U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

THE SOUTHERN CALIFORNIA NETWORK BULLETIN JANUARY - DECEMBER 1991

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Errata

The following are corrections to the 1990 Network Bulletin, Open-File Report 91-255 (Wald *et al.*, 1990):

1) The rest of the sentence on p.4 is: "All of the data in the figure were converted to ground velocity using the instrument constants listed in the article entitled TERRAscope Broad-Band Stations."

2) The VBB value in Table 3 is a generic value based on the average of all instruments rather than the measured value which has some dependance on the generator constant, except for the PAS station which has measured values.

3) In Table 3, the LG component for station SVD is recorded at 80 samples/sec as stated in the preceding paragraph, not at 100 samples/sec.

4) In Table 3, the LG value for SVD was incorrectly determined. The correct value should be $2.14*10^6$ counts/m/sec^2 from installation to 8/26/91, and $2.14*10^5$ counts/m/sec^2 from 8/26/91 to present, and...

5) In Table 3, ULP values have been added for all the stations.

A current corrected table to replace Table 3 from the 1990 Network Bulletin is found below.

Table 3. Broad-Band Data Streams

Station	LG 100sps	VSP 80sps	VBB 20sps	LP 1sps	VLP 0.1sps	ULP 0.01sps
GSC	3330	-----	$9.88x10^8$	$3.95x10^9$	$1.58x10^{10}$	$6.32x10^{10}$
ISA	3330	-----	$9.88x10^8$	$3.95x10^9$	$1.58x10^{10}$	$6.32x10^{10}$
PAS	3738	-----	$1.04x10^9$	$4.16x10^9$	$1.66x10^{10}$	$6.64x10^{10}$
PFO	3330	-----	$9.88x10^8$	$3.95x10^9$	$1.58x10^{10}$	$6.32x10^{10}$
SBC	3330	-----	$9.88x10^8$	$3.95x10^9$	$1.58x10^{10}$	$6.32x10^{10}$
SVD	$2.14x10^5$ (80sps)	$5.99x10^8$	$5.99x10^8$	$5.99x10^8$	$2.39x10^9$	$2.39x10^9$

LG value is counts/m/sec^2. All others are counts/m/sec.

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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 300 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. Phase arrival times for these events are picked by analysts and archived along with digital seismograms. All data acquisition, 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 201,000 events. This data set is critical to the evaluation of earthquake hazards in California and to the advancement of geoscience as a whole.

This and previous Network Bulletins are intended to serve several purposes. The most important goal is to make Network data 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

Station Codes

On January 1, 1991 the Southern California Network operations began using a new station code. This code has been used for quite some time by the Northern California Network. The three letter code which describes the location of the station remains and is joined by a letter designating the agency which operates and maintains the station. This letter for the Southern California Network is "C". The one letter code describing the component has been replaced by a three letter code:

letter 1: Instrument
- V - short period
- W - Wood-Anderson
- B - broad-band
- A - accelerometer(FBA)
- L - long-period

letter 2: Gain
- H - high
- L - low
- F - very low
- S - strong-motion

letter 3: Orientation
- Z - vertical
- N - north-south
- E - east-west

The conversion from the old codes to the new code is as follows:

Computer Channels:

old		new
V		VHZ
Z		VLZ
N		VLN
E		VLE
A	0.2g	AFZ
B		AFN
C		AFE
I	2.0g	ASZ
J		ASN
K		ASE
1		BLZ
2		BLN
3		BLE

Helicorders and Photographics:

old	new
Z	VHZ
photo Wood-Anderson	
N	WLN
E	WLE
100x photo	
B	WFN
C	WFE

TERRAscope Data:
(all new)

BHZ	LHZ
BHN	LHN
BHE	LHE

New Stations

Several new sites have been added since publication of the last Network Bulletin. As in past Bulletins, reports of network changes are not restricted to those that occurred during the reporting period but are as current as possible. An explanation for the addition of each station is provided, followed by Table 1 which contains information about each station. An explanation of the conventions used for full station codes is found above. Figure 1 is a current station map.

<u>ARB</u>

A network portable station (Wald *et al.*, 1991) was installed here after many small earthquakes occurred in the area.

AZU
The ARB network portable station was moved to this location immediately after the Sierra Madre earthquake in order to get close-in recordings of aftershocks.

BC3
This site was renamed from BC2 when the location of the seismometer was moved.

CFL
A 3-component FBA was added to this already-existing site.

GAV
Two horizontal components were added to an already existing site.

VET
A portable station at UPL was moved to this location immediately after the Sierra Madre earthquake to provide good recordings of the aftershocks.

WRV
A network portable station was moved from VET to this site during a Coso swarm on February 21, 1992.

Table 1. New Stations

Code	Site Name	Lat.	Long.	Elev. (m)	Date Installed	Instr.	Orient.
ARBC VHZ	Archibald Ranch	34° 13.23' N (34.221 °)	117° 36.32' W (117.605°)	221	04/02/91	L4	vertical
ARBC VLE	"	"	"	"	"	"	East
ARBC ASZ	"	"	"	"	"	FBA	vertical
ARBC ASN	"	"	"	"	"	FBA	North
ARBC ASE	"	"	"	"	"	FBA	East
ARBC VLN	"	"	"	"	"	L4	North
ARBC VLZ	"	"	"	"	"	L4	vertical lo-gain
AZUC VHZ	Azusa	34° 13.23' N (34.221 °)	117° 54.24' W (117.904°)	1182	07/02/91	L4	vertical
AZUC VLE	'	'	'	'	'	L4	East
AZUC ASZ	"	"	"	"	"	FBA	vertical
AZUC ASN	"	"	"	"	"	FBA	North
AZUC ASE	"	"	"	"	"	FBA	East
AZUC ASN	"	"	"	"	"	L4	North
AZUC VLZ	"	"	"	"	"	L4	vertical lo-gain
BC3C VHZ	Big Chuckawalla Mtns	33° 39.25' N (33.654°)	115° 27.25 'W (115.454°)	1098	05/08/91	L4	vertical
CFLC ASZ	Chilao Flat	34° 19.97' N (34.333°)	118° 1.38 W (118.023°)	1586	06/30/91	FBA	vertical
CFLC ASN	"	"	"	"	"	FBA	North
CFLC ASE	"	"	"	"	"	FBA	East
GAVC VLE	Glen Avon	34 ° 1.35' N 34.023 °)	117 ° 30.74'W (117.512 °)	186	04/04/91	L4	East
GAVC ASN	"	"	"	"	"	L4	North
VETC VHZ	Mount Vetter	34 ° 17.8'N (34.297°)	118 ° 2.2'W (118.037 °)	1788	07/01/91	L4	vertical
VETC VLE	"	"	"	"	"	L4	East
VETC ASZ	"	"	"	"	"	FBA	vertical
VETC ASN	"	"	"	"	"	FBA	North
VETC ASE	"	"	"	"	"	FBA	East
VETC VLN	"	"	"	"	"	L4	North
VETC VLZ	"	"	"	"	"	L4	vertical lo-gain
WRVC VLE	Rose Valley Canyon	36 ° 0.47N (36.008°)	117 ° 53.42'W (117.890 °)	1066	02/21/92	L4	East
WRVC ASN	"	"	"	"	"	FBA	North
WRVC ASE	"	"	"	"	"	FBA	East
WRVC VLN	"	"	"	"	"	L4	North

Discontinued Stations

Ten stations have been removed since the last Bulletin was released. The removal dates are shown below. Station ARB was moved after the Sierra Madre earthquake to the AZU site. At the same time, the station at UPL was moved to the VET site, and PMC, PMCN, and PAD were replaced with the three-component CFL site. VET was discontinued to provide multiple components at the WRV site near a Coso swarm in February of 1992.These removals are summarized in Table 2.

Table 2. Discontinued Stations

Station Code	Date Discontinued
ARBC	07/02/91
BC2C	05/08/91
CLMC	04/02/91
IRNC	10/20/91
PADC	06/30/91
PMCC	06/30/91
SDWC	06/14/91
SPMC	07/30/91
UPLC	07/01/91
VETC	02/21/92

Phasing-out of CaltechPhotographic Stations

Photographic recording is being discontinued as soon as possible for the following reasons:

1) Kresge has no more space for storage of paper records.
2) The new TERRAscope stations provide superior data.
3) Photographic paper is expensive and the funds are better used for support of other projects such as TERRAscope.
4) Personnel can be better utilized in other areas.

The immediate goal is to reduce the number of photographic records from 30 to 20 per day. In the next two years that number will decrease to zero. All these sites will be replaced with TERRAscope stations.

At remote sites Wood-Anderson instruments only will be kept running for, at most, two more years. Some records at PAS have been discontinued also.

TABLE 3. Caltech Instruments Recorded on Photographic Paper on Site

Station	Instr.	Comp.	days/sheet	Discontinued
CWC	WLN	north	d/sheet	
	WLE	east	d/sheet	
	Benioff	vertical	d/sheet	
	1-90	vertical	d/sheet	
	SM (LG torsion)	vertical, north, east	7d/5 strips of film	
PLM	WLN	north	d/sheet	
	WLE	east	d/sheet	
	1-90	vertical	d/sheet	
	SM	vertical, north, east	7d/6 sheets	
RVR	WLN	north	d/sheet	
	WLE	east	d/sheet	
	1-90	vertical	d/sheet	
	1-90	north, east	d/sheet	
	SM	vertical, north, east	7d/5 strips of film	
SBC	WLN	north	d/sheet	
	WLE	east	d/sheet	
	SM	vertical, north, east	7d/5 strips of film	
TIN	WLN	north	d/sheet	
	WLE	east	d/sheet	
	Benioff	vertical	d/sheet	
	1-90	vertical	d/sheet	
	1-90	north, east	d/sheet	

TABLE 3. (continued) Caltech Instruments Recorded on Photographic Paper on Site

Station	Instr.	Comp.	days/sheet	Discontinued
GSC	Sprengnether	vertical	d/sheet	1 April 91
	Sprengnether	north	d/sheet	1 April 91
	Sprengnether	east	d/sheet	1 April 91
PAS	Benioff	vertical	d/sheet	
	Benioff	north, east	d/sheet	
	30-90	vertical	d/sheet	
	30-90	north	d/sheet	
	30-90	east	d/sheet	
	1-90	vertical	d/sheet	
	1-90	north, east	d/sheet	
	WLN	north	2d/sheet	
	WLE	east	2d/sheet	
	Lp	vertical	3d/sheet	
	ULP/LG	north	7d/sheet	
	ULP/LG	east	7d/sheet	
	SM	vertical, north, east	7d/3 sheets	
	SM	vertical, north, east	7d/3 sheets	

NETWORK OPERATIONS

Status of Processing

The status of each month of the catalog data since the advent of digital recording is described in Table 4. 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 timed crudely on a few stations and smaller events are absent. A period in 1980-1981 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. An increased effort has been made in the last couple of years to finalize the backlog of incompletedata.

Table 4. Processing Status of Network Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1932-1974	PRE-DIGITAL RECORDING - COMPLETE FOR M≥3.0											
1975-1976	ALL PRELIMINARY											
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	PNK	PNK	PNK	PNK	PNK	PNK	PNK	PNK	PNK	PNK	PNK	PNK
1981	PNK	PNK	P	P	P	P	P	P	P	P	P	P
1982	P	P	P	P	P	P	P	P	P	P	P	P
1983	P	PNK	PNK	PNK	PNK	PNK	PNK	P	P	P	P	P
1984	F	F	F	F	F	F	F	F	F	F	F	F
1985	F	F	F	F	F	F	F	F	F	F	F	F
1986	F	F	F	F	F	F	F	F	F	F	F	F
1987	F	F	F	F	F	F	F	F	F	F	F	F
1988	F	F	F	F	F	F	F	F	F	F	F	F
1989	F	F	F	F	F	F	F	F	F	F	F	F
1990	F	F	F	F	F	F	F	F	F	F	F	F
1991	F	F	F	F	F	F	F	F	F	F	F	F
1992	P	P	P	P								

Southern California Network Computer Upgrades

The old pair of VAX 11/750 computers that were used for research and off-line processing of SCSN earthquake data have been replaced. Network processing is now accomplished on a VAXcluster consisting of a VAX 4300 server and five VAXstation 3100/76 workstations. All these machines run under VMS v.5.4. This upgrade represents a 30-fold increase in CPU power. The whole cluster has about 8Gb of disk space.

The MicroVAX II backup on-line system has been upgraded to a VAX 3900 and is now the primary on-line data acquisition computer. The MicroVAX 3200 which previously functioned as the primary acquisition machine is now the backup system. These machines also participate in the VAX cluster.

This upgrade has removed some serious computer resource limitations that have contributed to processing delays and data loss in the past. The new equipment will also allow development of new, more sophisticated applications in seismic data collection and processing, e.g. real-time location and notification, integration of "exotic" data streams, interaction with the SCEC data center mass storage jukebox.

For questions regarding an account on the new cluster please contact Doug Given at e-mail address zot@bombay.gps.caltech.edu or (818)405-7812.

Location of .MEM Files

The .MEM files, the files that contain all the information about each earthquake recorded by the network, are now on-line on bombay. gps. caltech. edu and easily accessible. Their locations have recently been defined by a logical name so that the person interested in obtaining or accessing the .MEM files does not have to know where they are. The logical for each month is named as follows:

MEM1$:[yrmth]	for 1932-1990
MEM2$:[yrmth]	for 1991-present

where "yr" is the year and "mth" is the month. For example, if you want to run **MAKEPHAS** to obtain phase data for March of 1990, you would first type:

DEF CUSPIN MEM$:[90MAR]

and then run **MAKEPHAS**.

SPIGOT: USGS-Caltech SCSN Data Access

A SPIGOT account is now working on the new VAX cluster. It is a captive account which allows only a few functions. To use it, login as SPIGOT; there is no password. It will present the user with a menu describing the following functions:

MENU or ?.............this menu
CATREAD ....search/extract catalog data
COPY ....copy files
DIR.......................list directory
TYPE filename.typ .....type a file
KERMIT................run kermit file transfer program
DELETE filename.typ;# delete files
PURGE filename.typ ..purge all but the latest file version #
STATUS.................list status of catalog data by month
LOGOUT................logout (all files are deleted)

Files are deleted after three days. Four minutes of inactivity will result in a forced logout.

TIMIT : A New Earthquake Location Program

Since early January 1992, we have been processing data using a new and improved version of CUSP from Menlo Park, thanks to Alan Walter, Sam Stewart, and Bob Dollar. The most visible changes involved were 1) a transfer of all off-line processing to a new VAX 4000, and 2) the switch to a program called TIMIT for our interactive phase picking and locations. TIMIT runs on a VAX workstation, which replaces the fifteen-year-old Tektronics 4014 "green screen" that we used to use.

There are advantages and disadvantages to TIMIT; one advantage is the speed. Part of the increase is inherent in the hardware; the rest is because each workstation has its own memory and CPU, and multiple users do not compete with each other for resources, except with I/O and network traffic. We recently timed and located 889 members of a swarm near Coso Junction, in the space of about 10 days. At no time did we write unprocessed events to tape because of disk space problems, and we were "caught up" twice for the Weekly Report during the swarm. As our long term readers will know, this is unprecedented. Normally, such a swarm would have produced a "data gap" and a "backlog" of at least several weeks.

Under the new processing scheme, newly recorded events are transferred from the on-line system to a "WARM" directory on the 4000, where they are p-picked automatically, located, and assigned a duration magnitude within a few minutes. Based on the error statistics of the hypocenter solution, the events are then automatically transferred to either the proper monthly directory, where they are timed accurately later using TIMIT, or to directories called TROUBLE and NOPIX, whose names are self explanatory. This procedure ensures that the monthly directory is seldom more than about 20 minutes behind the times, and that most telemetry glitches and other "garbage" are directed elsewhere. Since multiple events within the same trigger are handled by the analyst using TIMIT, the monthly directory is never a complete catalog. It should be a representative one, however, and a continually improving one as the analysts routinely locate events. And it is definitely a more current one than we are used to having on hand.

Southern California Earthquake Center / Data Center (SCECDC)

The SCECDC has been online since January of 1992. It consists of a mass storage device capable of holding 50 WORM (Write Once - Read Many times) platters hosted by a SUN SPARC2 workstation. Each platter holds approximately 6 gigabytes of data. In order to access the data stored by the SCECDC, the user must first get an account on the data center UNIX machine. You may request an account via telnet or rlogin, e.g.

telnet scec2.gps.caltech.edu
username: addme (no password required)

rlogin scec2.gps.caltech.edu -l addme

Upon logging in as addme, you will be asked a series of questions concerning user name, affiliation, phone number, and internet/bitnet address. Within a day you will be contacted regarding the status of your account, including information on how to access the various data sets.

Types Of Data

The following types of data are currently stored by the SCECDC:

1) Southern California Seismic Network (SCSN) catalog listings from 1932 to the present.

2) Digital seismograms for local, regional and teleseismic events recorded by the SCSN from July 1983 through December 1991 and July 1981 through July 1982; NOTE: These files are currently standard-order 2-byte-integer files, i.e. in SUNsparc short binary format.

3) ASCII data files (compressed) containing event information associated with each digital seismogram; e.g. phase, epicentral location, magnitude, and coda information. NOTE: In order to read these data files, they must first be uncompressed. This is done as follows:

```
uncompress -c filename > /tmp/outputfile
```

example:

```
uncompress -c 91sep.out.Z > /tmp/91sep.out
```

VMS Users

Digital seismograms, online at the SCECDC, are also readily available to VMS users. They can accessed by remote login to

bombay.gps.caltech.edu.

telnet (or ftp) bombay.gps.caltech.edu
username: spigot (no password required)

A program called GETSEIS will appear as one of the options available to this account. This program will retrieve a seismogram from the data center mass storage device, byte swap the file from SUNsparc short to DECVAX short binary format order, and return a xcuspid.grm file into the **SPIGOT** directory. To use this program simply type:

GETSEIS CUSPID# e.g. GETSEIS 52035

where cuspid# is the number of the event you are interested in (obtained from a catalog listing or by using CATREAD).

