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EXPLOSION DATA ACQUIRED AT ONSHORE STATIONS DURING THE LOS ANGELES REGION EXPERIMENT (LARSE) 1994

Submitted By

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PASSCAL Data Report 96-020

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

REPORT FOR EXPLOSION DATA ACQUIRED IN THE 1994 LOS ANGELES REGION SEISMIC EXPERIMENT (LARSE 94), LOS ANGELES, CALIFORNIA

BY

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OPEN-FILE REPORT 96-536

1996

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TABLE OF CONTENTS

TABLES

FIGURES

INTRODUCTION

In the fall of 1994, the U.S. Geological Survey (USGS), the Southern California Earthquake Center (SCEC), the Geological Survey of Canada (GSC), and the Incorporated Research Institutes for Seismology (Program for Array Seismic Studies of the Crust And Lithosphere; IRIS/PASSCAL) jointly conducted an active-source seismic-imaging survey in Southern California, known as the Los Angeles Region Seismic Experiment, 1994 (LARSE94). This was the first active-source survey of a multi-year experiment that is intended to characterize the crust in this region of significant earthquake hazard. In 1993, a passive experiment (LARSE93) had been conducted along Line 1 (Kohler and others, 1996). The goal of LARSE94 was to: (1) produce, high-resolution images of the crust and upper mantle of the offshore region, the San Gabriel Mountains, and the northern part of the San Gabriel Valley, and (2) produce lower-resolution, reconnaissance images of the crust and upper mantle under the Los Angeles basin and Mojave Desert combining refraction and reflection techniques from both air-guns offshore and explosions on land. During the first phase of LARSE94 (Fuis and others, 1996), air-gun sources were fired along multiple traverses of the offshore segments of three lines (Fig. 1). The air-guns were recorded by a 4-km-long streamer, 10 ocean-bottom seismographs, and 172 land-based seismographs (Fig. 1, TABLE 1). In the second phase of the experiment, explosions were detonated along the onshore segment of Line 1, from Seal Beach, CA, to a point northwest of Barstow, CA. The explosions were recorded by a stationary array of 649 seismographs assembled from numerous institutions in North America (Fig. 2, TABLE 1). In this report, we will present the onshore explosive-source data from Line 1.

During the second phase of LARSE94, 62 shots were recorded over a three-night period at a 649 separate recording sites. Three quarry explosions were recorded at a smaller number of sites. More than one third of the recording sites were occupied by three-component seismographs. The seismographs included 228 three-component IRIS/PASSCAL, University of Texas at El Paso (UTEP), and SCEC RefTeks, 187 vertical-component Stanford University Seismic Group Recorders (SGR's), 183 GSC vertical-component Portable Refraction Seismographs (PRS1's), 33 Geological Survey of Canada (GSC) three-component Portable Refraction Seismographs (PRS4's), and 18 U.S. Geological Survey three-component General Earthquake Observation Systems (GEOS) (TABLE 1). (See below for a detailed description of these seismic recorders.)

The U.S. Geological Survey and the Southern California Earthquake Center jointly led the planning (since 1992) and the execution (1994) of the experiment. Persons from numerous individual institutions participated in the field (Table 2). Data recovery was about 95 percent.

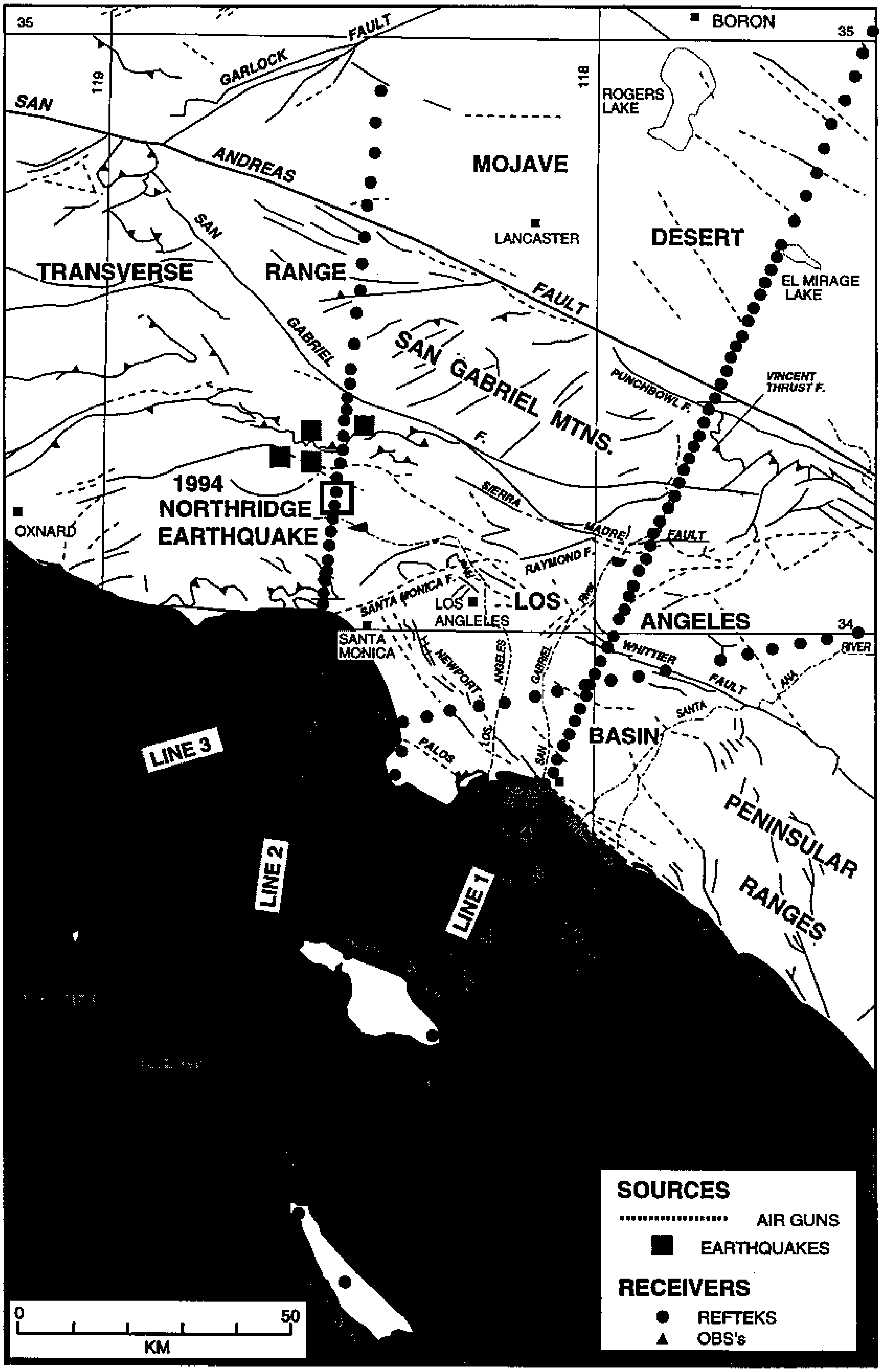


Figure 1. Fault map of the Los Angeles region showing 1) the airgun sources and receivers for LARSE94, and 2) the location of the 1994 Northridge earthquake and four large aftershocks. Faults taken from Jennings (1975).

TABLE 1. Summary of LARSE94 Sources and Receivers

		AIR-GUN SURVEY	EXPLOSION SURVEY
Sources			
	Type	**Air-guns**	**Explosions**
	Provider	LDEO[7]	USGS, SCEC
	Size	20-element, totaling 137.7 l (8370 in ^{3})	**20-2000 kg**
	Number	**25,000**	**62**
Receivers			
	Type	**Streamer**	**Refteks**
	Provider	LDEO	IRIS-PASSCAL, UTEP, SCEC, LANL
	Size or No.	**160-channel, 4.2 km long**	228, 3-component
	Type	**OBS's**	**SGR's**
	Provider	USGS, GSC	Stanford Univ., IRIS-PASSCAL
	No.	10	187, 1-component
	Type	**Refteks**	**PRS1's/PRS4's**
	Provider	IRIS-PASSCAL	GSC
	No.	170, 1-component	183, 1-component/ 33, 3-component
	Type		**GEOS**
	Provider		USGS
	No.		18, 3-component

---

[7] Abbreviations for institutions are: LDEO--Lamont-Doherty Earth Observatory, USGS--U.S. Geological Survey, SCEC--Southern California Earthquake Center, IRIS-PASSCAL--Incorporated Research Institutes in Seismology/Program for Array Seismic Studies of the Continental Lithoshpere, UTEP--University of Texas at El Paso, LANL--Los Alamos National Laboratory, and GSC--Geological Survey of Canada.

Abbreviations for seismographs are: OBS's--ocean-bottom seismographs (generic), SGR's--Seismic Group Recorders III, Refteks--Refraction Technology seismographs, PRS1's/4's--Portable Refraction Systems, GEOS--Geological Earth Observation Systems. See Borcherdt et al. (1985), Murphy et al. (1993), and Brocher et al. (1995) for a description of these seismographs.

TABLE 2

Personnel of the LARSE94 Explosion Survey

Institution	Number of persons
USGS (Including 7 European volunteers from Karlsruhe University, Germany, GeoForschungZentrum, Potsdam, Germany, Milan University, Milan, Italy, and University of Durham, UK)	37
SCEC:	
University of Southern California	9
California Institute of Technology	12
University of California at Los Angeles	14
University of California at Santa Barbara	3
University of Texas at El Paso	10
IRIS/PASSCAL	4
Geological Survey of Canada	3
University of California at Riverside	1
Orange Community College	9
California State University at Long Beach	5
University of Nevada at Reno	1
Other volunteers	8
Total	116

Signal-to-noise ratios were moderate to excellent in the San Gabriel Mountains and Mojave Desert and moderate to poor in the Los Angeles basin. The data have been archived at the IRIS Data Management Center (DMC) in Seattle, Washington, and are available at:

IRIS DMC
1408 NE 45th Street
Seattle, WA 98105
Telephone: (206) 547-0393

A description of the tape format and headers is given below in the Data Processing section.

GEOLOGIC SETTING

Southern California is a geologically complex region. Line 1 was chosen to minimize the effects of 3-D structure of the crust. Line 1 traverses three markedly different regions, including the Los Angeles basin, the central Transverse Ranges (San Gabriel Mountains), and the Mojave Desert (Figs. 1, 2).

The Los Angeles basin occupies a region at the eastern boundary of the (offshore) Continental Borderland, the southern boundary of the Transverse Ranges and the northwestern boundary of the Peninsular ranges. The Los Angeles basin is fault bounded by the Palos Verde, the Santa Monica, Hollywood, Raymond, and Sierra Madre faults, and is juxtaposed the structurally complex northwestern boundary of the Peninsular Ranges. The present day Los Angeles basin began its evolving in late Miocene by subsidence between the right-oblique Whittier and Palos Verde fault zones and the left-oblique Santa Monica fault system (Wright, 1991). Since the mid-Pliocene, deformation has involved southward shortening of the crust and propagation of blind thrusts beneath the basin.

The Newport-Inglewood fault zone, a major internal structure of the basin, was the location of a Magnitude 6.3 earthquake in 1933. Other large earthquakes near Line 1 include the 1987 M5.9 Whittier Narrows earthquake (Hauksson, and others, 1988) and the 1991 M5.8 Sierra Madre earthquake (Hauksson, 1994). The San Gabriel Valley is a sub-basin of the Los Angeles basin and is bounded on the southeast by the Puente Hills and on the north by the San Gabriel Mountains.

