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THE SOUTHERN CALIFORNIA NETWORK BULLETIN JANUARY — JUNE, 1987

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This report is preliminary and has not been reviewed for conformity with U. S. Geological Survey editorial standards and stratigraphic nomenclature.

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INTRODUCTION

The California Institute of Technology together with the Pasadena Office of the U.S. Geological Survey operates a network of approximately 250 remote seismometers in southern California. Signals from these sites are telemetered to the central processing site at the Caltech Seismological Laboratory in Pasadena. These signals are continuously monitored by computers that detect and record thousands of earthquakes each year (Appendix A.). Phase arrival times for these events are picked by human analysts and archived along with digital seismograms. All data aquisition, processing and archiving is achieved using the CUSP system. These data are used to compile the *Southern California Catalog of Earthquakes*; a list beginning in 1932 that currently contains more than 150,000 events.

This data set is critical to the evaluation of earthquake hazard in California and to the advancement of geoscience as a whole. A partial list of research papers that have used Network data appears in Appendix B.

This and previous Network Bulletins are intended to serve several purposes. The most important goal is to promote the use of Network data by making it more accessible to current and potential users. It is also important to document the details of Network operation, because only with a full understanding of the process by which the data are produced can researchers use the data responsibly. In order to maximize the Bulletins' usefulness, a cumulative index of subjects that have appeared in this and earlier Bulletins appears in Appendix C.

NETWORK CONFIGURATION

New Stations. The following stations and instruments have been added to the Network since the last Bulletin. This description is not limited to those changes made during the reporting period of this report, but include all changes made as of "press time" in order to provide the most current data available. Several of these new instruments were installed in response to the Whittier Narrows earthquake of October 1, 1987.

A full explanation of the conventions used for full station codes can be found in Given *et al.* (1987).

GSA/GST Three components of L4, short-period seismometers were installed in the basement of the U.S.G.S. office in Pasadena. The signals from the instruments are recorded twice; one signal, called GSA, is recorded directly and the other, called GST, after passing through normal network telemetry. These can be compared to study the effects of the VCO-discriminator telemetry on seismic signals. In response to the Whittier Narrow earthquake a triaxial FBA (Force Balance Accelerometer) was also installed in the U.S.G.S. office in Pasadena. The calibration of the FBA is 1.22×10^{-3} g/count.

Site name:	Geological Survey
Latitude:	34° 8.22′ N (34.1370°)
Longitude:	118° 7.62′ W (118.1270°)
Elevation:	233 m (764 ft.)
Date installed:	February 19, 1987 (L4's)
Date installed:	October 8, 1987 (FBA)

Full Code	Inst.	Orientation	
GSACV	L4	vertical	no telemetry
GSACN	L4	north/south	no telemetry
GSACE	L4	east/west	no telemetry
GSTCV	L4	vertical	telemetry
GSTCN	L4	north/south	telemetry
GSTCE	L4	east/west	telemetry
GSACI	FBA	vertical	
GSACJ	FBA	north/south	
GSACK	FBA	east/west	

GVR A new site was installed at Garvey Reservoir in Monterey Park. The site has six telemetered components; triaxial L4, short period seismometers and a triaxial, low gain FBA. The calibration of the FBA is 1.0×10^{-3} g/count.

Site name: Garvey Reservoir
Latitude: 34° 3.00′ N (34.0500°)
Longitude: 118° 7.13′ W (118.1188°)
Elevation: 177 m (580 ft.)
Date installed: October 8, 1987

Full Code	Inst.	Orientation
GVRCI	FBA	vertical
GVRCJ	FBA	north/south
GVRCK	FBA	east/west
GVRCV	L4	vertical
GVRCN	L4	north/south
GVRCE	L4	east/west

TCC An FBA was temporarily installed at the existing Network site at Turnbull Canyon (TCC). Its purpose was to record S-waves to constrain aftershock depths, therefore, the instrument was oriented at N45°E and only one horizontal component was recorded. It was removed after the aftershock activity had reached a low level.

Site name: Turnbull Canyon (temporary FBA)
Full code: TCCCJ
Latitude: 33° 59.67′ N (33.9945°)
Longitude: 118° 0.77′ W (118.0128°)
Elevation: 299 m (981 ft.)
Orientation: N45°E
Date installed: October 2, 1987
Date removed: January 11, 1988

<u>SIM</u> A new site was installed at the existing radio receive site at Simmler in the Carrizo Plain. This site will probably replace an existing site at Yegas Mountain (YEG).

Site name: Simmler
Full code: SIMCV
Latitude: 35° 21.02′ N (35.3503°)
Longitude: 119° 59.74′ W (119.9957°)
Elevation: 616 m (2021 ft.)
Date installed: October 28, 1987

Progress of Installation of New VCO's. Installation of the new J502 voltage controlled oscillators (VCO) is continuing. The new VCO's have higher dynamic range than older units. The stations that now have J502 VCO's and the dates of installation are listed in Table 1.

Table 1. Stations with J502 VCO's Installed

ABL	29 June	1987	NW2	29 May	1987
ADL	24 April	1986	PKM	28 May	1987
BAT	23 June	1987	PLE	24 August	1987
BCH	1 June	1987	RAY	11 November	1987
BTL	1 July	1987	RMR	11 June	1987
CFT	24 February	1987	RYS	9 April	1987
CJV	1 July	1987	SBK	20 January	1987
CRG	29 May	1987	SDW	3 July	1986
DBM	30 April	1987	SIM	28 October	1987
ECF	22 July	1987	SIP	20 July	1987
ELM	23 April	1986	SLT	29 May	1987
ELR	9 April	1987	SMO	27 October	1986
FAL	18 June	1987	SUN	30 June	1987
FRK	22 May	1987	THC	19 February	1987
INS	4 March	1987	TMB	2 June	1987
LAQ	2 December	1987	VG2	10 June	1987
MAR	6 April	1987	WIS	30 June	1987
MIR	8 April	1987	WSP	26 June	1987

New Discriminator Parameters. A method for calculating the response of each station in the Network was given in a previous Bulletin (Given *et al.*, 1986). The method is based on the work of Stewart and O'Neill (1980). The necessary parameters for individual stations were given in Table 1 of that Bulletin and parameters for each discriminator type appeared in Table 2.

The following table lists corrected parameters for J110 discriminators and new parameters for J120 discriminators according to O'Neill-Allen (1987, personal communication).

Table 2. New and Corrected Discriminator Parameters

Discriminator type	LTYPE	LN	F_0	β
J110	2	0	30.0	0.3827
	2	0	30.0	0.9239
J120	2	0	20.0	0.3827
	2	0	20.0	0.9239

Calibration Pulses. In June of 1987 an effort was begun to record the calibration pulse or "calpulse" for each station in the Network. Stations which produce a pulse include all seismometers with J2, J4 or J5 type VCO's. Calibration pulses are important for the maintenance of the seismometer because they provide an indication of the condition and performance of the instrument. Calpulses are also valuable sources of instrument response for analyzing waveforms in studies to determine earthquake source parameters or propogation path structure.

Figure 1 shows an actual calpulse. The interval of record between labels 2 and 3 in Figure 1 contains the response of the entire recording and telemetry system. In this interval an additional 24 db of attenuation is added to the setting of the station. This section includes the release test, where the seismometer mass is displaced from its equilibrium position and released. Neglecting any effects due to the decay of the electromagnetic field in the coil, this calibration test is equivalent to a step in acceleration. A FORTRAN program is available to calculate the calpulse for the seismometer release test for any set of station parameters.

The amplitude of the step in acceleration during the calpulse test can be calculated by:

$$F = MA = IG = \frac{VG}{R} \tag{1}$$

$$A = \frac{VG}{MR} \tag{2}$$

where,

F = Force
M = Suspended mass (1,000 gm)
A = Acceleration
I = Calibration current
G = Motor constant (2.73×10^7 dyne/amp)
V = Calibration voltage
R = Coil resistance (5,500 ohms)

The calibration voltages and corresponding steps in acceleration are given in Table 3. Note that the attenuation listed in the table is the attenuation set on the VCO. The true attenuation during the calibration test is 24 db higher.

▪ Table 3. Calpulse Accelerations at Different Attenuations

Attenuation Setting (db)	Calibration Voltage	Acceleration (cm/sec^2)
0	0.0025	0.0124
6	0.005	0.0248
12	0.010	0.0496
18	0.020	0.0992
24	0.040	0.198
30	0.080	0.397
36	0.161	0.799
42*	0.161	0.799
48†	0.161	0.799

* pulse amplitude is 1/2 full amplitude
† pulse amplitude is 1/4 full amplitude

During the interval of calpulse record labeled 3 to 4 in Figure 1, the seismometer is isolated from the system and the VCO and telemetry electronics are tested alone. By comparing the normal station background noise level with that in the interval from 3 to 4, it is possible to judge the relative contributions of the site background noise and the electronic noise of the station.

A calibration pulse should occur on each station once every 24 hours. The time of day at which the calpulse occurs has been programmed according to the frequency at which the signal is transmitted (Table 4). Therefore, all the calibration pulses should occur at one of four times as shown in Table 4.

▪ Table 4. VCO Frequency vs. Calpulse Time

VCO Frequency	Calpulse Time (Gmt)
680/2040	1600
1020/2380	1700
1360/2720	1800
400/1700/3060	1900

Calibration pulses can be digitally recorded by two different methods at present. The simplest method is the unintentional recording of a calpulse during an unrelated event trigger of the on-line computer system. This hit-or-miss method is not very efficient for successfully recording calpulses for all the Network stations on a regular basis. The second method is to manually trigger the on-line system at the four designated calpulse times. This works only if the calpulses are, in fact, occurring when they should.

The actual calpulse times for Network stations were determined by both the methods described above and by continuous drum recording. For the drum recordings, each phone line was recorded for a period of 19–24 hours, including the four one hour periods for which calpulses are scheduled.

After obtaining multiple recordings for many stations, it became apparent that the calibration pulses were not behaving as expected. A large number of calpulses were not occurring at any one of the four assigned times; some stations showed a large drift, and a few stations had randomly occurring calpulses. Other stations had calpulses that occurred at regular intervals for a few days or weeks and then jumped to another time. This erratic behavior may be caused by frequent lightening near these stations. It was also discovered that a "jam box" being used to set calpulse times on northern stations was defective causing unexpected calpulses times at those locations. The jam box has since been repaired and the calibration pulses for many of the northern stations have returned to normal.

Calibration pulse times for approximately 50% of all the Network stations have been determined. Of these, 40% have calpulses that occur at regular intervals and only half of these occur at the correct times; therefore, only 20% of all the stations show calibration pulses occurring regularly at the correct time. As a result, digital recordings of the calibration pulses have been obtained for only 40% of the Network.

Calpulses are continuing to be saved if they occur during an event trigger, although the best solution to the problem is to correct the timing of the calibration pulses so that they occur when expected. A determined effort is being made in this direction. In the future, we hope to develop software which recognizes the calibration pulse and triggers the on-line system so the pulse can be digitally recorded regardless of the time. The microVAX which was recently installed to take over real-time recording will be capable of handling such an operation.

