-121.5199	3.89	1.62	11.3	0.52
	1989.162.112214	36.8040	-121.5197	2.86	1.62	
	1991.060.122450	36.8105	-121.5195	4.06	1.60	
	1995.259.224551	36.8078	-121.5205	4.75	1.76	
43	36.7990	-121.5240	7.34	2.49	18.8	0.86
	1986.102.115112	36.7997	-121.5267	7.57	2.14	
	1992.306.175815	36.7982	-121.5212	6.82	2.50	
	1998.150.125144	36.7992	-121.5242	7.63	2.49	
44	36.7985	-121.5204	7.05	2.23	32.3	1.48
	1989.311.071244	36.7983	-121.5220	7.98	2.38	
	1992.307.030916	36.7987	-121.5195	6.98	2.33	
	1995.148.040959	36.7975	-121.5203	6.90	1.97	
	1999.172.034437	36.7990	-121.5197	6.24	2.13	
	2005.038.002158	36.7992	-121.5207	7.15	2.23	

45 36.7983 -121.5094 6.67 1.25 27.3 1.25

1990.294.214701 36.7985 -121.5102 7.10 1.19

1992.344.120245 36.7968 -121.5050 6.80 1.23

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1998.234.025259 36.7993 -121.5095 6.54 1.25

2001.043.025659 36.7978 -121.5085 6.96 1.25

2002.018.024738 36.7980 -121.5113 7.25 1.33

46 36.7822 -121.4809 4.38 1.74 24.2 1.11

1990.034.230635 36.7808 -121.4778 2.97 1.77

1993.028.160939 36.7815 -121.4778 5.04 1.74

1995.333.173115 36.7837 -121.4825 4.58 1.61

1999.330.111921 36.7832 -121.4830 5.50 1.62

2002.054.105024 36.7818 -121.4833 3.82 1.78

47 36.7748 -121.4719 4.73 2.85 46.5 2.13

1985.305.104857 36.7750 -121.4700 4.53 2.88

1991.322.191637 36.7753 -121.4712 4.95 2.87

1997.072.032429 36.7740 -121.4733 5.01 2.84

2000.217.073214 36.7743 -121.4723 4.73 2.85

2004.121.080214 36.7755 -121.4727 4.42 2.84

48	36.7738	-121.4744	6.46	1.58	5.5	0.25
	1989.325.133541	36.7742	-121.4717	6.38	1.54	
	1998.225.082335	36.7735	-121.4772	6.55	1.62	
49	36.7689	-121.4740	6.49	2.27	8.3	0.38
	1984.251.040304	36.7692	-121.4727	6.47	2.42	
	1993.270.182605	36.7685	-121.4752	6.51	1.96	
50	36.7702	-121.4741	6.89	2.02	14.3	0.65
	1987.127.161215	36.7697	-121.4740	6.86	2.10	
	1999.002.054002	36.7703	-121.4742	6.89	2.02	
	2000.167.020225	36.7707	-121.4740	6.93	2.00	
51	36.7711	-121.4742	7.22	1.63	17.0	0.78
	1987.211.121238	36.7732	-121.4722	7.21	1.59	
	1997.327.175442	36.7687	-121.4755	7.31	1.68	
	1998.227.081101	36.7710	-121.4757	7.09	1.56	
	1999.318.021134	36.7715	-121.4732	7.29	1.66	
52	36.7731	-121.4699	7.06	1.22	17.9	0.82
	1991.007.075803	36.7738	-121.4723	7.39	1.19	

	1992.059.214445	36.7767	-121.4722	7.86	1.22		
	1998.225.071559	36.7747	-121.4717	7.02	1.35		
	1998.343.154558	36.7710	-121.4720	6.99	1.20		
	2000.209.004651	36.7695	-121.4615	6.02	1.22		
53	36.7680	-121.4666	7.04	1.65	17.2	0.79	
	1992.185.004039	36.7728	-121.4688	7.72	1.74		
	1998.216.111435	36.7663	-121.4693	6.72	1.62		
	1999.343.232200	36.7667	-121.4657	7.15	1.55		
	2002.199.151747	36.7662	-121.4625	6.55	1.67		
54	36.7627	-121.4642	6.94	2.98	12.6	0.57	
	1986.112.174750	36.7633	-121.4618	6.80	3.02		
	1998.340.141448	36.7620	-121.4667	7.08	2.94		
55	36.7662	-121.4578	4.92	2.27	24.8	1.14	
	1988.146.060417	36.7660	-121.4572	4.87	2.24		
	1994.162.040419	36.7668	-121.4568	5.15	2.29		
	2000.062.204842	36.7665	-121.4578	4.88	2.26		
	2005.029.130812	36.7655	-121.4592	4.77	2.28		
56	36.7609	-121.4567	6.50	2.20	15.9	0.73	