To obtain more information regarding the SCECDC contact one of the following:

Katrin Douglass
katrin@seismo.gps.caltech.edu
(818)356-2106

or

Dr. Rob Clayton
clay@seismo.gps.caltech.edu
(818)356-6909

both at:

Seismological Laboratory,
Mail Code 252-21
CALTECH
Pasadena, CA 91125

Pasadena Office Expansion & Changes

The Pasadena USGS Field Office underwent quite a few changes during 1991. In addition to the house at 525 S. Wilson Ave. which is leased from Caltech, we now occupy half of the house at 535 S. Wilson Ave. which is next door. The other half is occupied by the Southern California Earthquake Center. A portion of the ground floor is also occupied by personnel from the Branch of Engineering Seismology (see article below).

We also acquired the convenience (or the curse) of Voice Mail.

As a result of several factors, there is a new main office number. It is (818)405-7823. It will be answered by the secretary, Linda Rosenthal-Curtis, in most cases, or a message can be left on Voice Mail. All other phone numbers remain unchanged.

There are several new staff members, as well. Sue Perry is our new office manager. Lorraine Hwang is a two-year NRC post-doc. Sue Hough is a new scientist with the Branch of Engineering Seismology. Bob Dollar is a new computer programmer with the Branch of Seismology. And Arnold Acosta and Edna Anjal are two technicians from the Branch of Engineering Seismology Strong-Motion Program who transferred to our office from another location (see below).

Strong-motion Instrumentation Program in Southern California

The southern California strong-motion network is a part of the USGS strong-motion program under the Branch of Engineering Seismology which includes nearly 900 instruments in the United States. The program operates out of headquarter facilities in Menlo Park and Fresno, and field offices in Las Vegas, Seattle, and most recently Pasadena.

The two technicians in the Pasadena Office operate and maintain a network of approximately 115 acceleration stations in the southern California area (see Appendix B and Figure 2); technicians stationed elsewhere are in charge of the remaining 18 stations in southern California. A significant part of the network includes instrumentation owned by other agencies, most notably the Corps of Engineers, Veterans Administration, and the Metropolitan Water District, each of which provides the financial support for the USGS operation of the individual networks.

Projects underway or in the planning stage include:

1) The San Bernardino ground motion array being installed between the San Andreas and San Jacinto faults on a range of soil conditions including those with a high liquefaction potential.

2) A liquefaction array to be located near San Bernardino that will include downhole pore pressure and acceleration sensors.

3) Wadsworth (Los Angeles) and Loma Linda VA Hospitals where obsolete sensors are to be replaced and the structural recording system expanded.

4) Newport Beach structural array - relocation of sensors and upgrading of data transmission system.

5) Installation of WWVB receivers at selected ground stations.

6) Temporary retrieval of existing field instruments for overhaul and upgrading, some of which were installed as long as 20 years ago.

A summary of the strong-motion instrumentation in southern California follows:

Structural Program:

Extensive Instrumentation
10 buildings
2 dams

1 bridge

Moderate Instrumentation
10 buildings
11 dams

Minimal Instrumentation
19 structures (includes L.A. code buildings)

Ground Motion Program:

100 triaxial instrument stations
1 liquefaction array

TERRAscope, Gopher, & CUBE Update

In 1985 the Seismological Laboratory of the California Institute of Technology decided to deploy several modern broadband seismographic stations in southern California. With seed funding from the James Irvine Foundation, the first modern, high quality seismographic station was installed in Pasadena (PAS) at the Kresge Laboratory in November 1987, just after the 1987 Whittier Narrows earthquake. This station is a joint project between Caltech, the University of Southern California, the USGS, and IRIS. The PAS station consists of a broadband Streckeisen STS-1 seismometer and Quanterra data logger with a 24 bit digitizer and a Kinemetrics FBA-23 strong-motion sensor. PAS is included in the IRIS open system of seismographic stations where anyone can access the data through a telephone dial-up modem.

In 1988, when Caltech received a grant from the L. K. Whittier Foundation, the name TERRAscope was adopted, and development of the new network began. The initial goal for TERRAscope was to install at least a dozen modern broadband (10 Hz to DC) and wide-dynamic range (nominally 200 db) seismographic stations with "real-time" data retrieval capability. The PAS station served as a prototype, and various calibrations and tests continue to be done at this station.

Analysis of the new high quality data recorded at PAS from numerous regional earthquakes, including the December 1988 (M_L=4.9) Pasadena earthquake at an epicentral distance of 3 km, have demonstrated that the high quality broadband data are the cornerstone needed for significant advances in both regional seismology and studies of teleseisms. In particular, the broadband data recorded at PAS from the October 1989 (M_S=7.1) Loma Prieta earthquake were easily available immediately after the event to determine the style of faulting and other seismological parameters of the earthquake. The encouraging results from our analysis of TERRAscope data so far have led us to modify our initial goal from a dozen stations to 20 stations in southern California.

Current Status

As of February 1991, six TERRAscope stations, Pasadena (PAS), Goldstone (GSC), Piñon Flats (PFO), Santa Barbara (SBC), Isabella (ISA), and Seven Oaks Dam (SVD), are in operation. The station PFO is operated jointly with the University of California, San Diego, and the station SVD was installed and operated by the USGS. The five stations, PAS, GSC, PFO, SBC, and ISA and the data retrieval and analysis system at Caltech comprise the Whittier Advanced Geophysical Observatory, funded by the L. K. Whittier Foundation.

In addition to the permanent stations, TERRAscope includes portable PASSCAL type recorders with broadband sensors and GPS (Global Positioning System) receivers. The portable seismic instruments enable seismologists to easily reconfigure the network for their own projects, thereby increasing the versatility of TERRAscope.

TERRAscope complements and extends the capabilities of the existing 220 station (300 components) short-period Southern California Seismographic Network (SCSN). The data from TERRAscope will also be included in the SCSN data base used for generating the CIT/USGS southern California earthquake catalog. Because of their real-time capability and location in a populous earthquake-prone area, both networks enable seismologists to provide the public and state officials with timely information about significant earthquakes.

The TERRAscope stations are also included as a subnetwork of the global seismographic network, operated by IRIS, and the US National Seismic Network, operated by the USGS.

Data Availability

TERRAscope data are recorded in both continuous and event-triggered modes on site. The tape cartridges that contain continuous data are sent to the IRIS Data Collection Center at Albuquerque and archived at the IRIS Data Management Center. These data area available upon request from the IRIS DMC. The data stored on disk at each station are available through a dial-up modem, which is open to the general user.

For quick and efficient data access, an automatic dial-up data retrieving system called Caltech Gopher (adapted from the IRIS Gopher system) has been implemented. The Caltech Gopher receives mail from NEIC for teleseisms and the Southern California Seismographic Network with origin time, location, and magnitude for regional events. The Gopher retrieves data from all six TERRAscope stations for these events. The data reside in a FTP anonymous account (seismo.gps.caltech.edu; password: "your e-mail address") at the Caltech Seismological Laboratory, and are available to users through INTERNET. Usually the data are available within 15 minutes after the occurrence of a regional event and within several hours after the occurrence of a teleseism. When the Data Center of SCEC begins full operation in early 1992, it will take over distribution of earthquakes from southern California, including both TERRAscope Gopher data and continuous data from the tape cartridges.

Future Developments

With funds provided by the L. K. Whittier Foundation and Arco Foundation the plan is to deploy ten more broadband stations during 1991 and 1992. Although the actual locations have not been finalized, the following locations are being evaluated: San Nicolas Island, Los Angeles basin, Barrett, Glamis, Western Mojave, Eastern Mojave, Owens Valley, Superstition Mountain, the Coast Ranges of California, and Kaiserville, Nevada.

To have the data available for immediate analysis following a major event, two real-time telemetry systems are being tested. One is a satellite telemetry system that is being installed in cooperation with the USNSN. The other is based on data transmission over telephone lines or radio links and a local real-time data collection system developed by Adebahr Systemtechnik. Although the two systems provide different capabilities, they will complement each other; redundancy is desirable, especially in emergency situations after a large earthquake.

The CUBE Project

For several years the USGS has been developing an improved real-time data processing system which sends information about earthquakes to pagers carried by SCSN personnel. With the addition of the TERRAscope stations, more strong-motion stations, and recent advances in communications systems, the response time and accuracy of the earthquake information has been steadily improving.

In 1990, after a period of in-house testing with a prototype sytem, Caltech and the USGS initiated a new project called CUBE (Caltech-USGS Broadcast of Earthquakes). The goal of CUBE is to provide near real-time information for emergency response following significant earthquakes in southern California. At this time several transportation and utility companies have joined the USGS, Caltech, and SCEC in a cooperative research project to develop a sophisticated real-time seismic information system. The participants are actively helping with the research and development of the new system. The CUBE project has already demonstrated its usefulness for response in seismic emergencies and has gained support in the community. After the Sierra Madre earthquake on 28 June 1991, the Santa Fe Railroad was able to significantly reduce their "down" time because of the rapid information that the CUBE system provided by pinpointing potentially hazardous areas of track.

The current system transmits information about the location and size of the earthquakes to pagers. Some of the pagers are connected to DOS-based computers with video terminals that display the earthquake on a map. Several interactive capabilities are available such as zoom. One of the options is the ability to display a circular region around the epicenter for which specified levels of peak ground acceleration would be exceeded. An important goal is the ability to more accurately estimate the spatial distribution of ground shaking following an earthquake. Plans are tentatively being drawn to develop a dense network of approximately 50 strong-motion instruments over the next few years in order to accommodate this goal.

RESEARCH NOTES

The June 28, 1991 Sierra Madre Earthquake

This M_L5.8 earthquake that occurred on June 28, 1991 at 14:43:54.5 GMT (7:43:54.5 PDT) under the San Gabriel Mountains was the largest event of the year. The epicenter was located 11 km (7 miles) north of Monrovia and 18 km (11 miles) NE of Pasadena (34° 15.7'N, 117° 59.7'W), and the depth of the rupture initiation was 12.3 km (7.7 miles). It was the most well-recorded earthquake to date. The mainshock was followed by 6 aftershocks of M≥2.5 within 24 hours, but was deficient in the number of small aftershocks (Hauksson and Jones, 1991; Ma and Kanamori, 1991).

All six TERRAscope stations (PAS, SVD, PFO, GSC, ISA, and SBC) recorded the earthquake on scale, and within two hours after the mainshock, several important determinations had been made (Kanamori *et al.*, 1991). The maximum accelerations at several local sites were determined along with the M_L and radiated energy, the mechanism, and the seismic moment.

Hauksson and Jones (1991) used first motion polarities to determine a mechanism of almost pure thrust on a plane striking ENE and dipping 50° to the north. Using the aftershock distribution and the mechanisms, they attributed the event to the Clamshell-Sawpit Canyon fault, a branch of the Sierra Madre fault system. They resolved aftershock depths between 9 and 14km, and some aftershock mechanisms indicated the existence of complex faulting. Ma and Kanamori (1991) used 21 aftershocks recorded on the broad-band TERRAscope stations and determined their mechanism and seismic moment. Their findings indicate that most of the aftershocks had a thrust mechanism like the main shock except a few east of the main shock which had a strike-slip mechanism.

Using acceleration records from California Division of Mines and Geology (CDMG) and USGS strong motion stations, in addition to short-period and broad-band records within 40km of the epicenter, Wald *et al.* (1991) resolved details of the rupture process using a finite fault source inversion. The event consisted of two distinct pulses ~0.3 seconds apart on a relatively small rupture area of 16 km^2 which was located down dip of the mainshock. The average slip on the fault was ~26 cm, and the maximum slip was 100 cm. They determined a seismic moment of $3.5 \pm 1 * 10^{24}$ dyne-cm, a potency of 0.01km^3, and a stress drop of 250 bars.

Zumberge *et al.* (1991) conducted a GPS (Global Positioning System) study with 12 Rogue receivers which they used to detect surface displacement associated with the earthquake. They found that the Jet Propulsion Laboratory (JPL) in Pasadena moved ~3 mm in the direction of W26°S. And finally, a geodetic study done by Hudnut *et al.* (1991) in which the geodetic measurement of the displacement field associated with the earthquake was compared to the synthetic displacement from elastic dislocation modeling, showed that there was no horizontal displacement >10 cm.

Anomalous seismicity in the San Gabriel Valley 1987-1991

The rate of occurrence of moderate earthquakes in the San Gabriel Valley, east of the Los Angeles basin in southern California, has increased since 1987. Six earthquakes above M_L 4.5 have occurred in this region after more than 50 years with no earthquake of this size, and without a similar increase in the rate of smaller earthquakes. We are at present undertaking research to better understand the characteristics of this increased seismicity. The most active fault system in the northern Los Angeles basin, where the earthquakes have been occurring, is the frontal fault of the Transverse Ranges which is raising the San Gabriel Mountains at 3-5 mm/yr (Crook *et al.*, 1987) and was the causative fault of the 1971 San Fernando earthquake (Figure 3). The central portion of the frontal fault, called the Sierra Madre fault, has been seismically quiescent at the $M_L \geq 1.5$ level for at least the last 20 years (where the Caltech catalog is complete at this level) until the occurrence of the M_L5.8 Sierra Madre earthquake on this fault in June 1991 (Figure 3). To the east of San Antonio Canyon, the frontal fault is called the Cucamonga fault and is characterized by a higher level of background seismicity.

The moderate earthquakes of the last four years have been in the foot wall of the Sierra Madre fault (Figure 3). The two largest have resulted from thrust faulting on east-striking planes south (M_L5.9 1987 Whittier Narrows) and north (M_L5.8 1991 Sierra Madre) of the San Gabriel Valley. Two other events have resulted from left-lateral strike-slip faulting along the western (M_L4.9 1988 Pasadena) and eastern (M_L4.7 1988 and M_L5.2 1990 Upland) edges of the Valley. Three of the four largest events (Whittier Narrows, Sierra Madre and Pasadena) have occurred within a narrow band along the western edge of the San Gabriel Valley. The faults of these three earthquakes all strike between N60°E and east-west, even though the rakes have varied from 0° (pure strike-slip) to 90° (pure thrust).

Several features of the recent seismicity have been unusual. First, four of the six moderate earthquakes (all but the two Upland earthquakes) that occurred in a small region of the western San Gabriel Valley have all occurred below 10 km depth. The most unusual aspect of the depth distribution of these earthquakes is that not only did these events nucleate at relatively great depths, but that the full extent of all the rupture planes (as delineated by the aftershock hypocenters) are below 10 km. Second, the aftershock sequences of the western San Gabriel earthquakes have been deficient in small aftershocks, with b-values for the two largest events of 0.65 (Whittier Narrows) and 0.6 (Sierra Madre), among the lowest recorded in California. The greater depths of the western San Gabriel Valley earthquakes could be the cause of their low b-values (Figure 4). Third, the western San Gabriel earthquakes have also had high stress drops, an order of magnitude larger than those of other earthquakes recorded on TERRAscope. Fouth, the larger earthquakes of the last four years ($M \geq_L 4.9$) have been moving north-northeastward towards the Sierra Madre fault at 6.7 km/yr. Three of the events (Whittier Narrows, Pasadena and Sierra

Madre) lie within a very narrow east-west band. The Upland earthquake is 30 km east of the other three events but is within the region of the seismicity gap on the Sierra Madre fault. Fifth, the dramatic increase in the rate of moderate earthquakes seen in the San Gabriel Valley has occurred without a similar change in the microseismicity. A comparison of the distribution for the five years from 1981 to 1986 with the distribution for the 3 3/4 years from 1/1987 to 10/1991 for earthquakes within the box shown in Figure 3 shows that for the period 1987 to 1991, the magnitude-frequency distribution of the earthquakes departs significantly from the normal, linear distribution, with more earthquakes above magnitude 4 than would be predicted by the rate of occurrence of the smaller earthquakes (Figure 5).

One way to explain these findings is through a model of aseismic creep on a detachment surface below the San Gabriel Valley. If a detachment surface exists between the brittle and ductile crust, a creep event could have moved along this detachment over the last four years with a surge in the horizontal slip, i.e., an edge dislocation. A dislocation moving along this surface will lead to decompression of the overriding crust. The changes in the stress state associated with the creep front will trigger faults with the correct orientation if they are close to failure and pass by faults not advantageously oriented or those not already close to failure. The question of whether future earthquakes will occur within this episode becomes a question of the orientation of the fault and how close it is to failure - the last, of course, being unanswerable with the present state of knowledge. Research is continuing on this anomaly in the seismicity and possible ways to explain it.

Radiated Energy Estimates

Kanamori has suggested a method of estimating radiated energy by using the integrated value of a velocity-squared seismogram ($\int v^2 dt$). Using this quantity with appropriate expressions for the distance attenuation, q(r), and the assumed source radiation pattern, one can determine a value for the radiated energy.

$$E = 7.87 \times 10^5 r^2 \, [r_o q(r_o) / r q(r)]^2 \int v^2 dt$$

where r is the epicentral distance and r_o is the depth. The distance attenuation used was

$$q(r) = c r^{-n} \exp(-kr)$$

with c=0.497, n=1.28 and k=0.0053. This method was tested using 66 events of magnitude 3.5 to 5.5 that were well-recorded over the last several years by the low-gain and FBA components of the network. Each event was recorded by 5 to 27 components. The results of the energy estimated from each record are compared to estimate of the local magnitude (M_L) as determined from the same record. There is a good correlation between the radiated energy and the local magnitude (Figure 6). A regression of these data gives a relationship,

$$\log E = 8.7 + 2.2\, M_L$$

A similar relationship has also been derived from data recorded on the broadband TERRAscope instruments. This result is quite different from the traditional Gutenberg-Richter relationship,

$$\log E = 11.4 + 1.5\, M_L$$

Southern California Historical Magnitudes

The early history of the Southern California Seismographic Network is intimately connected with the development of the local magnitude scale by Charles Richter and Beno Gutenberg in the mid-1930's. Until now, the staff of the Seismological Laboratory have tried to preserve as much as possible the original intent and techniques of this so-called "Richter scale" for most of our recorded events. The result is one of the more consistently calibrated local earthquake catalogs in the world (Hileman et al., 1974; Friedman et al., 1976; Hutton et al., 1985; previous Southern California Network Bulletins). No history of measurements of any natural phenomenon can be completely consistent in the face of technological change, and with earthquake magnitude the challenge is compounded by the arbitrary nature of its definition.