The Network Configuration Database. The southern California Network is continuously changing; many stations have been installed and some have been removed, site components have been updated, gains have been changed, polarities have become reversed and been corrected and network telemetry has evolved. Many of these factors are important to researchers who work with the data produced by the Network. Therefore, it is desirable to be able to get a "snapshot" of the network configuration at any point in its history. Toward this end, information about network station configuration and telemetry has been collected and entered into a commercially available data base management program (dBase III) on a personal computer.

The database actually consists of four related databases, grouped by information type; MAIN.DBF, SEISMO.DBF, VCO_DISC.DBF and POL.DBF. Each entry in the database is accompanied by a DATE field, which tells when that particular information became current. This means that the information in that record was true from the time shown in the DATE field until it is superseded by another record with a more recent DATE field. Because of this, the station history database may contain several records for each station, tracing the history of changes that have been made and allowing the station attributes to be determined for any point in time.

Characteristics of the individual data items available in the data base are described in Appendix D. Each item is listed by the field name, data type and field length as they occur in the data base.

Listings of these data in certain pre-set formats are available to workers who need it by contacting Lisa Stach in the Pasadena Office of the U.S.G.S. The raw data on floppy disk in dBase format and sort routines may also be obtained by sending a blank 5.25 inch floppy disk with your request.

NETWORK OPERATIONS

Status of Processing. Data processing is preliminary for the first half of 1987. It has been completely timed but awaits final checking and magnitude calibration. A two week outage of the Navy microwave system in May, 1987 caused us to lose signals from about two dozen stations from the Indian Wells Valley-Southern Sierra area. As a result, the record of activity in that area during that period is incomplete (Figure 5b, Region 11). It is estimated that approximately 200–300 earthquakes were missed during the outage.

The status of each month of catalog data since the advent of digital recording is described in Table 5. Events for months marked preliminary (**P**) have been timed but have not yet run the gauntlet of quality checking, addition of helicorder amplitudes and rearchiving necessary to become final (**F**). For months marked "pinked" (**Pnk**), larger events (≈ 3.0) have only been time crudely on a few stations and smaller events are absent. A long period from 1981 through 1983 has actually been timed and digital seismograms are available, but the "pinked" version is still used for any purpose requiring good magnitudes or completeness for large earthquakes; some events and magnitudes are missing otherwise.

■ Table 5. Processing Status of Network Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1977	P	P	P	P	P	P	P	P	P	P	P	P
1978	F	F	F	F	F	F	F	F	F	F	F	F
1979	P	P	P	P	P	P	P	P	P	P	P	P
1980	P	P	P	P	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk
1981	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk
1982	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk
1983	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	Pnk	F	F	F
1984	F	F	F	F	F	F	F	F	F	F	F	F
1985	F	F	F	F	F	F	F	F	F	P	P	P
1986	F	F	F	F	F	F	P	P	P	P	P	P
1987	P	P	P	P	P	P	P	P	P	P	P	Pnk
1988	P	P	P									

F = final, Pnk = "pinked", P = preliminary

Meaning of Phase Descriptions. Phase data in the CUSP data base includes the arrival time and a phase description. Times are given to a precision of 0.02 second for computer recorded seismograms and 0.1 second for helicorder picks. This phase description is made by the analyst at the time the arrival is picked and describes four different aspects of the picked arrival; phase type, onset, first motion and pick weight (e.g. IPD0, ES2, EP+3). CUSP programs are not sensitive to the order of these descriptors but they are traditionally given in the same order as they are described below.

Onset This one letter code is a qualitative description of the character of the first motion of the picked phase. It is either **I** for impulsive or **E** for emergent. Generally impulsive arrivals can be picked more accurately than emergent arrivals. Consequently impulsive phases are usually assigned a weight of **0** or **1** and emergent phases are generally given weights of **2**, **3** or **4**.

Phase Type This simply states which phase the analyst believes is being picked on the trace. It is usually either **P** for a P-wave or **S** for an S-wave. Some older phase descriptions may be modified, on rare occasions, with **N** for Moho refractions or **G** for direct waves, Helicorder readings may include more complex arrivals from teleseisms. Such phase descriptors follow the usual seismological conventions (e.g. PKP, ScP, SSS).

First Motion This is the direction that the first arrival caused the seismogram to deviate from the zero line. **U** indicates *UP* or compression and **D** indicates *DOWN* or dilatation on vertical seismometers. In the past, if the direction of first motion was somewhat ambiguous "+" was substituted for **U** and "–" was substituted for **D**. The current convention is to use "+" and "–" to indicate nodal arrivals and uncertain first motions are ignored. First motions are sometimes given for S-wave picks when they are clearly visible. While these are not used for conventional focal mechanism solutions they may be of value for some specialized studies.

Pick Weight A pick weight integer in the range from **0** to **4** is assigned to each phase pick when it is made. The error bars associated with each weight is shown in Table 6. At a sample rate of 100Hz an error bar of 0.02 second corresponds to a pick error of only two sample points. While the pick weight assigns an absolute error estimate on a pick, it should be kept in mind that these weights are assigned somewhat subjectively by the analysts and strict interpretation of their meanings is not appropriate.

▪ Table 6. Phase Pick Error Bars

Weight	Error (sec)
0	$\pm$ 0.02
1	$\pm$ 0.05
2	$\pm$ 0.10
3	$\pm$ 0.30
4	$>$ 0.30

Different location programs treat pick weights differently, but generally a **0** pick will be given full weight in the location calculation, picks of **1**, **2** and **3** will be scaled according to some scheme and **4** picks will be given no weight at all.

Survivability of the Network. In a recent study, Given (in press) has evaluated the likely effects of a large damaging earthquake in southern California on the ability of the Network to record and process seismic data. One of the main goals of the study was to identify the components of the Network that are most vulnerable to damage or overload and suggest measures to prevent data loss.

The most likely cause of loss or delay of data is simply the inability of the present seismic processing system to deal with the huge increase in data that accompanies a large earthquake sequence.

For example, during the North Palm Springs earthquake of July 8, 1986 the on-line computer system was saturated by the intense aftershock sequence situated in the middle of the Network. The six hour data gap that resulted is now being retrieved from a backup data source but the unavailability of the data has delayed study of that sequence. Data have also been significantly delayed following earthquake sequences at Mammoth Lakes, Coalinga and, most recently, Superstition Hills (see Table 5).

Data loss due to physical damage to Network components is of secondary importance. Individual seismic stations are spatially distributed and quite resistant to shaking. All station signals are carried to Caltech over some combination of three different telemetry systems; radio, leased telephone lines and U.S.G.S. microwave. Telemetry links are of greater concern because they are more fragile and loss of a single component could cause loss of signal from as many as 100 sites. 47% of Network signals are carried by FM radios somewhere in their path. The radio systems are quite rugged and failure of a radio would result in loss of only a single signal. 93% of Network signals are carried at some point by leased telephone lines. Because of the complexity of the commercial telephone system, the actual signal path is unknown in most cases and the survivability of these lines is difficult to determine. At any rate, we have no control over the equipment used and can take no measures to mitigate problems short of choosing not to use leased telephone lines. Risk of data loss is reduced by the fact that no more than eight station signals can be multiplexed on a single telephone line. 43% of Network signals are ultimately carried to Pasadena on the U.S.G.S. microwave system. This system is particularly vulnerable to loss of signal due to shaking because transmit and receive dishes must be place on tall masts and the signal strength is very sensitive to dish alignment. Furthermore, loss of any one of several components in the system would result in complete loss of data from 43% of the Network.

Clearly, the most serious blow to data collection would be loss of any unique component of the system. This common-point-of-failure problem is addressed at the Seismological Lab by recording Network signals on redundant on-line computer systems. Signals are also recorded on an analog FM tape backup system that has a battery backup power source.

The Hawaiian Volcano Observatory on Kilauea was knocked off-line during the Kaoiki earthquake of November 16, 1983 ($M_S = 6.6$) which occurred about 15 km away from the facility (Tom English and Carl Johnson, personal communication, 1987). Their computer systems, which are similar to those at Caltech, "walked" across the room, disconnecting their umbilicals. Power was lost, tape rack and shelves fell and some cables were damaged.

The Seismological Lab was subjected to Modified Mercalli Intensity VII shaking during the Whittier Narrows earthquake of October 1, 1987. There was some minor damage to the laboratory building and its contents, some helicorder records were obscured by shaking of the recording units and one discriminator was shaken loose, but otherwise there was no interruption of data recording. Data recording was not threatened with saturation because the aftershock sequence of this earthquake was quite depressed.

The data collection capability of the present system was severely taxed during the November 24, 1987 Superstition Hills earthquake sequence. No data were lost but our ability to monitor the sequence as it unfolded was seriously impaired by insufficient computing resources to locate the earthquakes in real-time.

The solution to the real-time location problem is on-line recording on more powerful processors. The U.S.G.S. has purchased a microVAX computer for this purpose and a more advanced version of the CUSP data aquisition system will be running in Pasadena in the near future. This new system will be capable of calculating earthquake locations automatically in near real-time. A parallel RTP (Real Time Processor) is also planned for the Network. Long term processing delays will also be reduced by the increased throughput of the more powerful computer hardware and the new generation of CUSP.

SYNOPSIS OF SEISMICITY

4,800 earthquakes were recorded by the Network during the first half of 1987 (Figure 2). Of these only 83 were greater than or equal to M_L 3.0 (Figure 3, Appendix E). The Network also recorded 629 quarry blasts. The only events larger than M_L 3.9 were both on the edges of the Network; a M_L 5.4 event in Baja California on February 7, 1987 and a M_L 5.1 Coalinga aftershock on February 14, 1987. Focal mechanisms for seven selected earthquakes are shown in Figure 3.

The aftershock sequences of the North Palm Springs (M_L 5.6) earthquake of July 8, 1986 and the Oceanside earthquake (M_L 5.3) of July 13, 1986 continued to be active but are decaying.

As in previous Bulletins, southern California has been divided into eleven sub-regions (Figure 4). This practice is arbitrary, but useful in discussing characteristics of seismicity in a manageable context. Plots summarizing the activity of each sub-region over the past four years are given in Figures 5a and 5b. Those sub-regions that have been of seismic interest during this reporting period are discussed in more detail below.

Imperial Valley – Region 1. The largest earthquake of the reporting period, a M_L 5.4 event, occurred at the north end of the Cerro Prieto fault in Baja California on February 7, 1987 (Figure 6). A M_L 3.0 foreshock preceded it by 10 hours. This sequence occurred under the Cerro Prieto volcano and immediately west of the aftershock zone of the Mexicali Valley earthquake (M_L 6.1, sometimes referred to as the Estación Victoria earthquake) of June 9, 1980.

Although the epicentral solutions are poorly constrained because the events are outside the Network, they suggest a north-south lineation. A parallel feature 15 km to the east was suggested by an intense earthquake swarm (eleven events of M_L 3.0 to 3.6) that began at the southern end of the Imperial fault five months earlier, on September 6, 1986 (Given *et al.*, 1986).