The Transverse Ranges are late Cenozoic, east-west trending ranges that resulted from compression across the left-stepping bend in the San Andreas fault and block rotations. Mesozoic plutonic rocks and Precambrian gneissic rocks form the upper-plate in the San Gabriel mountains. The Vincent thrust fault separates these upper-plate rocks

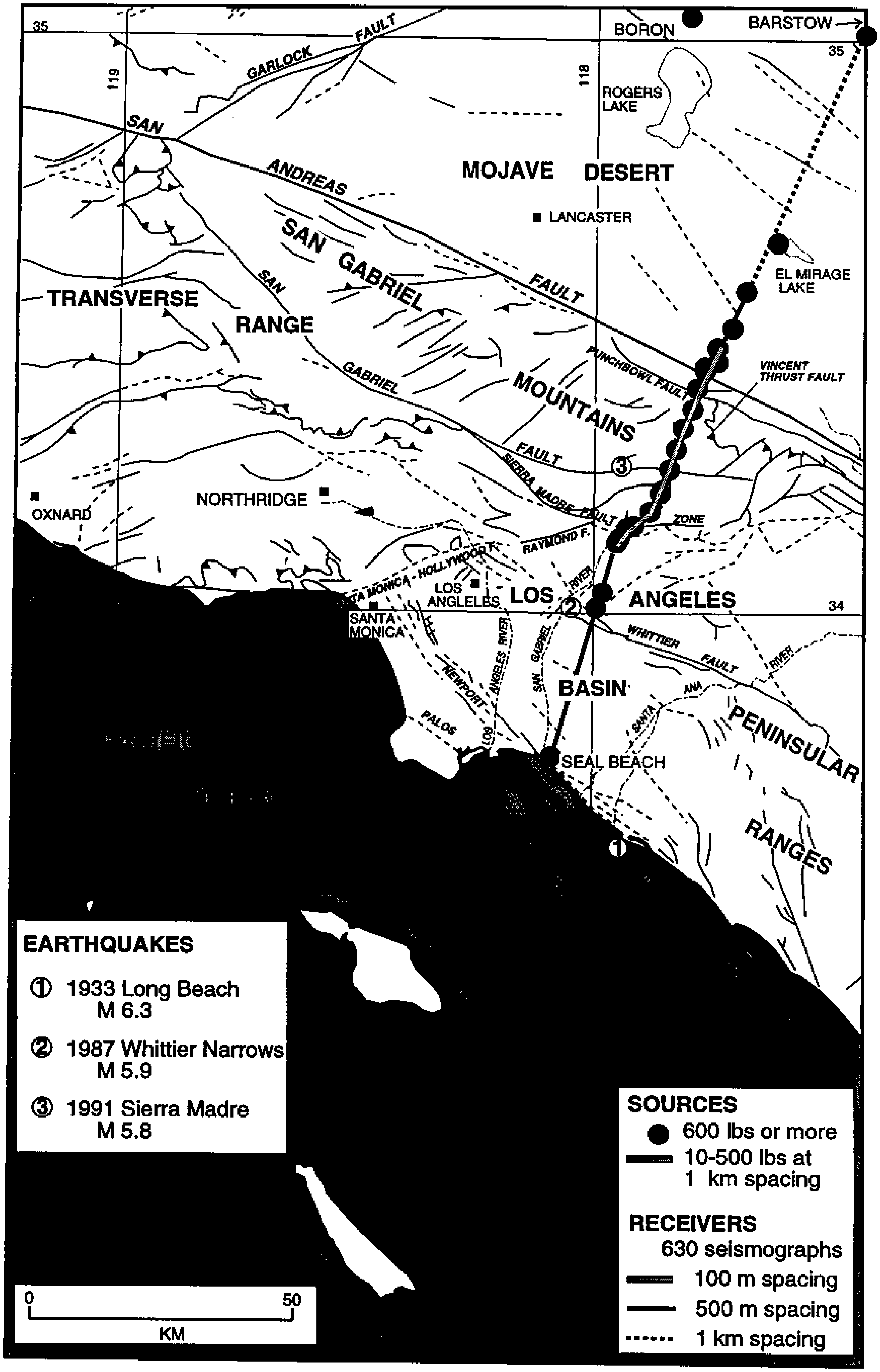


Figure 2. Fault map of the Los Angeles region showing 1) the explosive sources and receivers for LARSE94, and 2) the location of three recent moderate-sized earthquakes. Faults taken from Jennings (1975).

from the lower-plate Pelona schist (Fig. 3D; Jennings, 1977). Catalina greenschists from the Continental Borderland are similar to the Pelona schist (Wright, 1991). However, if and how they are related is not clear.

In the San Gabriel Mountains, north-south shortening is being accommodated by reverse faulting along the southern boundary and broad arching across the interior and northern margin (Ehlig, 1981). The San Gabriel fault, a major internal structural feature and a formerly active strand of the San Andreas fault, experienced 60 kilometers of right-lateral slip during late Miocene and Pliocene (Crowell, 1952). The Punchbowl fault, also an older strand of the San Andreas fault, and the modern trace of the San Andreas fault (which developed to the northeast of the San Gabriel fault, near the northeastern margin of the San Gabriel Mountains (Fig. 3D)), have subsequently offset the North American and Pacific plates by more than 200 km (Powell, 1993).

The Mojave Desert is underlain by topographically low mountains of Mesozoic plutonic and volcanic rocks with minor Paleozoic rocks, separated by basins filled with Tertiary and Quaternary sediments. Rocks in the Mojave Desert are offset by northwest-trending strike-slip faults that have been active in the Quaternary (Fig. 3E).

The main imaging targets of the LARSE94 investigation are the San Andreas fault, the Transverse range frontal fault system (Sierra Madre fault), and blind thrust faults in the Los Angeles basin. Although the San Andreas fault poses the threat of a rare, great earthquake, moderate-sized events that can cause considerable damage have occurred and will occur more frequently in the highly populated areas of metropolitan Los Angeles. In many cases, these moderate-sized earthquakes occur on blind thrusts faults--i.e., thrust faults that are not exposed at the surface (past examples: the 1971 M_L 6.4 San Fernando, the 1987 M5.9 Whittier Narrows, and the 1994 M6.7 Northridge earthquakes). Active-source seismic surveys, such as LARSE94, are one of the best ways to identify blind thrust faults prior to rupture during an earthquake. Unfortunately, as designed, LARSE94 will obtain only a reconnaissance image of the upper crust of most of the Los Angeles basin. Follow-on surveys are required for more detailed imaging.

EXPERIMENT PLANNING AND DESIGN

The 1994 Los Angeles Region Seismic Experiment (LARSE) was conceived by scientists at the USGS in 1991. A internal proposal was submitted to the National Earthquake Hazards Reduction Program (NEHRP) for fiscal year 1992 and seed money was authorized for planning. In 1992, the participation of the Southern California Earthquake Center (SCEC) was assured.

After examining several possible routes, a route extending 160 km from Seal Beach northeastward to a point in the Mojave Desert northwest of Barstow was chosen for Line 1 (Fig. 2). This route had the following scientific and logistical advantages: (1) It traversed a region of Los Angeles that has experienced 3 moderate earthquakes in the past 75 years, the 1933 M6.3 Long Beach earthquake, which ruptured deep parts of the Newport-Inglewood fault zone (Fig. 3B; Richter, 1958), the 1987 M5.9 Whittier Narrows earthquake, which ruptured a part of a blind thrust fault located beneath the Puente Hills and the area to the northwest (Fig. 3B; Hauksson and others, 1988; Davis and others, 1989), and the 1991 M5.8 Sierra Madre earthquake, which ruptured a deep part of the Sierra Madre fault system (Clamshell-Sawpit Canyon fault, Fig. 3D; Hauksson, 1994). (2) Line 1 crossed the region roughly perpendicular to the strikes of most mapped fault (Figs. 2, 3). (3) Line 1 crossed the Los Angeles basin along the San Gabriel river and other waterways that provided access for seismograph locations (Fig. 2). (4) Line 1 crossed areas of the Los Angeles basin that contained enough open space for shotpoints and relatively quiet seismograph locations, including the U.S. Naval Weapons Station at Seal Beach (SP 9450, Fig. 3B), the Puente Hills (SP9160-SP9170, Fig. 3B), and a flood control basin in the northern San Gabriel Valley (SP9000-SP9040, Fig. 3C). (5) Line 1 crossed the San Gabriel Mountains along one of the very few routes accessible by roads.

Obtaining permits for Line 1 was an expensive and lengthy process. In the San Gabriel Mountains, under the jurisdiction of the U.S. Forest Service, each shot point required an environmental assessment, including an archeological and biological study. In the Mojave Desert, under the jurisdiction of the U.S. Bureau of Land Management, each shotpoint, recording site, and the access to these sites required a similar environmental assessment. All persons working in the Mojave Desert were required to attend training sessions on the desert tortoise. In the Los Angeles basin, jurisdictions included numerous local, state, and federal government agencies and private businesses, and a variety of requirements had to be met in permitting shot point and seismograph locations. The permitting process in the Los Angeles basin included addressing city councils and other government bodies, extensive radio, television, and newspaper interviews, and correspondence with numerous individuals and private groups.

The land-based explosion survey of LARSE94 was designed as a combined reflection and refraction imaging experiment, with the reflection part in the center, covering the San Gabriel Valley and the San Gabriel Mountains. Shot points were spaced every kilometer from the flood control basin in the San Gabriel Valley through the San Gabriel Mountains (Figure 3C). In the Mojave Desert and Los Angeles basin, shotpoint spacing was greater, from 5 to 50 kilometers apart (figures 3B and 3E). Seismograph spacing was 100 m through the region of dense shots, from the San Gabriel Valley through the San Gabriel Mountains (shotpoints 9040-8040, Figs. 3C, 3D). In the southern Los Angeles basin and the southern Mojave Desert, seismograph spacing was 500 meters

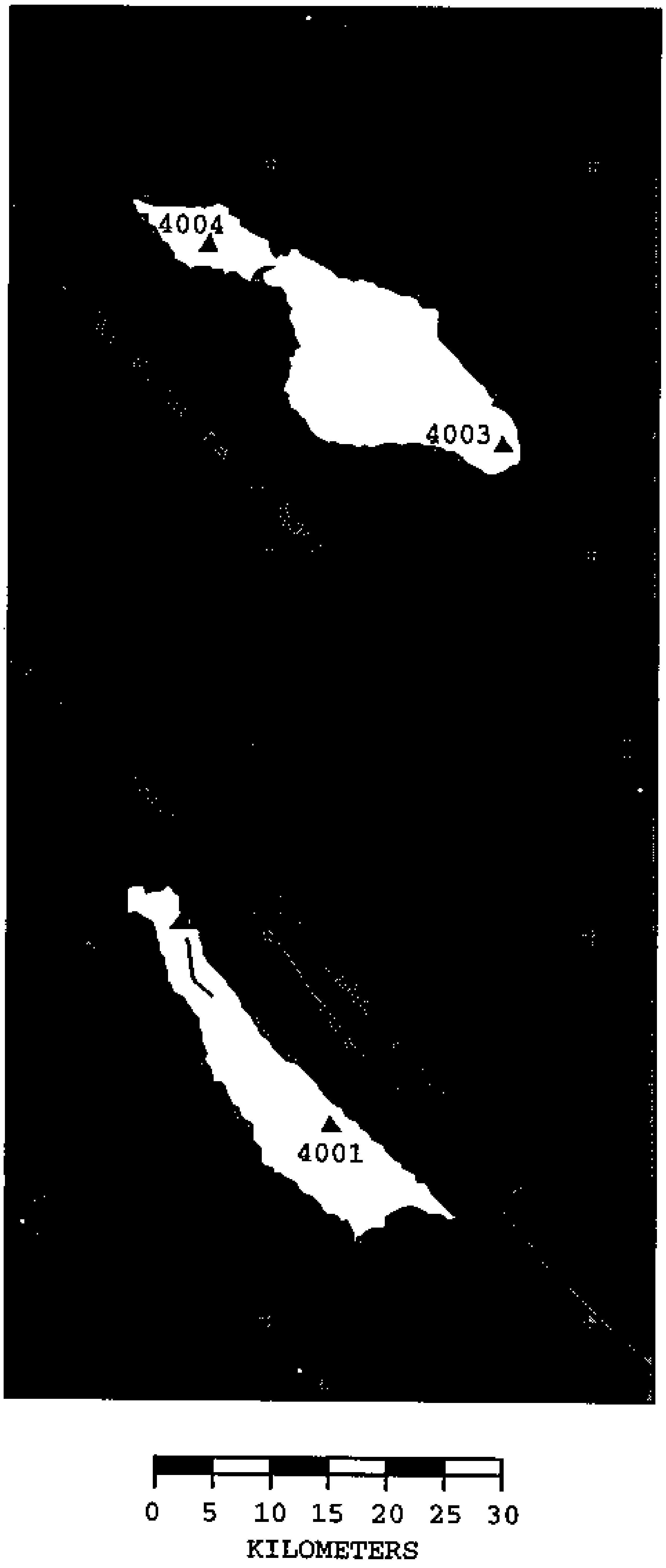


Figure 3A. Fault map showing seismograph sites on San Clemente Island and Santa Catalina Island.