In its summary form, which is widely utilized, the southern California earthquake catalog contains only date, time, epicentral location, depth, and one magnitude, plus some other incidental information. In order to conserve space and to avoid confusing the non-scientific users of the catalog, it is left to us to decide which magnitude is "the right one" for each event. Depending on the size of the event and the equipment available when it occurred, that magnitude could have been determined in any of several ways. Local magnitude (M_L) is only one of the possibilities. Each of the various magnitude types is designated by a code, such as M_L, M_{CA}, M_D, etc. and will be discussed individually.

At the time of this writing, we stand at the edge of completely revising our methods of "sizing" local earthquakes. Seismic moment (M_o) and moment magnitudes, as well as energy magnitudes (M_W), have been used for a long time with large teleseisms. Modern broadband instrumentation can now bring such physical measurements to smaller events, as well. The "Richter scale" is deeply ingrained in the public and, to a lesser extent, the professional concept of earthquakes. Better results than ever are certain to come out of the new technology, but some care must be given to maintaining continuity with the past.

Now is a good time to summarize this past. The intent here is to bring together as much lore and real information as possible about the Seismological Laboratory's historical determination of magnitude for local earthquakes, and to alleviate some of the confusion that arises from the proliferation of magnitude types.

M_L

The original Richter scale, or more properly, local magnitude scale, was defined by Richter (1935) in order to distinguish small, medium, and large earthquakes in the early southern California earthquake catalog. All estimates of earthquake size up to that time were intensities, or estimates of the level of damage or perception of the severity of shaking caused by the quake, and these were considered too skewed by uneven population density to provide much information about the earthquake itself. The new Wood-Anderson torsion seismometers (Anderson and Wood, 1925), which were intended mainly to record local earthquakes at short-periods, had then been operating for several years at the various stations managed by the Seismological Laboratory. The Wood-Anderson's optics and mechanics are simple and the instrument was considered easily understood and stable over a long period of time. Richter arbitrarily defined the earthquake magnitude as the logarithm of the peak amplitude (in microns) of a hypothetical Wood-Anderson record, made 100 km from the epicenter. Corrections for distances other than 100 km were then determined empirically using a set of 12 well-recorded southern California earthquakes and expressed in tabular form (Richter, 1958). For fear of causing a discontinuity in the routine determinations, that table has been in use ever since.

In the beginning, magnitudes were only assigned to the nearest half unit, in most cases, which was considered accurate enough for the purpose at hand. Furthermore, at that level of precision, the magnitude determinations from most stations were in agreement, so a rigorous procedure for averaging various estimates is not necessary. At times magnitudes were listed with quarter unit precision. However, a magnitude of 5 3/4 tends to quickly be translated to 5.75 by the press (implying more precision than intended), so it is not difficult to understand why this practice evolved into the tenth of a unit precision that is now commonly used. Hileman et al. (1974), in their much quoted earthquake catalog for 1932 through 1972, list all magnitudes this way, even though most of them prior to 1944 are M3.0 or 3.5, etc.

Richter's protocol seems simple enough. However, quoting magnitudes to the nearest 0.1 unit requires attention to a few details which, unfortunately, have not been documented very well. Station corrections for each site, for example, significantly reduce the standard deviation of the various readings for a given earthquake. The station corrections were determined empirically, based on the residuals in routine magnitude computations, but only the person who carried out the procedure knows which earthquakes were used. It should be added that the station corrections have since been recomputed with various data sets. By far the largest one was that of Hutton and Boore (1987). The results agree very well with Richter's originals.

Also, current routine practice is an oral history, handed down from analyst to analyst over the years. An example of how this is a problem is the reading of the amplitude itself. The amplitudes are currently read, on the photographic Wood-Andersons, as one-half the peak-to-peak distance on the largest single swing of the S wave. This procedure differs slightly from that specified in Richter's book. Richter (1958) calls for use of the largest amplitude regardless of what phase it belongs to, whereas Gutenberg and Richter (1956) say to ignore any P phase. The largest overall amplitude is the preferred measurement for a computer program, for simplicity's sake. However, the actual routine procedure seems to have been in effect for a long time. A change to the overall peak might introduce a systematic error. Since the largest wave is often asymetrical, the peak amplitude would tend to give a higher reading. Of course, a new set of station corrections would offset a systematic error like that. Ideally, the type of measurement that proves most consistent is the one that should be used, but it is not clear which that would be. It is not even clear exactly how the early measurements were done, as we will see below.

Another question that comes up is the procedure for determining the assigned earthquake magnitude from the suite of station magnitude estimates. The current routine is to compute a magnitude for each Wood-Anderson instrument (generally two per station, if both horizontal components are being recorded), apply the station corrections, and then take the median of the values to obtain the local magnitude of the earthquake. In the past the local magnitude appears to have been chosen from the list of station magnitudes by an undefined and somewhat subjective method, based partly on the analyst's experience with the reliability of individual stations. Richter (1958) states that the mean of the estimates should be used. Statisticians prefer the mean. However, the median tends to minimize the influence of outlying readings and provides a more robust estimate for a small number of readings.

If any readings were excluded because the stations were considered unreliable, this information has generally been lost.

The distance correction table is also systematically skewed compared with the averaged data (Hutton and Boore, 1987), at least for stations at distances beyond about 250 km. Because the larger earthquakes have legible records only beyond that distance, that makes their magnitudes wrong as well. "Wrong" in this context means inconsistant with the determinations for the smaller earthquakes made at nearer distances and with the definition of the local magnitude as a logarithmic scale. Hutton and Boore concluded, however, that because so many other types of earthquake magnitudes were calibrated to "look like" the local magnitude as historically practiced in southern California, it makes no sense to say that the magnitudes in the historical catalog are wrong. Furthermore, a substantial downward revision of the magnitudes of famous and damaging historical earthquakes can be expected to produce somewhat of a public outcry.

The smallest amplitude readable on a photographic drum record such as those produced by the Wood-Anderson instruments is about 0.1 mm. The largest, practically speaking, is about 100 mm; even at amplitudes smaller than 100 mm, the record may be so underexposed that the analyst cannot identify the peaks with certainty. Caltech's Wood-Andersons are equipped with a switch triggered by the high-gain short-period vertical instrument at the site, which brightens the light source during recording of an earthquake. Even then, peak identification can be difficult. These constraints limit the usefulness of the optical Wood-Andersons to local earthquakes between magnitudes of about 2.5 and 6.0. In the computer age any digitally recorded or digitizable seismogram can be transformed into a synthetic Wood-Anderson recording, provided that the instrument response is well enough understood. The synthetic records allow M_L's to be determined for much larger or much smaller earthquakes. It turns out, however, that there is some controversy over the magnification of the real Wood-Anderson instruments. Shake-table calibrations are presented by Gutenberg (1957) that verify the theoretical (Anderson and Wood, 1925) amplification of 2800. On the other hand, Urhammer and Collins (1990) argue a good case for an amplification of 2100. As long as a magnitude scale is defined in terms of the actual performance of real Wood-Anderson instruments, the exact magnification does not matter. However, the synthesis of Wood-Anderson records requires that an assumption be made about the magnification. Use of empirical station corrections based on earthquakes with "real" local magnitudes can eliminate any uncertainty about magnification. However, there must be enough data for them to be determined.

The distance correction problem could be more serious. The use of nearby synthetic records for large earthquakes makes the median magnitude lower than that determined from real records at distances greater than 250 km. This could produce a noticable discontinuity in the historical catalog for larger events. Fortunately perhaps, the local magnitude saturates above about 6.5 anyway (Kanamori, 1983), meaning that although quakes can be larger and longer in duration, they do not produce higher amplitudes on a short-period instrument like the Wood-Anderson. It makes sense to use other magnitudes above that level.

This distance correction problem has already shown up with the use of the several film-recorded low-gain torsion instruments operated by the Seismological Laboratory. With these, the magnification is nominally either 4 or 100, instead of 2800. The earthquakes that have usable records on both these and the regular Wood-Anderson's are few, however, so the station (instrument) corrections are very poorly known. In any case, these recordings will be discontinued soon because of a unique problem: the films are identified by a "stamp" with radioactive paint on it. These have now decayed to the point that the stamps are completely unreadable, and for safety reasons they are not replacable. At the moment we lean toward not using the 100X torsions at all. However, any number of the old magnitudes above about 6.0 could be based on these instruments.

For now, the distance correction table, the procedures, and the magnitudes remain as they have always been.

M_S

Following Richter's original work, the concept of instrumental magnitude was broadened to include larger earthquakes, smaller earthquakes, earthquakes at teleseismic distances, and instruments other than the Wood-Anderson torsions (Gutenberg and Richter, 1942 and 1956; Kanamori 1983).

Prior to 1973, the Network located very few earthquakes smaller than M2.5, so M_L was adequate at the small end of the scale. But occasionally there were large earthquakes which generally elicited a large scientific and public interest. Some events, like the Long Beach earthquake of 1933 (M_L 6.3), have fairly well documented magnitudes (Richter 1935). In that case, the local magnitude was deduced by comparing lower amplitude parts of the seismogram to the same parts of some aftershocks whose peak amplitudes were readable. With other events, for example the 1940 Imperial Valley earthquake (M_L 6.4 or 6.7, or 7.1, depending on the reference), it is far less clear where the catalog magnitude came from. Many values may have been teleseismic surface-wave magnitudes (M_S, as in the case of the 1952 Kern County earthquake (M_S 7.7).

Currently we prefer to insert published surface wave magnitudes, or moment magnitudes (Hanks and Kanamori, 1979) when they are available, for all earthquakes above about M6.0 (Hutton and Jones, 1992).

M_H

The number of stations deployed in southern California began increasing in the early 1970's, with the beginning of collaboration between Caltech and the U.S. Geological Survey. Additional earthquakes were recorded, most of them too small to be recorded on the Wood-Anderson instruments. Until the advent of computerized recording in 1977, methods of data recording and analysis tended to differ somewhat between the two offices. Therefore, a couple of different schemes evolved to estimate the magnitudes of these smaller events.

Caltech continued to emphasize the recording and analysis of a complete catalog of earthquakes above a certain magnitude, which had been about M_L3.0 inside of the Network. The addition of several new stations caused the threshold of completeness to drop about M_L2.5, thus covering most of the earthquakes that were felt by the general populace. In addition to the Wood-Anderson instruments, each station was equipped with a high-gain, short-period vertical seismometer of Benioff or equivalent design. The seismometers had an electrical output and were either recorded photographically via galvanometer or telemetered to Caltech and recorded on visible drum recorders (helicorders, hence the designation M_H) . The Benioff-type instruments do not have the exact frequency response of the Wood-Anderson, but they are close enough that the usual procedure, with the application of station (instrument) corrections produces relatively consistent estimates. The station corrections were determined from earthquakes whose local magnitudes could be determined from the Wood-Andersons.

Because no great effort was ever made to keep the gains of the telemetry systems or the drums constant, the M_H magnitudes are last resort magnitudes, to be used when nothing else is available. M_H was often used for immediate release to the press, however, since the visible drum rack provided a convenient place to measure as many amplitudes as possible.

As the catalog stands now, many events that occurred in 1977 and 1978 have either no magnitude or an M_H magnitude. This is because the software for magnitude computation developed more slowly than that for timing and epicentral location. As we finalize that part of the catalog, coda amplitude magnitudes (discussed below) will replace most of the M_H magnitudes.

M_D

In the 1970's, the U.S. Geological Survey tended to install stations and concentrate analysis in a few geographic areas of selected interest, like Imperial Valley or the eastern Mojave. They used recording and analysis methods already established in Menlo Park for northern and central California. All stations, including the Caltech ones which were also on drums, were recorded on malodorous microfilm units called develocorders. In most cases, the earthquakes themselves are very underexposed on develocorder films, so that amplitudes were unreadable. The total duration of the signal was used as an estimate of the magnitude (Lee et al., 1972). The central California formula was probably used; no calibrations specific to southern California were ever published.

M_D is the most common type of magnitude found in the catalog for events smaller than about M2.5 to 3.0 (depending on the epicentral location), between 1974 and 1976. Beginning in 1992, M_D again appears on a few events for which the coda amplitude algorithm (M_{CA}) will not work properly, because of noise or other reasons. As before, the calibration is the central California calibration, and at first glance, the M\S\DO3(D)'s appear to be 0.1 or 0.2 smaller than the M_{CA}'s for the same events. This conflict deserves further investigation.

M_{CA}

With the advent of digital on-line recording of the telemetered signals in 1977, a more easily automated method was needed for measuring magnitude. Because of limits on the dynamic range of the signals imposed by the instrumentation and telemetry, many peak amplitudes are lost to clipping, even for relatively small earthquakes. A peak amplitude magnitude is therefore impractical. Since the archived seismogram data is in triggered form rather than continuous, the trigger often clips off the end of the coda, so M_D is often not practical. Between the time the amplitude is clipped and the end of the trigger, however, there is usually a section of the coda that is usable (if it isn't cluttered by aftershocks). It is now well established (Aki, 1969; Aki and Chouet, 1975; Rautian and Khalturin, 1978; Aki, 1980, among many others) that the coda of a local earthquake is made up of S waves that have been scattered off of various subsurface features and topography in the crust. The larger the earthquake, the greater the distance over which scattered waves are detectable, and the longer the coda. This is why M_D, total signal duration, works as a magnitude estimate. Johnson (1979) fit an exponential decay curve to the usable portion of each coda and then used that curve to estimate what the coda amplitude would be at a standard time after the P arrival, even if the record was unreadable or missing at that time. This pseudo-amplitude is then related to the magnitude of the earthquake through the station magnification. We call this magnitude estimation M_{CA}, for coda amplitude magnitude.

In practice, each station is calibrated for M_{CA} every three months, to account for the changes that are made to the field instrumentation and telemetry, against all earthquakes during that time period for which M_L was determined. The method works rather well below about M4.0. Above that level, most triggers do not contain enough on-scale coda for a good estimate. Even earthquakes as small as M0.8 are commonly assigned an M_{CA}, although many small ones do not contain enough coda. M_{CA} is not workable for some earthquakes that are very close together in time.

Historical Summary

1932 - 1943

During this time period an ever increasing but still small number of stations were operated by the Seismological Laboratory. All recordings were made photographically, and all stations were equipped with at least a Benioff short-period vertical and a pair of Wood-Andersons. Most earthquakes of M_L 3.0 or larger inside the network were included in the catalog, except during aftershock sequences. In the greater Los Angeles area many smaller earthquakes appear as well. Except for events over M_L6.0, all magnitudes are presumed to be M_L. Most above that limit are probably teleseismic magnitudes, notably M_S.

Most magnitudes were only reported to the nearest half unit, and amplitudes were apparently only very roughly measured. Hutton and Jones (1992) have remeasured the amplitudes for most earthquakes above M_L4.8 and found many of them to have been overestimated. Many of the magnitudes, therefore, were also overestimated by a few tenths of a point.

1944 - 1971

Over this time period, the number of recording stations increased slowly. In the late 1960's a trend toward telemetered stations was apparent. The old Wood-Anderson instruments remained, and a few were moved to other sites, but no new ones were added. A somewhat larger number of earthquakes per year appear in the catalog, indicating a greater degree of completeness. The amplitudes seem to have been read according to modern standards. The difference between the M_L and what would be computed today from those amplitudes shows a degree of scatter, but the systematic difference is less than 0.1 unit.

1972 - 1976

The Network was transformed during this period into a large regional operation through a cooperative agreement with the U.S. Geological Survey. Although the original visible drums and the Wood-Andersons remained, most of the newly installed stations were short-period vertical only with standardized instrumentation specified for the U.S.G.S. Central California Network. The bulk of the recording was on develocorder. An unknown number of the smaller cataloged shocks are listed with duration magnitudes (M_D) or amplituded magnitudes computed from the visible drums (M_H).

1975 - 1976

Duration magnitudes are intermixed with M_L's and M_H's during this period. Earthquakes in different geographic areas were processed either by Caltech or by the U.S. Geological Survey, depending on special research interests. The completeness of the catalog is geographically uneven. Efforts are currently being made to finalize the earthquakes above about M2.5 during this period and to identify the source of the magnitude estimate in each case.

1977 - 1979

This time period was that of our earliest attempt at computer automation; the CEDAR system (Caltech Earthquake Detection and Recording). Some of the software was slow to become operational, and all of the data need to be finalized. As the catalog stands now, many of the magnitudes are M_L, some are M_H, and some are just plain zero, meaning that no magnitude was computed.

1980 - March 1981

During much of 1980, data were recorded on computer, but not processed due to lack of software. An interim catalog was constructed, using mostly M_L and M_H magnitude estimates. Clearly, this period of time needs a great deal of attention.

April 1981 - present

Although some of this time period is still being finalized and some (May through July 1983) still needs to be processed (another interim catalog is used during that gap in processing), the rest is in good shape. Most earthquakes of M2.5 or larger have M_L magnitudes. The bulk of the rest of them are M_{CA}. The smallest ones have no magnitudes (ie. 0.0), since they were too short in duration for the M_{CA} algorithm. Since the beginning of 1992, a few M_D's, in a computer automated incarnation, have crept in.

What Now?

With our seven broadband TERRAscope stations and our increased understanding of the response of the short-period instruments, we now have the capability of computing M_L or moment magnitude, or both, from literally dozens of stations for most earthquakes, very large and very small. Long-term plans are being laid to place the whole Network at the mercy of the microwave telemetry system by scrapping the outside photographic stations, including the Wood-Andersons in the not-too-distant, geologically speaking, future.

There are strong advantages to these changes, not the least of which are better and faster locations and more usable waveforms. More internal consistency would probably result from such use of the same algorithms across the whole dynamic range of earthquake recording. Also, more reliable magnitudes would be available faster after a damaging earthquake, when the most people are the most interested.

However, a discontinuity in the historical magnitudes will certainly occur. For example, the distance correction problem may show itself in the data from high-dynamic-range TERRAscope instruments, which can produce synthetic Wood-Anderson records for just about any earthquake at any distance. As mentioned above, use of nearby measurements where this was not possible before can be expected to produce magnitudes smaller than we are used to seeing for the larger earthquakes.

One obvious alternative would be to computerize all the archival amplitude readings and recompute all the magnitudes, old and new, based on a revised distance table. The computerization part is a project currently being undertaken by the Southern California Earthquake Center. Many earthquakes could end up with magnitudes 0.3 or 0.4 smaller than their traditional values, however.