	1989.072.002258	36.7612	-121.4535	6.66	2.20	
	1998.225.011917	36.7608	-121.4575	6.53	2.29	
	1998.353.200952	36.7607	-121.4592	6.31	2.14	
57	36.7498	-121.4537	8.82	1.65	28.7	1.32
	1985.095.064200	36.7508	-121.4525	8.51	1.62	
	1988.263.021511	36.7492	-121.4552	8.46	1.62	
	1991.209.205109	36.7523	-121.4557	9.08	1.68	
	1999.095.102853	36.7483	-121.4548	8.77	1.67	
	2000.116.011028	36.7493	-121.4507	8.83	1.71	
	2001.262.150343	36.7488	-121.4535	9.26	1.61	
58	36.7487	-121.4602	9.44	2.58	19.9	0.91
	1985.327.071004	36.7483	-121.4582	9.27	2.59	
	1994.194.172839	36.7498	-121.4615	9.53	2.53	
	2001.006.050451	36.7480	-121.4610	9.52	2.58	
59	36.7533	-121.4444	6.10	2.09	29.8	1.36
	1984.289.215729	36.7557	-121.4457	6.67	2.09	
	1989.321.234406	36.7498	-121.4405	6.28	2.11	
	1993.101.194113	36.7565	-121.4457	6.82	2.03	
	1999.296.183454	36.7547	-121.4440	6.93	2.01	

	2002.055.120708	36.7498	-121.4463	3.78	2.10	
60	36.7538	-121.4394	6.71	1.87	19.6	0.90
	1985.159.231028	36.7533	-121.4392	6.71	1.90	
	1998.244.220656	36.7520	-121.4402	6.41	1.92	
	2000.067.154112	36.7580	-121.4390	7.25	1.79	
	2003.028.000004	36.7518	-121.4393	6.49	1.85	
61	36.7488	-121.4469	8.03	2.48	18.7	0.86
	1987.185.042914	36.7488	-121.4453	7.74	2.40	
	1993.088.045244	36.7493	-121.4463	8.09	2.53	
	1999.173.205648	36.7482	-121.4490	8.26	2.48	
62	36.7449	-121.4317	6.34	2.21	31.9	1.46
	1988.220.121341	36.7447	-121.4310	6.32	2.25	
	1991.153.184838	36.7447	-121.4313	6.60	2.21	
	1996.138.173617	36.7458	-121.4342	5.92	2.29	
	2002.103.012118	36.7440	-121.4300	6.34	1.97	
	2002.103.021916	36.7453	-121.4318	6.52	2.07	
63	36.7400	-121.4166	6.85	1.58	22.1	1.01
	1989.006.030820	36.7417	-121.4178	7.18	1.58	

	1995.315.173538	36.7333	-121.4155	6.02	1.67	
	1998.256.115341	36.7375	-121.4178	6.49	1.71	
	1999.315.091119	36.7435	-121.4157	7.14	1.57	
	2001.299.234030	36.7440	-121.4162	7.42	1.55	
64	36.7401	-121.4106	6.77	1.79	12.5	0.57
	1990.249.172655	36.7402	-121.4098	6.88	1.79	
	1998.255.060027	36.7412	-121.4103	6.59	1.79	
	2005.053.120810	36.7390	-121.4118	6.83	1.84	
65	36.7360	-121.4051	6.95	1.96	20.7	0.95
	1987.174.202249	36.7370	-121.4055	6.83	1.95	
	1993.126.105054	36.7343	-121.4060	7.19	1.97	
	1999.239.181509	36.7353	-121.4028	6.80	1.99	
	2003.208.042843	36.7372	-121.4060	6.97	1.82	
66	36.7350	-121.4026	6.33	2.38	26.5	1.21
	1985.353.195842	36.7352	-121.4018	6.37	2.33	
	1990.197.195820	36.7352	-121.4040	6.42	2.36	
	1999.079.122740	36.7350	-121.4027	6.32	2.40	
	2002.294.021906	36.7347	-121.4018	6.19	2.40	

67	36.7356	-121.4030	6.89	1.78	31.0	1.42
	1985.106.121635	36.7355	-121.4032	6.81	1.77	
	1987.173.031808	36.7378	-121.4028	7.24	1.71	
	1990.082.205956	36.7352	-121.4043	7.06	1.76	
	1997.036.194807	36.7365	-121.4028	6.55	1.79	
	2001.040.011508	36.7343	-121.4012	6.63	1.89	
	2003.144.085124	36.7342	-121.4037	7.03	1.90	
68	36.7329	-121.3867	2.91	1.85	19.4	0.89
	1985.328.100232	36.7327	-121.3868	2.97	1.82	
	1989.358.061213	36.7320	-121.3862	2.77	1.85	
	1995.238.132825	36.7337	-121.3865	3.07	1.88	
	2001.095.120433	36.7332	-121.3873	2.81	1.86	
69	36.7234	-121.3680	2.80	2.08	37.0	1.69
	1986.112.050420	36.7238	-121.3678	2.91	1.97	
	1991.112.234049	36.7232	-121.3682	2.71	2.11	
	1995.011.172006	36.7232	-121.3698	2.59	2.16	
	1999.074.185312	36.7238	-121.3673	2.88	2.13	
	2000.211.152009	36.7232	-121.3677	2.93	1.98	
	2003.317.000629	36.7230	-121.3673	2.81	2.04	