This pair of sequences appears to be the northward extension of a very similar swarm-mainshock pair that occurred immediately to the south in 1978 (Figure 6). A large swarm of quakes began on March 10, 1978 (four events of M_L 4.1 to 4.9) east of the Cerro Prieto fault and was followed three months later by a M_L 5.2 mainshock and its aftershock sequence about 15 km to the west. The aftershock zone of Mexicali Valley earthquake (M_L 6.1) of 1981 was in the area bounded by the swarms and the faults.

The swarms between the Imperial and Cerro Prieto faults appear to represent a seismic zone between the two faults analogous to the Brawley seismic zone between the Imperial and San Andreas faults to the north. The mainshock-aftershock sequences to the west may represent cross faults similar to those west of the Imperial fault in the Imperial Valley.

About ten earthquake swarms occurred in the Brawley seismic zone during the first half of 1987 (Figures 7 and 8). Such swarms are the normal mode of stress release in the area.

Los Angeles Coast – Region 5. The western Los Angeles basin was the site of two small swarms in February (Figure 9). The first, on February 8, 1987, included six earthquakes of $M_L \geq 2.0$. The second sequence which began on February 26, 1987 included five events of $M_L \geq 2.0$. It occurred about 4 km northwest of the earlier swarm. Both sequences were located along the northern section of the Newport-Inglewood fault zone. Focal mechanisms are consistent with right lateral strike-slip on northwest striking vertical planes (Figure 3). These swarms were more energetic than any in the area in the past five year period.

San Bernardino – Region 7. Three small bursts of activity occurred near Fontana in the first half of 1987 (Figure 10). The first began on February 5, 1987 with a M_L 2.4 earthquake and at least seven accompanying events. These events migrated eastward and northward toward the location of the second cluster of activity. This second and larger group began about February 17, 1987 with a M_L 3.1 event and included a M_L 3.9 quake on February 21. These two groups of activity occurred very close in time but appear to be spatially distinct in map view (Figure 10). The second group also occurred at a depth of about 7.5 km in contrast to 4.5 km for the first group.

The last group was located about 4 km west of the first two and began on May 14, 1987. The group included at least nine events, four of which were larger than M_L 2.2. This cluster occurred at a focal depth of about 3.5 km. A renewal of seismicity it the area of the earlier M_L 3.9 quake accompanies this last cluster.

These first two bursts of seismicity occurred between two postulated subsurface faults (dotted lines in Figure 10). The northern feature was proposed by Dutcher and Garret (1963) on the basis of an abrupt change in the level of ground water; it is commonly referred to as the Fontana Water Barrier. The southern feature was postulated by Hadley and Combs (1974) based on a lineation of microseismicity. The focal mechanism of the M_L 3.9 quake indicates either right lateral strike-slip on a N40°E vertically dipping plane or left lateral strike-slip on a N50°W vertically dipping plane (Figure 3). Therefore, this activity suggests either the existance of other buried faults parallel to the two postulated subsurface features or the existence of a conjugate feature, possibly connecting the two.

A swarm of earthquakes began on May 30, 1987 in the Indio Hills about 8 km northeast of the San Andreas fault (Figure 11). The sequence included ten events of $M_L \geq 3.0$ and persisted for about six weeks. The swarm continued with several surges of intensified activity into late August. As it progressed the center of activity migrated about 2 km to the southwest, toward the San Andreas fault. The largest event was M_L 3.4. Focal mechanisms indicate either right lateral strike-slip on planes oriented about N30°W and dipping about 60° to the northeast or left lateral strike-slip on nearly vertical planes striking N50°E (Figure 3). Both orientations have a minor normal component. The northeast strike is the most consistent with the lineation of the seismicity in map view.

APPENDIX A.

NUMBER OF EVENTS IN SOUTHERN CALIFORNIA CATALOG BY YEAR

Year	Number of Events	M_L of Completeness	Year	Number of Events	M_L of Completeness
1932	333	3.0	1960	245	3.0
1933	370	3.0[1]	1961	307	3.0
1934	523	3.0	1962	233	3.0
1935	608	3.0	1963	281	3.0
1936	445	3.0	1964	176	3.0
1937	313	3.0	1965	199	3.0
1938	270	3.0	1966	161	3.0
1939	311	3.0	1967	263	3.0
1940	326	3.0	1968	486	3.0
1941	275	3.0	1969	560	3.0
1942	298	3.0	1970	468	3.0
1943	231	3.0	1971	760	3.0
1944	235	3.0	1972	727	3.0
1945	206	3.0	1973	1,415	3.0
1946	434	3.0	1974	1,220	3.0
1947	529	3.0	1975	2,729	2.5
1948	425	3.0	1976	3,198	2.5
1949	527	3.0	1977	4,188	1.5
1950	485	3.0	1978	5,644	1.5
1951	294	3.0[2]	1979	8,447	1.5
1952	516	3.0	1980	4,860	1.5[3]
1953	600	3.0	1981	5,685	1.5[3]
1954	602	3.0	1982	11,875	1.5
1955	363	3.0	1983	14,318	1.5[4]
1956	430	3.0	1984	21,040	1.5
1957	263	3.0	1985	19,808	1.5
1958	257	3.0	1986	20,287	1.5[5]
1959	333	3.0	1987	9,211+	1.5

[1] The catalog is complete only to the M_L 4.0 level during the Long Beach earthquake sequence.

[2] The catalog is complete only to the M_L 4.0 level during the Kern County earthquake sequence.

[3] Data are not complete for the period from 5/80 to 2/81 because of a CUSP software switch-over and the Mammoth Lakes earthquake sequence.

[4] Data are not complete for the period from 2/10/83 to 7/11/83 because of a CUSP software switch-over and the Coalinga earthquake sequence.

[5] The catalog is only complete at the M_L 3.0 level for the six hours following the North Palm Springs earthquake.

APPENDIX B.

PARTIAL LIST OF PAPERS USING NETWORK DATA

The following reference list contains many of the published papers that have used Southern California Network data. This list is incomplete, especially for earlier periods. The list does not include published abstracts.

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APPENDIX C.

CUMMULATIVE INDEX TO SOUTHERN CALIFORNIA NETWORK BULLETINS

Entries for all five Bulletins published thus far are included in this cummulative index. Each entry is listed by Bulletin and page number. Bulletins are designated by year and letter as follows:

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3.	86a	January–June,	1986	86–590
4.	86b	July–December,	1986	87–488
5.	87a	January–June,	1987	88–409

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Appendex D.

Description of Data Fields in the Network Data Base

Characteristics of the individual data items available in the data base are described in here. Each item is listed by the field name, data type and field length, in bytes, as they occur in the data base. See the text for a complete description of the Network data base.

AGEN *Character* 4
Agency that "owns" the site. GSP = Geological Survey Pasadena, GSMP = Geological Survey Menlo Park, CIT = California Institute of Technology, USC = the University of Southern California, and DWR = the Department of Water Resources.

ATT *Character* 3
The attenuation setting.

BAT_DATE *Date* 8
Date of the last seismometer battery change.

BAT_TYP *Character* 1
Type of seismometer battery.

CIRCUIT *Character* 12
Telephone circuit number.

CO *Character* 2
Component; V for high gain verticals, Z for low gain verticals, and N and E for horizontals.

CODE2 *Character* 4
Other station names that may have been used for a site.

DATE *Date* 8
The time at which the information was current, as described in text above.

DISC_TYPE *Character* 8
Discriminator type.

D_SER *Character* 5
Discriminator serial number.

D_SLOT *Numeric* 3
Discriminator slot.

D_VOLT *Numeric* 4.2
Discriminator voltage.

ELEV *Numeric* 5
Elevation of site above sea level in meters.

FM *Character* 5
Channel number of the FM tape used for backup purposes.

FREQ *Numeric* 5
Transmission frequency.

JK *Numeric* 2
Jack number on in-house patch panel.

Lat_D *Numeric* 3
LAT_M *Numeric* 6.2
Latitude degrees and minutes of location.

LON_D *Numeric* 3
LON_M *Numeric* 6.2
Longitude degrees and minutes of location.

NOTES *Memo* 10
Pointer to a memo file that holds miscellaneous comments.

OFF *Character* 3
It is blank if the station is active and labeled OFF if it is turned off.

PIN *Numeric* 3
Computer channel number.

PO *Character* 1
Polarity of the station. Blank = polarity is correct, R = reversed and U = polarity is uncertain.

RF *Character* 2
Radio transmission frequency.

RX_SITE *Character* 15
Radio receive site for the station.

SEIS_TYPE *Character* 8
Type of seismometer at the site.

STA_CODE *Character* 6
Five letter station code as described by Given *et al.* (1986).

STA_NAME *Character* 20
The full name of the station.

S_SER *Character* 4
Serial number on the seismometer.

S_VAL *Numeric* 4
T_VAL *Numeric* 4
Seismometer damping factors.

VCO_BAT *Date* 8
Date of last VCO battery change.

VCO_TYPE *Character* 3

Voltage controlled oscillator (VCO) type. An X indicates a specially modified low gain VCO (pre-amp) where the total gain is 66db rather than the usual 90db.

V_NEG *Numeric* 3.1

Negative voltage deflection of the seismometer mass showing the relative position of the mass from center.

V_POS *Numeric* 3.1

Positive voltage deflection of the seismometer mass showing the relative position of the mass from center.

APPENDEX E.

SIGNIFICANT SOUTHERN CALIFORNIA EARTHQUAKES

All event of $M_L \geq 3.0$. Times are GMT, RMS is the root-mean-squared of the location error, NPH is the number of phases picked. The CUSPID is the unique number assigned to the event by the CUSP system.