Another alternative would be to stop using the local magnitude scale altogether and switch to moment magnitude, which is now, in the computer age, a reasonable option to consider. Some people think that moment magnitude makes more physical sense than the arbitrary local scale, and it has already been calibrated to approximate traditional local magnitudes in the range where both are applicable. A break in the magnitude scale, between local magnitudes before a certain date and moment magnitudes afterward, might be tolerable. Because moment magnitude has been calibrated to "look like" traditional M_L, the difference might be less than that caused by using nearby readings for large earthquakes.

Such options are currently under discussion.

SYNOPSIS OF SEISMICITY

A total of 12,194 earthquakes and 1485 blasts were cataloged for 1991 (Figure 7). Of the cataloged events, 133 were greater than or equal to $M_L3.0$ (Appendix A, Figure 8). The largest earthquake in 1991 had an M_L of 5.8 and was located near Sierra Madre. Focal mechanisms for 18 events ($M_L \geq 3.5$) are shown in Figure 9.

For the following discussion southern California has been divided into eleven sub-regions (Figure 10). These regions are arbitrary, but useful for discussing characteristics of seismicity in a manageable context. Figures 11a and 11b summarize the activity of each sub-region over the past four years. A separate discussion section follows for those regions with notable activity.

Imperial Valley - Region 1

Swarms, common to this area, occurred on several occasions throughout the year, in addition to a few solitary events of $M_L \geq 3.0$. An $M_L3.3$ was the largest event in a swarm in the Cerro Prieto area (in Mexico ~30 miles SW of Yuma, Arizona) near the southern end of the Imperial Fault on 16 July. On 10 September there was a swarm of five events in the lower Brawley Seismic Zone. A relatively large swarm of about 21 events occurred in the Cerro Prieto area (42 km SSE of Mexicali) at the beginning of November with the largest events being an $M_L3.3$ and $M_L3.4$.

South San Jacinto - Region 2

The San Jacinto Fault is always highly active with many small events and 1991 was no exception. An $M_L3.4$ earthquake occurred on 24 May near Ocotillo Wells on the San Jacinto fault and was followed by two small aftershocks On 9 July there was an $M_L3.7$ event (Figure 9, Number 6) 23 km SE of Anza on the section of the fault that separates into several distinct branches. This earthquake was felt in Palm Springs and followed by five aftershocks in the proceeding days. An $M_{CA}3.1$ also was located at this site in late November.

An $M_L4.0$ (Figure 9, Number 8) occurred on 19 July near Salton City and was followed by ten aftershocks of $M_L \leq 2.0$. The mainshock had a strike-slip mechanism with a trend parallel to the San Jacinto Fault. This earthquake was felt in the Palm Desert area. An $M_L3.5$ with seven aftershocks shook the Salton City area again on 26 September. On 27 October an $M_{CA}3.5$ (Figure 9, Number 10) with five small aftershocks occurred near Idyllwild and was felt by local residents.

South Elsinore - Region 3

This area was relatively quiet with only two notable events. A group of nine events (all $M_{CA}<3.0$) occurred in early November 42 km west of El Centro in the Yuha Desert. An $M_L3.7$ occurred on 30 May near Julian. On 4 December there was an $M_L4.2$ (Figure 9, Number 11) 8 km NE of Ramona (or 18 km west of Julian) that was felt as far away as San Diego. This event was located in an historically very quiet area west of the Elsinore Fault, and it did not have any aftershocks.

San Diego - Region 4

Almost all the activity in this region was located offshore. The first sizable earthquake of the year was an $M_L3.7$ located 34 km south of San Diego on 5 March that was felt in the San Diego area. An Oceanside aftershock (the mainshock was an $M_L5.3$ on 13 July, 1986) of M_L 3.4 occurred on 13 June. The remainder of the year was relatively quiet.

Los Angeles Coast - Region 5

The Los Angeles area experienced a number of small earthquakes throughout the year, some of which were felt by local residents. An $M_L3.5$ occurred on 9 April that was located near Avalon, Catalina Island, but no inquiries were received about it. Later that month there was an $M_L3.2$ near Redondo Beach that had two aftershocks. This earthquake was widely felt in the South Bay area.

North Elsinore - Region 6

Aftershocks from the 28 February , 1990 Upland earthquake continued throughout most of the year, and the activity in the Ontario area that began in October 1990 also persisted.

The largest earthquake of the year in southern California occurred on 28 June at 14:43 GMT. It was an $M_L5.8$ located 11 km north of Monrovia (Figure 9, Number 4) under the San Gabriel Mountains. It was a thrust event with a trend roughly parallel to the Sierra Madre fault zone, with the north side moving up and over the south side. For further details see the article entitled *The June 28, 1991 Sierra Madre Earthquake* in the Research Notes section.

On 2 October there was an $M_L3.4$ event near Yorba Linda that was felt in the epicentral area. The three aftershocks, however, were not felt.

San Bernardino - Region 7

This region, as usual, had the most activity, as far as numbers of significant earthquakes are concerned. The swarm in Lucerne Valley that began near the end of December 1990 continued through the first few months of 1991. The Big Bear area experienced an $M_L3.7$ (Figure 9, Number 1) with three aftershocks on 8 March that was felt in the area, and an $M_L4.0$ (Figure 9, Number 12) on 4

December that was felt as far away as San Bernardino. The San Bernardino area also experienced an earthquakeof $M_L3.5$ on 3 August.

In April a swarm occurred near Indio that included about 16 events. In mid-October there was a swarm near Pushawalla Canyon in the Little San Bernardino Mountains. On 12 October there were five events that exceeded magnitude 3.0, including two $M_{CA}3.5$'s 5 minutes apart. Several swarms of this nature occurred in the area in April of 1990.

In July the Anza area experienced a small swarm of ten events during one week. In May, an $M_L3.7$ (Figure 9, Number 3) and an $M_L3.5$ occurred on the San Jacinto Fault 3 km NE of Hemet followed by nine aftershocks $\geq M_L1.5$ within 24 hours. These events are common for this portion of the fault below the locked zone. An $M_L3.4$ was the largest member of a swarm of events near Indio in April. An $M_L3.4$ was located near Mecca in January that was deeper than most earthquakes in this area. There was a cluster of events in the Bombay Beach area, on the east shore of the Salton Sea, on 20 July, and on 4 February there was a small swarm in the nearby Brawley Seismic Zone under the Salton Sea; the largest event was an $M_L2.7$.

North Mojave - Region 8

A cluster of events occurred during the later part of July into the beginning of August near Barstow with about 35 events total; the largest event was an $M_L2.7$. On 29 June there was an $M_L3.6$ and an $M_L4.0$ (Figure 9, Number 5) a few seconds apart 48 km east of Barstow.

South Sierra Nevada - Region 9

In the Lake Isabella area an $M_L3.4$ event occurred on 23 September at a site 40 km NNE of the lake. An $M_L3.5$ was the largest of a sequence of six events 23 km SE of Lake Isabella on 3 April. On 11 November an $M_L3.4$ shook the area under Rocky Point on the NE shore along with four small aftershocks. The mainshock was felt in the area.

An unusual sequence of 29 events occurred December 19-25 very near the Garlock Fault about 27 km ESE of Ridgecrest. The largest events included an $M_L3.4$ and $M_L4.1$ (Figure 9, number 13) on 20 December. The mechanisms were strike-slip, consistent with the east-west trend of the Garlock Fault. This activity occurred on the less seismic western portion of the fault (Astiz and Allen, 1983), and the $M_L4.1$ was the second largest event on this portion of the fault since 1930. The largest event was an $M_L4.3$ in 1974.

Santa Barbara - Region 11

The Santa Barbara Channel had prolific seismicity during the first week in August including 11 events on 3 August within a seven hour period (the only one larger than $M_L2.0$ was an $M_L2.3$). This activity was located about 14 km SW of Santa Barbara.

An event with an unusually long-period signal was recorded 31 January and located 14 km SSE of Santa Maria. The event had an M_L of 3.5, and although the signal was unusual, this phenomenon had been recorded in this area previously.

An $M_L3.5$ (Figure 9, Number 2) was felt in Fillmore on 12 April,and on 5 July an $M_L4.1$ (Figure 9, Number 7) was located 5 km SE of Castaic dam. It was followed by 19 aftershocks in the following weeks.

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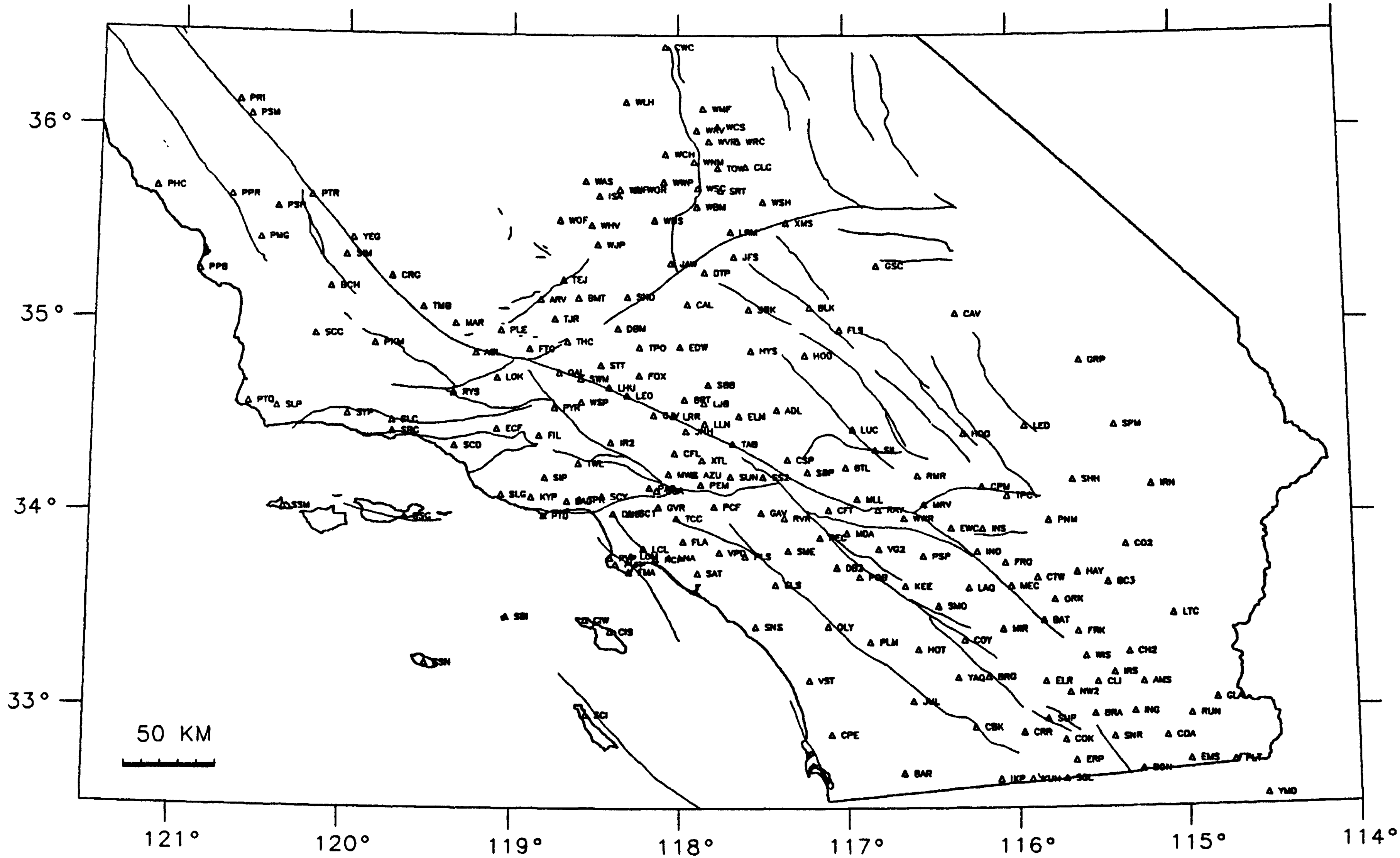

Figure 1. Southern California Seismic Network. Map of all stations operated and maintained by the Pasadena Field Office as well as several stations operated by other agencies that are also digitally recorded.

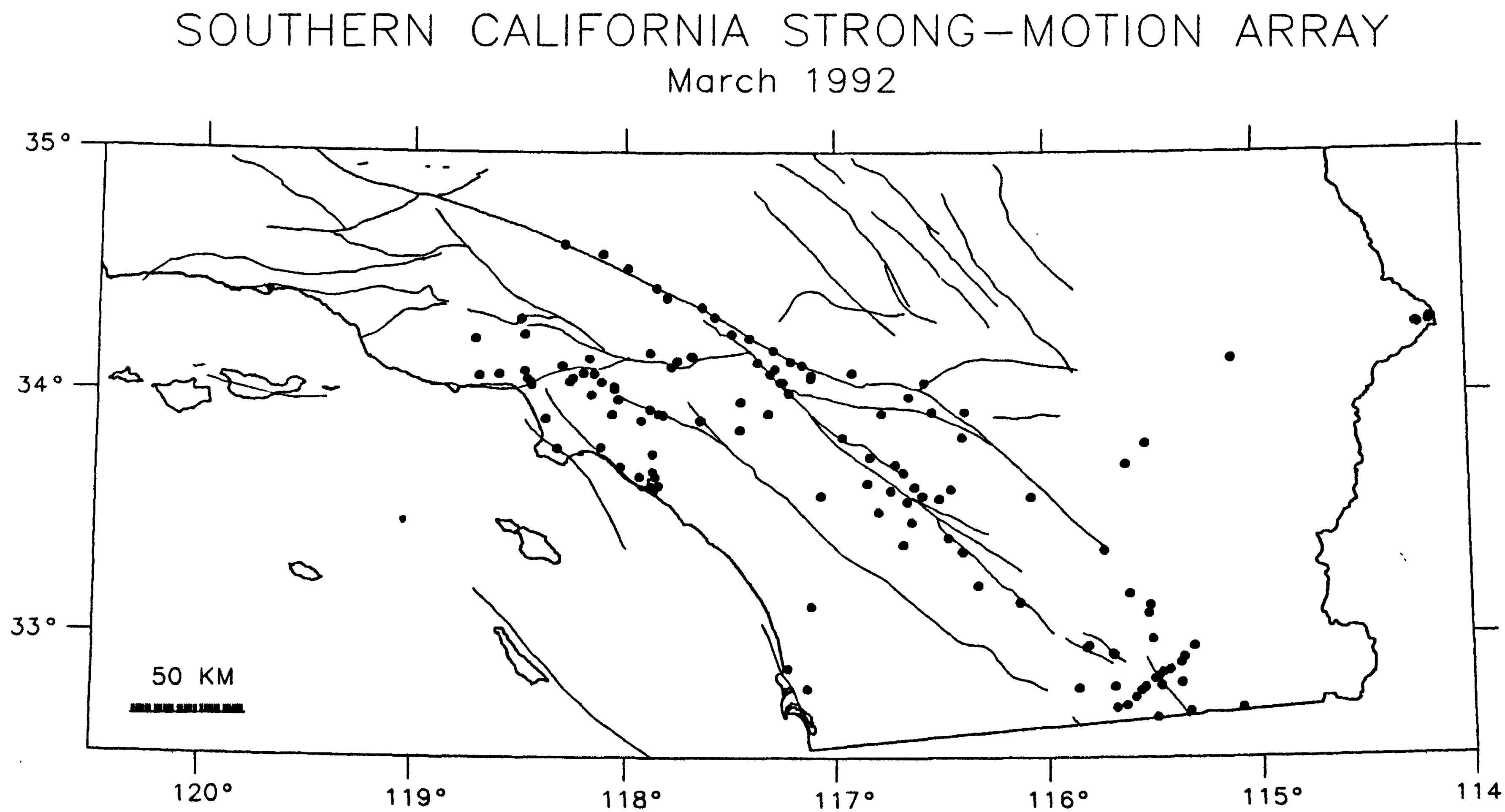

Figure 2. Southern California Strong-Motion Network. Map of all stations operated and maintained by the Pasadena Field Office as well as several stations operated by other agencies.

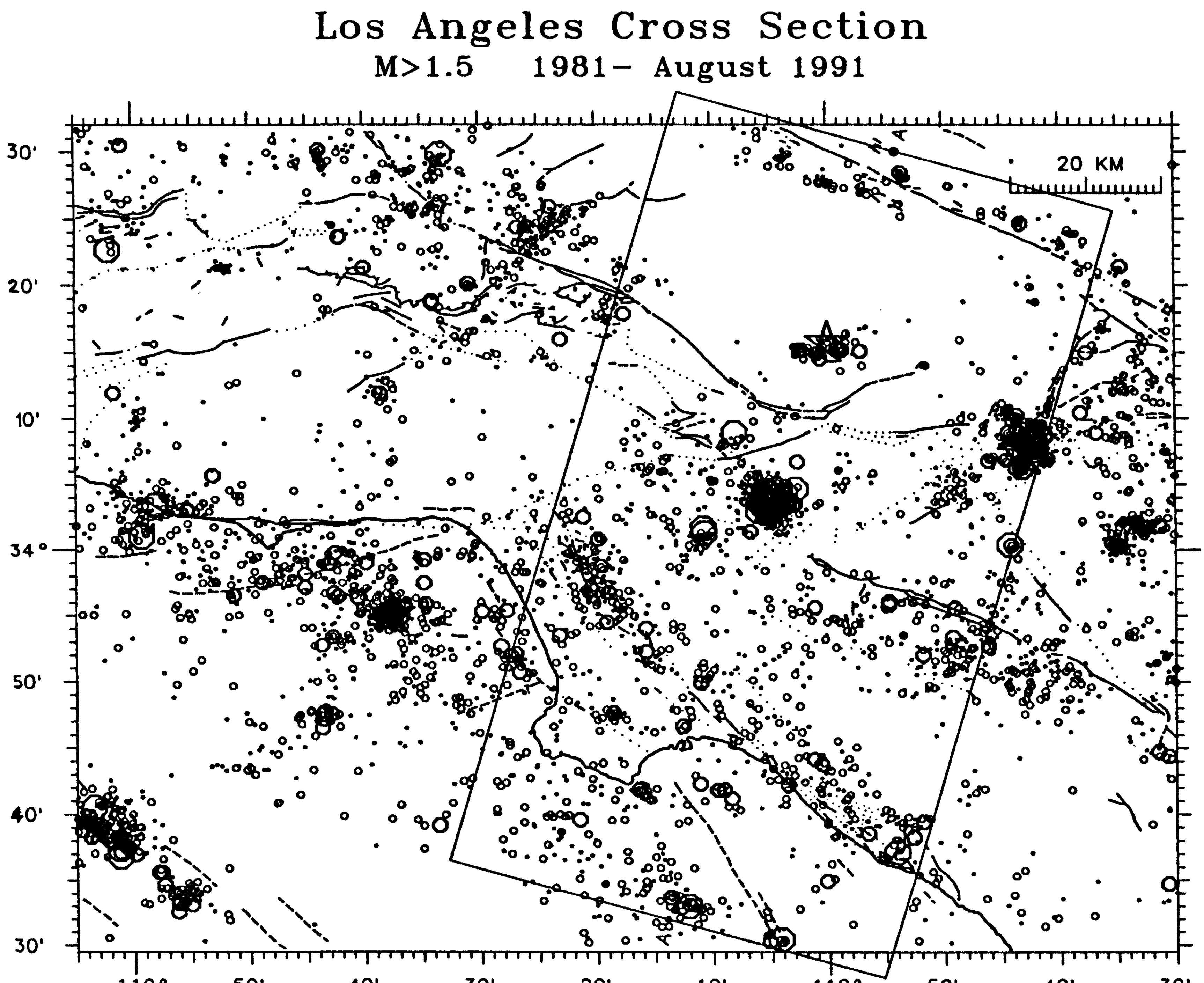

Figure 3. A map of the Los Angeles region showing the region of increased moderate earthquake activity, enclosed by box A-A', and all earthquakes M≥1.5 recorded by the SCSN between 1981 and October 1991. The hatched region is the aftershock zone of the 1971 San Fernando earthquake (M6.6).