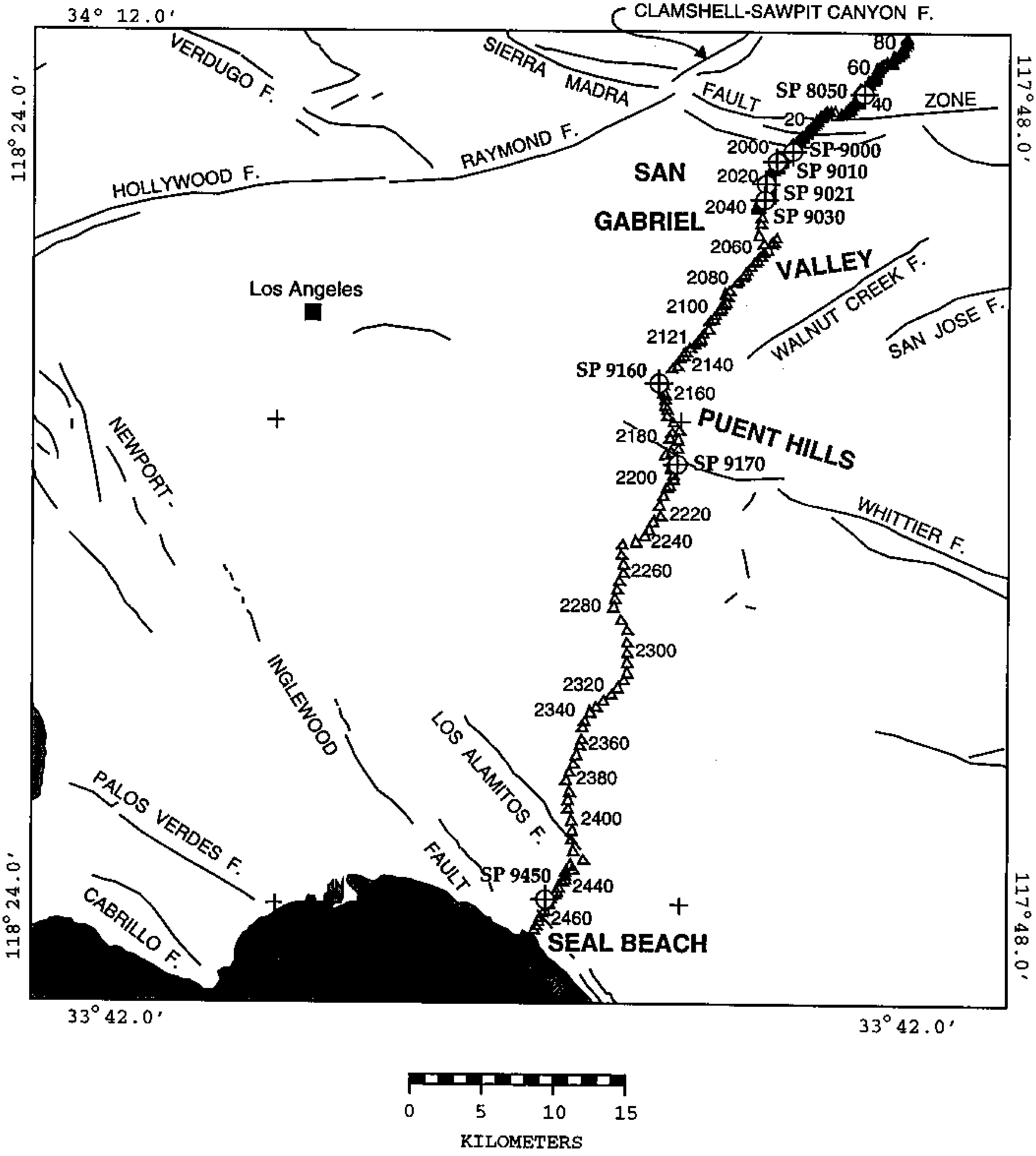


Figure 3B. Fault map showing seismograph sites in the Los Angles basin. Shot points that had more than ~225 kg (500 lbs.) of explosives are shown with crossed circles.

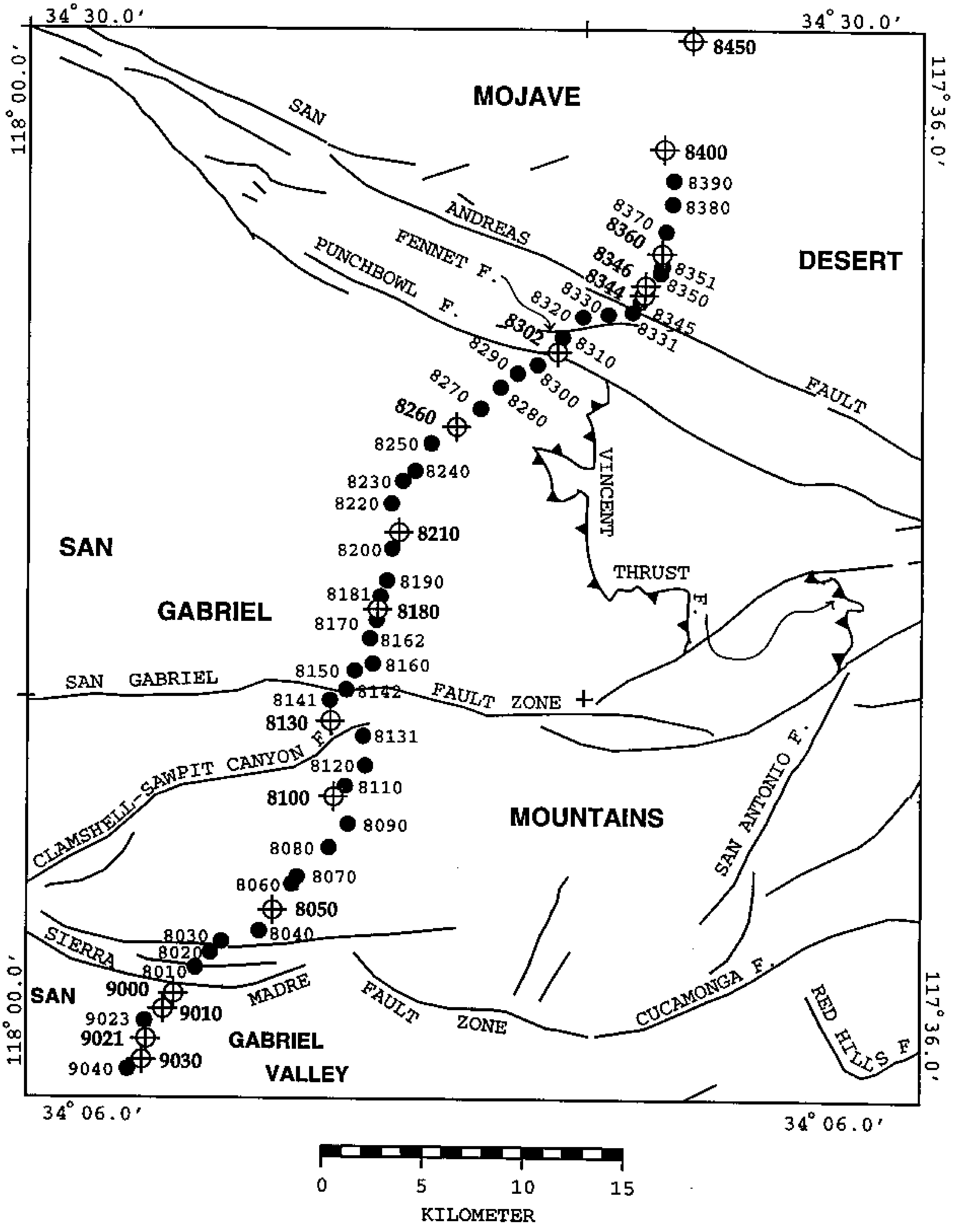


Figure 3C. Fault map showing shot points in the San Gabriel Mountains. Shot points that had more than ~225 kg (500 lbs.) of explosives are shown with crossed circles. Low-yield shots are shown with grey circles.

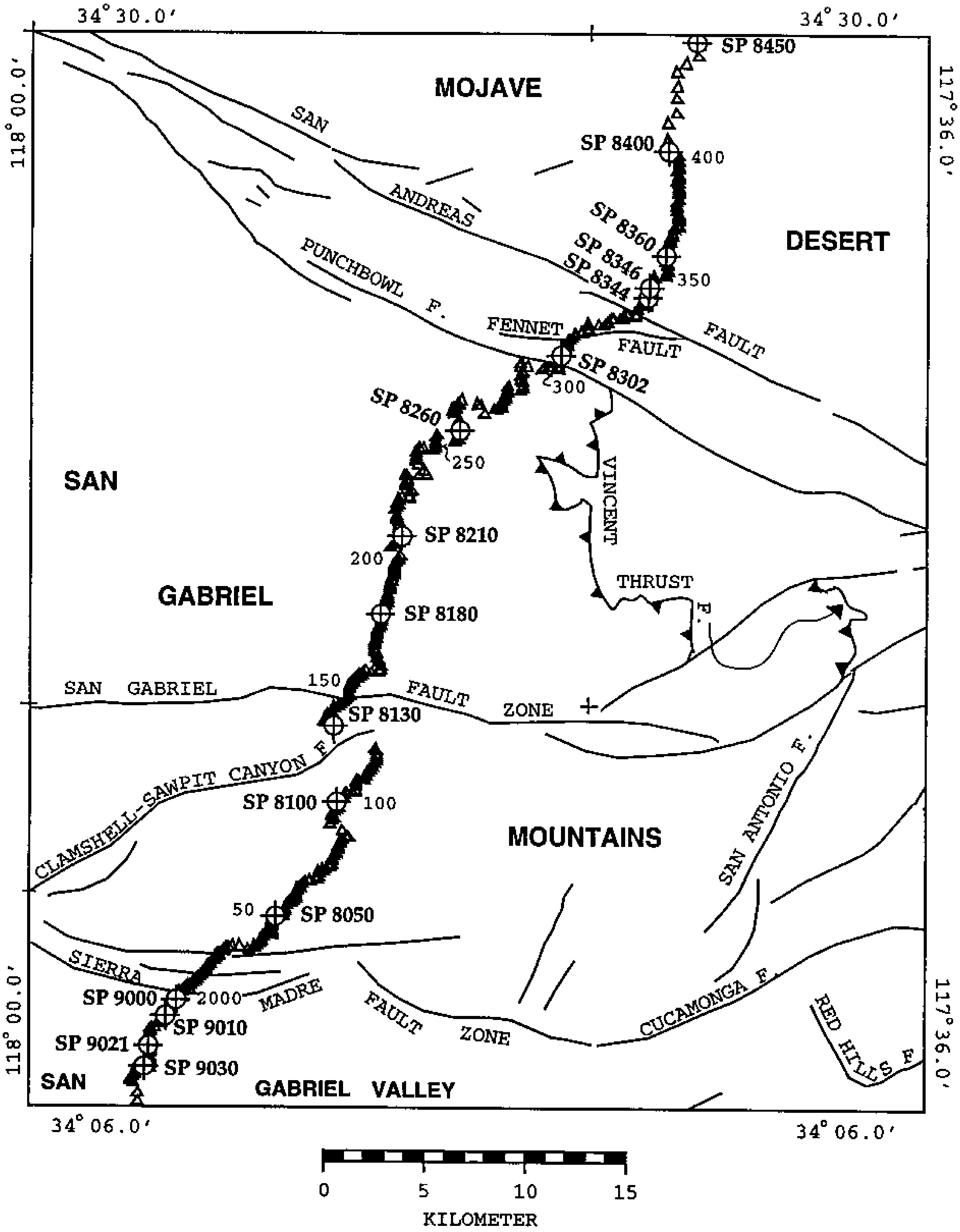


Figure 3D. Fault map showing seismograph sites in the San Gabriel Mountains. Shot points that had more than ~225 kg (500 lbs.) of explosives are shown with crossed circles.