YEAR	MO	DY	HRMN	SEC	LAT	LON	Z	Q	M	TYP	RMS	NPH	CUSPID
1987	JAN	1	341	36.35	32.9611	-117.7853	-6.00	C	3.0	M_{CA}	0.23	26	715301
1987	JAN	1	825	6.43	34.0349	-116.6484	-11.59	A	3.3	M_{CA}	0.22	93	715307
1987	JAN	3	1801	6.24	33.4989	-116.4801	-7.64	A	3.5	M_{CA}	0.22	56	715379
1987	JAN	9	1909	32.16	32.0973	-115.4996	-6.00	D	3.0	M_{CA}	0.40	10	715652
1987	JAN	10	1803	21.29	32.3158	-115.6608	-6.00	C	3.1	M_{CA}	0.34	18	715695
1987	JAN	15	746	49.08	34.0190	-116.7733	-10.40	A	3.1	M_{CA}	0.23	64	715906
1987	JAN	24	1405	10.00	32.9733	-115.5457	-13.62	A	3.4	M_{CA}	0.23	28	716262
1987	JAN	31	302	58.32	36.4620	-121.6463	-6.00	D	3.1	M_{CA}	0.42	21	716517
1987	FEB	6	1606	38.84	34.0242	-116.7373	-11.86	A	3.0	M_{CA}	0.12	29	716728
1987	FEB	6	1704	12.02	32.3978	-115.3065	-6.00	C	3.0	M_{CA}	0.35	13	716730
1987	FEB	7	345	14.79	32.3929	-115.3113	-6.00	C	5.4	M_L	0.39	15	716756
1987	FEB	7	417	19.92	32.4333	-115.3033	-6.00	C	3.3	M_{CA}	0.54	24	716761
1987	FEB	7	451	2.26	32.3161	-115.3326	-6.00	D	3.0	M_{CA}	0.31	6	716768
1987	FEB	7	959	34.59	32.3715	-115.3350	-6.00	C	3.7	M_{CA}	0.41	16	129712
1987	FEB	7	1005	24.94	32.3013	-115.3558	-6.00	C	3.1	M_{CA}	0.44	13	716793
1987	FEB	7	1025	39.11	32.4050	-115.3394	-6.00	C	3.8	M_{CA}	0.31	14	716796
1987	FEB	7	1515	51.53	32.4217	-115.3309	-6.00	C	3.1	M_{CA}	0.27	11	716817
1987	FEB	7	1533	38.74	32.4182	-115.3350	-6.00	C	3.0	M_{CA}	0.26	12	716819
1987	FEB	7	1537	9.35	32.4226	-115.3405	-6.00	C	3.3	M_{CA}	0.34	14	716821
1987	FEB	9	338	56.36	32.4285	-115.3249	-6.00	C	3.7	M_H	0.25	11	716937
1987	FEB	14	330	45.98	34.7857	-120.5053	-6.00	C	3.0	M_{CA}	0.12	13	717243
1987	FEB	14	554	13.85	36.1955	-120.2555	-6.00	C	3.2	M_{CA}	0.26	14	717249
1987	FEB	14	726	50.78	36.1820	-120.2679	-6.00	C	5.1	M_H	0.35	35	717253
1987	FEB	17	1502	3.23	34.1337	-117.4562	-7.63	A	3.1	M_{CA}	0.19	91	717361
1987	FEB	21	2315	30.00	34.1333	-117.4495	-7.65	A	3.9	M_{CA}	0.20	134	129763
1987	FEB	25	2330	2.13	33.2274	-116.0659	-6.66	C	3.2	M_{CA}	0.17	43	717809
1987	FEB	26	1104	31.32	32.9600	-117.7296	-6.00	C	3.1	M_{CA}	0.20	34	717856
1987	FEB	27	620	26.16	35.7059	-117.7068	-4.72	A	3.1	M_{CA}	0.16	38	129778
1987	FEB	27	2243	19.85	34.4697	-120.8047	-6.00	D	3.6	M_{CA}	0.36	22	718003
1987	FEB	28	2333	33.56	32.9617	-115.8346	-4.61	A	3.0	M_{CA}	0.25	40	718062
1987	MAR	1	1853	41.29	33.9064	-116.7790	-18.32	A	3.2	M_{CA}	0.19	57	718087
1987	MAR	4	955	28.56	36.1704	-120.1870	-6.00	C	3.3	M_{CA}	0.16	13	129793
1987	MAR	11	1559	37.38	32.9934	-117.7422	-6.00	C	3.1	M_{CA}	0.22	29	718660
1987	MAR	15	1744	7.26	32.5800	-118.0132	-6.00	C	3.3	M_{CA}	0.43	15	718841
1987	MAR	17	521	16.44	33.9352	-115.8252	-10.45	C	3.0	M_{CA}	0.13	34	718892

YEAR	MO	DY	HRMN	SEC	LAT	LON	Z	Q	M	TYP	RMS	NPH	CUSPID
1987	MAR	18	1659	47.43	36.2218	-120.2985	-6.00	C	3.1	M_{CA}	0.17	16	718958
1987	MAR	19	1408	18.18	32.9937	-117.7431	-6.00	C	3.2	M_{CA}	0.23	37	718999
1987	MAR	23	1522	43.83	36.0860	-119.9236	-6.00	C	3.3	M_{CA}	0.34	19	719176
1987	MAR	28	1929	0.36	33.9802	-118.3239	-6.19	C	3.1	M_{CA}	0.23	44	719471
1987	MAR	31	2104	24.30	35.9203	-118.3528	-5.29	C	3.2	M_{CA}	0.11	36	719660
1987	APR	3	323	13.03	32.9856	-117.7355	-6.00	C	3.4	M_{CA}	0.21	35	719883
1987	APR	3	533	29.22	34.0286	-117.2671	-10.48	A	3.3	M_{CA}	0.11	72	719892
1987	APR	3	914	49.88	34.0282	-117.2669	-10.00	A	3.0	M_{CA}	0.11	56	719911
1987	APR	3	2126	24.40	34.0302	-117.2678	-11.41	A	3.0	M_{CA}	0.12	48	719998
1987	APR	7	1821	29.50	32.9538	-117.7784	-6.00	C	3.2	M_{CA}	0.31	22	720231
1987	APR	10	824	49.03	32.9581	-117.8173	-6.00	C	3.4	M_{CA}	0.35	36	720410
1987	APR	10	1840	57.04	35.7402	-117.5641	-4.26	A	3.3	M_{CA}	0.19	36	720440
1987	APR	12	2335	32.20	32.9826	-117.7668	-6.00	C	3.0	M_{CA}	0.21	25	720529
1987	APR	14	642	24.19	35.6388	-120.9760	-6.00	C	3.1	M_{CA}	0.16	12	720591
1987	APR	20	8	43.03	32.9680	-117.7996	-6.00	C	3.1	M_{CA}	0.26	33	720916
1987	APR	20	1859	3.59	32.0607	-114.9462	-6.00	D	3.0	M_{CA}	0.39	9	720947
1987	APR	23	1042	14.11	34.1904	-116.2276	-1.03	A	3.0	M_{CA}	0.17	70	721068
1987	APR	27	1741	24.00	33.0582	-115.5706	-6.00	C	3.5	M_{CA}	0.14	30	721269
1987	APR	28	2148	45.93	34.0278	-116.7371	-11.26	A	3.1	M_{CA}	0.19	67	721343
1987	APR	30	219	20.07	33.4963	-116.5942	-12.92	A	3.0	M_{CA}	0.17	50	721405
1987	MAY	3	1457	54.41	33.7837	-115.8971	-9.63	A	3.0	M_{CA}	0.20	53	721556
1987	MAY	4	843	14.27	32.9863	-117.7274	-6.00	C	3.0	M_{CA}	0.19	38	721593
1987	MAY	9	447	1.83	34.9139	-116.9068	-3.35	A	3.0	M_{CA}	0.19	52	721881
1987	MAY	10	1317	41.20	34.2864	-116.3756	-7.34	C	3.2	M_{CA}	0.16	57	721934
1987	MAY	11	1023	44.19	32.9653	-117.8143	-6.00	C	3.3	M_{CA}	0.20	32	721967
1987	MAY	11	1510	10.18	34.3087	-116.9210	-4.00	C	3.9	M_{CA}	0.27	138	721973
1987	MAY	15	508	14.97	32.0130	-114.9131	-6.00	D	3.3	M_{CA}	0.51	12	722148
1987	MAY	19	353	51.06	36.4372	-117.8242	-6.00	C	3.5	M_{CA}	0.18	42	722339
1987	MAY	25	1816	32.61	33.8616	-117.8736	-8.25	A	3.1	M_{CA}	0.21	44	722676
1987	MAY	25	1818	24.72	34.3867	-119.0909	-4.07	A	3.1	M_{CA}	0.34	23	722677
1987	MAY	29	1516	28.83	33.7035	-118.1703	-13.38	A	3.1	M_{CA}	0.29	29	722978
1987	MAY	29	1849	57.36	32.9696	-117.7304	-6.00	C	3.0	M_{CA}	0.25	32	722993
1987	MAY	30	2306	40.87	33.8649	-116.1791	-4.47	A	3.1	M_{CA}	0.23	66	723104
1987	JUN	1	1918	29.70	33.8605	-116.1755	-3.92	A	3.2	M_{CA}	0.21	74	723217
1987	JUN	1	1919	58.61	33.8649	-116.1773	-4.15	A	3.1	M_{CA}	0.16	47	131949

YEAR	MO	DY	HRMN	SEC	LAT	LON	Z	Q	M	TYP	RMS	NPH	CUSPID
1987	JUN	2	2353	41.43	36.3250	-120.3669	-11.92	C	3.2	M_{CA}	0.29	23	723312
1987	JUN	7	915	53.78	32.6416	-115.8810	-13.92	A	3.1	M_{CA}	0.35	51	723568
1987	JUN	8	1229	38.93	33.7707	-118.1966	-15.35	A	3.2	M_{CA}	0.22	40	723603
1987	JUN	14	816	8.12	33.8609	-116.1765	-2.36	A	3.4	M_{CA}	0.19	59	723940
1987	JUN	14	1429	5.59	33.2729	-115.6914	-1.33	A	3.1	M_{CA}	0.21	47	723973
1987	JUN	15	1305	41.47	34.0915	-116.4912	-5.67	C	3.2	M_{CA}	0.24	79	724025
1987	JUN	16	2332	34.17	33.9694	-116.5712	-6.57	C	3.1	M_{CA}	0.16	68	724125
1987	JUN	21	856	39.26	32.6539	-115.7842	-13.64	A	3.3	M_{CA}	0.28	39	132613
1987	JUN	22	1254	46.04	33.8642	-116.1839	-4.38	A	3.0	M_{CA}	0.09	47	724479
1987	JUN	23	2222	44.62	35.7310	-116.5067	-6.00	C	3.3	M_{CA}	0.35	42	724611
1987	JUN	26	52	16.80	32.1608	-115.3294	-6.00	C	3.1	M_{CA}	0.33	15	724797
1987	JUN	29	620	36.60	33.8588	-116.1874	-4.51	A	3.1	M_{CA}	0.10	74	725028
1987	JUN	29	829	22.23	33.8610	-116.1867	-4.58	A	3.0	M_{CA}	0.11	54	725038

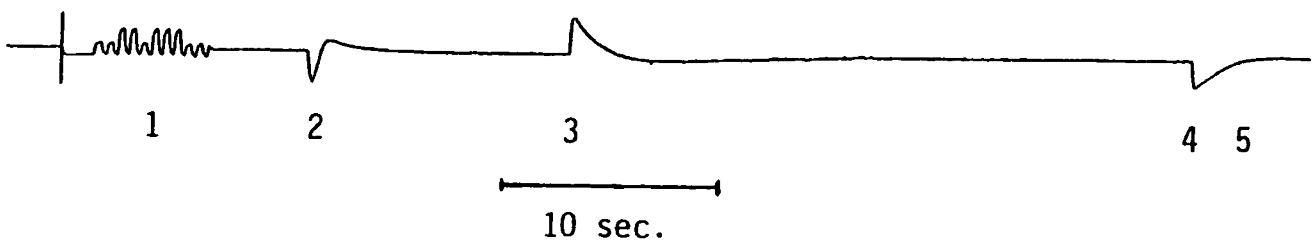

Figure 1. Example of an actual calpulse.
1 Binary ID code which identifies the attenuation setting
2 Mass released
3,4 Voltage step applied to preamp input
5 Return to normal operation