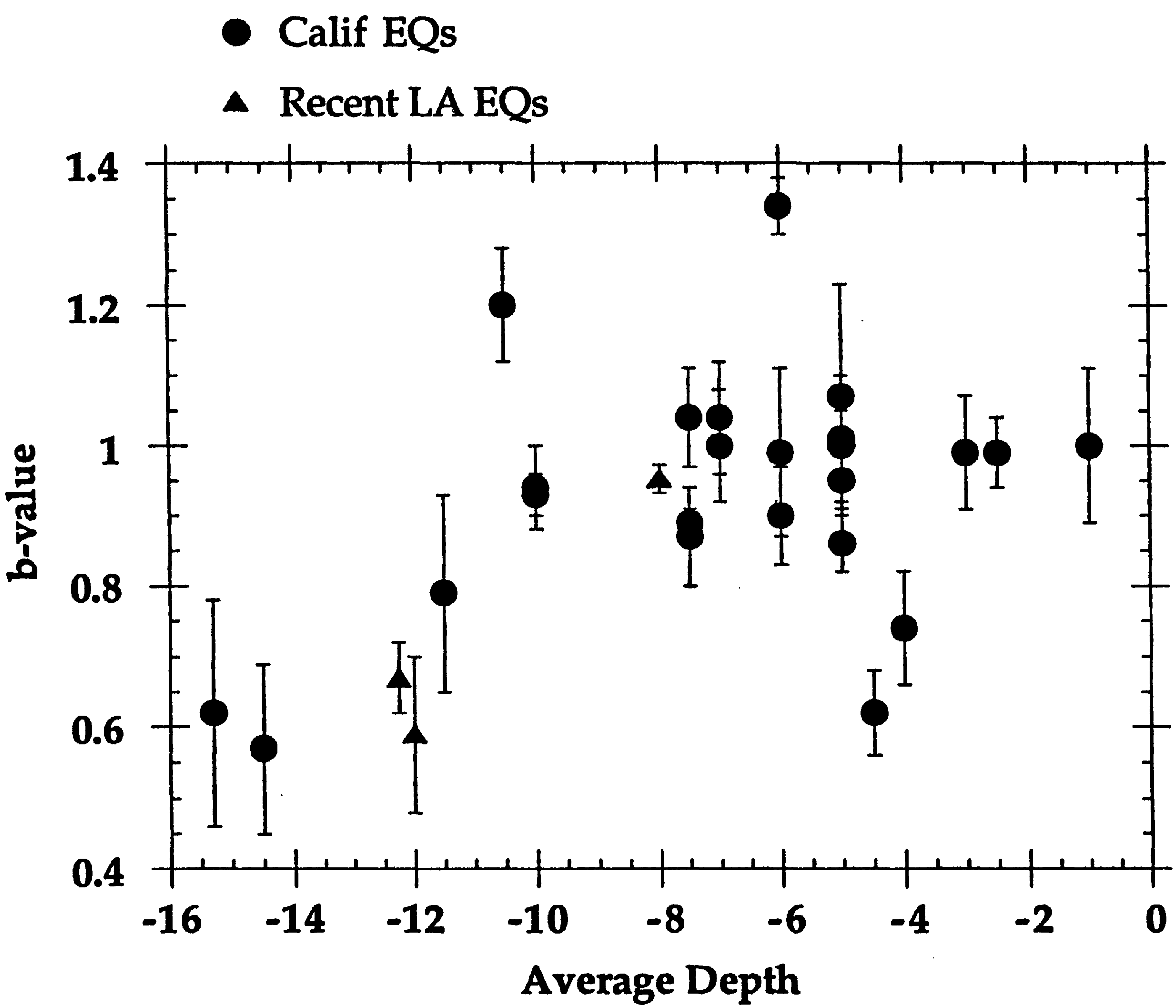

Figure 4. The b-values determined for the aftershock sequences of M≥5.0 Californian mainshocks plotted against the average depth (depth of the shallowest aftershock plus the depth of the deepest aftershock, divided by 2) of the aftershock sequence.

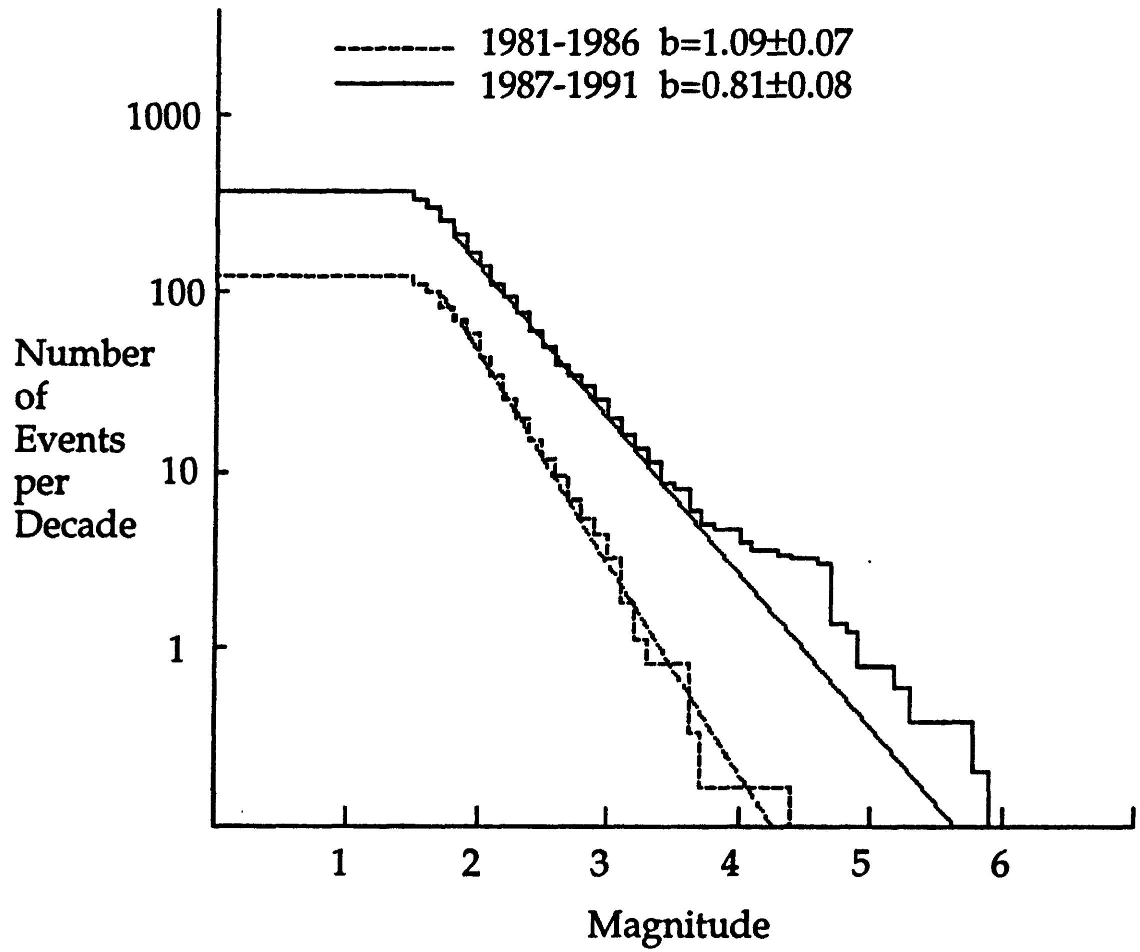

Figure 5. Cumulative number of earthquakes plotted versus magnitude for earthquakes within the box in Figure 1 for 1981 to 1986 (dotted lines) and 1987-1991 (solid lines).

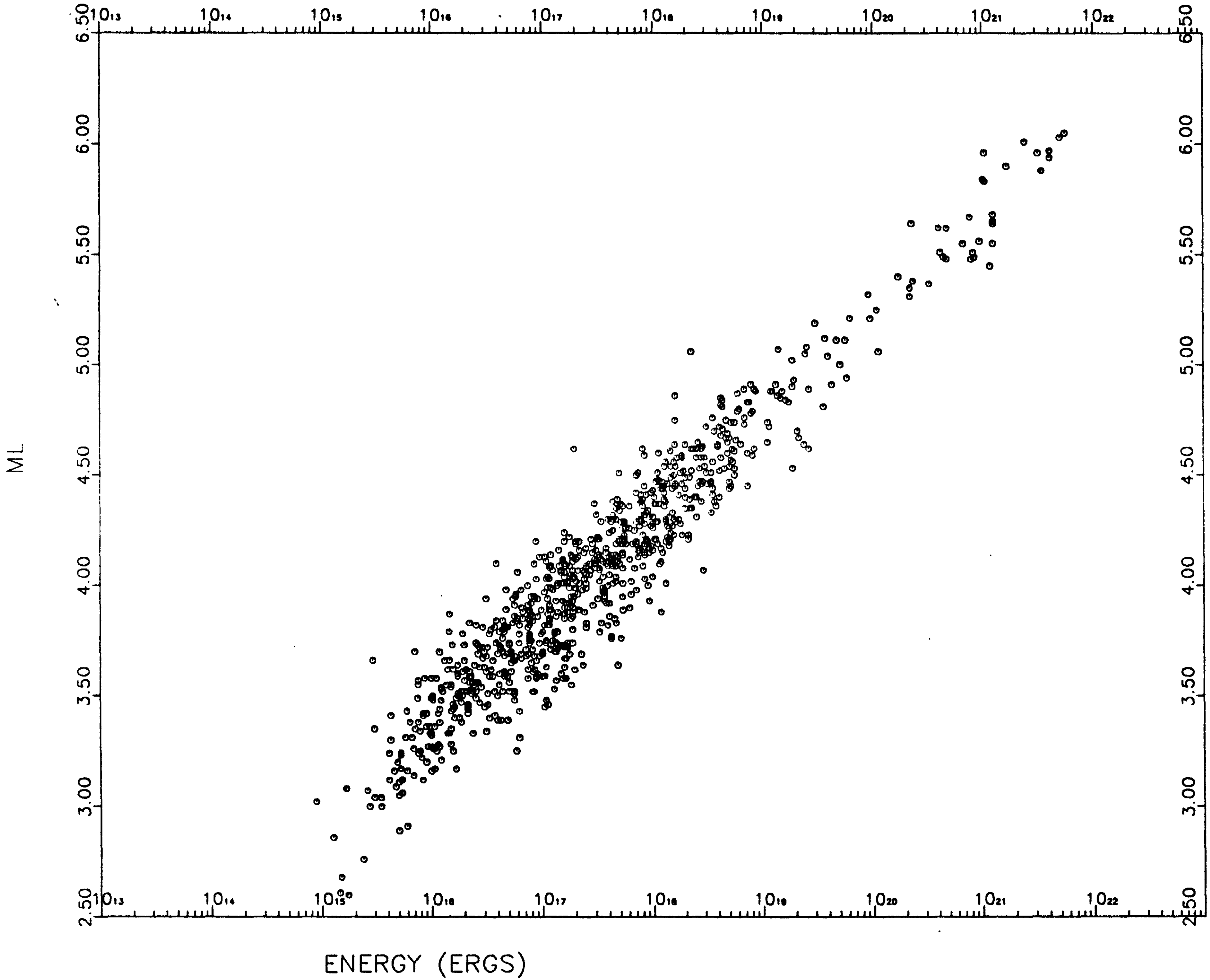

Figure 6. Correlation between the radiated energy and the local magnitude using 66 events of magnitude 3.5 to 5.5 that were well-recorded over the last several years by the low-gain and FBA components of the network. A regression of these data gives a relationship, $\log E = 8.7 + 2.2 M_L$.

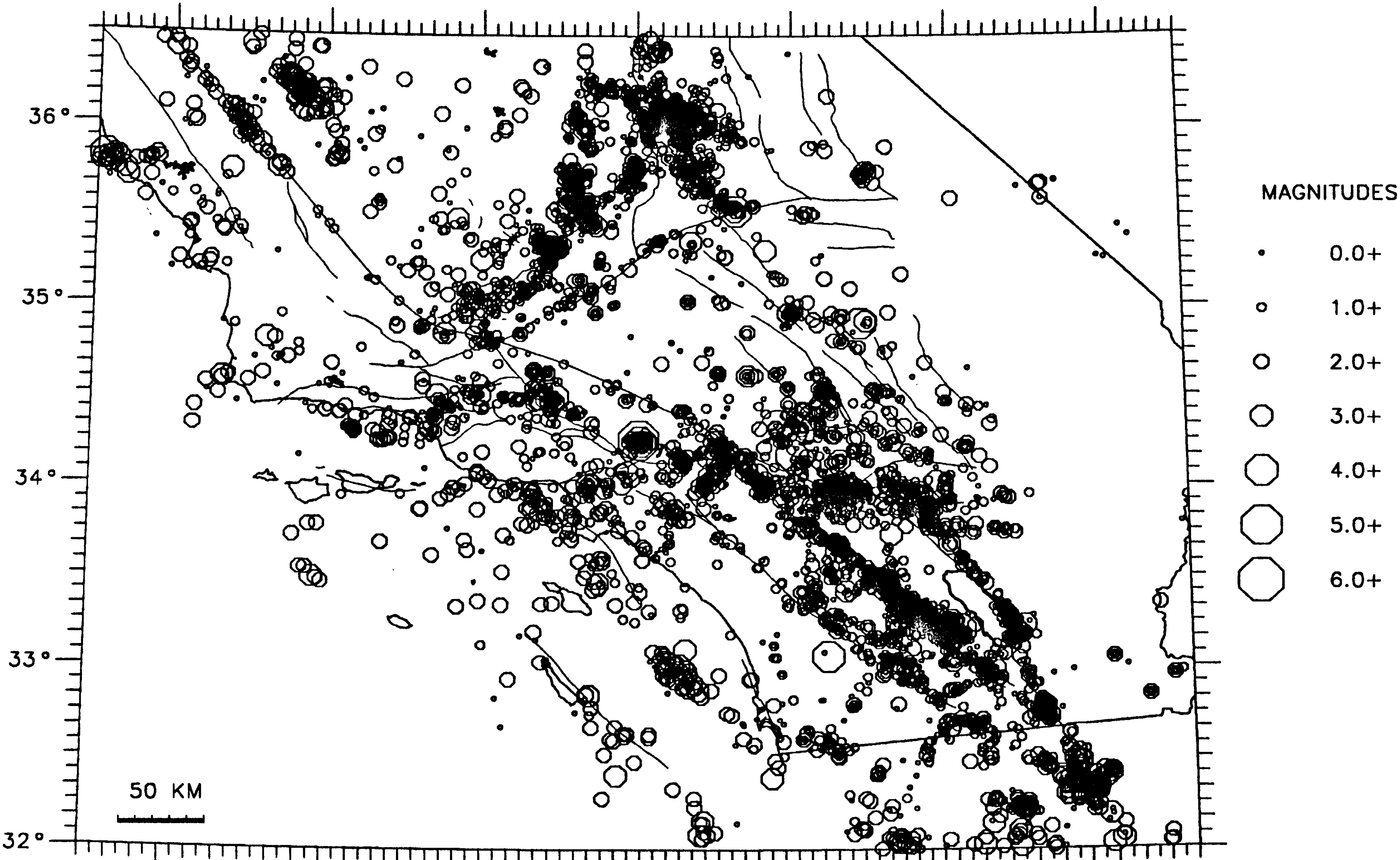

Figure 7. Map of all located earthquakes in southern California for the period of January through December 1991.