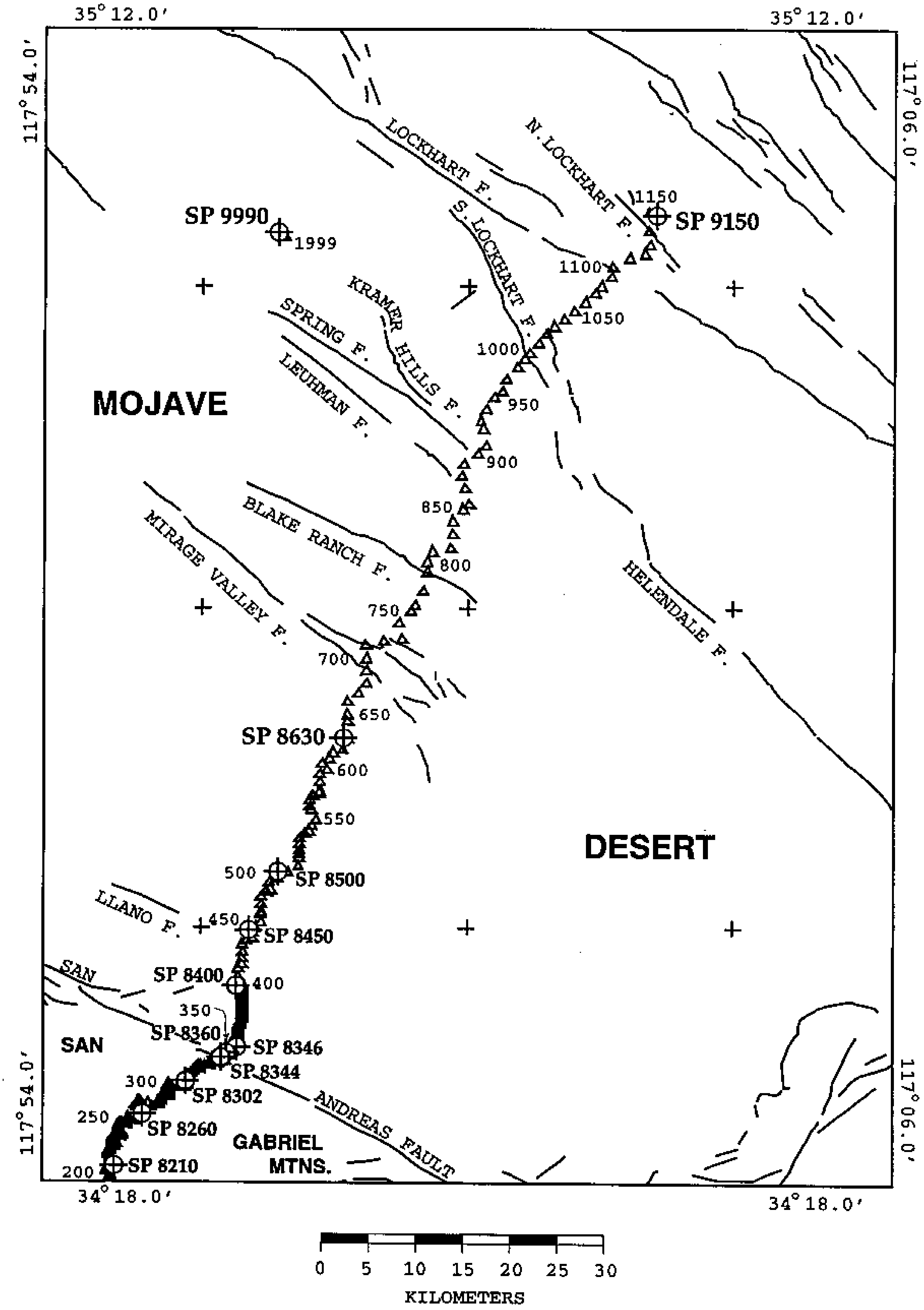


Figure 3E. Fault map showing seismograph sites in the Mojave Desert. Shot points that had more than ~225 kg (500 lbs.) of explosives are shown with crossed circles.

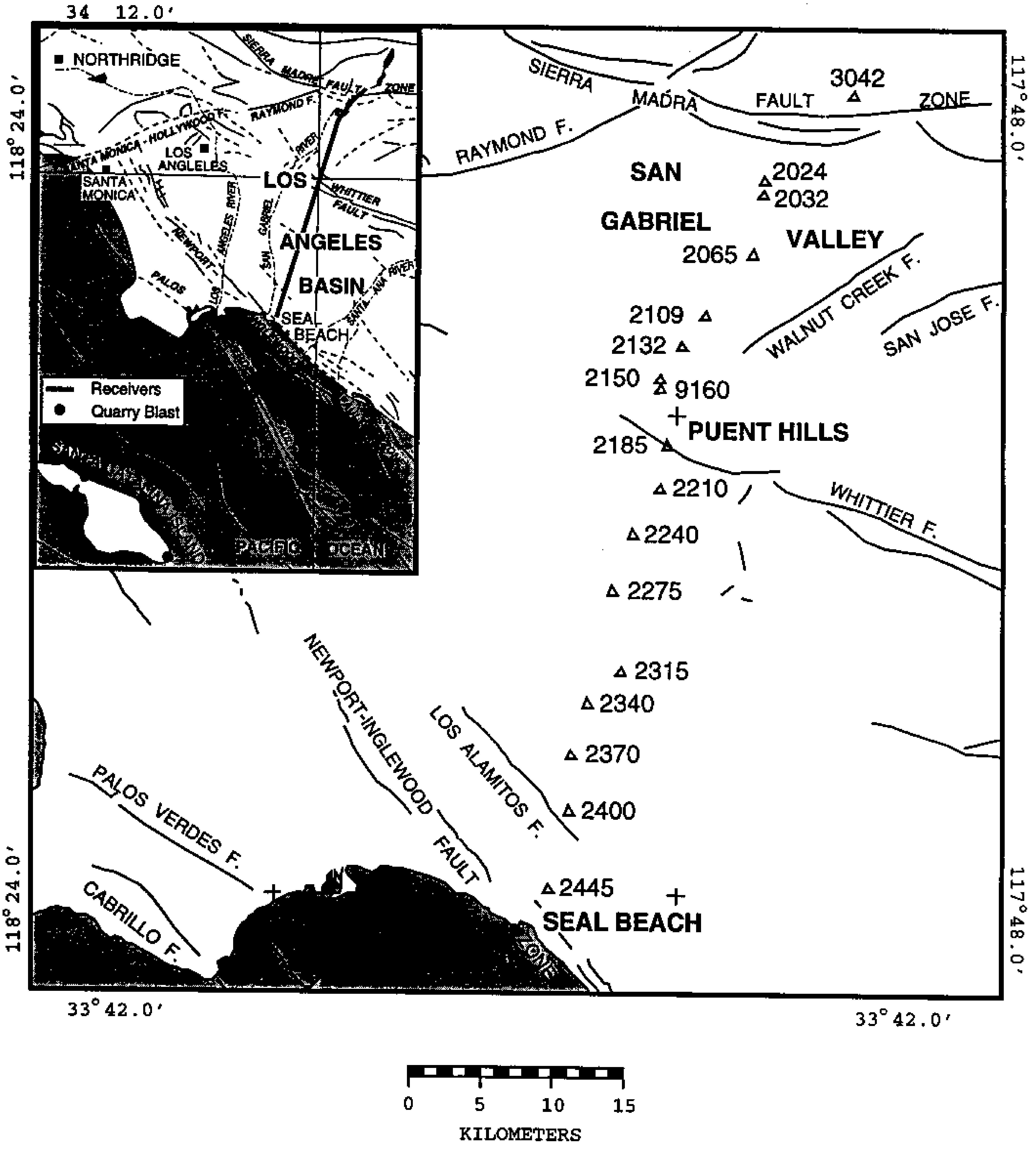


Figure 3F. Fault map showing seismograph sites in the Los Angles basin that recorded the Catilina quarry blast. The inset shows the location of of the blast with respect to the receiver sites.

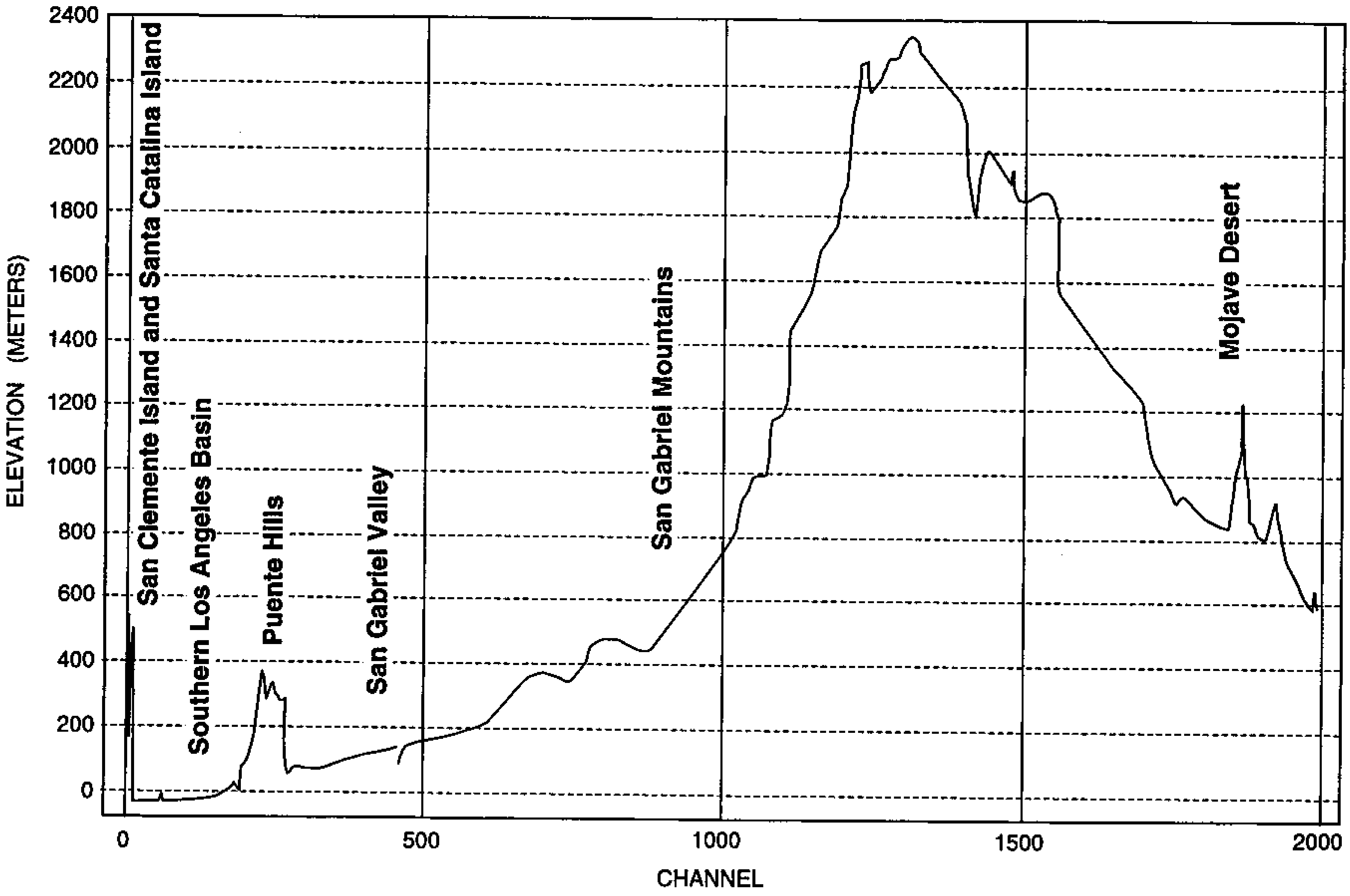


Figure 4. Plot of recording site elevations. Site is given as a channel number. Each seismograph location was assigned 3 channel numbers, which increase northeastward along line 1 from San Clemente Island through the Mojave Desert.