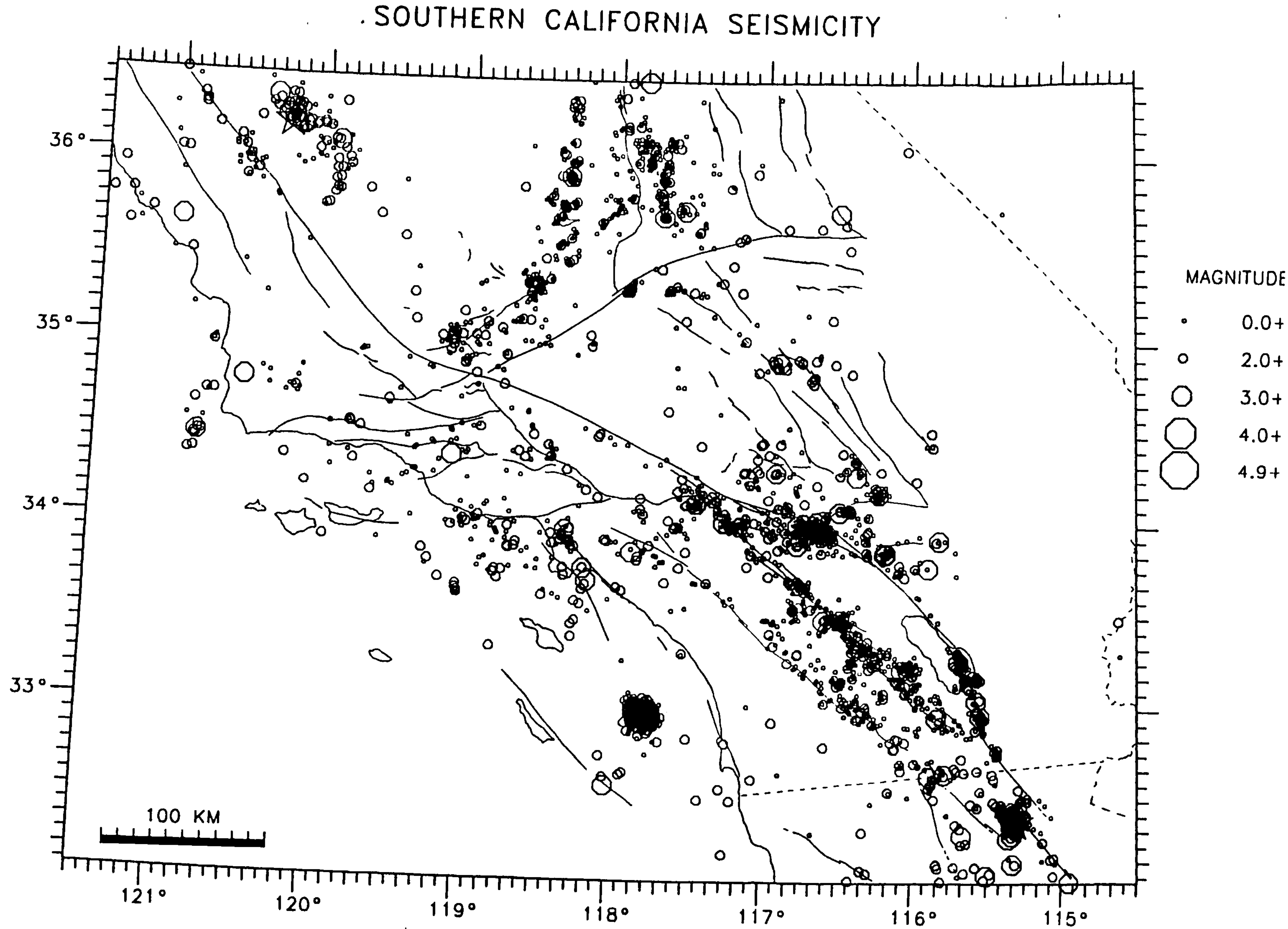

Figure 2. Map of all located earthquakes in southern California for the period of January through June 1987.

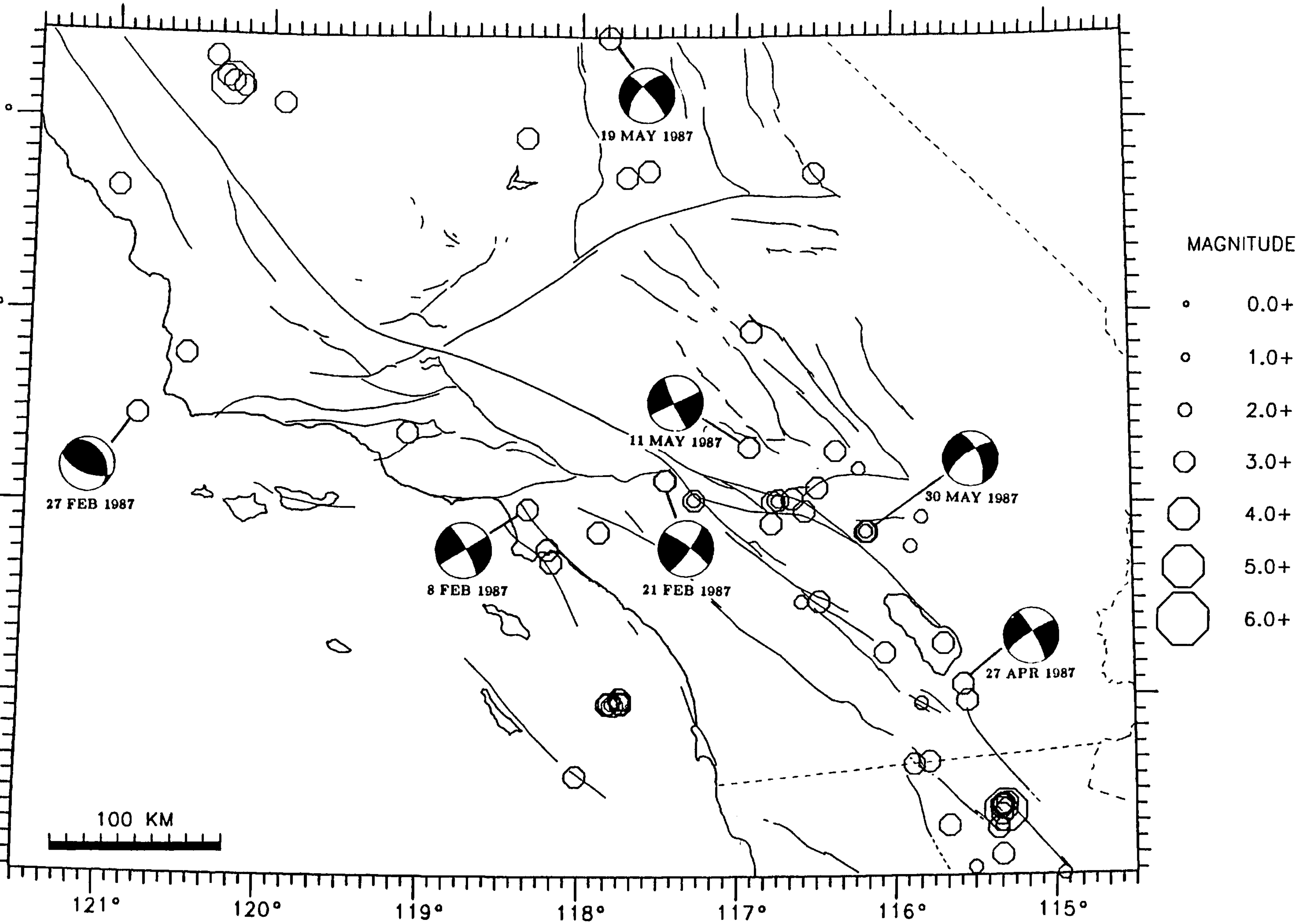

Figure 3. Map of all southern California earthquakes with $M_L \geq 3.0$ for the period of January through June 1987. Mechanisms are lower hemisphere projections.

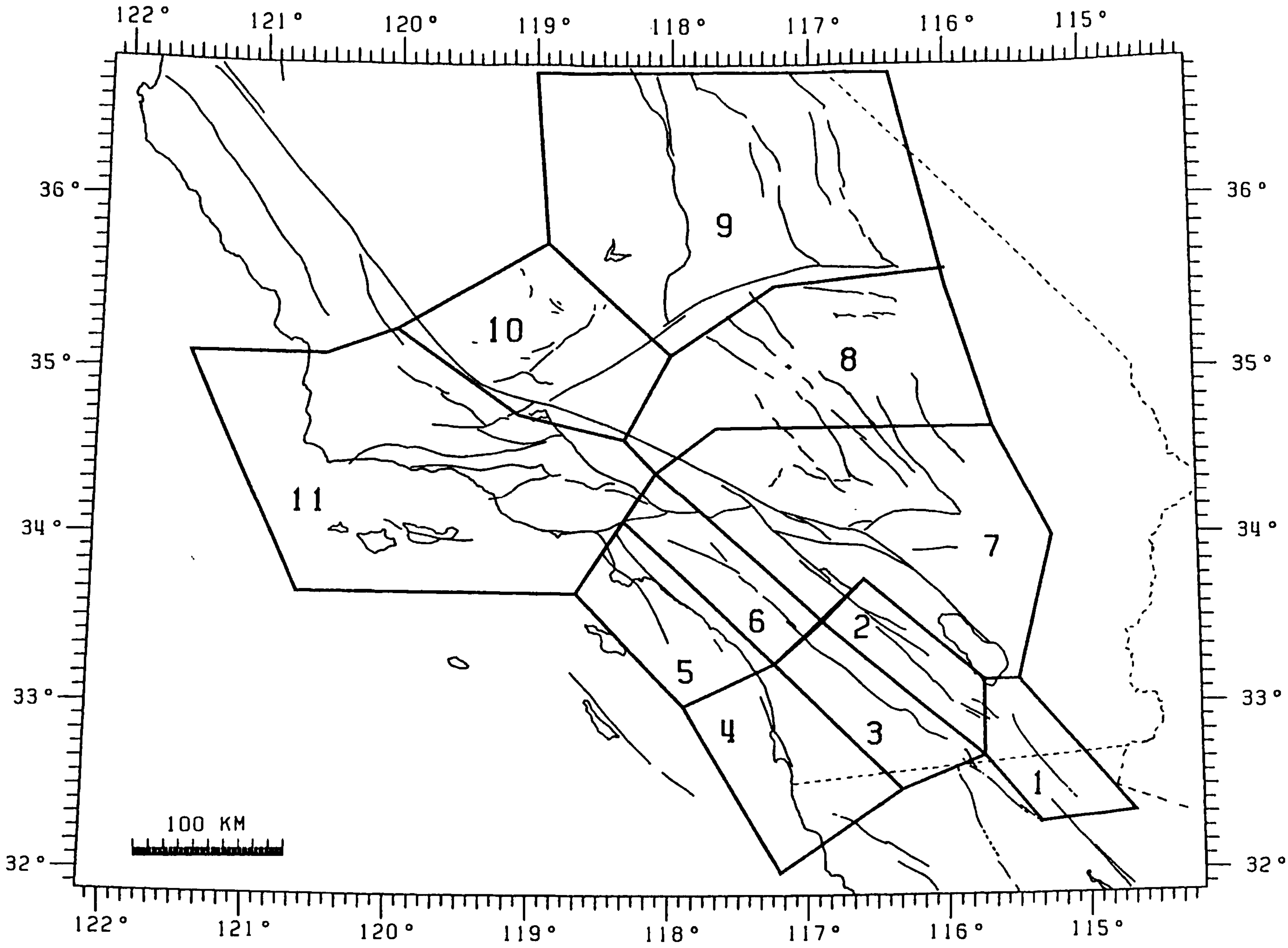

Figure 4. Map of sub-regions used in Figures 5a and 5b. The geographic name of each sub-region, as used in the text, can be found in the headings of Figures 5a and 5b.