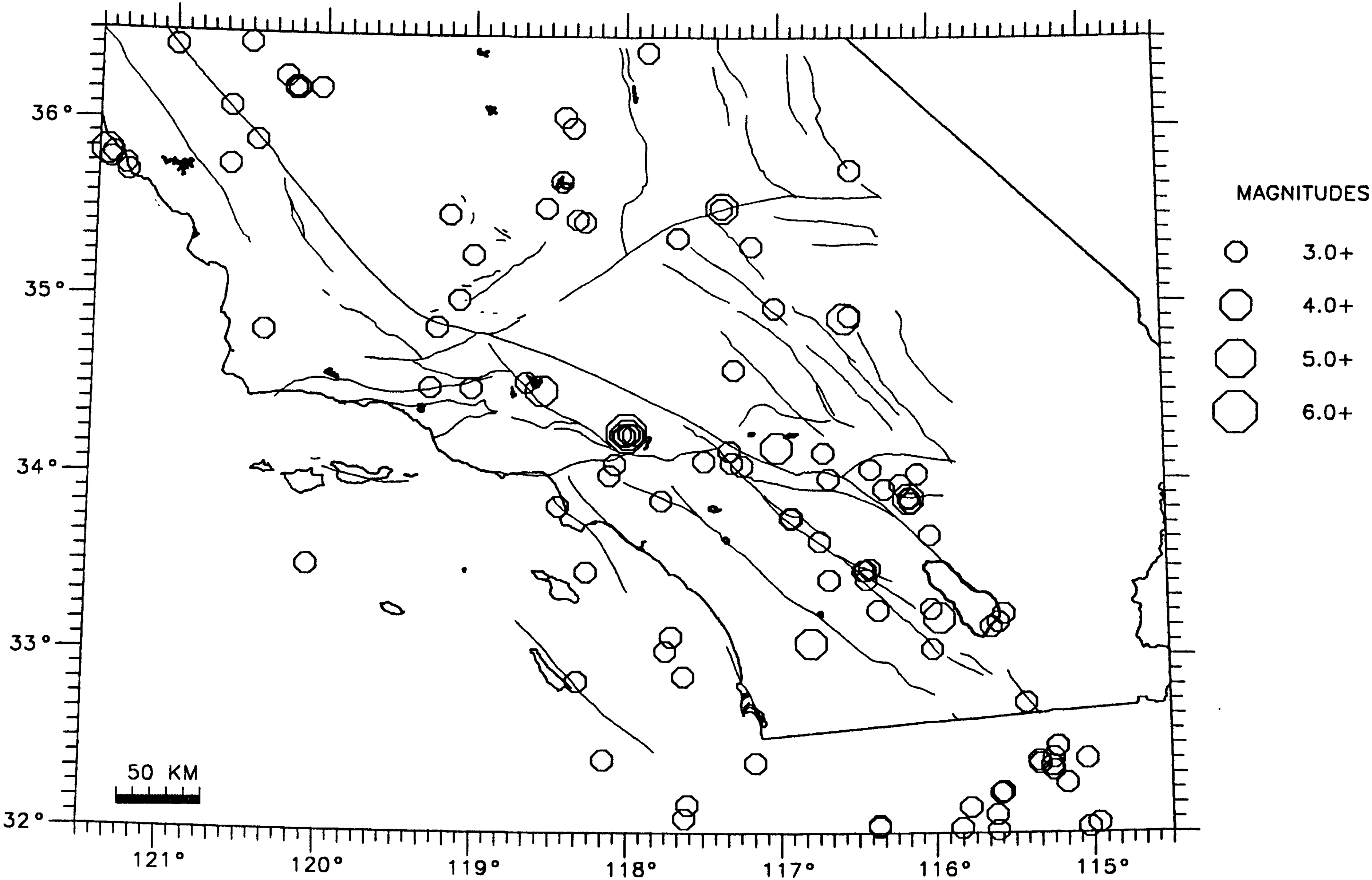

Figure 8. Map of located earthquakes of magnitude 3.0 and larger in southern California for the period of January through December 1991.

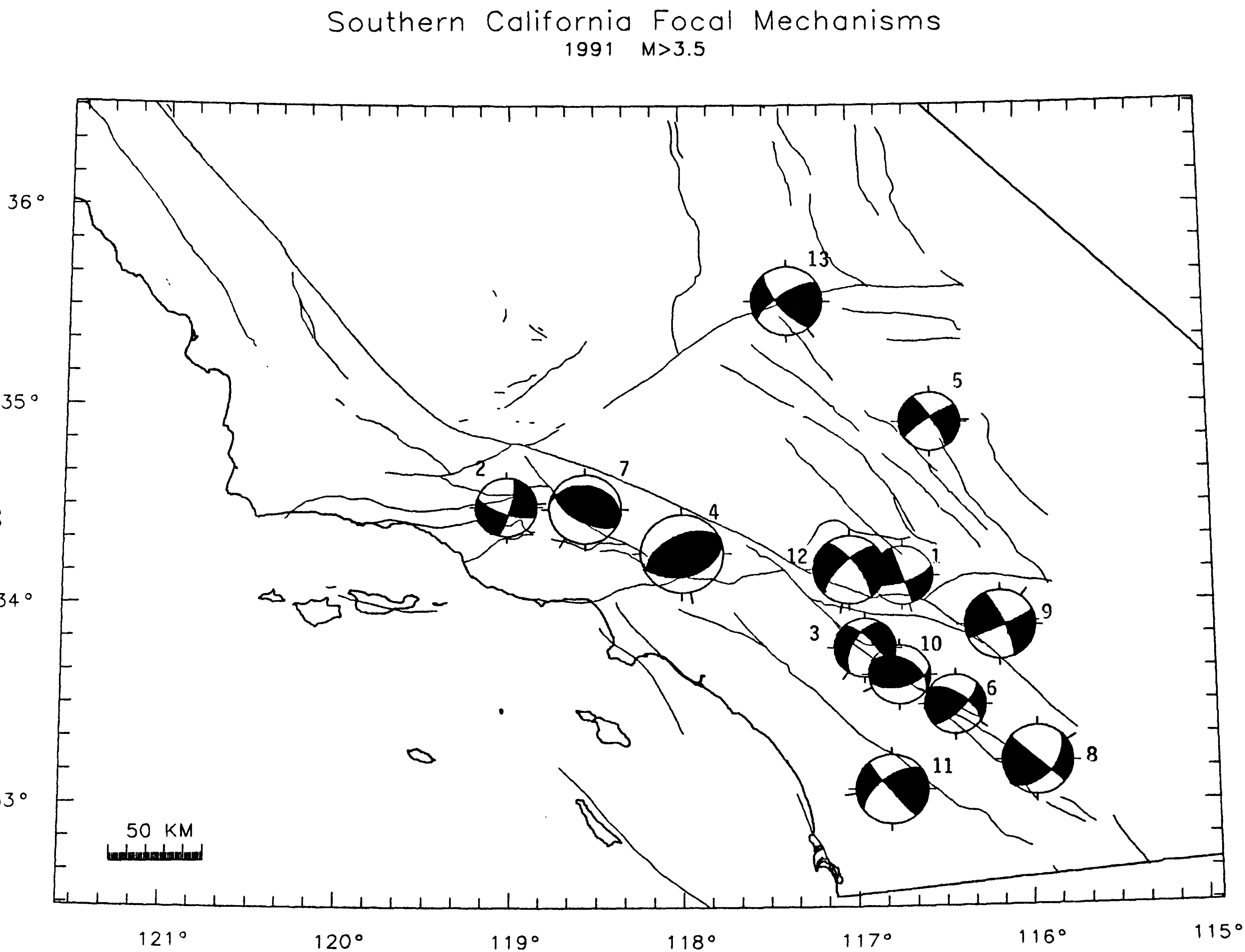

Figure 9. Lower hemisphere focal mechanisms for selected events for the period January through December 1991. Event numbers correspond to numbers in FM column of Appendix A.

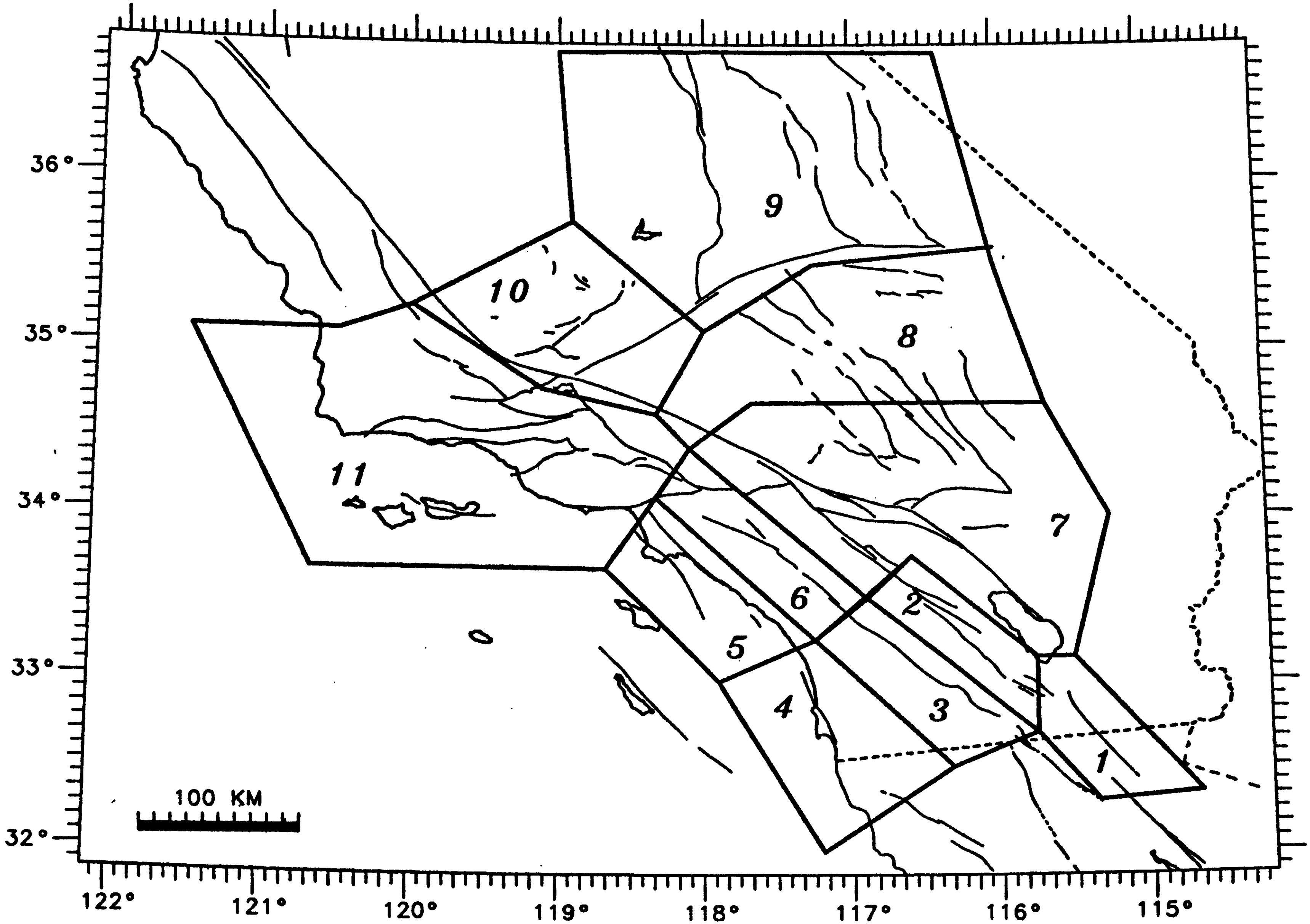

Figure 10. Map of sub-regions used in Figures 11a and 11b. The geographic name of each sub-region, as used in the text, can be found in the headings of Figures 11a and 11b.

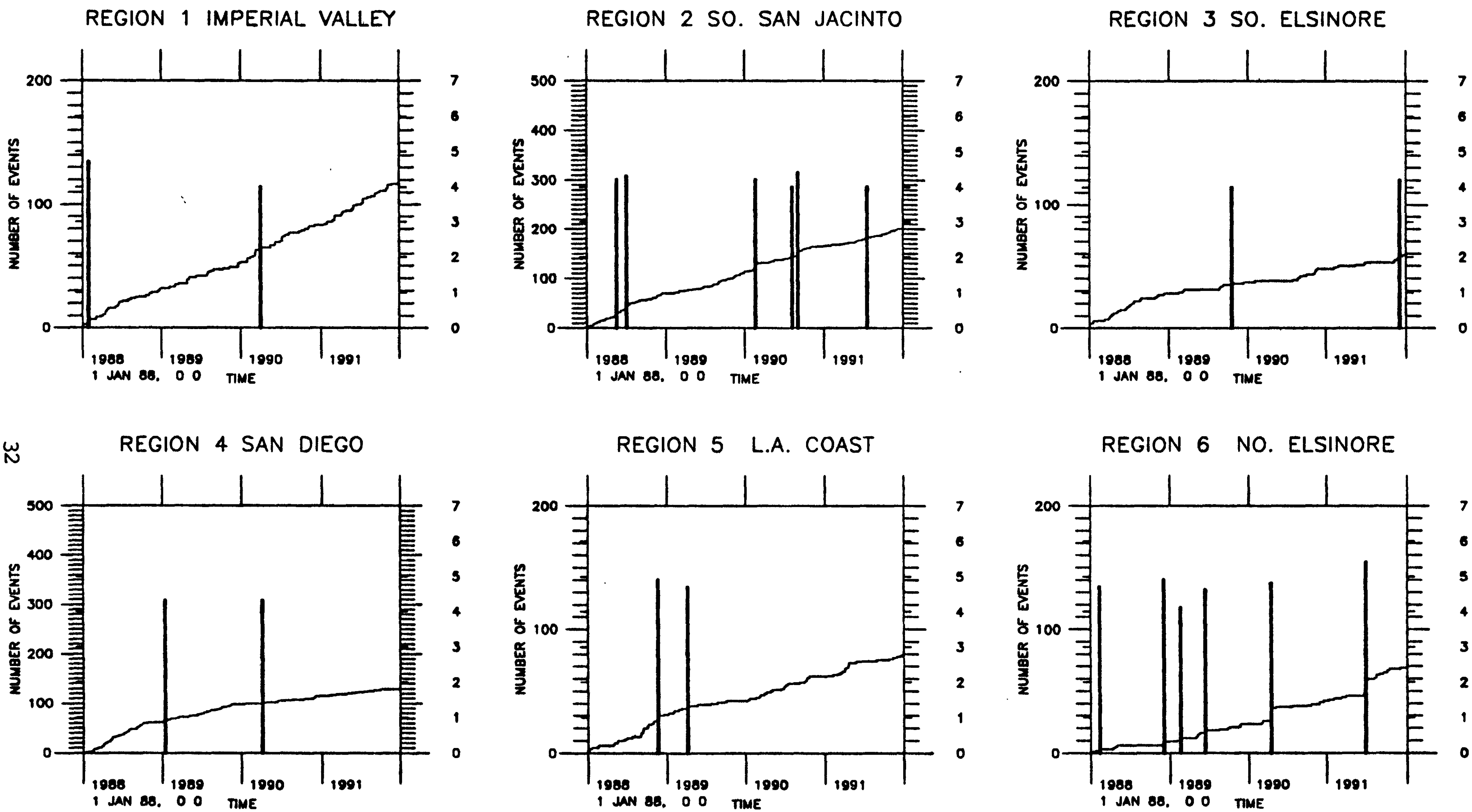

Figure 11a. Cumulative number of events ($M_L \geq 2.5$) in sub-regions 1through 6 over the four year period ending December 1991. The boundaries of the sub-regions are shown in Figure 10. Vertical bars represent time and magnitude (scale on right) of large events ($M_L \geq 4.0$). Note that the vertical scales of the plots may not be the same.

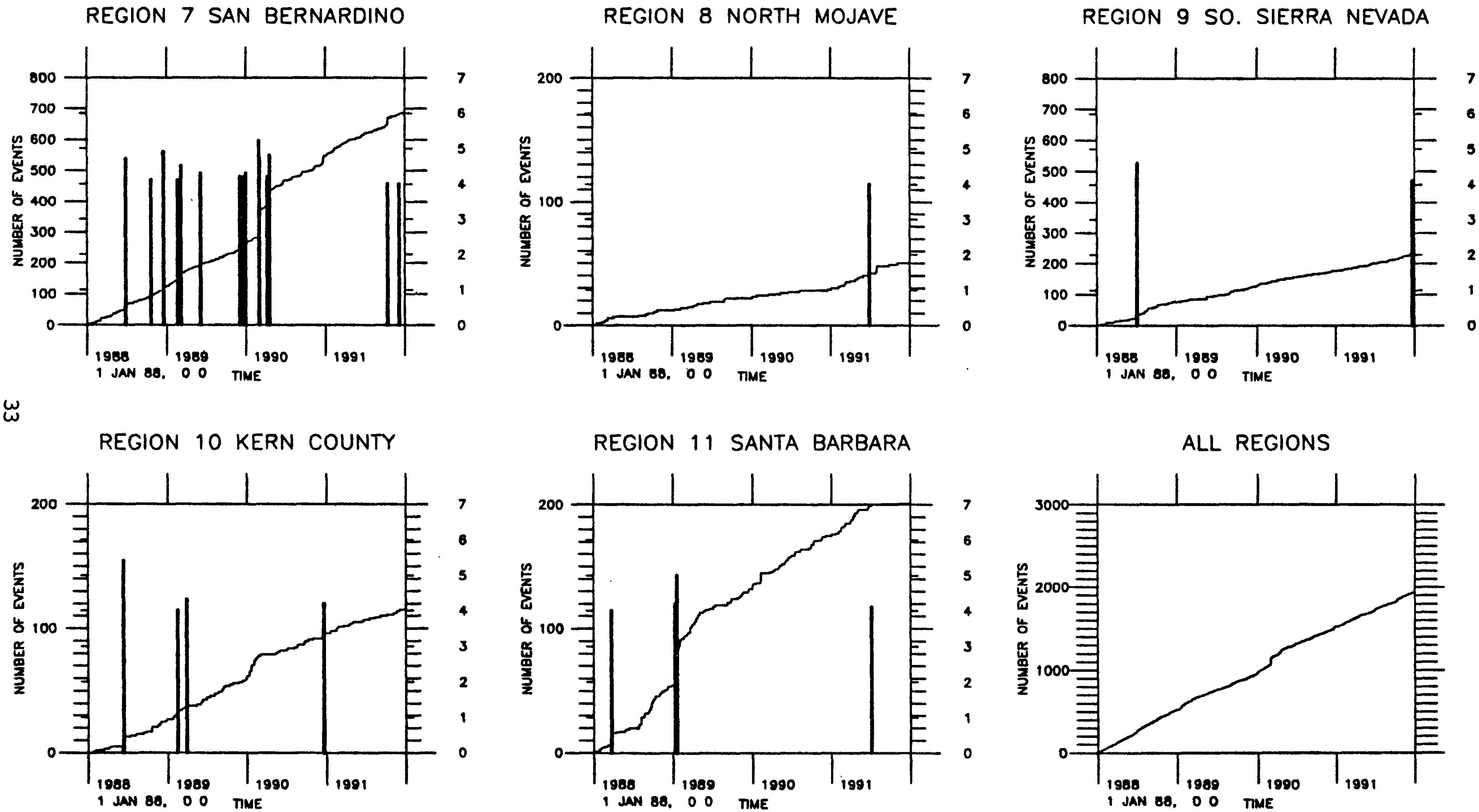

Figure 11b. Cumulative number of events ($M_L \geq 2.5$) in sub-regions 7 through 11 and for all sub-regions over the four year period ending December 1991. The boundaries of the sub-regions are shown in Figure 10. Vertical bars represent time and magnitude (scale on right) of large events ($M_L \geq 4.0$). Note that the vertical scales of the plots may not be the same.