70	36.7226	-121.3674	2.98	1.84	51.4	2.36

1986.161.183027	36.7228	-121.3678	3.04	1.84
1989.061.014251	36.7225	-121.3672	3.17	1.79
1991.130.024009	36.7223	-121.3668	2.96	1.94
1994.214.054226	36.7230	-121.3682	2.97	1.83
1996.105.182755	36.7228	-121.3682	2.95	1.57
1997.262.012045	36.7227	-121.3682	2.94	1.56
2000.166.182318	36.7222	-121.3670	2.88	1.85
2001.275.130200	36.7222	-121.3675	2.98	1.92
2004.235.131809	36.7230	-121.3660	2.96	1.97

71	36.7207	-121.3638	2.97	2.14	30.7	1.40

1988.206.144307	36.7177	-121.3645	2.66	2.30
1990.203.233821	36.7218	-121.3623	3.21	2.02
1994.211.150946	36.7210	-121.3653	2.83	2.14
1998.014.211000	36.7223	-121.3638	3.13	2.08
2001.284.133104	36.7208	-121.3632	3.02	2.14

72	36.7145	-121.3560	2.96	2.21	47.9	2.19

1984.173.071357	36.7148	-121.3540	3.14	2.45
1989.279.091415	36.7147	-121.3522	2.42	2.21
1991.334.013427	36.7143	-121.3573	3.18	2.27

	1994.353.112838	36.7143	-121.3577	2.97	2.21		
	1999.001.205139	36.7155	-121.3565	3.06	2.28		
	2001.221.202011	36.7145	-121.3577	3.16	2.21		
	2003.181.023150	36.7133	-121.3567	2.80	2.09		
73	36.7139	-121.3577	2.67	1.91	46.9	2.15	
	1984.279.061109	36.7140	-121.3553	2.88	1.68		
	1988.253.114707	36.7135	-121.3588	2.69	1.89		
	1990.307.022934	36.7135	-121.3577	2.50	1.94		
	1992.196.005405	36.7145	-121.3595	2.50	1.92		
	1995.348.212833	36.7135	-121.3575	2.64	2.10		
	1998.243.125717	36.7143	-121.3570	2.70	1.97		
	2000.199.005258	36.7138	-121.3590	2.70	1.89		
	2004.314.150629	36.7137	-121.3567	2.73	1.91		
74	36.7142	-121.3558	3.08	1.90	39.9	1.83	
	1987.098.022828	36.7132	-121.3570	3.12	1.84		
	1990.081.213256	36.7142	-121.3543	3.12	2.09		
	1993.033.063257	36.7148	-121.3575	3.04	2.01		
	1996.142.235807	36.7142	-121.3555	2.84	1.83		
	1999.279.012625	36.7142	-121.3570	3.15	1.82		
	2001.326.220435	36.7140	-121.3568	3.14	1.90		

	2004.089.053853	36.7147	-121.3522	3.16	2.07		
75	36.7127	-121.3457	1.51	2.27	41.4	1.89	
	1986.167.212217	36.7122	-121.3428	1.38	2.27		
	1990.335.095610	36.7128	-121.3455	1.44	2.46		
	1994.061.193902	36.7130	-121.3467	1.61	2.24		
	1996.170.075924	36.7128	-121.3470	1.45	2.09		
	2000.217.032941	36.7130	-121.3468	1.54	2.27		
	2003.108.121919	36.7123	-121.3452	1.65	2.30		
76	36.7120	-121.3477	1.33	2.11	7.5	0.34	
	1989.086.154047	36.7117	-121.3468	1.32	2.11		
	1994.070.013245	36.7122	-121.3485	1.33	2.10		
77	36.7082	-121.3458	2.95	1.73	42.2	1.93	
	1989.289.195623	36.7063	-121.3453	2.71	1.88		
	1990.246.140820	36.7078	-121.3478	2.83	1.55		
	1991.316.183808	36.7090	-121.3457	2.95	1.64		
	1995.085.053821	36.7082	-121.3463	2.85	1.84		
	1997.290.081219	36.7083	-121.3453	3.04	1.79		
	2000.294.081240	36.7092	-121.3442	3.21	1.76		
	2002.178.232517	36.7095	-121.3460	3.09	1.71		