(Fig. 3B). Seismograph spacing was 250m in the northern Los Angeles basin (shotpoints 9170-9040; Fig. 3B) and 1 kilometer in the northern Mojave Desert (north of SP8063; Fig. 3C).

To enhance recording reflections in the central part of the experiment, seismographs with high-frequency response (Refteks, SGR's) were deployed through the northern San Gabriel Valley and San Gabriel Mountains (shotpoints 9170 to 8040, Figs. 3B, 3C). Seismographs in the southern Los Angeles basin and Mojave Desert generally had a lower-frequency response (PRS1's, PRS4's, GEOS) and were more suitable for recording refractions and wide-angle reflections. Thus, of the 160-km profile length (excluding the 4 stations on Santa Catalina and San Clemente Islands, Fig. 3A), a 57-km-length segment was recorded by higher-frequency instruments and is suitable for producing a low-fold, common-midpoint (CMP) stacked section.

In designing the experiment, we used curves relating particle velocity to shot size and distance to determine the maximum amount of explosive that could be detonated at each shot point without damage, perceived or real, at nearby structures (see Kohler and Fuis, 1989, 1992). By using a combination of small and large shots (5-2700 kg), we hoped to obtain both high-frequency vertical-incidence reflections and energy at long offsets for refraction/wide-angle-reflection analysis.

To locate suitable seismograph sites, we conducted noise tests along Line 1. Background noise levels in the Los Angeles basin range from 24dB (relatively quiet) to 42 dB (unacceptably noisy, usually near freeways or major throughfares), with an average around 36dB. For comparison, quiet sites in the San Gabriel Mountains and Mojave Desert had noises levels around 6dB.

Recording sites were selected along the edge of fenced drainage canals, highways, and other roads, where possible. In some areas, home owners and private companies granted permission to record on their property. In many cases, security for the seismographs required complete burial of the recorder and batteries.

Locations for the recording sites and shot points were obtained using a Global Positioning Satellite navigation system (GPS; the Trimble Navigation Pathfinder). These locations (Apendix B) are estimated to be accurate to within ±5 meters horizontally and ±10 meters vertically. The GPS coordinates given in longitude and latitude were converted to Universal Transverse Mercator (UTM) coordinates (zone 11) using an algorithm by Okaya and others (1996a).

Drill-hole shotpoints consisted of a 20-cm-diameter drill hole filled with an ammonium-nitrate-based blasting agent, boosters, and detonating cord. The amount of explosive and the depth to the top of the charge for each shot point are listed in TABLE 3, as well as the depth to any standing water in the holes. Shot crews used signals from a master clocks and shooting systems designed by the USGS to fire an electric blasting cap, which in turn detonated the cord, boosters, and blasting agent. The shot times reported in TABLE 3 are generally master-clock trigger times; delays for the caps, detonation cord, boosters, and blasting agent, which explode at ~5.5-6.0 km/s, are ignored. Master clocks generally drift less than 1 millisecond per week. However, during this experiment some master clocks had larger errors, and, in a few cases, quit or failed to generate a proper trigger, necessitating a manual firing sequence. In some manual firing sequences, where the clock was still running, shot times could be inferred from a strip-chart record displaying simultaneously the master-clock time code and the cap break. In other cases, where the clock quit, shot time had to be inferred from the "uphole time" or arrival time at the nearest seismograph corrected for shot-receiver distance using a known or assumed velocity (see "Comments" column, TABLE 3). The quarry blasts at Boron mine and on Santa Catalina Island were timed using the arrival time recorded at an onsite seismograph, corrected for shot-receiver distance using a known or assumed velocity. Differences between "nominal shot times and actual shot times were written to the headers of all seismograms (see Data Processing section below).

EXPERIMENT SCHEDULE

The LARSE field experiment began in August, 1994. One field crew supervised shot hole drilling and loading and several survey parties staked, flagged, and logged recording sites. Personnel and instruments were assembled from numerous institutions in early October, and instrumentation was tested. The air-gun survey (Fig. 1) was conducted from October 13-20. Eight scientists from the USGS and SCEC supervised the marine part of the air-gun survey aboard the *R/V Ewing* (see Brocher et al., 1995). Two USGS scientists deployed ocean bottom seismographs from the deck ofthe *Yellowfin* (see tenBrink et al., 1996), and a number of scientists, technicians, and students from the USGS, SCEC, and other institutions (TABLE 2) deployed and maintained 170 continuously recording Reftek seismographs on land (Lines 1, 2, and 3, Fig. 1; Okaya et al., 1996a, 1996b).

The land-based explosion survey (Fig. 2) was conducted during the period of October 25-28, when approximately 110 scientists, technicians, and students from a number of institutions (TABLE 2) deployed and maintained 640 seismographs along Line 1 (TABLE 1) and detonated 62 shots during the 3-night period (TABLE 3). In addition, for two days during the land-based survey, 228 Reftek seismographs, dispersed throughout Line 1 in the San Gabriel Mountains and San Gabriel Valley, recorded quarry blasts at Boron Mine, in the Mojave Desert. Following the explosion survey, a cleanup crew returned shotpoint sites to their former conditions.

TABLE 3. SHOT LIST

SHOT POINT ORDER	ORIGINAL SHOT POINT NUMBER	NEW SHOT POINT NUMBER	LATITUDE		LONGITUDE		ALTI TUDE	SHOT TIME ORDER	NOMINAL SHOT TIME jjj:hh:mm:ss	ACTUAL SHOT TIME (CAP BREAK) jjj:hh:mm:ss	COMMENTS	TEAM	TOTAL DEPTH (FT)	SIZE OF EXPLOSIVE (KG)	DEPTH TO TOP OF EXPLOSIVE (FT)	SITE GEOLOGY AND WATER SATURATION (DURING DRILLING/LOADING)	DEPTH TO TOP OF WATER (DURING DRILLING/LOADING)
1	245	9450	33	45.17076	-118	4.85232	-31	60	301:10:10	301:10:10:02.725	range. Estimated error ±0.025 s.	Criley /Kaderabek	113	408	97	Alluvium (wet)	60/15
2	217	9170	33	58.73382	-118	0.33006	142	59	301:10:08	301:10:08:00.000	Oil at 50 ft in hole	Benz /Bursiaga	74	272	64	ne (dry of water but oil at 50 ft)	
3	216	9160	34	0.78552	-118	0.6738	283	63	301:10:16	301:10:16	No strip chart with time code	Luetgert /Keller	100	399	85	Siltstone/sandstone (dry?)	?
4	204	9040	34	6.82112	-117	57.32348	109	53	301:08:42	301:08:42:00.000	clock; cap break agrees with shooting clock minute mark	Croker /Underwood	79	86	76	Alluvium (dry)	
5	203B	9030	34	6.85044	-117	56.95218	109	61	301:10:12	301:10:12:00.000		Croker /Underwood	140	680	114	Alluvium (dry)	
6	202A	9021	34	7.30662	-117	56.835	116	58	301:10:06	301:10:06:00.000		Laird /Rutledge	100	340	87	Alluvium (dry)	
7	202C	9023	34	7.71492	-117	56.85426	131	52	301:08:36	301:08:36:00.000		Laird /Rutledge	79	181	72	Alluvium (dry)	
8	201	9010	34	7.99074	-117	56.35758	86	57	301:10:04	301:10:04:00.000	Shooting clock frozen; master clock used; ok	Burdette /Benz	100	454	83	Alluvium (dry)	
9	200	9000	34	8.3352	-117	56.10216	145	51	301:08:34	301:08:34:00.000		Burdette /Benz	74	408	56	Alluvium (dry)	
10	1	8010	34	8.925	-117	55.50384	167	64	301:11:32	301:11:32:00.000		McCleam /Farrell	71	23	70	Alluvium (wet)	63
11	2	8020	34	9.25344	-117	55.12392	180	56	301:10:02	301:10:02:00.000		McCleam /Farrell	69	227	60	Alluvium (dry)	
12	3	8030	34	9.49698	-117	54.80346	198	50	301:08:32	301:08:32:00.000		McCleam /Farrell	59	9	59	Alluvium (wet)	46
13	4	8040	34	9.73872	-117	53.81976	218	55	301:10:00	301:10:00:00.000		Reneau /Meyer	71	7	71	Hard rock (wet)	55
14	5	8050	34	10.20012	-117	53.43066	234	49	301:08:30	301:08:30:00.000		Reneau /Meyer	104	544	83	Hard rock (wet)	20
15	6	8060	34	10.7991	-117	52.91472	362	54	301:08:44	301:08:44:00.000		Jenson /Fisher	76	5	76	Hard rock (wet)	45
16	7	8070	34	10.9767	-117	52.7829	351	62	301:10:14	301:10:14:00.000		/Fisher	76	5	76	Hard rock (dry)	
17	8	8080	34	11.62332	-117	51.93972	350	47	300:11:46	300:11:46	No strip chart with time code	Jenson /Fisher	75	113	71	Hard rock (wet)	45
18	9	8090	34	12.13578	-117	51.41604	330	38	300:10:16	300:10:16	No strip chart with time code	Jenson /Fisher	85	227	76	Hard rock (wet)	45/30
19	10	8100	34	12.75924	-117	51.82848	472	29	300:08:46	300:08:46	No strip chart with time code	Jenson /Fisher	112	454	95	Hard rock (dry/wet)	. . /98
20	11	8110	34	13.01652	-117	51.49932	481	46	300:11:44	300:11:44:00.000	Cut off time slip	McCleam /Farrell	65	113	61	Hard rock (wet)	45
21	12	8120	34	13.48434	-117	50.93814	431	37	300:10:14	300:10:14:00.000		McCleam /Farrell	61	113	57	Alluvium (dry); well cemented	
22	13A	8131	34	14.13804	-117	51.0315	427	28	300:08:44	300:08:44:00.000		McCleam /Farrell	85	227	76	Hard rock (wet)	75