Appendix A

Significant Southern California Earthquakes

All events of $M_L \geq 3.0$ for the period January to December 1991. Times are GMT, Z is the depth in km, Q is the overall quality of the location, RMS is the root-mean-square of the location error, and PH is the number of phases picked. The CUSPID is the unique number assigned to the event by the CUSP system. FM denotes the number of the accompanying focal mechanism in Figure 10.

DATE	TIME		LAT	LON	Z	Q	M	TYP	RMS	PH	CUSPID	FM
1991 JAN 8	0851	28.63	33.6814	-116.0260	-11.42	A	3.4	M_L	0.10	61	2010062	
1991 JAN 9	2209	5.70	35.8923	-120.4535	-8.41	A	3.1	M_{CA}	0.08	43	2010172	
1991 JAN 10	1854	16.93	35.5294	-118.5288	-10.13	A	3.1	M_{CA}	0.02	8	2010217	
1991 JAN 11	1942	36.31	32.0319	-115.0325	-6.00	D	3.1	M_L	0.30	9	2010275	
1991 JAN 16	1415	55.09	32.3789	-115.2644	-6.00	C	3.2	M_{CA}	0.33	25	2010438	
1991 JAN 31	0039	5.37	36.0533	-121.6956	-6.00	D	3.5	M_L	0.39	16	2011299	
1991 JAN 31	2328	18.00	34.8204	-120.3834	-1.00	C	3.5	M_L	0.13	17	2011371	
1991 FEB 4	1638	32.31	36.1074	-121.8743	-6.00	D	4.3	M_L	0.56	32	2011726	
1991 FEB 5	1609	20.63	36.6558	-121.1522	-6.00	D	3.7	M_L	0.48	24	2011790	
1991 FEB 8	1457	10.95	32.2336	-115.5771	-6.00	C	3.3	M_L	0.30	20	2012056	
1991 FEB 16	1340	57.91	35.0055	-119.0976	-13.39	A	3.1	M_L	0.11	50	2012653	
1991 FEB 24	0239	36.89	36.2566	-120.2689	-6.00	C	3.4	M_L	0.20	33	2013162	
1991 MAR 3	1740	15.45	36.4176	-121.0023	-6.00	C	3.4	M_L	0.21	24	2013615	
1991 MAR 5	1029	29.92	32.3955	-117.1662	-6.00	C	3.7	M_L	0.39	58	2013719	
1991 MAR 7	0443	22.32	34.0854	-118.0745	-13.46	A	3.1	M_L	0.16	61	2013812	
1991 MAR 8	0927	35.57	34.1499	-116.7185	-11.16	A	3.7	M_L	0.11	97	2013964	1
1991 MAR 11	1915	45.45	36.5735	-121.1915	-6.00	D	3.0	M_{CA}	0.31	12	2014168	
1991 MAR 15	0206	21.15	33.1060	-117.7051	-6.00	C	3.0	M_L	0.29	30	2014380	
1991 MAR 17	2125	49.08	32.1452	-115.7833	-6.00	C	3.4	M_L	0.35	42	2014527	
1991 MAR 21	0112	19.56	36.9000	-116.7500	0.00	A	3.1	M_{CA}	0.49	8	2014952	
1991 MAR 22	0022	56.34	35.4879	-119.1648	-6.00	C	3.0	M_{CA}	0.38	62	2014989	
1991 MAR 22	2317	59.68	36.5887	-121.2122	-6.00	D	3.1	M_{CA}	0.41	11	2015041	
1991 MAR 29	0454	55.85	32.0811	-117.6204	-6.00	C	3.0	M_L	0.56	32	2015468	
1991 MAR 31	0529	21.74	32.0134	-115.6133	-6.00	C	3.5	M_L	0.47	39	2015587	
1991 APR 3	1729	46.99	35.4643	-118.3242	-8.91	A	3.5	M_L	0.10	104	2015771	
1991 APR 9	0751	20.18	33.4709	-118.2627	-6.92	B	3.5	M_L	0.17	81	2016096	
1991 APR 12	0414	54.93	33.8678	-116.1514	-2.46	A	3.0	M_L	0.17	57	2016334	
1991 APR 12	1945	6.77	34.5085	-119.0154	-3.76	A	3.5	M_L	0.14	82	694013	2
1991 APR 14	0842	39.37	33.8661	-116.1502	-2.73	A	3.4	M_L	0.10	67	2016539	
1991 APR 19	1802	6.61	33.1915	-115.5935	-1.23	A	3.1	M_L	0.28	48	2016941	
1991 APR 20	0058	13.51	33.8454	-118.4450	-6.09	A	3.1	M_L	0.16	63	694409	
1991 APR 20	0136	12.46	34.5449	-118.6564	-13.03	A	3.1	M_L	0.15	67	2016964	
1991 APR 23	1512	14.40	32.1574	-117.6013	-6.00	D	3.0	M_L	0.52	28	2017101	
1991 APR 29	0704	48.72	32.1038	-115.6188	-6.00	C	3.5	M_L	0.48	36	2017313	
1991 MAY 3	1855	26.41	34.0580	-116.4136	-7.16	A	3.2	M_L	0.07	61	2017538	

DATE	TIME		LAT	LON	Z	Q	M	TYP	RMS	PH	CUSPID	FM
1991 MAY 4	2304	54.25	34.5093	-119.2842	-5.15	A	3.3	M_L	0.13	81	2017603	
1991 MAY 20	1500	53.43	33.7813	-116.9347	-12.77	A	3.7	M_L	0.12	111	695381	3
1991 MAY 20	1504	10.03	33.7789	-116.9336	-12.39	A	3.5	M_L	0.13	79	695382	
1991 MAY 21	1830	18.64	33.7839	-116.9282	-13.39	A	3.0	M_L	0.10	39	2018405	
1991 MAY 22	0118	59.09	36.4404	-120.5076	-6.00	C	3.1	M_{CA}	0.18	19	2018438	
1991 MAY 24	1808	33.67	33.0367	-116.0153	-5.93	C	3.4	M_L	0.17	58	2018630	
1991 MAY 28	1158	47.69	35.7380	-121.3178	-6.00	C	3.7	M_L	0.09	18	2019701	
1991 MAY 28	1219	58.99	35.7688	-121.4240	-6.00	C	3.1	M_{CA}	0.24	14	2019705	
1991 MAY 31	1301	41.89	35.3144	-117.1826	-10.00	A	3.0	M_{CA}	0.17	56	2019952	
1991 JUN 11	0729	16.04	32.2254	-115.5923	-6.00	C	3.2	M_L	0.31	25	2020563	
1991 JUN 13	0355	54.40	33.0251	-117.7413	-6.00	C	3.4	M_L	0.57	67	2020709	
1991 JUN 14	1109	6.12	33.1633	-115.6394	-1.00	C	3.3	M_{CA}	0.11	50	2020781	
1991 JUN 16	1146	23.02	32.3904	-115.3409	-6.00	C	3.2	M_L	0.29	32	2020887	
1991 JUN 19	1853	2.08	36.6142	-121.2221	-6.00	D	3.1	M_{CA}	0.36	21	2021058	
1991 JUN 21	1741	43.08	35.2576	-119.0058	-28.61	A	3.2	M_L	0.24	87	696455	
1991 JUN 28	1443	54.50	34.2615	-117.9995	-10.53	A	5.4	M_L	0.13	156	2021449	4
1991 JUN 28	1459	32.58	34.2531	-118.0390	-9.06	A	3.4	M_L	0.15	120	2021451	
1991 JUN 28	1537	58.84	34.2530	-117.9778	-12.60	A	3.9	M_L	0.13	135	696662	
1991 JUN 28	1616	14.79	33.4280	-116.6847	-14.48	A	3.0	M_L	0.09	36	2021466	
1991 JUN 28	1658	45.86	34.2555	-117.9851	-9.78	A	3.4	M_L	0.10	137	2021472	
1991 JUN 28	1700	55.56	34.2529	-117.9920	-9.47	A	4.3	M_L	0.11	119	2021473	
1991 JUN 28	1852	58.17	34.2486	-118.0145	-11.10	A	3.2	M_L	0.13	76	2021479	
1991 JUN 29	1753	39.65	34.9220	-116.5412	-6.00	C	3.6	M_L	0.15	55	151520	5
1991 JUN 29	1753	52.05	34.9085	-116.5794	-6.00	C	4.0	M_L	0.32	51	2021565	
1991 JUL 5	1741	57.12	34.4970	-118.5555	-10.91	A	4.1	M_L	0.16	131	2022113	7
1991 JUL 6	2254	38.99	34.2425	-118.0100	-10.32	A	3.8	M_L	0.12	138	2022072	
1991 JUL 9	0906	11.50	33.4915	-116.4242	-7.35	A	3.7	M_L	0.13	139	2022070	6
1991 JUL 11	1531	24.04	33.7795	-116.9255	-13.08	A	3.2	M_L	0.12	91	2022232	
1991 JUL 16	1844	30.90	32.4181	-115.0415	-6.00	C	3.4	M_L	0.34	21	2022575	
1991 JUL 17	1612	17.85	33.4815	-116.4494	-9.78	A	3.2	M_L	0.14	60	2022683	
1991 JUL 19	0241	36.81	33.2125	-115.9682	-3.10	A	4.0	M_L	0.15	62	697556	8
1991 JUL 22	2329	56.09	33.4989	-120.0776	-6.00	C	3.1	M_{CA}	0.25	12	2023069	
1991 AUG 2	0128	26.73	32.8819	-117.6275	-6.00	C	3.1	M_L	0.36	76	2023828	
1991 AUG 3	0959	49.87	34.0934	-117.3122	-17.28	A	3.5	M_L	0.14	115	698180	
1991 AUG 4	1154	11.84	34.9670	-117.0363	-3.65	A	3.1	M_L	0.19	94	152075	
1991 AUG 6	1434	34.61	32.4235	-115.2544	-15.56	A	3.0	M_L	0.28	28	2025169	
1991 AUG 14	2150	25.58	34.2516	-117.9511	-9.80	A	3.2	M_L	0.09	82	2026766	
1991 AUG 15	1600	0.95	37.0000	-116.0500	0.00	D	4.1	M_L	0.32	23	699182	
1991 AUG 24	0748	0.54	32.4075	-115.3483	-6.00	C	3.0	M_L	0.34	35	2027499	
1991 AUG 26	0602	25.71	36.0447	-118.4095	-9.27	A	3.0	M_{CA}	0.08	36	2027609	
1991 AUG 30	1308	37.50	32.8526	-118.3215	-6.00	C	3.2	M_L	0.13	68	2027964	
1991 SEP 6	2341	5.99	34.8502	-119.2425	-11.67	A	3.2	M_L	0.16	47	2028593	
1991 SEP 7	0511	51.24	32.0347	-116.3748	-6.00	C	3.6	M_L	0.35	38	750112	
1991 SEP 10	0730	3.05	32.4853	-115.2289	-6.00	C	3.2	M_L	0.33	39	2028814	
1991 SEP 10	0746	59.55	32.4885	-115.2280	-6.00	C	3.0	M_L	0.29	36	2028815	

DATE	TIME	LAT	LON	Z	Q	M	TYP	RMS	PH	CUSPID	FM
1991 SEP 10	0818 30.87	32.0437	-116.3753	-6.00	C	3.1	M_L	0.24	14	2028818	
1991 SEP 14	1754 30.60	34.0233	-118.1122	-9.71	A	3.3	M_L	0.14	80	750392	
1991 SEP 15	1549 44.51	32.0537	-114.9727	-6.00	D	3.4	M_L	0.35	17	2029177	
1991 SEP 15	1953 55.35	34.1611	-117.3279	-8.78	A	3.2	M_L	0.12	109	2029203	
1991 SEP 16	1622 57.79	34.6200	-117.3000	0.00	D	3.1	M_{CA}	0.13	5	750462	
1991 SEP 17	2110 28.16	35.8104	-121.4516	-6.00	D	4.8	M_L	0.26	61	2029412	
1991 SEP 17	2114 2.78	35.7002	-121.3030	-6.00	C	3.0	M_{CA}	0.07	13	152611	
1991 SEP 19	1303 54.73	35.7993	-121.4068	-6.00	C	3.1	M_{CA}	0.11	16	2029570	
1991 SEP 23	1455 10.17	35.9840	-118.3558	-5.47	C	3.4	M_L	0.07	47	2029952	
1991 SEP 25	0350 56.77	34.1037	-117.4918	-15.52	A	3.1	M_L	0.11	88	750805	
1991 SEP 26	1429 30.53	33.2651	-116.0191	-2.14	A	3.5	M_L	0.18	73	2030277	
1991 OCT 2	1842 21.37	33.8786	-117.7699	-8.39	A	3.4	M_L	0.13	67	2030758	
1991 OCT 3	0636 47.10	36.1934	-120.0390	-6.00	C	3.3	M_L	0.38	53	2030804	
1991 OCT 6	0416 38.16	35.4506	-118.2766	-3.15	A	3.2	M_L	0.13	93	2031028	
1991 OCT 12	0541 20.19	33.8958	-116.1621	-4.35	A	3.1	M_L	0.09	48	751466	
1991 OCT 12	0833 19.90	32.0276	-115.8415	-50.00	D	3.7	M_{CA}	0.79	25	2031493	
1991 OCT 12	1150 53.14	33.8966	-116.1612	-4.17	A	3.5	M_L	0.10	68	751493	
1991 OCT 12	1439 28.37	33.9443	-116.3235	-50.00	A	3.5	MD	2.09	87	2031528	
1991 OCT 12	1439 32.10	33.8902	-116.1637	-2.90	A	4.0	M_L	0.25	70	751510	9
1991 OCT 12	1444 42.19	33.9717	-116.2179	-50.00	A	3.5	M_{CA}	1.59	78	2031529	
1991 OCT 12	1444 46.70	33.8902	-116.1650	-4.00	A	3.6	M_L	0.10	67	751511	
1991 OCT 12	1445 25.08	33.8914	-116.1651	-3.00	A	3.6	M_L	0.12	13	154356	
1991 OCT 12	1457 49.94	33.8946	-116.1616	-3.80	A	3.1	M_{CA}	0.09	58	751514	
1991 OCT 12	1458 49.96	33.8919	-116.1604	-2.93	A	3.3	M_L	0.18	46	2031531	
1991 OCT 12	1500 44.78	34.0319	-116.1037	-50.00	A	3.0	M_{CA}	1.82	28	2031532	
1991 OCT 12	1521 35.15	33.8936	-116.1605	-3.78	A	3.3	M_L	0.13	61	2031534	
1991 OCT 17	0309 42.18	33.2364	-115.5583	-1.00	C	3.3	M_{CA}	0.08	5	2031894	
1991 OCT 23	1253 5.25	33.4293	-116.4446	-13.24	A	3.7	M_{CA}	0.17	9	2032425	
1991 OCT 25	1419 55.60	35.3608	-117.6586	-12.25	A	3.3	M_{CA}	0.04	20	2032667	
1991 OCT 27	2054 5.78	33.6466	-116.7453	-13.61	A	3.8	M_L	0.23	118	2032895	10
1991 OCT 29	0327 4.45	34.0781	-117.2473	-13.06	A	3.4	M_L	0.21	127	2032999	
1991 OCT 30	1827 40.17	33.2556	-116.3700	-11.17	A	3.2	M_{CA}	0.04	11	2033098	
1991 NOV 1	1404 35.33	32.2815	-115.1701	-6.00	C	3.3	M_L	0.64	23	2033295	
1991 NOV 1	1528 34.80	35.7485	-116.5304	-6.00	C	3.0	M_L	0.27	41	2033299	
1991 NOV 4	0644 30.40	34.0058	-116.6851	-9.04	A	3.0	M_L	0.16	76	2033562	
1991 NOV 8	0300 49.16	36.0806	-120.6337	-4.54	A	3.2	M_L	0.27	38	2033968	
1991 NOV 8	2308 13.73	32.3536	-115.2538	-6.00	C	3.6	M_L	0.63	27	2034077	
1991 NOV 11	0453 27.02	35.6801	-118.4270	-4.15	A	3.4	M_L	0.22	80	2034274	
1991 NOV 13	1356 26.02	36.4135	-117.8582	-6.00	C	3.5	M_L	0.25	35	2034399	
1991 NOV 20	0955 8.79	36.2005	-120.2063	-6.00	C	3.9	M_L	0.30	50	2034972	
1991 NOV 20	1006 45.50	36.1924	-120.2048	-6.00	C	3.5	M_L	0.33	45	2034973	
1991 NOV 20	1009 17.50	36.1857	-120.2108	-6.00	C	3.1	M_L	0.26	27	2034974	
1991 NOV 20	1012 26.46	36.1903	-120.1865	-6.00	C	3.9	M_L	0.44	73	2034975	
1991 NOV 26	1744 47.06	33.4799	-116.4649	-10.75	A	3.4	M_L	0.23	72	2035478	
1991 NOV 30	0645 58.07	36.7233	-116.1872	-6.00	D	3.4	M_L	0.26	15	2035692	

DATE			TIME		LAT	LON	Z	Q	M	TYP	RMS	PH	CUSPID	FM
1991	DEC	3	0221	31.18	32.4112	-118.1493	-6.00	D	3.3	M_L	0.37	57	2035919	
1991	DEC	4	0710	57.59	33.0696	-116.8035	-14.90	A	4.2	M_L	0.28	158	2036037	11
1991	DEC	4	0817	3.51	34.1777	-117.0224	-10.71	A	4.0	M_L	0.21	150	2036038	12
1991	DEC	6	1827	37.75	33.8887	-116.1633	-1.86	A	3.2	M_L	0.20	58	2036263	
1991	DEC	9	0102	36.58	35.7527	-120.6306	-6.00	C	3.2	M_L	0.25	28	2036436	
1991	DEC	20	0319	30.00	35.5317	-117.3747	-7.25	A	3.4	M_L	0.22	72	2037397	
1991	DEC	20	1038	29.38	35.5349	-117.3713	-7.89	A	4.1	M_L	0.21	98	2037403	13
1991	DEC	30	0213	0.72	32.7350	-115.4249	-17.19	A	3.1	M_L	0.25	28	2038270	

Appendix B

Strong-Motion Accelerograph Stations in Southern California

The following stations are operated by the Branch of Engineering Seismology and maintained by the technicians now stationed in the Pasadena office (see the article entitled Strong-Motion Instrumentation Program in Southern California under the Network Operations section). Figure 2 shows a map of the stations.