	2004.122.132326	36.7077	-121.3460	2.92	1.70		
78	36.7031	-121.3383	4.73	2.17	39.0	1.79	
	1984.210.101151	36.7025	-121.3393	4.57	2.17		
	1989.280.025207	36.7030	-121.3383	4.99	2.14		
	1993.272.164939	36.7033	-121.3375	4.56	2.18		
	1998.176.161229	36.7033	-121.3392	4.61	2.15		
	2001.213.173228	36.7042	-121.3385	4.71	2.21		
	2004.225.064948	36.7022	-121.3368	4.94	2.17		
79	36.7045	-121.3354	2.96	2.35	8.7	0.40	
	1990.237.192644	36.7048	-121.3340	3.09	2.36		
	1995.004.150157	36.7043	-121.3368	2.83	2.33		
80	36.6994	-121.3314	2.97	2.06	29.2	1.34	
	1984.309.180200	36.6998	-121.3322	2.82	2.09		
	1992.149.231117	36.6983	-121.3315	2.82	2.06		
	1996.090.162312	36.7008	-121.3292	3.27	2.09		
	2000.044.152259	36.6992	-121.3325	2.84	1.94		
	2001.318.123934	36.6988	-121.3318	3.12	1.92		
81	36.6992	-121.3326	4.07	2.27	16.5	0.76	

	1989.352.174944	36.6995	-121.3332	4.06	2.27	
	1995.316.215126	36.6988	-121.3335	4.08	2.27	
	2003.246.121537	36.6992	-121.3310	4.06	2.15	
82	36.6942	-121.3248	4.78	2.47	9.3	0.43
	1988.171.105206	36.6947	-121.3248	4.71	2.43	
	1995.344.083813	36.6937	-121.3248	4.85	2.51	
83	36.6930	-121.3244	4.67	1.95	34.3	1.57
	1984.263.113325	36.6927	-121.3257	4.76	1.92	
	1989.041.112609	36.6938	-121.3243	4.51	1.96	
	1989.346.171312	36.6928	-121.3220	4.20	2.03	
	1990.276.134057	36.6928	-121.3245	4.76	1.94	
	2001.185.075855	36.6930	-121.3248	4.96	2.19	
	2003.299.055436	36.6930	-121.3252	4.83	1.84	
84	36.6932	-121.3240	3.85	1.84	45.0	2.06
	1985.111.045120	36.6933	-121.3248	3.84	1.82	
	1986.135.032532	36.6927	-121.3243	3.71	1.85	
	1990.028.180726	36.6940	-121.3232	3.96	2.30	
	1990.346.094147	36.6932	-121.3228	3.92	1.83	
	1994.355.204615	36.6932	-121.3255	3.72	1.78	

	2001.031.100529	36.6927	-121.3238	3.84	1.94	
	2001.285.234151	36.6932	-121.3248	3.73	1.91	
	2004.032.035957	36.6930	-121.3227	4.07	1.74	
85	36.6890	-121.3171	4.23	2.23	24.2	1.11
	1986.105.130251	36.6883	-121.3167	4.30	2.29	
	1990.247.135110	36.6888	-121.3172	4.32	2.18	
	1996.081.232952	36.6890	-121.3172	3.93	2.19	
	2001.185.103913	36.6897	-121.3175	4.38	2.27	
86	36.6882	-121.3171	4.40	1.85	58.2	2.67
	1984.061.093357	36.6882	-121.3177	4.54	1.83	
	1987.164.095910	36.6882	-121.3163	4.28	1.63	
	1990.025.134829	36.6880	-121.3163	4.27	1.95	
	1990.044.035222	36.6882	-121.3170	4.44	1.85	
	1991.256.141444	36.6880	-121.3165	4.53	1.87	
	1996.015.125014	36.6880	-121.3167	4.28	1.85	
	1997.324.185928	36.6888	-121.3175	4.49	2.03	
	2001.184.220417	36.6883	-121.3180	4.32	1.65	
	2001.249.102634	36.6878	-121.3173	4.40	1.95	
	2003.302.220109	36.6885	-121.3180	4.45	1.80	

87 36.6859 -121.3172 5.97 1.68 17.6 0.80

1989.353.200532 36.6857 -121.3177 5.85 1.71

1990.252.071717 36.6860 -121.3165 6.07 1.74

1999.090.011908 36.6862 -121.3172 5.76 1.61

2001.258.075954 36.6855 -121.3175 6.20 1.65

88 36.6852 -121.3143 5.52 1.84 25.7 1.18

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1990.253.174412 36.6855 -121.3152 5.57 1.84