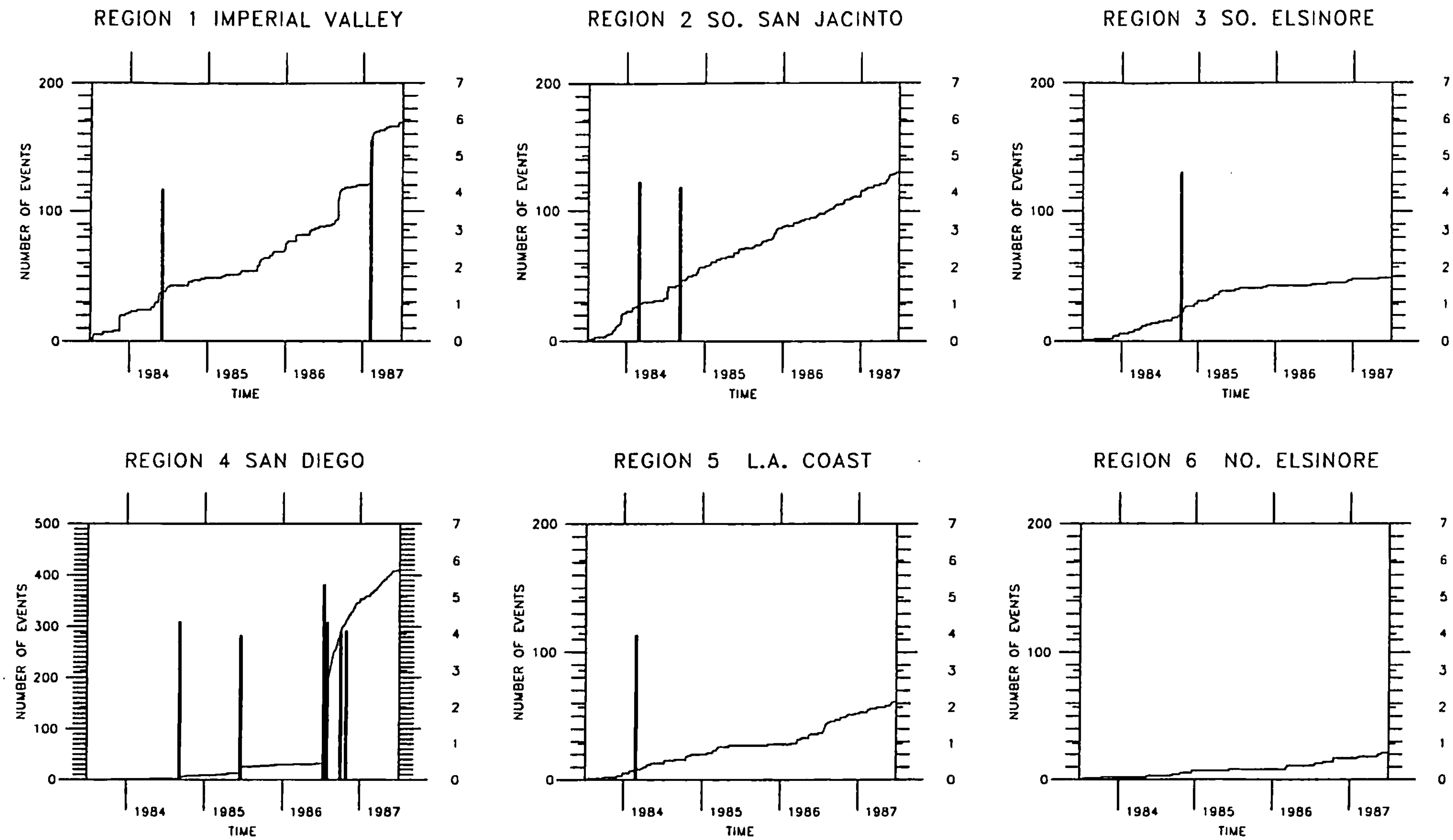

Figure 5a. Cumulative number of events ($M_L \geq 2.5$) in sub-regions 1 through 6 over the four year period ending June 1987. The boundaries of the sub-regions are shown in Figure 4. Vertical bars represent time and magnitude (scale on right) of large events ($M_L \geq 4.0$). Note that the vertical scales of the plots may not be the same.

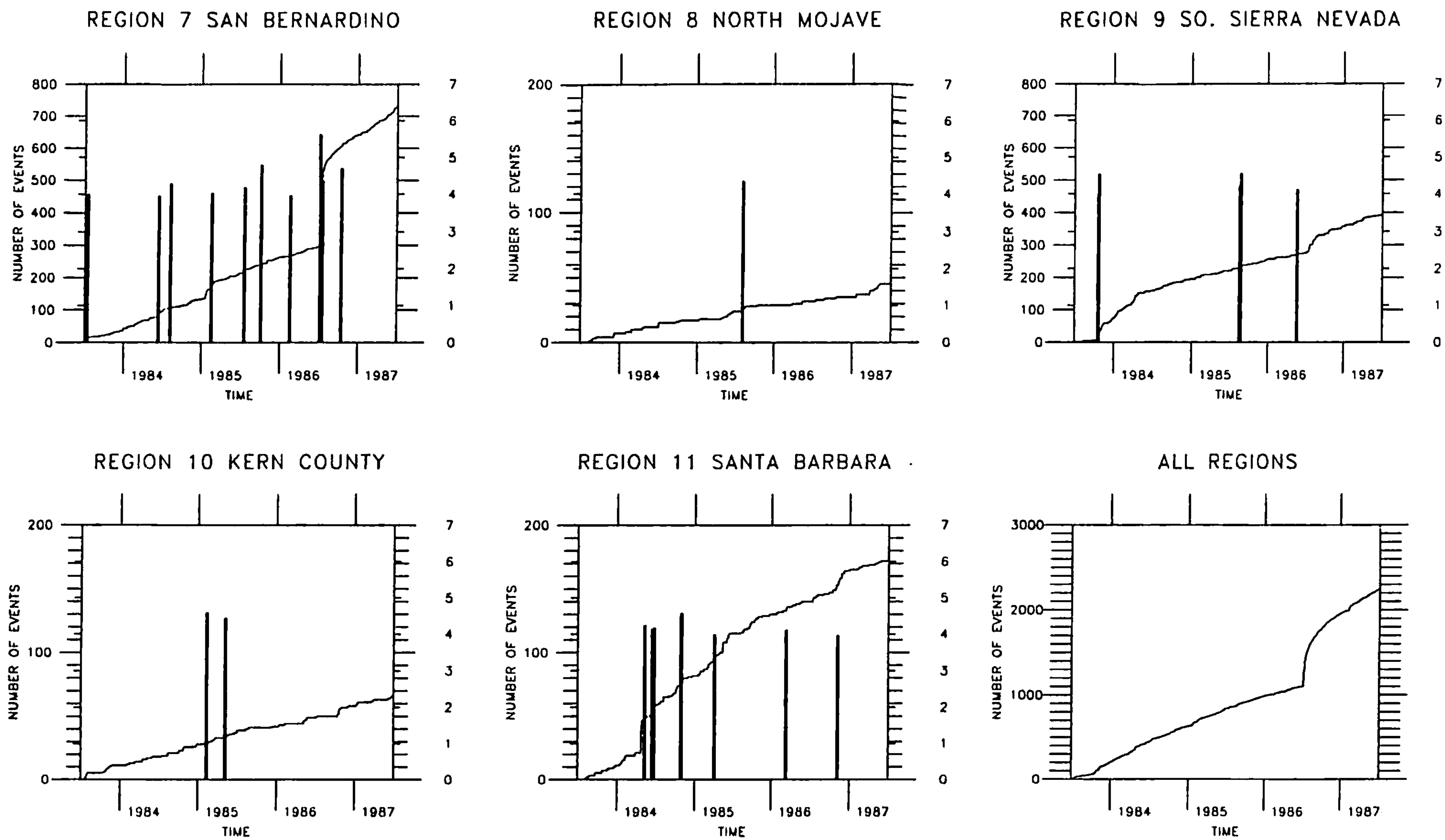

Figure 5b. Cumulative number of events ($M_L \geq 2.5$) in sub-regions 7 through 11 and for all sub-regions over the four year period ending June 1987. The boundaries of the sub-regions are shown in Figure 4. Vertical bars represent time and magnitude (scale on right) of large events ($M_L \geq 4.0$). Note that the vertical scales of the plots may not be the same.