* station is maintained by personnel other than those in the Pasadena Office

Alhambra		STA.# 482	34.085	118.149
	900 South Fremont			
	Structural Array	CRA-316		
Anza Array				
	Anza Fire Station	STA.# 5160	33.555	116.661
	56560 Highway 371, Ground Site	SMA-1524		
	Cahuilla Valley	STA.# 5241	33.512	116.798
	Lake Riverside Estates			
	Fire Station, Ground Site	SMA-1642		
	Chihuahua Valley	STA.# 5221	33.38	116.68
	Residence, Garage, Ground Site	SMA-2030		
	Cranston Forest Service	STA.# 5157	33.738	116.838
	Fire Station, Ground Site	SMA-1461		
	Garner Valley	STA.#5242	33.616	116.627
	CDF Fire Station, Ground Site	SMA-1992		
	Herkey Creek	STA.# 5043	33.676.	116.680
	County Park, Ground Site	SMA-1474		
	Keenwild Forest Station	STA.# 5232	33.707	116.716
	Heliport, Ground Site	SMA-359		
	Pine Meadows Ranch	STA.# 5223	33.578	116.589
	Mountain Center, Ground Site	SMA-1991		
	Pinyon Flat Observatory	STA.# 5044	33.607	116.453
	Underground Vault	SMA-1493		
	Rarick Springs	STA.# 5230	33.568	116.510
	Ground Station	SMA-1893		
	Red Mountain Ranger Station	STA.# 5224	33.630	116.847
	Fire Lookout Tower, Garage, Ground Site	SMA-2029		
Anza Array (continued)				
	San Jacinto	STA.# 5284	33.821	116.967
	MWD West Portal Tunnel			
	20600 Soboba Road, Ground Station	SMA-1467		
	Tripp Flats	STA.# 5222	33.60	116.74
	36401 Tripp Flats Road	SMA-2031		
	Ground Site	SSA-292		
	Tule Canyon	STA.# 5231	33.47	116.64
	Ground Station	SMA-1895		
*Bombay Beach		STA.# 5271	33.353	115.732
	Fire Station, Ground Site	SMA-5303		

*Bonds Corner			STA.# 5054	32.693 115.338
	Maintenance Shop		SMA-820	
	Maintenance Shop		RFT-156	
	Ground Station		RFT-180	
*Borrego Springs			STA.# 5220	33.210N 116.330
	Scripps Clinic, Ground Site		SMA-1473	
*Brawley			STA.# 5060	32.991N 115.512
	Airport Hanger, Ground Site		SMA-1472	
Brea Dam			STA.# 951	33.889N 117.926
	Crest		SMA-386	
	Left Abutment		SMA-385	
	Downstream		SMA-387	
*Cabazon			STA.# 5073	33.918N 116.782
	Post Office, Ground Site		SMA-1495	
*Calexico			STA.# 5053	32.669 115.492
	Fire Station		SMA-1484	
*Calipatria			STA.# 5061	33.13 115.52
	Fire Station, Ground Site		SMA-1530	
Carbon Canyon Dam			STA.# 108	33.916 117.842
	Crest		SMA-383	
	Right Abutment		SMA-384	
	Left Abutment		SMA-382	
*Collins Valley			STA.# 5046	33.405 116.467
	Ground Station		SMA-1531	
*Copper Basin Dam			STA.# 819	
	Abutment	34.283 114.235	SMA-1047	
	Crest	34.279 114.222	SMA-6700	
Costa Mesa			STA.# 5286	33.658 117.931
	2300 Placenta			
	Ground		SMA-354	
Costa Mesa			STA.# 5287	33.677 117.869
	John Wayne Airport			
	Ground		SMA-2017	
Diemer Filteration Plant			STA.# 698	33.913 117.819
	Plant Basement		SMA-1044	
	Reservoir Roof		SMA-1045	
*El Centro Array				
	#1-Borchard Ranch		STA.# 5056	32.960 115.319
	Ground Site		SMA-1457	
	#2-Feed Mill		STA.# 5115	32.916 115.366
	Ground Station		SMA-587	
	#3-Pine Union School		STA.# 5057	32.894 115.380
	Ground Site		SMA-1529	
	#4-Schafter		STA.# 955	32.864 115.432
	2905 Anderson Road, Ground Station		SMA-1427	
	#5-Gilbert		STA.# 952	32.855 115.466
	2801 James Road, Ground Station		SMA-2339	
	#6-Pitchie		STA.# 5158	32.839 115.487
	551 Huston Road, Ground Station		SMA-1426	

	#7-Imperial Valley College	STA.# 5028	32.829 115.504
	Shop Building, Ground Site	SMA-1526	
	#9-Imperial Vly Irr. Dist.	STA.# 5115	32.794 115.549
	302 Commercial, Ground Site	SMA-1459	
	#10-Hospital	STA.# 412	32.780 115.567
	Ground Site	SMA-3932	
	#11-McCabe School	STA.# 1504	32.752 115.594
	701 McCabe, Ground Site	SMA-1504	
	#12-Meloland Cattle Co.	STA.# 931	32.718 115.637
	907 Brockman Road, Ground Station	SMA-1503	
	#13-Strobel	STA.# 5059	32.709 115.683
	Residence, Ground Site	SMA-1460	
*El Centro Differential Array		STA.# 5165	33.796 115.535
	Recorder Building, Ground Site	SMA-826	
*El Centro		STA.# 464	32.800 115.473
	Meadows Union School, Ground Site	SMA-588	
*El Centro		STA.# 5272	32.708N 115.092
	Midway Well		
	Junction I-8/Hwy 98, Ground Site	SMA-499	
Escondido Power Station		STA.# 5109	33.125 117.117
	1623 W. Mission Road, Ground Site	RFT-209	
*Forest Falls		STA.# 5075	34.088 116.919
	Post Office, Ground Site	SMA-1510	
*Fun Valley		STA.# 5069	33.925 116.389
	Reservoir 361, Ground Site	SMA-1532	
Garvey Reservoir		STA.# 709	
	Crest 34.050 118.114	SMA-6698	
	Abutment 34.048 118.111	SMA-1055	
*Gene Pumping Plant		STA.# 818	34.290 114.171
	Plant Basement	SMA-1049	
*Gene Wash Dam		STA.# 5276	34.300 114.166
	Crest	SMA-6701	
Hawthorne		STA.# 5243	33.896 118.377
	15000 Aviation Blvd. FAA BLDG.	SMA-360	
*Hinds Pumping Plant		STA.# 817	33.71 115.63
	Head Gate House, Ground Site	SMA-1057	
*Holtville		STA.# 5055	32.812 115.377
	Post Office, Ground Site	SMA-1482	
Huntington Beach		STA.#5288	33.697 118.023
	18401 Springdale		
	Ground Site	SMA-1128	
*Imperial Wildlife Refuge		STA.# 5201	33.097 115.530
	Liquefaction Array, Ground Station	CRA-265	
*Iron Mountain Pumping Plant		STA.# 820	34.148 115.122
	Plant Basement	SMA-1058	

Irvine			STA.# 5281	33.656	117.859
	19900 Macarthur Blvd.				
	Structural Array		CRA-318		
	Basement		SMA-4223		
Jensen Filteration Plant			STA.# 655	34.312	118.496
	Admin Building Basement		SMA-259		
	Filter Gen. Room		SMA-6757		
	Reservoir Roof		SMA-6756		
Lake Mathews Dam			STA.# 5163	33.852	117.451
	Dike Toe		SMA-1050		
*Leona Valley			STA.#5029	34.62	118.29
	Fire Station, Ground Site		SMA-1499		
*Littlerock			STA.#5030	34.52	117.99
	Post Office, Ground Site		SMA-1521		
Live Oak Reservoir			STA.# 656		
	Structural Array	34.137 117.753	CRA-225		
	Abutment	34.14 117.750	SMA-258		
*Loma Linda			STA.#129	34.05	117.26
	University Medical Center, Basement		SMA-813		
*Loma Linda			STA.#5229		
	V.A. Hospital				
	Structural Array	34.050 117.249	CRA-230		
	Ground Station, North		SMA-4233		
	Ground Station, South		SMA-4234		
*Lone Pine Canyon			STA.#5034	34.32	117.57
	Clyde Ranch, Ground Site		SMA-1527		
Long Beach			STA.# 5106	33.778	118.118
	V.A. Hospital				
	Basement		SMA-845		
	6th Floor		SMA-809		
	11th Floor		SMA-749		
	Ground Site (USGS)		SMA-1731		
Los Angeles (Bell)			STA.# 5129	33.996	118.162
	Postal Facility				
	5555 Bandini Blvd., Ground Floor		SMA-1295		
Los Angeles (Brentwood)			STA.# 638	34.063	118.463
	V.A. Hospital				
	Building #259, Ground Site		SMA-750		
Los Angeles			STA.# 141	34.118	118.299
	Griffith Observatory, Basement		SMA-3822		
Los Angeles (ACOSTA RES.)			STA.# 5291	34.088	118.201
	981 Montecito Dr., Ground Site		SMA-1418		
Los Angeles			STA.# 5284	34.040	118.445
	1955 1/2 Purdue Ave.				
	Ground		SMA-3914		
	First Level		SMA-2019		
	Third Level		SMA-929		
Los Angeles (Sepulveda)			STA.# 637	34.249	118.478
	V.A. Hospital, Ground Site		SMA-751		
Los Angeles			STA.# 757	34.097	118.478
	Sepulveda Canyon		SMA-1054		

Los Angeles	STA.# 872	34.067	118.248
1111 Sunset Blvd.			
Roof	SMA-1076		
4th Floor	SMA-1075		
Basement	SMA-1074		
Los Angeles (Wadsworth)	STA.# 5082	34.053	118.452 *
V.A. Hospital			
Structure Array*	CRA-233		
Ground Site-North (USGS)	SMA-4980		
Ground Site-South (USGS)	SMA-4979		
Los Angeles	STA.# 5233	34.052	118.263
1100 Wilshire			
Structural Array	CRA-270		
Basement, North-West	SMA-6063		
Basement, North-East	SMA-6064		
Basement, South-East	SMA-6065		
*Lytle Creek	STA.#5283	34.251	117.490
Ground Site	SMA-1488		
Malibu Canyon	STA.# 5080	34.078	118.693
Monte Nido Fire Station, Ground Site	SMA-1453		
*Mecca	STA.#5270	33.572N	116.076
Fire Station, Ground Site	SMA-5302		
*Mentone	STA.#5162	34.067	117.117
Fire Station, Ground Site	SMA-1517		
Mills Filter Plant	STA.# 5275	33.920	117.320
Ground Site	SMA-6695		
*Morongo Valley	STA.#5071	34.048	116.577
Fire Station, Ground Site	SMA-1483		
Morris Dam	STA.# 756	34.173	117.879
Left Abutment	SMA-1051		
Newport Beach	STA.# 5285	33.600	117.866
800 Marguerite, Ground Site	SMA-981		
Newport Beach	STA.# 5246	33.618	117.878
840 Newport Center Drive			
Structural Array	CRA-231		
*North Palm Springs	STA.#5070	33.924	116.543
Post Office, Ground Site	SMA-1456		
Norwalk	STA.# 634	33.917	118.067
12400 Imperial Hwy			
Roof	SMA-418		
Basement	SMA-424		
4th Floor	SMA-425		
Ground Site, North	SMA-419		
Ground Site, South	SMA-823		
Norwalk	STA.# 5239	33.917	118.066 *
12440 Imperial Highway			
Building #43			
Structure Array*	CRA-127		
Structure Array*	CRA-128		
Basement (West)*	SMA-2218		
Ground Site, North	SMA-824		
Ground Site, South	SMA-922		

*Ocotillo Wells				STA.#5050	33.14	116.13
	Burro Bend Cafe, Ground Site			SMA-1486		
Olive Del Ranch				STA.# 5037	34.004	117.223
	Ground Site			SMA-1514		
Orange County Reservoir				STA.# 697		
	Crest	33.936	117.884	SMA-6696		
	Abutment	33.935	117.883	SMA-1046		
*Palmdale				STA.#262	34.58	118.11
	Fire Station, Ground Site			SMA-1458		
Palos Verdes Reservoir				STA.# 710		
	Abut. Chlor. Bldg	33.774	118.321	SMA-1056		
	Crest	33.772	118.319	SMA-6699		
*Parachute Test Site				STA.#5051	32.929	115.700
	Control Building, Ground Site			SMA-1465		
*Parachute Test Site				STA.#5247	32.926	115.695
	Base, Ground Station			SMA-1470		
*Paradise Springs Camp				STA.#5032	34.40	117.80
	Kitchen, Ground Site			SMA-1469		
Pasadena				STA.# 5180	34.149	118.172
	535 S. Wilson Ave.			SMA-553		
				SSA-291		
*Plaster City				STA.# 5052	32.79	115.86
	Storehouse, Ground Site			SMA-1497		
Prado Dam				STA.# 969		
	Crest	33.890	117.641	SMA-389		
	Downstream	33.888	117.640	SMA-381		
	Left Abutment	33.890	117.637	SMA-388		
*Rancho De Anza				STA.# 5047	33.348	116.400
	Ground Site Vault			SMA-1522		
Riverside				STA.# 5235	33.968	117.447
	Santa Ana River Bridge			CRA-310		
	Structural Array (base isolated)			SMA-267		
*Salton Sea				STA.# 5062	33.178	115.615
	Wildlife Refuge			SMA-1471		
	Structural Array (base isolated)			SSA-485		
San Antonio Dam				STA.# 287		
	Crest	34.157	117.676	SMA-476		
	Right Abutment	34.158	117.682	SMA-477		
	Downstream	34.156	117.675	SMA-475		
*San Bernardino Array						
	Devore Water Co.			STA.#5265	34.235	117.407
	Ground Site			SMA-3560		
	East Valley Water District			STA.#5266	34.122	117.158
	Plant #108, Ground Station			SMA-3560		
	Highland Fire Station			STA.#5161	34.136	117.213
	Ground Site			SMA-1476		
	5931 North "F" Street			STA.#5267	34.183	117.295
	Ground Station			SMA-4905		

	Mill Creek Ranger Station			STA.#5076	34.080	117.114
	Ground Site			SMA-116		
	Rialto Fire Station			STA.#5268	34.134	117.368
	Ground Site			SMA-1082		
	San Bernardino Cty. Serv. Bldg.			STA.#5245	34.106	117.287
	385 North Arrowhead Avenue					
	Structural Array			CRA-302		
	Building Ground Floor			SMA-1462		
	Ground Station, East			SMA-4904		
	San Bernardino Vly College			STA.#5269	34.086	117.309
	Ground Station			SMA-1080		
San Diego				STA.# 5116	32.788	117.138
	Mission Power Station, Ground Site			RFT-206		
San Diego				STA.# 5105	32.870	117.230
	V.A. Hospital					
	Structural Array			CRA-305		
	Basement			SMA-603		
San Joaquin Reservoir				STA.# 5257		
	Crest	33.620	117.842	SMA-6697		
	Left Abutment	33.620	117.844	SMA-4222		
Santa Ana				STA.# 281	33.751	117.870
	400 Civic Center Drive, Basement			SMA-3559		
Santa Barbara				STA.# 283	34.423	119.700
	Court House, Basement			SMA-415		
Santa Susana				STA.# 5108		
	ETEC, DOE					
	Ground	34.231	118.713	SMA-1280		
	BLDG.026	34.232	118.710	SMA-1278		
	" 356	34.232	118.711	SMA-1279		
	" 462	34.230	118.712	SMA-1277		
	" "		"	SMA-1276		
	463	34.230	118.713	SMA-1275		
*Seeley				STA.# 5273	32.795	115.691
	Elementary School					
	1800 Rio Vista Avenue, Ground Site			SMA-393		
Skinner Dam				STA.# 720	33.580	117.070
	Structure Array			CRA-232		
	Control Building			SMA-1048		
*Superstition Mountain				STA.# 286		
	Camera Site #8, Grd.	32.955	115.823	SMA-1491		
	Mountain Base	32.962	115.813	SMA-1470		
*Thousand Palms				STA.# 5068	33.82	116.40
	Post Office, Ground Site			SMA-5304		
Topanga				STA.# 5081	34.084	118.599
	Fire Station, Ground Site			SMA-1520		
*Valyermo				STA.# 5031	34.44	117.85
	Forest Station, Ground Site			SMA-1512		
Weymouth Filteration Plant				STA.# 5164	34.115	117.779
	Chemical Building			SMA-1053		
	East Water Tank			SMA-1052		

Whittier		STA.# 804	33.977	118.036
	7215 Bright Ave			
	Basement	SMA-1069		
	5th Level	SMA-1070		
	10th Level	SMA-1071		
Whittier Narrows Dam		STA.# 289		
	Baseyard (Upstream) 34.031 118.054	SMA-376		
	Crest 34.020 118.053	SMA-478		
White Water Trout Farm		STA.# 5072	33.989	116.655
	White Water Canyon	SMA-1463		
Wrightwood Post Office		STA.# 5282	34.360	117.629
	Ground	SMA-2894		

Appendix C

Cumulative Index to Southern California Network Bulletins

Entries for all nine Bulletins published thus far (1985-1991) are included in this cumulative index. Each entry is listed by Bulletin and page number. Bulletins are designated by year and letter as follows:

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86a	January-June 1986	86-590
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88	January-December 1988	90-499
89	January-December 1989	90-483
90	January-December 1990	91-255
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