1995.242.141910 36.6852 -121.3160 5.43 1.74

2000.208.181914 36.6850 -121.3128 5.24 1.71

2004.323.040749 36.6860 -121.3147 5.79 1.94

89 36.6857 -121.3137 4.28 1.85 45.2 2.07

1984.306.193748 36.6852 -121.3153 4.05 1.75

1990.014.062004 36.6868 -121.3140 4.03 1.88

1990.362.133316 36.6860 -121.3130 4.34 1.83

1993.242.081357 36.6850 -121.3135 4.33 1.76

1996.086.055845 36.6850 -121.3145 4.25 1.79

1998.127.124117 36.6860 -121.3128 4.45 1.86

2001.185.014052 36.6857 -121.3137 4.38 1.90

2003.137.041722 36.6862 -121.3128 4.40 1.91

90	36.6837	-121.3083	4.01	2.05	14.5	0.67
	1984.246.034042	36.6837	-121.3082	3.80	1.97	
	1990.354.162410	36.6833	-121.3083	4.07	2.05	
	1996.215.095348	36.6842	-121.3083	4.17	2.20	
91	36.6827	-121.3075	3.89	2.05	29.1	1.33
	1986.156.004300	36.6818	-121.3073	4.16	2.09	
	1990.053.230943	36.6833	-121.3070	3.52	2.11	
	1991.200.161019	36.6827	-121.3080	4.06	2.05	
	1994.032.162954	36.6830	-121.3075	3.93	1.91	
	2001.353.005000	36.6825	-121.3077	3.78	2.02	
92	36.6802	-121.3065	2.78	2.04	14.4	0.66
	1984.063.031604	36.6802	-121.3065	2.54	1.95	
	1994.104.043353	36.6805	-121.3062	2.86	2.09	
	2002.340.012241	36.6798	-121.3067	2.94	2.04	
93	36.6788	-121.3039	5.38	2.47	9.3	0.43
	1990.243.190518	36.6788	-121.3032	5.26	2.47	
	1998.233.173333	36.6787	-121.3045	5.51	2.46	

94	36.6769	-121.2996	3.00	2.19	23.7	1.08

1988.089.012614	36.6773	-121.2982	3.01	2.21
1993.068.215401	36.6775	-121.2990	3.07	2.18
1998.191.102738	36.6757	-121.3008	2.94	2.16
2003.126.193620	36.6770	-121.3003	2.96	2.19

95	36.6746	-121.2967	3.85	1.81	31.6	1.45

1987.238.215037	36.6755	-121.2948	3.61	1.83
1990.245.101402	36.6745	-121.2963	3.93	1.78
1993.137.181546	36.6745	-121.2968	3.91	1.86
1996.050.083959	36.6750	-121.2980	3.76	1.80
1999.079.053238	36.6740	-121.2970	3.94	1.73
2001.223.124508	36.6742	-121.2975	3.92	1.88

96	36.6745	-121.2966	4.34	2.34	8.6	0.39

1985.117.060617	36.6740	-121.2968	4.28	2.28
1990.106.131341	36.6750	-121.2965	4.40	2.39

97	36.6741	-121.2959	3.93	2.28	33.3	1.52

1984.221.075349	36.6742	-121.2967	3.81	2.30
1989.357.070129	36.6737	-121.2958	3.68	2.22
1995.206.140915	36.6740	-121.2952	4.07	2.31

	2000.179.223842	36.6747	-121.2960	4.08	2.28		
	2003.061.032209	36.6738	-121.2958	3.99	2.15		
98	36.6687	-121.2870	3.04	2.69	21.2	0.97	
	1986.200.110036	36.6692	-121.2870	3.03	2.69		
	1991.295.042930	36.6680	-121.2865	3.14	2.72		
	1998.239.173607	36.6688	-121.2875	2.94	2.66		
99	36.6683	-121.2860	3.25	3.07	39.7	1.82	
	1988.107.184738	36.6685	-121.2858	3.36	3.06		
	1993.088.201502	36.6685	-121.2865	3.36	3.03		
	1999.187.135516	36.6682	-121.2860	3.22	3.08		
	2004.287.232620	36.6678	-121.2858	3.07	3.10		
100	36.6663	-121.2869	2.92	2.32	17.0	0.78	
	1992.274.064600	36.6657	-121.2867	2.74	2.32		
	1998.197.225805	36.6663	-121.2878	3.06	2.31		
	2003.157.115207	36.6670	-121.2863	2.96	2.35		
101	36.6655	-121.2869	5.85	2.15	15.4	0.71	
	1990.245.194507	36.6650	-121.2865	5.73	2.23		
	1996.260.093456	36.6662	-121.2870	5.82	2.15		