TABLE 3. SHOT LIST

SHOT POINT ORDER	ORIGINAL SHOT POINT NUMBER	NEW SHOT POINT NUMBER	LATITUDE		LONGITUDE		ALTITUDE	SHOT TIME ORDER	NOMINAL SHOT TIME jjj:hh:mm:ss	ACTUAL SHOT TIME (CAP BREAK) jjj:hh:mm:ss	COMMENTS	TEAM	TOTAL DEPTH (FT)	SIZE OF EXPLOSIVE (KG)	DEPTH TO TOP OF EXPLOSIVE (FT)	SITE GEOLOGY AND WATER SATURATION (DURING DRILLING/LOADING)	DEPTH TO TOP OF WATER (DURING DRILLING/ LOADING)
23	13	8130	34	14.4603	-117	51.89436	463	45	300:11:42	300:11:42	No strip chart with time code	Mooney /Ren	104	454	87	Hard rock (wet)	76
24	14A	8141	34	14.93592	-117	51.83192	498	36	300:10:12	300:10:12	No strip chart with time code	Mooney /Ren	75	113	71	Hard rock (dry?)	?
25	14B	8142	34	15.15954	-117	51.48654	529	27	300:08:42	300:08:42	No strip chart with time code	Mooney /Ren	60	9	60	Alluvium (wet)	35
26	15	8150	34	15.60564	-117	51.23838	594	44	300:11:40	300:11:40	No strip chart with time code	Croker /Underwood	71	113	67	Hard rock (dry)	
27	16	8160	34	15.75942	-117	50.75592	673	35	300:10:10	300:10:10	No strip chart with time code	Croker /Underwood	59	113	55	Debri flow; well cemented (dry)	
28	16B	8162	34	16.30554	-117	50.83422	726	26	300:08:40	300:08:40	No strip chart with time code	Croker /Underwood	65	113	61	Alluvium (wet)	51
29	17	8170	34	16.7379	-117	50.66298	791	43	300:11:38	300:11:38	master clock that was 2 ms off next day	Burdette /Benz	80	227	71	Alluvium (wet)	40
30	18	8180	34	16.99014	-117	50.63874	921	34	300:10:08	300:10:08	master clock that was 2 ms off next day	Burdette /Benz	109	454	92	Hard rock? (dry)	
31	18A	8181	34	17.25564	-117	50.54304	975	25	300:08:38	300:08:38:00.000		Burdette /Benz	60	113	56	Hard rock (dry)	
32	19D	8190	34	17.61522	-117	50.403	992	42	300:11:36	300:11:36:00.000		Luetgert /Dres	80	91	77	Hard rock (wet)	33
33	20C	8200	34	18.32568	-117	50.26704	1319	33	300:10:06	300:10:06:00.000		Luetgert /Dres	61	23	60	Hard rock (dry)	
34	21B	8210	34	18.7152	-117	50.0661	1496	24	300:08:36	300:08:36:00.000		Luetgert /Dres	73 + 81	454	53 + 61	Hard rock (wet)	ave 42
35	22	8220	34	19.35354	-117	50.28078	1685	41	300:11:34	300:11:34:00.000		Laird /Rutledge	83	113	73	soft matrix; (dry/wet)	. /79
36	23A	8230	34	19.86852	-117	49.97178	1824	32	300:10:04	300:10:04:00.000		Laird /Rutledge	77	181	70	Hard rock (wet)	50
37	24A	8240	34	20.07888	-117	49.63164	1986	23	300:08:34	300:08:34:00.000		Laird /Rutledge	84	113	80	Hard rock (dry/wet)	. . /73
38	25	8250	34	20.70534	-117	49.21008	2202	40	300:11:32	300:11:32:00.125	Manual fire	Reneau /Meyer	74	113	70	Hard rock (wet)	43
39	26	8260	34	21.07152	-117	48.53166	2285	31	300:10:02	300:10:02:00.000		Reneau /Meyer	113	318	101	Hard rock (wet)	59
40	27	8270	34	21.48402	-117	47.91048	2323	22	300:08:32	300:08:32:00.000		Reneau /Meyer	74	113	70	Hard rock (dry)	
41	28A	8280	34	21.939	-117	47.34834	2248	39	300:11:30	300:11:30:00.015	interpolated to be 15.4 ms late at shot	VanSchaack /Criley	76	113	72	Hard rock (dry)	
42	29A	8290	34	22.28898	-117	46.91208	2184	30	300:10:00	300:10:00:02.893	Manual fire. Fired off master clock interpolated to be 14.6 ms late at shot	VanSchaack /Criley	75	113	71	Hard rock (dry)	
43	30	8300	34	22.48194	-117	46.36596	2101	21	300:08:30	300:08:30:00.014	interpolated to be 13.8 ms late at shot	VanSchaack /Criley	76	113	72	Hard rock (dry)	
44	30B	8302	34	22.74786	-117	45.84048	1803	15	299:10:14	299:10:14:00.000		Croker /Underwood	145	907	110	Alluvium (dry/wet)	. /90

TABLE 3. SHOT LIST

SHOT POINT ORDER	ORIGINAL SHOT POINT NUMBER	NEW SHOT POINT NUMBER	LATITUDE		LONGITUDE		ALTI TUDE	SHOT TIME ORDER	NOMINAL SHOT TIME jjj:hh:mm:ss	ACTUAL SHOT TIME (CAP BREAK) jjj:hh:mm:ss	COMMENTS	TEAM	TOTAL DEPTH (FT)	SIZE OF EXPLOSIVE (KG)	DEPTH TO TOP OF EXPLOSIVE (FT)	SITE GEOLOGY AND WATER SATURATION (DURING DRILLING/LOADING)	DEPTH TO TOP OF WATER (DURING DRILLING/ LOADING)
45	31	8310	34	23.07954	-117	45.67752	2000	7	299:08:44	299:08:44	No strip chart with time code	Croker /Underwood	76	113	72	Hard rock (wet/dry)	70/. .
46	32	8320	34	23.54394	-117	45.12408	1917	19	299:11:42	299:11:41:59.932	Manual fire	VanSchaack /Criley	76	113	72	Hard rock (wet/dry)	55/. .
47	33	8330	34	23.6172	-117	44.46486	1862	14	299:10:12	299:10:11:59.313	Manual fire;10:42 written on strip chart; master clock 3	VanSchaack /Criley	70	113	66	Hard rock (wet)	38/22
48	33A	8331	34	23.66202	-117	43.81578	1855	6	299:08:42	299:08:42:00.018	Manual fire; master clock 3 (type 1)	VanSchaack /Criley	75	113	71	Hard rock (wet)	40
49	34E	8345	34	23.90256	-117	43.59102	1657	18	299:11:40	299:11:40:00.000		Kaderabek /Cartwright	68	23	67	Hard rock (wet)	48
50	34D	8344	34	24.06168	-117	43.4862	1866	13	299:10:10	299:10:10:00.000		Kaderabek /Cartwright	90	408	74	Hard rock (wet)	60
51	34F	8346	34	24.2832	-117	43.50174	1853	5	299:08:40	299:08:40:00.000		Kaderabek /Cartwright	145	998	107	Alluvium?;well cemented; (wet)	90
52	35	8350	34	24.54984	-117	43.05498	1587	17	299:11:38	299:11:38:00.000		McCleam /Farrell	76	227	67	Hard rock (wet)	52
53	35A	8351	34	24.70026	-117	43.04034	1548	12	299:10:08	299:10:08:00.000		McCleam /Farrell	75	227	66	Hard rock (wet)	38
54	36	8360	34	24.96918	-117	43.02246	1511	4	299:08:38	299:08:38:00.000		McCleam /Farrell	101	454	84	Hard rock (wet)	34
55	37	8370	34	25.46838	-117	42.92724	1458	16	299:11:36	299:11:36:00.000		Reneau /Meyer	78	7	78	Hard rock (dry)	
56	38A	8380	34	26.0937	-117	42.76062	1369	11	299:10:06	299:10:06	chart record ok at 299:09:10	Reneau /Meyer	74	113	70	Sandstone (dry)	
57	39	8390	34	26.63202	-117	42.71988	1286	3	299:08:36	299:08:36	No strip chart; test strip chart record ok at 299:07:52	Reneau /Meyer	76; belled	68	75	Sandstone (dry)	
58	40	8400	34	27.3129	-117	42.98766	1221	10	299:10:04	299:10:04:00.000		Laird /Rutledge	136	680	110	Sandstone (dry)	
59	45	8450	34	29.7567	-117	42.23832	1013	2	299:08:34	299:08:34:00.000		Laird /Rutledge	150	680	124	Hard rock? (dry)	
60	50	8500	34	32.52456	-117	40.85724	916	9	299:10:02	299:10:02:00.000		Burdette /Benz	150	907	115	Hard rock? (dry)	
61	63	8630	34	38.76114	-117	36.83808	827	1	299:08:32	299:08:32:00.000		Burdette /Benz	156	907	121	Playa mudstone? (dry)	
62	115	9150	35	3.42408	-117	19.85736	590	8	299:10:00	299:10:00	Tamp sank 20-30 feet in one hole after loading; third hole drilled to compensate	Criley /Whitelaw	132 + 149 + 143	2,722	52 + 89 + 63	Playa mudstone (dry)	

TABLE 3. SHOT LIST

SHOT POINT ORDER	ORIGINAL SHOT POINT NUMBER	NEW SHOT POINT NUMBER	LATITUDE		LONGITUDE		ALTI TUDE	SHOT TIME ORDER	NOMINAL SHOT TIME jjj:hh:mm:ss	ACTUAL SHOT TIME (CAP BREAK) jjj:hh:mm:ss	COMMENTS	TEAM	TOTAL DEPTH (FT)	SIZE OF EXPLOSIVE (KG)	DEPTH TO TOP OF EXPLOSIVE (FT)	SITE GEOLOGY AND WATER SATURATION (DURING DRILLING/LOADING)	DEPTH TO TOP OF WATER (DURING DRILLING/ LOADING)
63	Boron	9990	35	2.41584	-117	40.50384	639	20	299:22:00	299:22:03:59.263	±0.005, calculated assuming 40 m to explosive pattern & 3 km/s local velocity. 40 holes with 600 lbs each; arranged into 5 lines;100 ms delay between each line	Koperwhats		10,886		Evaporite (borate) (dry)	
64	Boron	9991	35	2.41584	-117	40.50384	639	48	300:22:00	300:22:01:43.514	±0.005, calculated assuming 25 m to explosive pattern & 3 km/s local velocity	Koperwhats		10,886		Evaporite (borate)(dry)	
65	Santa Catalina Island	9992	33	18.76052	-117	18.36345	40	65	143:19:00	143:19:00:3.88	±0.06, time checked with RefTeks approximately 300 meters from blast pattern	Michnick		85,195		Catalina schist	

In addition to data acquisition in October 1994, a blast at the south end of Santa Catalina Island was recorded by 19 Refteks on May 23, 1995. Two Refteks at the quarry site were used to infer the origin time and, using internal GPS receivers, the location of the blast. 85,195 kg of ammonium nitrate/diesel-fuel mix was detonated simultaneously in an adit, producing a seismic event with a local magnitude of $M_L 2.97$. Receivers were only deployed in the Los Angeles basin and San Gabreil Valley to record the blast. Unfortunately the blast occurred at noon, a noisy time in the Los Angeles basin. Nevertheless, some signal can be discerned from recorders in the Los Angeles basin.

SEISMIC ACQUISITION SYSTEMS

Four different types of seismographs were used to acquire seismic data during LARSE94: GSC PRS's, Stanford SGR III's, RefTeks from IRIS/PASSCAL and other sources, and USGS GEOS (Table 1). A general description of each is given here, but for more detailed descriptions see Asudeh and others (1992) for the GSC PRSs, the SGR II seismic group recorder field system technical manual, by Globe Universal Sciences, Inc., and L-10 geophone specifications, by Mark Products, for the Stanford SGR III's, and Borcherdt and others (1985) for the GEOS.

Two models of PRS's were used, the single-channel PRS1 and the three-channel PRS4. Both instruments are designed similarly. Mark Products L4C, 2-Hz vertical component geophones were used with the PRS1 and 3-component L4C, 2-Hz geophones were used with the PRS4. Automatic gain-ranging from 1 to 1024 in binary steps allows a total dynamic range for these instruments of 132 dB. Seismic data are sampled at 120 samples per second (8.33 ms) by a 12-bit A/D converter and stored in memory (DRAM) until the data are transferred ("uploaded") to a PC. Phase and amplitude response curves for the overall system are shown in Figures 5C and 6B, respectively. The amplitude response peaks between 5 and 6 Hz. For each unit, timing is provided by a temperature-compensated oscillator (TCXO) that is synchronized to satellite time during the programming ("downloading") process. After retrieval of the recorders, the clock drift is measured and a clock correction is made assuming a linear drift rate. Most clocks drift less than 20 milliseconds during a 24-hour period. The PRS instruments were designed by the Geological Survey of Canada and built by EDA Instruments Ltd.