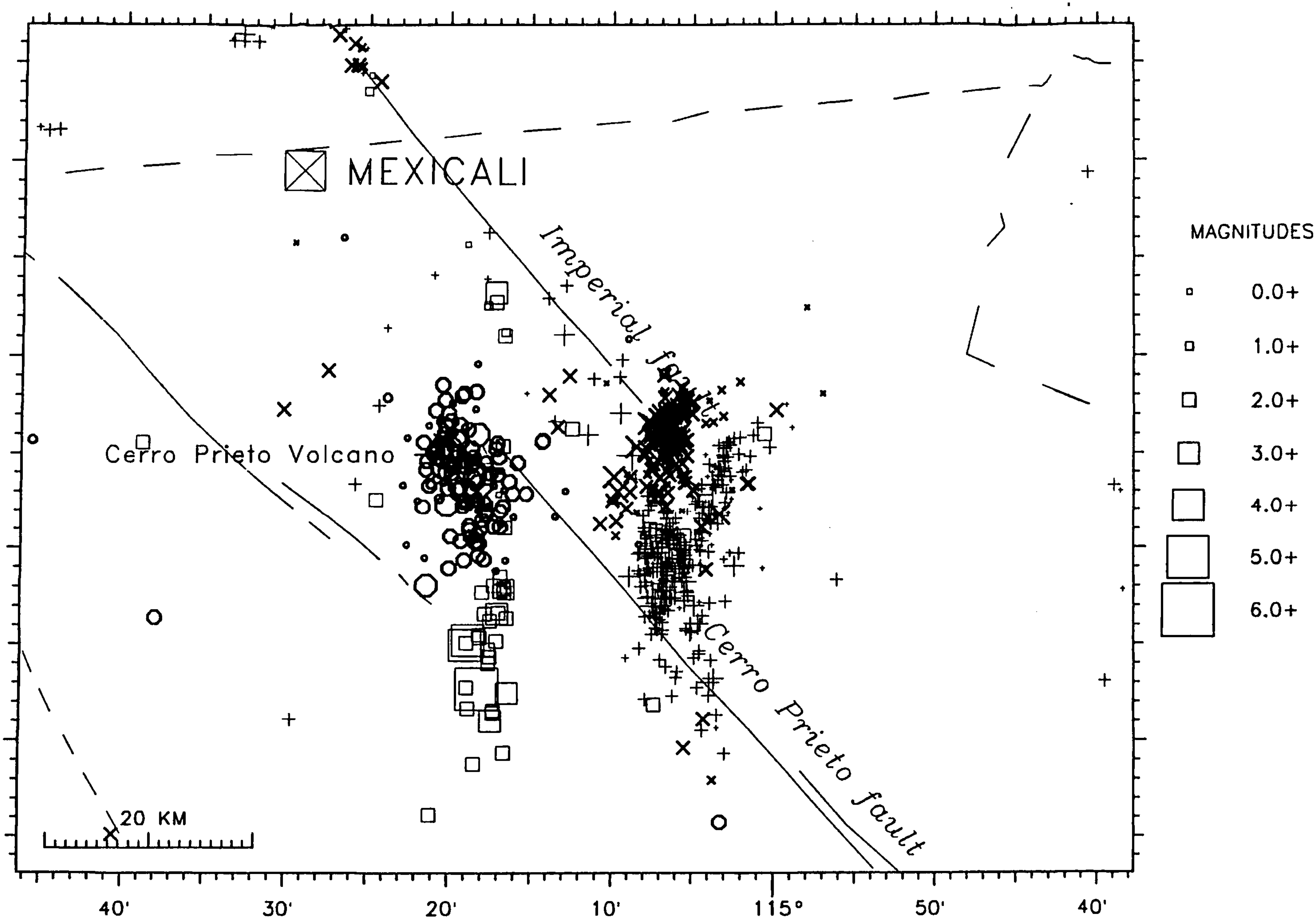

Figure 6. Earthquake sequences in the Cerro Prieto area of Baja California (see text). Four different sequences are indicated by different symbol types: "+" = swarm of March 1978, "□" = M_L 5.2 of June 1978 and aftershocks, "×" = swarm of September 1986, and "○" = M_L 5.4 of February 1987 and aftershocks.

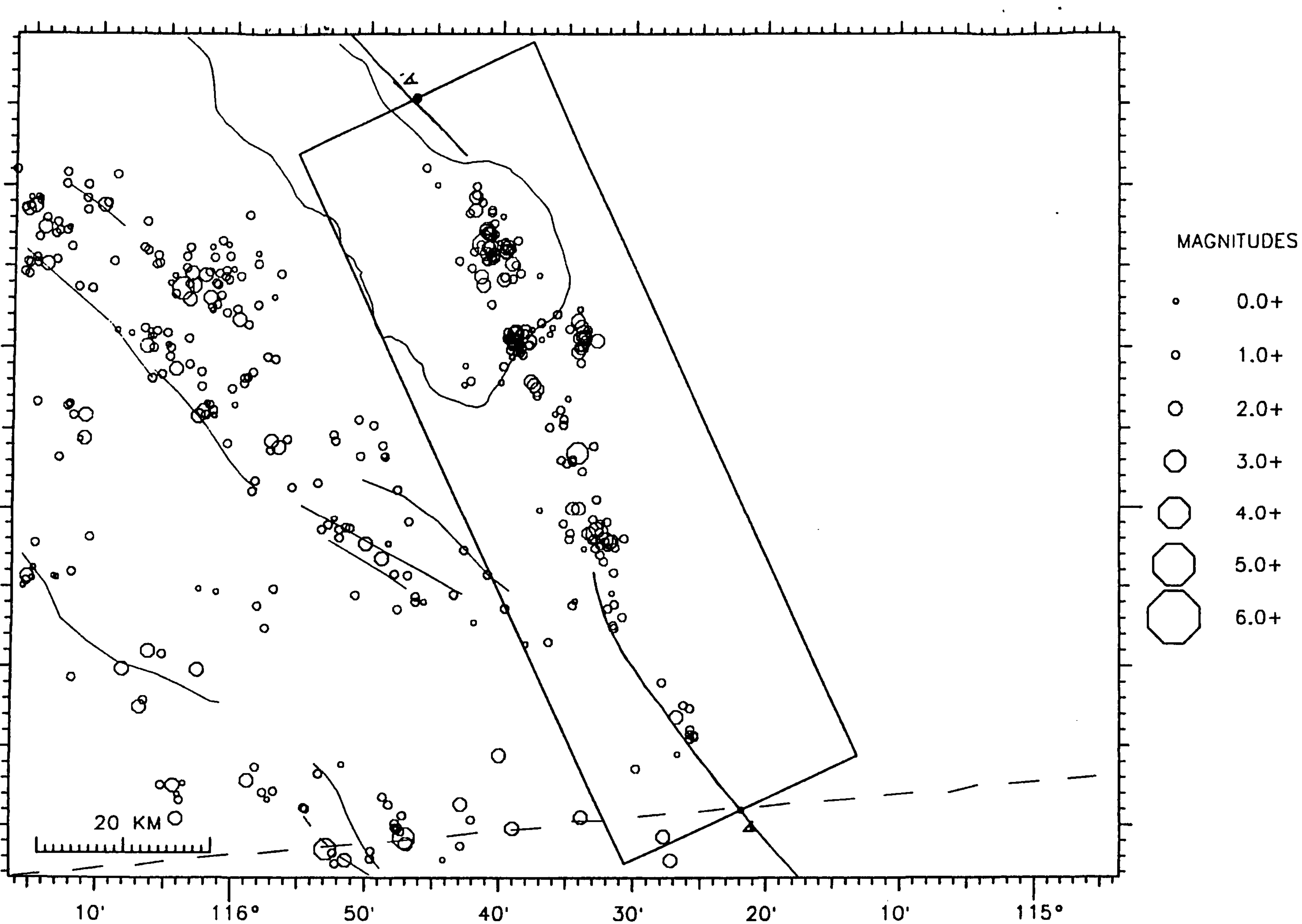

Figure 7. Earthquakes in the Brawley Seismic Zone from January through June 1987. The box marked A–A′ defines the area and axis of the time/distance plot in Figure 8.

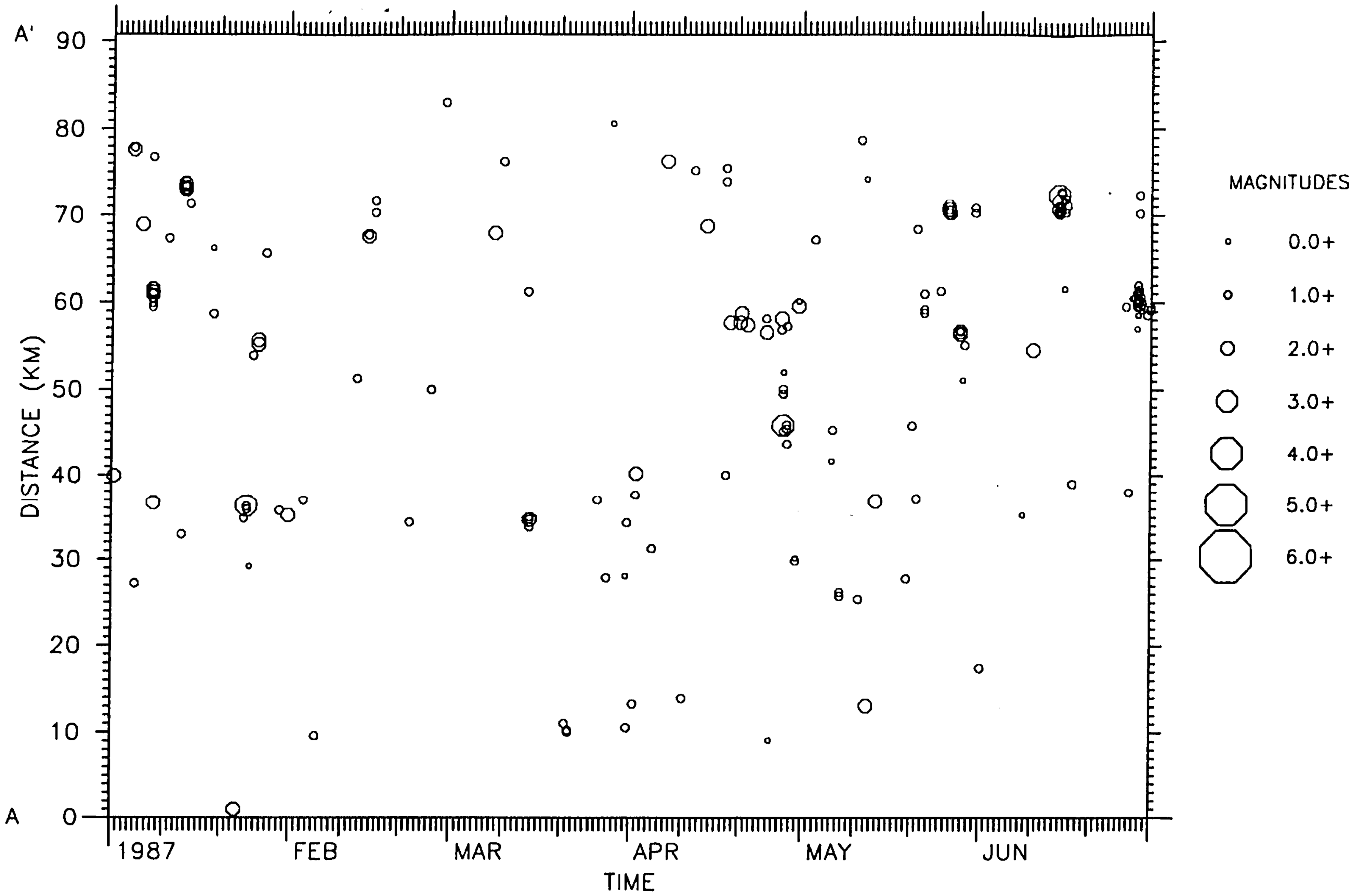

Figure 8. Time/distance plot of events in the Brawley Seismic Zone from January through June 1987. Several swarms are evident in this plot, especially in the northern part of the zone. Such swarms are normal in this region.