	2002.264.010328	36.6653	-121.2872	6.00	2.15		
102	36.6616	-121.2846	6.53	2.96	12.4	0.57	
	1990.136.042803	36.6610	-121.2842	6.50	2.99		
	1999.094.072725	36.6622	-121.2850	6.56	2.92		
103	36.6594	-121.2858	7.66	2.79	11.2	0.51	
	1990.138.030239	36.6588	-121.2858	7.75	2.88		
	1995.055.190220	36.6600	-121.2858	7.56	2.66		
104	36.6604	-121.2771	3.41	3.17	42.1	1.93	
	1985.316.221108	36.6603	-121.2767	3.33	3.23		
	1989.355.091807	36.6603	-121.2773	3.38	3.04		
	1994.220.003752	36.6605	-121.2768	3.45	3.24		
	1998.342.233233	36.6607	-121.2775	3.47	3.08		
105	36.6578	-121.2752	3.34	2.38	26.5	1.21	
	1989.355.094516	36.6573	-121.2752	3.22	2.57		
	1998.198.052712	36.6580	-121.2753	3.11	2.38		
	2001.121.135745	36.6585	-121.2758	3.87	2.32		
	2004.297.134459	36.6575	-121.2747	3.15	2.38		

106	36.6563	-121.2749	5.57	2.64	30.8	1.41	
	1985.121.030527	36.6560	-121.2758	5.54	2.71		
	1991.021.064045	36.6562	-121.2748	5.38	2.67		
	1996.331.092305	36.6563	-121.2745	5.66	2.61		
	2001.081.110253	36.6568	-121.2743	5.71	2.56		
107	36.6570	-121.2716	3.47	2.73	10.8	0.50	
	1986.350.184542	36.6567	-121.2703	3.48	2.72		
	1994.363.035619	36.6572	-121.2728	3.47	2.74		
108	36.6564	-121.2818	8.36	2.91	24.1	1.10	
	1986.023.211109	36.6557	-121.2818	8.14	2.95		
	1994.227.051346	36.6560	-121.2818	8.46	2.91		
	2002.259.122218	36.6575	-121.2818	8.49	2.88		
109	36.6550	-121.2807	7.52	2.50	18.9	0.87	
	1986.218.024949	36.6547	-121.2812	7.21	2.49		
	1995.004.233509	36.6552	-121.2812	7.63	2.55		
	2003.271.005919	36.6552	-121.2797	7.71	2.50		
110	36.6543	-121.2801	7.74	2.56	9.8	0.45	
	1986.216.091150	36.6540	-121.2807	7.54	2.46		

	1994.365.205933	36.6545	-121.2795	7.94	2.63	
111	36.6535	-121.2781	7.53	2.20	15.9	0.73
	1986.216.091358	36.6535	-121.2795	7.28	2.23	
	1994.365.210235	36.6532	-121.2785	7.77	2.20	
	2000.050.140809	36.6538	-121.2762	7.53	2.13	
112	36.6529	-121.2770	7.47	2.27	24.8	1.14
	1986.155.113658	36.6517	-121.2768	7.25	1.79	
	1993.098.155923	36.6533	-121.2773	7.62	2.27	
	1996.156.064609	36.6532	-121.2772	7.36	2.26	
	2000.329.151741	36.6532	-121.2768	7.67	2.34	
113	36.6527	-121.2742	6.58	2.43	36.4	1.67
	1985.326.221651	36.6525	-121.2742	6.17	2.40	
	1990.139.021414	36.6523	-121.2743	6.42	2.45	
	1994.118.030948	36.6527	-121.2740	6.86	2.43	
	1999.108.074753	36.6528	-121.2745	6.69	2.43	
	2002.103.182125	36.6533	-121.2742	6.74	2.33	
114	36.6521	-121.2733	6.80	2.16	15.5	0.71
	1991.304.153545	36.6517	-121.2728	6.64	2.22	

	1999.109.021106	36.6522	-121.2738	6.70	2.16	
	2002.103.214532	36.6523	-121.2732	7.06	2.04	
115	36.6507	-121.2721	6.61	2.23	32.3	1.48
	1985.327.202854	36.6503	-121.2722	6.75	2.23	
	1994.244.153928	36.6505	-121.2728	6.56	2.25	
	1999.108.071235	36.6508	-121.2717	6.63	2.35	
	2000.305.181651	36.6502	-121.2720	6.60	1.78	
	2002.107.124347	36.6515	-121.2720	6.53	2.17	
116	36.6506	-121.2710	6.73	2.55	39.0	1.79
	1985.327.202946	36.6500	-121.2717	6.55	2.79	
	1994.244.153553	36.6498	-121.2708	6.72	2.84	
	1998.336.171850	36.6513	-121.2707	6.73	2.55	
	2000.305.181714	36.6508	-121.2712	6.80	2.53	
	2002.107.113128	36.6512	-121.2708	6.83	2.35	
117	36.6530	-121.2700	3.34	2.04	14.4	0.66
	1986.154.124846	36.6525	-121.2720	3.31	1.86	
	1988.139.230744	36.6535	-121.2698	3.39	2.10	
	1998.094.174334	36.6530	-121.2682	3.31	2.04	