The SGR III is a single-channel, digital seismic recorder with a theoretical dynamic range of 156 dB. Data are sampled at 500 samples per second (2 ms) by a 12 bit A/D converter with gain ranging from 0-90 dB in 6 dB steps. The SGR's have been modified to turn on at preset

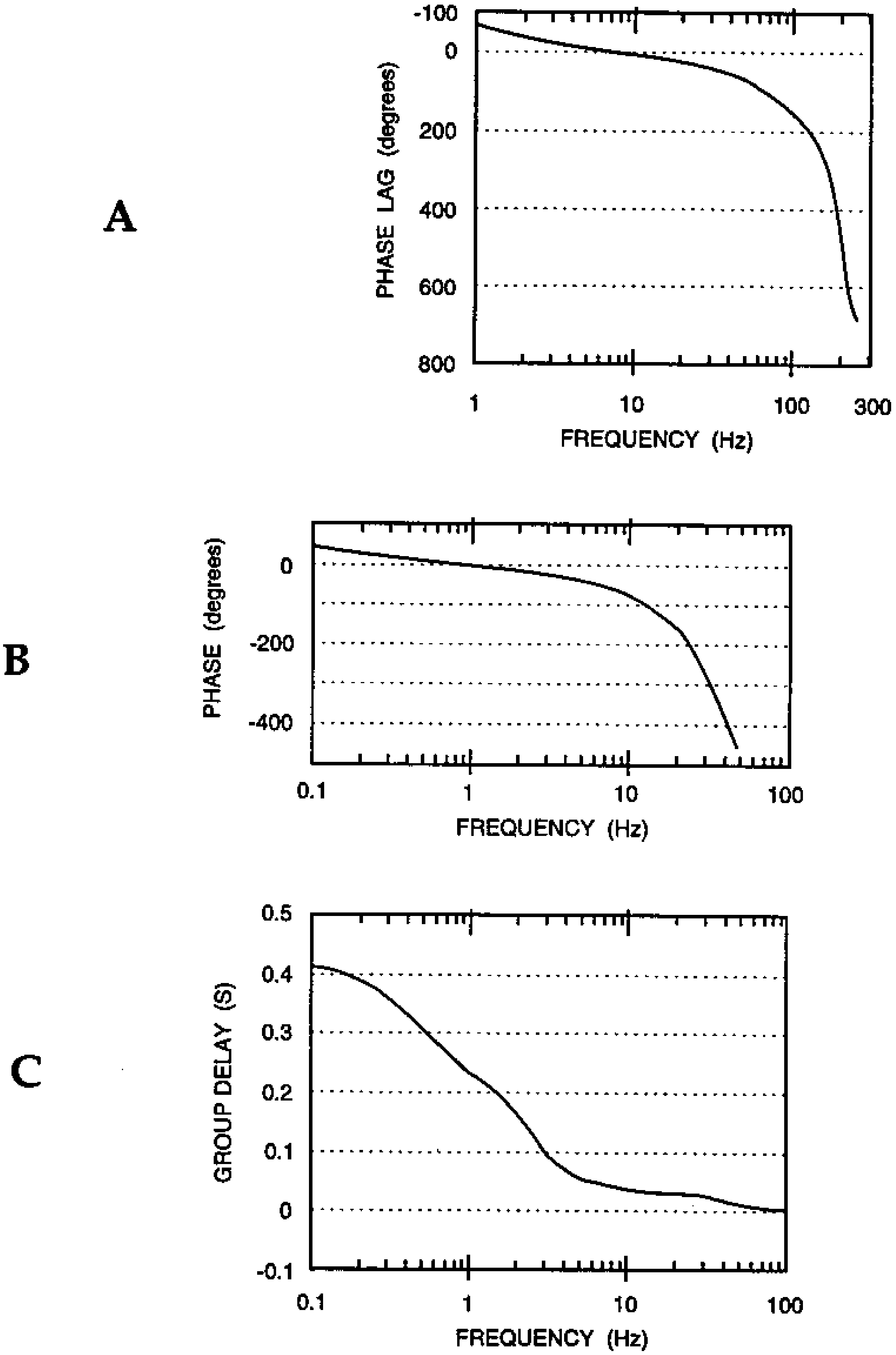
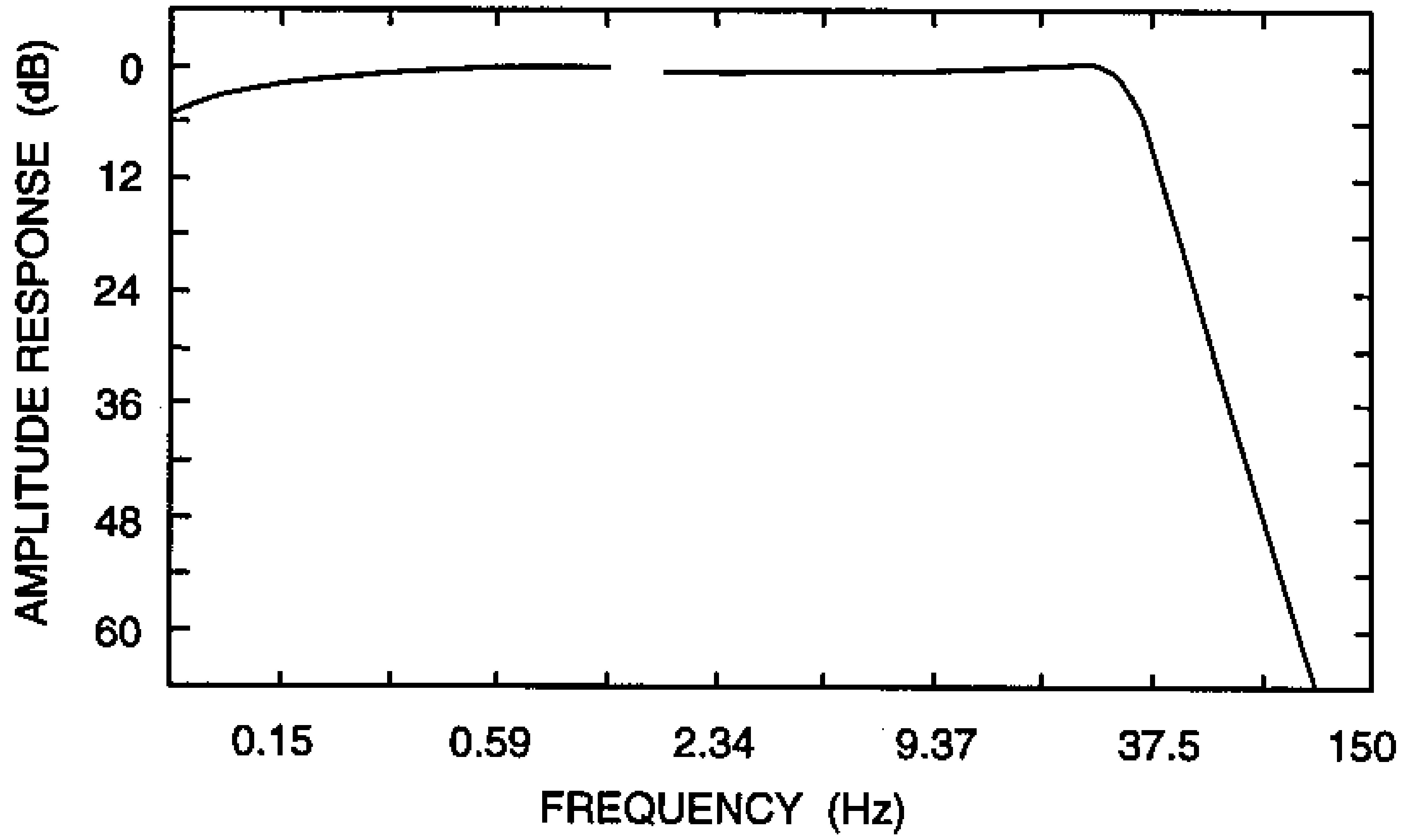
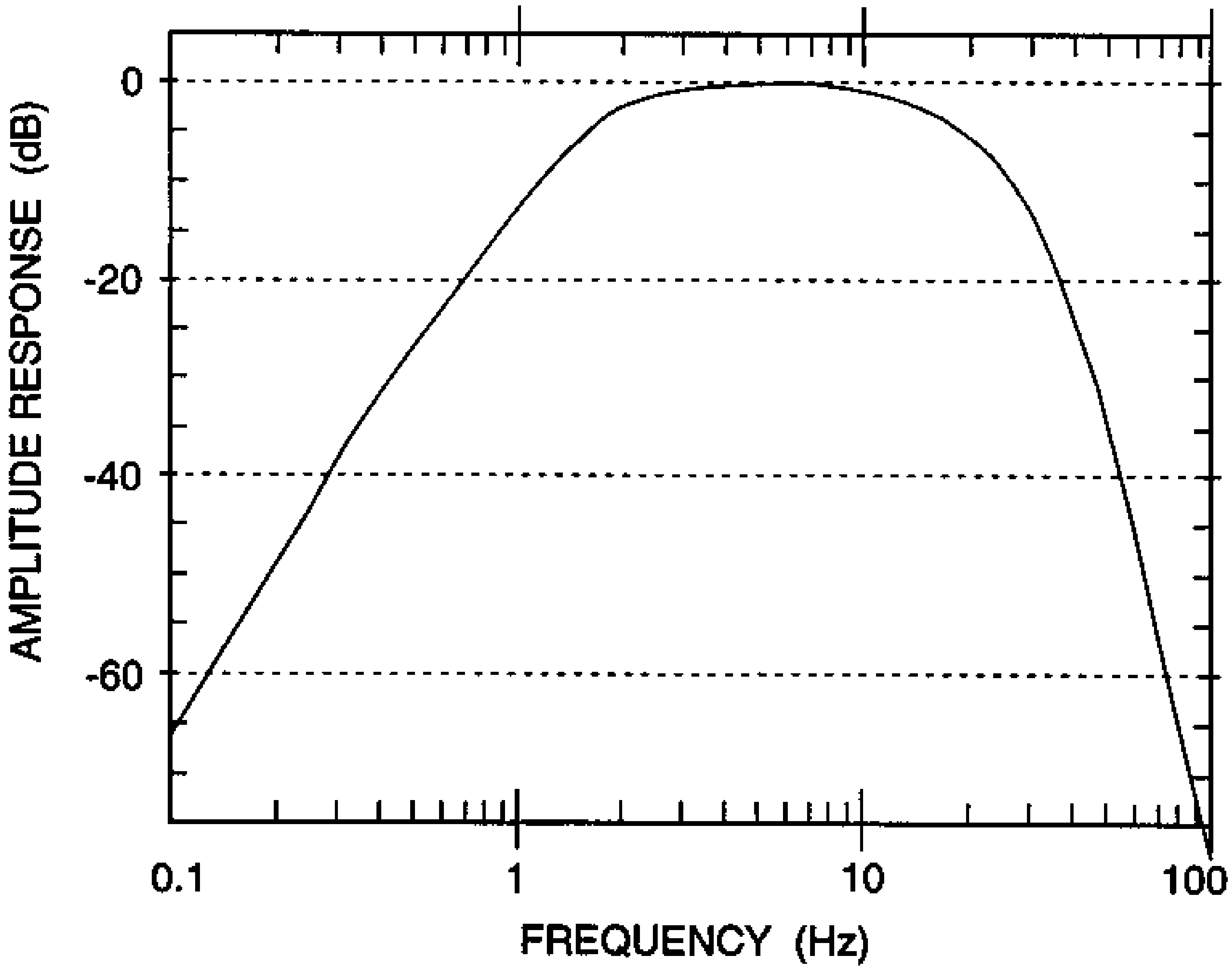


Figure 5. The phase characteristics of A.) SGR B.) GEOS C.) PRS1 with the filters as described in the text.