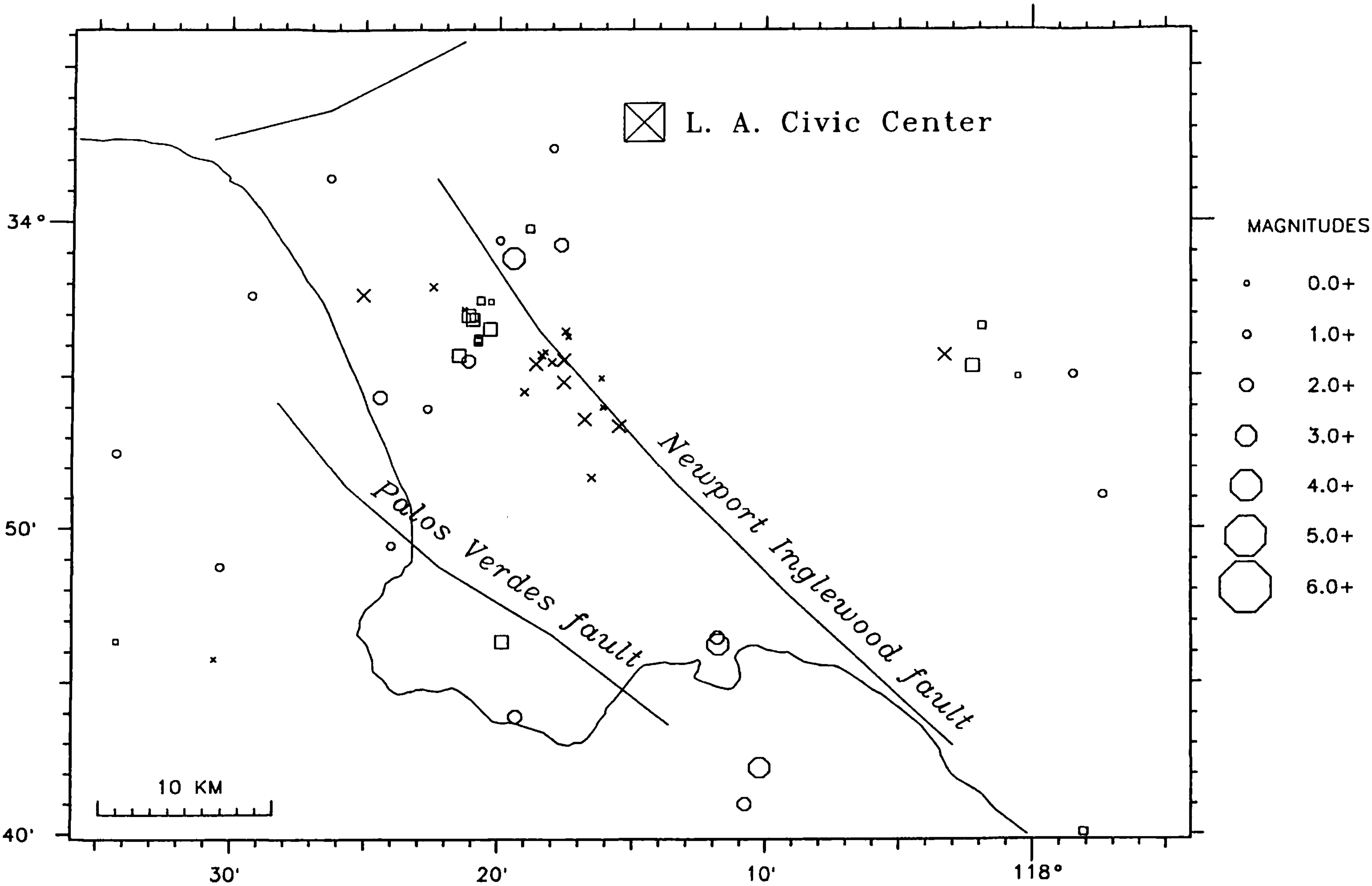

Figure 9. Seismicity of the Los Angeles basin area from January through June 1987. Different symbols represent different time periods. "×" = events from January through February 25 including the swarm of February 8, 1987, "□" = events through March 27 including events of February 26 swarm, "o" = events through June including two M_L 3.1 events on March 28 and May 29, 1987.

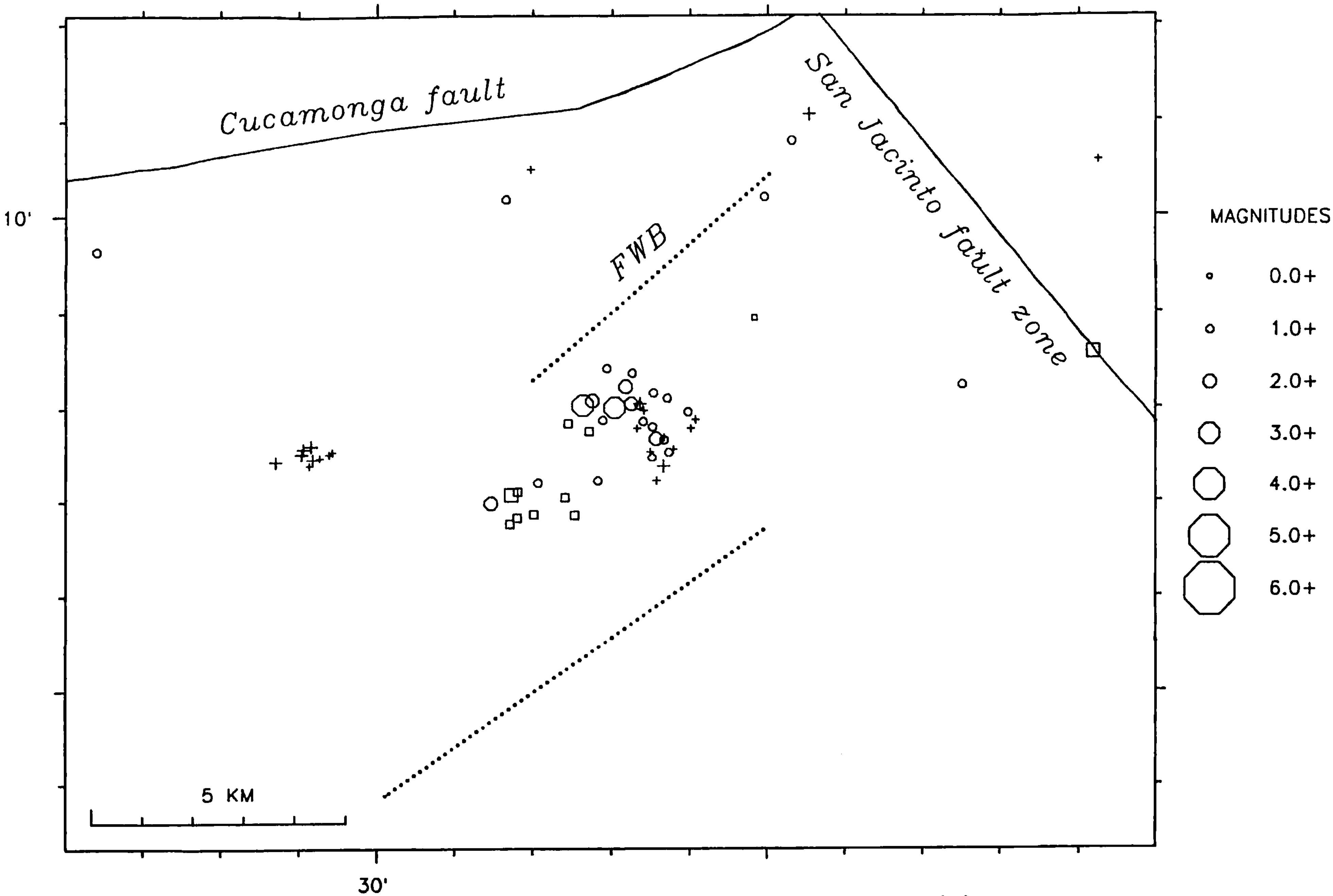

Figure 10. Seismicity of the Fontana area from January through June 1987. Different symbols represent different time periods. "□" = events from January through February 16 including the swarm of February 5, "o" = events through May 14 including the swarm of February 17 with events of M_L 3.1 and 3.9, "+" = events after May 14 including a small swarm to the west and a renewal of activity in the earlier swarm area.

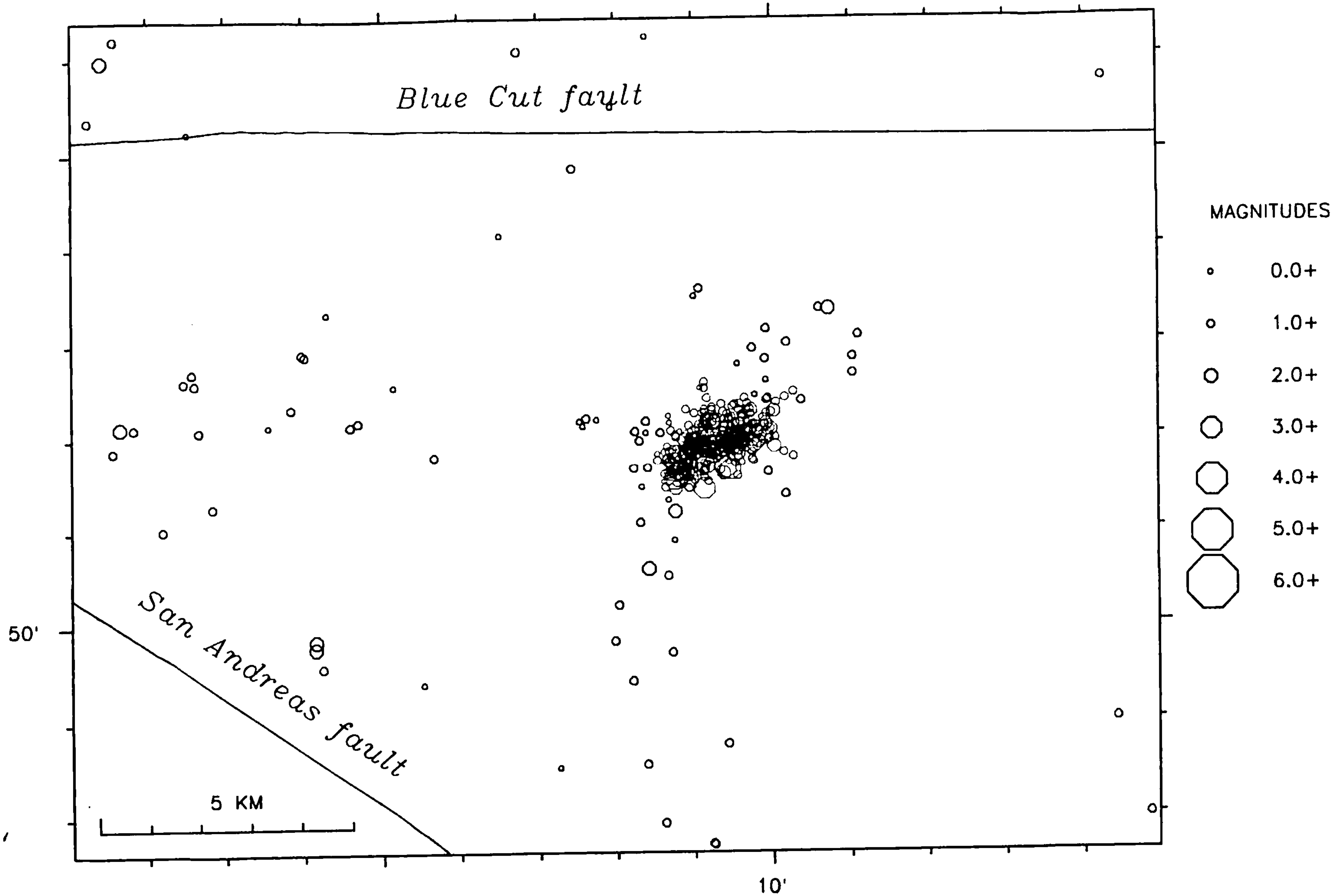

Figure 11. Seismicity in the Indio Hills area from January through June 1987. The swarm began on May 30, 1987. The largest event of the swarm had an M_L of 3.4. The focal mechanisms and the lineation of the seismicity suggests left-lateral slip on a plane oriented about N50°E.