118	36.6514	-121.2683	5.13	2.55	39.0	1.79	
	1987.335.172032	36.6520	-121.2685	5.06	2.69		
	1992.043.030827	36.6515	-121.2685	5.31	2.69		
	1996.035.100917	36.6502	-121.2677	5.05	2.53		
	1999.298.025613	36.6517	-121.2683	5.30	2.55		
	2002.118.141720	36.6515	-121.2687	4.92	2.37		
119	36.6515	-121.2649	3.72	3.07	26.5	1.21	
	1986.266.061550	36.6520	-121.2640	3.57	3.12		
	1992.170.095105	36.6512	-121.2655	3.78	3.07		
	1998.244.105644	36.6512	-121.2653	3.80	3.05		
120	36.6492	-121.2664	5.50	2.06	29.2	1.34	
	1987.163.184203	36.6492	-121.2657	5.45	2.02		
	1991.251.155325	36.6488	-121.2670	5.38	1.99		
	1996.054.122659	36.6498	-121.2667	5.58	2.16		
	2000.060.205813	36.6490	-121.2663	5.49	2.06		
	2003.162.082128	36.6490	-121.2662	5.58	2.15		
121	36.6458	-121.2677	7.29	2.54	19.4	0.89	
	1986.117.030200	36.6457	-121.2680	7.36	2.61		
	1991.225.233122	36.6453	-121.2675	6.93	2.47		

	1999.235.022044	36.6463	-121.2677	7.59	2.54		
122	36.6431	-121.2647	8.56	2.49	9.4	0.43	
	1987.320.081102	36.6428	-121.2645	8.41	2.57		
	1992.156.125436	36.6433	-121.2650	8.71	2.38		
123	36.6452	-121.2585	4.61	2.23	40.4	1.85	
	1986.200.045631	36.6442	-121.2582	4.14	2.11		
	1988.354.191400	36.6450	-121.2578	4.69	2.31		
	1993.156.021101	36.6452	-121.2590	4.69	1.96		
	1997.021.141616	36.6455	-121.2578	4.78	2.31		
	2000.185.030226	36.6457	-121.2587	4.70	2.38		
	2004.066.154827	36.6455	-121.2595	4.64	2.13		
124	36.6440	-121.2595	5.74	2.01	21.3	0.98	
	1986.152.014213	36.6435	-121.2595	5.63	2.04		
	1988.058.091109	36.6440	-121.2600	5.80	1.87		
	1996.259.234237	36.6447	-121.2590	5.62	1.98		
	2002.011.053501	36.6438	-121.2593	5.89	2.15		
125	36.6422	-121.2609	7.12	2.52	9.6	0.44	
	1994.344.065847	36.6420	-121.2610	7.00	2.54		

	1999.232.005458	36.6423	-121.2608	7.24	2.50		
126	36.6425	-121.2569	5.69	2.57	29.6	1.36	
	1986.151.225525	36.6425	-121.2573	5.38	2.40		
	1991.332.210241	36.6427	-121.2562	5.82	2.56		
	2000.004.134809	36.6422	-121.2568	5.66	2.60		
	2003.321.022746	36.6427	-121.2573	5.89	2.57		
127	36.6432	-121.2548	3.95	2.48	18.7	0.86	
	1990.039.171610	36.6430	-121.2558	4.00	2.49		
	1995.212.050051	36.6432	-121.2537	3.64	2.48		
	2002.327.110618	36.6433	-121.2548	4.20	2.45		
128	36.6422	-121.2554	4.50	2.19	39.5	1.81	
	1986.163.192731	36.6415	-121.2568	4.09	1.90		
	1990.013.095508	36.6420	-121.2548	4.47	2.21		
	1993.111.154535	36.6427	-121.2555	4.65	2.24		
	1999.081.195114	36.6420	-121.2548	4.53	2.28		
	2002.009.232435	36.6425	-121.2552	4.56	2.07		
	2004.074.223232	36.6423	-121.2553	4.68	2.18		
129	36.6411	-121.2542	5.58	2.77	11.1	0.51	

	1986.152.193445	36.6403	-121.2548	5.32	2.85	
	1994.086.153447	36.6418	-121.2535	5.84	2.67	
130	36.8036	-121.5311	8.30	1.49	5.2	0.24
	1998.148.203544	36.8045	-121.5302	7.86	1.56	
	1998.155.061233	36.8027	-121.5320	8.74	1.39	
131	36.7896	-121.5145	8.72	1.75	6.1	0.28
	1998.225.142100	36.7895	-121.5122	8.42	1.73	
	1998.255.195423	36.7897	-121.5168	9.03	1.77	
132	36.7911	-121.5034	6.92	1.47	5.2	0.24
	1998.225.004407	36.7902	-121.5043	7.01	1.46	
	1998.230.073240	36.7920	-121.5025	6.83	1.47	
133	36.7912	-121.5010	6.05	1.33	4.8	0.22
	1998.225.231814	36.7897	-121.5025	6.04	1.39	
	1998.233.021010	36.7927	-121.4995	6.07	1.24	
134	36.7867	-121.5000	6.51	1.88	6.6	0.30
	1998.224.170938	36.7858	-121.5007	6.41	1.92	
	1998.232.053858	36.7875	-121.4993	6.61	1.84	

135	36.7883	-121.4983	6.34	1.44	15.2	0.70
	1998.224.141621	36.7885	-121.5002	6.42	1.28	
	1998.225.121633	36.7875	-121.4987	6.53	1.60	
	1998.237.184653	36.7883	-121.4952	6.37	1.46	
	1999.274.012327	36.7888	-121.4993	6.04	1.26	
136	36.7832	-121.4975	6.69	1.77	6.2	0.28
	1998.224.205242	36.7837	-121.4987	6.84	1.78	
	1998.264.221727	36.7828	-121.4963	6.53	1.75	
137	36.7683	-121.4805	7.65	1.48	5.2	0.24
	1998.224.150639	36.7687	-121.4820	7.97	1.55	
	1998.229.083158	36.7680	-121.4790	7.33	1.38	
138	36.7658	-121.4783	8.31	1.70	17.8	0.81
	1998.224.145508	36.7672	-121.4792	8.41	1.73	
	1998.225.145957	36.7657	-121.4760	8.44	1.68	
	1998.229.100413	36.7657	-121.4790	8.20	1.72	
	1999.357.072207	36.7645	-121.4788	8.19	1.67	
139	36.7613	-121.4714	8.34	1.46	15.4	0.71

	1998.224.152428	36.7620	-121.4687	8.31	1.47		
	1998.227.082805	36.7593	-121.4777	7.16	0.93		
	1998.234.063121	36.7632	-121.4700	9.02	1.56		
	1999.007.231840	36.7608	-121.4693	8.85	1.56		
144	36.7391	-121.4641	15.17	1.60	5.6	0.26	
	1989.304.182116	36.7407	-121.4667	15.47	1.69		
	1989.313.021931	36.7375	-121.4615	14.87	1.48		
145	36.7195	-121.3571	5.92	1.39	4.9	0.23	
	1992.295.005810	36.7193	-121.3568	5.96	1.38		
	1992.295.015836	36.7197	-121.3573	5.89	1.40		
146	36.6994	-121.3368	4.61	1.72	6.0	0.27	
	1995.323.230644	36.6993	-121.3368	4.61	1.72		
	1995.323.230720	36.6995	-121.3368	4.60	1.72		
147	36.6789	-121.3097	5.81	1.47	5.2	0.24	
	1986.095.025601	36.6788	-121.3098	5.80	1.54		
	1986.096.220451	36.6790	-121.3095	5.83	1.37		
148	36.6767	-121.3052	5.89	1.67	5.8	0.27	

	1990.251.130136	36.6765	-121.3045	5.97	1.73		
	1990.252.022728	36.6768	-121.3058	5.82	1.60		
149	36.6774	-121.3048	6.40	2.77	11.1	0.51	
	1999.082.233354	36.6782	-121.3047	6.41	2.86		
	1999.101.024209	36.6767	-121.3050	6.39	2.62		
150	36.6766	-121.3045	5.35	1.69	5.9	0.27	
	1990.244.030248	36.6767	-121.3047	5.40	1.64		
	1990.253.084913	36.6765	-121.3043	5.29	1.73		
151	36.0401	-120.8766	10.28	2.10	7.5	0.34	
	1985.329.053319	36.0403	-120.8767	10.41	2.20		
	1985.329.053833	36.0398	-120.8765	10.15	1.94		
152	36.0008	-120.9794	11.67	1.70	5.9	0.27	
	1996.236.110248	36.0012	-120.9792	11.87	1.51		
	1996.237.093136	36.0005	-120.9797	11.47	1.81		
153	36.0194	-120.9681	7.58	1.83	6.4	0.29	
	1999.183.222527	36.0213	-120.9670	8.81	1.90		
	1999.225.023202	36.0175	-120.9692	6.34	1.74		

154	36.0182	-120.8778	11.14	1.90	6.7	0.30	
	1999.208.013103	36.0185	-120.8770	11.52	1.57		
	1999.213.165653	36.0178	-120.8787	10.76	2.04		
155	36.0997	-121.0300	11.00	1.22	17.9	0.82	
	2000.344.134929	36.0995	-121.0300	11.29	1.45		
	2000.352.163917	36.1005	-121.0300	10.62	1.48		
	2000.366.150039	36.0983	-121.0300	11.18	1.68		
	2000.344.202751	36.0995	-121.0300	11.29	1.68		
	2000.355.084002	36.1005	-121.0300	10.62	1.70		
156	35.9907	-120.9631	6.35	1.73	6.0	0.28	
	2003.188.191626	35.9900	-120.9642	6.27	1.52		
	2003.189.074547	35.9913	-120.9620	6.43	1.85		