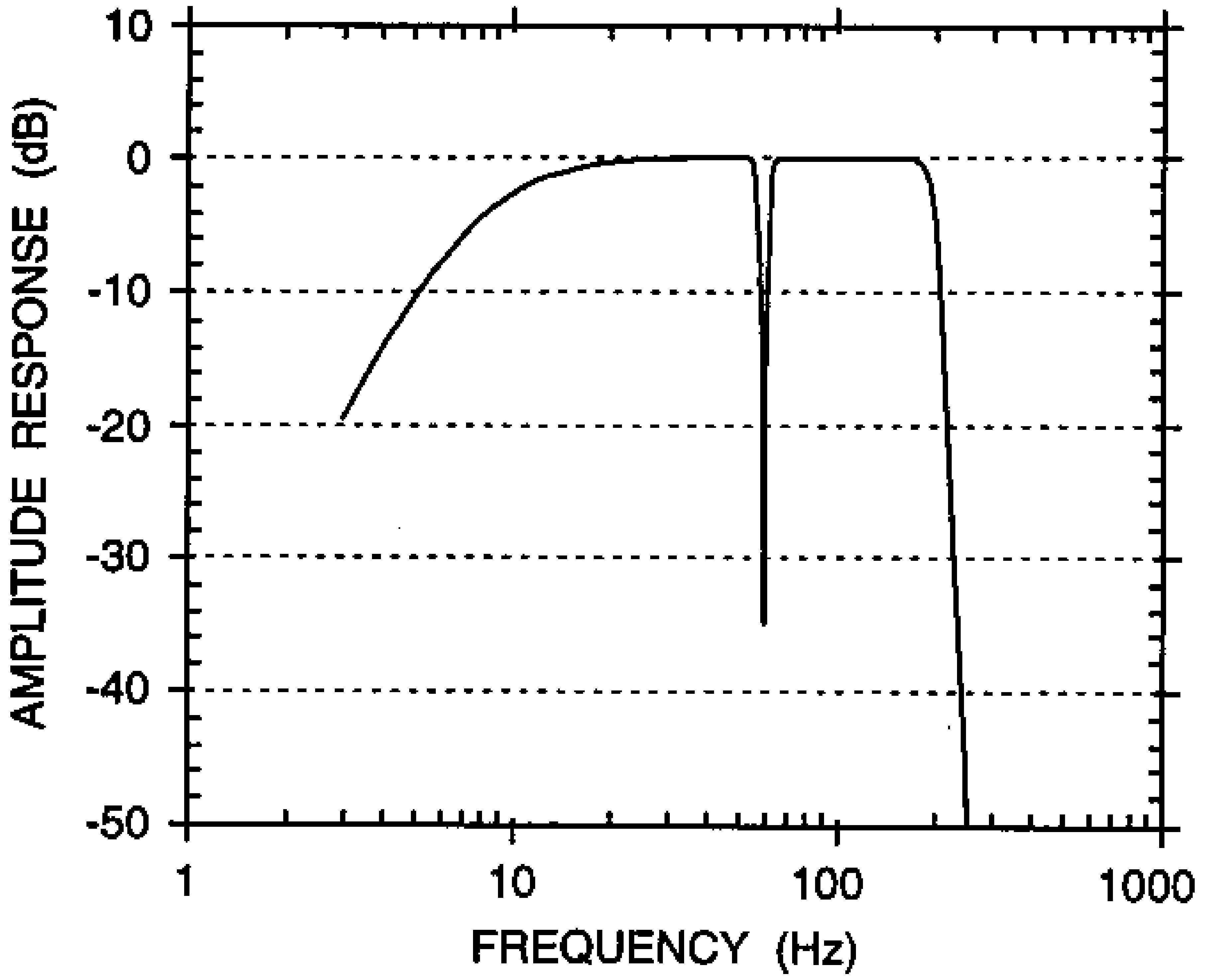


A



B

Figure 6. Amplitude response curves for A.) GEOS without geophone, B.) PRS1 with a Mark Products L4-C 2-Hz geophone, and C.) SGR with Mark Products L10-B 8-Hz geophone.



C

Figure 6C. Amplitude response curve for SGR with Mark Products L10-B 8-Hz geophone.

times instead of using the standard radio turn on. Timing is provided by a TXCO that is synchronized to a USGS master clock prior to deployment. Like the GSC PRS's, most SGR clocks drift less than 20 milliseconds during a 24-hour period. The USGS master clocks drift approximately one millisecond per week and are checked periodically against satellite clocks. The digital data and the clock drift at the time of instrument retrieval are recorded on cartridge tape. The drift rate (assumed linear) is used to calculate a chronometer correction at shot time. For this experiment, the SGR III pre-amplifier was set to 50 mV, the low-cut filter was "out", and the 60-Hz notch filter was "in". Figure 5A shows the phase characteristics of the system associated with these filter settings. Each SGR III was connected to a single string of 6 modified Marks Products L-10B vertical-component geophones (8 Hz) connected in series. The total system response is shown in Figure 6C. The SGR III recorders were designed by Amoco Production Company, built by Globe Universal Sciences, Inc., and modified by the USGS.

The RefTek 72A-06 and Ref-Tek 72A-07 instruments are a digital seismic data acquisition system (DAS) with three-input-channels and a 235 mB data-storage disk. The RefTek 72A-02 and Ref-Tek 72A-08 are DAS's designed similar to the Ref-Tek 72A-06 and Ref-Tek 72A-07 instruments but have 6 input channels. During this experiment, only three of the six channels were used to record data. Timing for all models of RefTeks is provided by an internal voltage controlled oscillator (VCXO). Each instrument was synchronized with a GPS clock when it was deployed and when it was retrieved. Some of the sites had external GPS clocks permanently attached to the instrument while they recorded data. RefTeks are programmable for a range of different sample rates. During this experiment, data were recorded at 250 samples per second (4 ms). The RefTek 72A-06 has 16-bit resolution and produces data at two gains per channel (six-channel output), a fixed low-gain (18 dB) and a variable high-gain (programmable for 0, 18, 30, 42, 54, 66, or 78 dB). The variable-high-gain preamplifier was set to 78 dB during this experiment. The RefTek 72A-07 has 24-bit resolution and outputs data at one of two gains, 1 or 32. During this experiment, the gain of the RefTek 72A-07's was set to 32. The RefTek 72A-02 and RefTek 72A-08 are 6 channel equivalents to the RefTek 72A-06 and RefTek 72A-07, respectively. All RefTeks are amplitude compatible, so that a given ground motion is recorded with the same amplitude on all systems. Ground motion was sensed by Mark Products L-28 4.5-Hz three-component geophones and by Marks Products L-22D 2-Hz three-component geophones. The geophone type was written to the headers of each trace. RefTeks filtered data digitally with a series of digital finite impulse response (FIR) filters before the data were decimated. These filters are zero phase and non-causal.

The General Earthquake Observation System (GEOS) is a six-channel seismic recording system with a dynamic range of 96 dB. The low-pass, anti-aliasing filter is software selectable for corner frequencies of 17, 33, 50, and 100 Hz. During this experiment, only three of the input channels were used, and ground motions were sensed by Marks Products L-22D 2-Hz, three-component geophones. Seismic data were filtered by an anti-aliasing filter with a corner frequency of 33 Hz. Because of low storage capacity, data were sampled at 100 samples per second (10 ms) by a 16-bit A/D converter, and the digital data were written to cartridge tapes. Phase- and amplitude-response curves for the system are shown in Figures 5B and 6A, respectively. The amplitude response curve shown, is for the GEOS recorder only and does not include the geophone. However, since the geophone response is flat at high frequencies and the amplitude of the low frequencies is primarily determined by the corner frequency of the geophone (2-Hz in this case), the response for frequencies below 2-Hz drops off rapidly. Timing is provided for each unit by a TCXO that was synchronized every three hours to WWVB.

DATA PROCESSING

The mix of instruments posed several unique recording problems. The PRS1's and PRS4's have an instrument response designed for lower-frequency refraction/wide-angle reflection recording (2-30 Hz), whereas the SGR and RefTek recorders are designed for higher-frequency reflection recording. Because of the limited data storage of the GEOS, they were programmed to record data at lower frequencies and were more suited to recording refraction/wide-angle reflection data. Although all of the playback systems produce SEG-Y data tapes, the header files and sample rates are different for each system. Merging the data required extensive processing (Fig. 7).

Processing of the data was undertaken at the U.S. Geological Survey on a SUN SPARC 2 computer using the Advance Products ProMAX processing system. Locations for shot points and recording sites were entered into the database. The geoid used for latitude, longitude, and elevation was WGS84 and coordinates were transformed to UTM coordinates (zone 11). Two sites were chosen to collocate different instrument types. The collocated data and the quarry blast on Santa Catalina Island were processed separately from the shot-gather data (see below). Processing of the shot gathers proceeded in 3 stages (Figure 7). In the first stage, major trace-header variables were established for each recorder type (including shot and receiver parameters), timing corrections (due to recorder clock drift in the field) were determined, and the data were resampled to 250 samples per second (4-ms sampling rate). In the second stage, data from all of the recorder types were merged and sorted into shot order. For the collocation sites, only data from one recorder type was retained. Additional trace-header variables were assigned, and all shots were plotted. Using these plots as a reference, additional timing corrections were made, and corrections were made for polarity problems and errors resulting from incorrect field notes (e.g. wrong location). Finally, in stage III, all header parameters were written to the database, and the shot-ordered data were written in SEG-Y format to tape.

The Santa Catalina Island quarry blast, shot 65, was recorded 7 months after the main experiment and is treated as a separate deployment. Data were sampled at 125 samples per second (8-ms sampling rate) for 80 seconds and in stage II, a new set of geographically ordered site numbers, SITE INDEX (1-19, south to north) and CHANNEL numbers (3 per station, 1-57, south to north) were assigned.

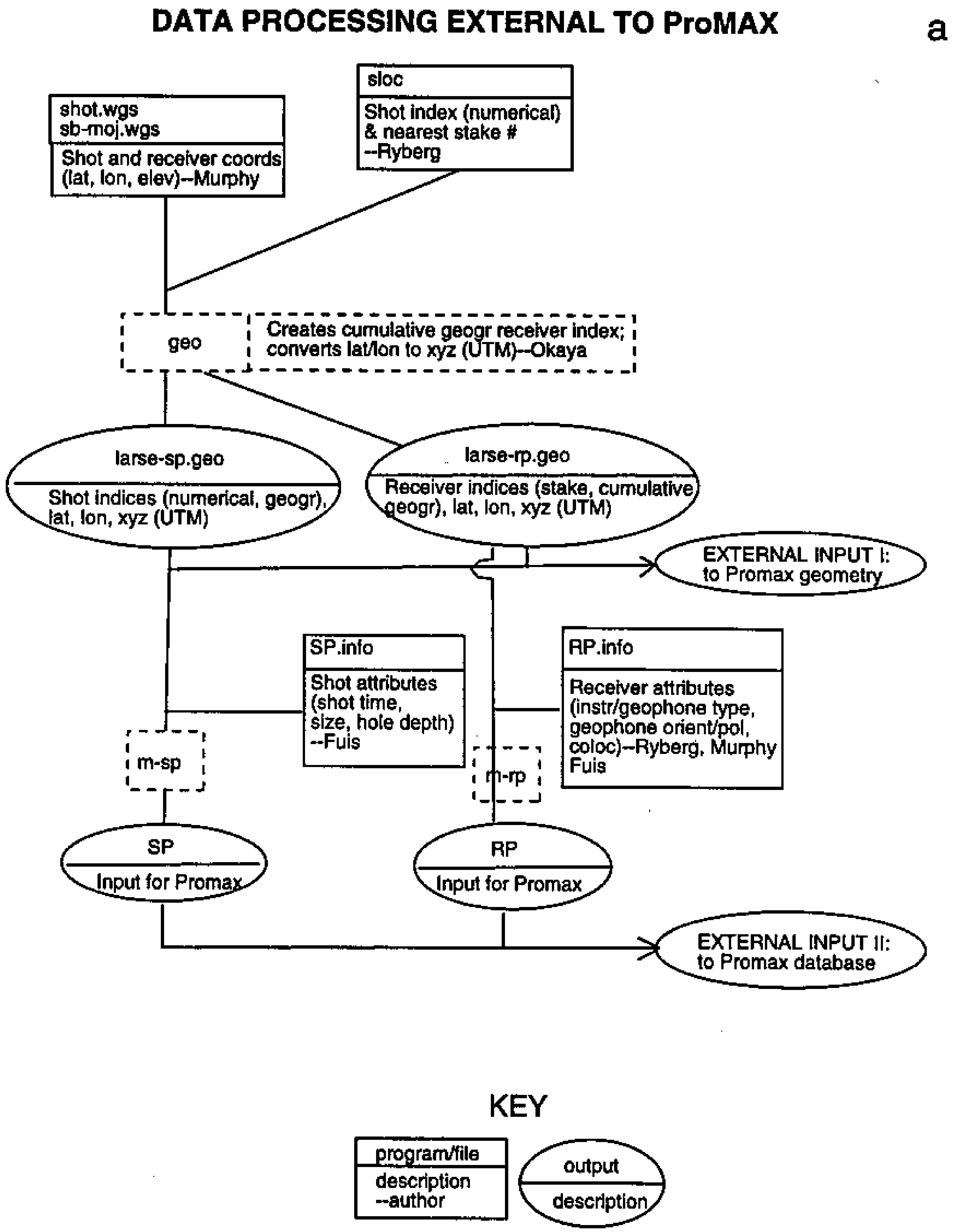
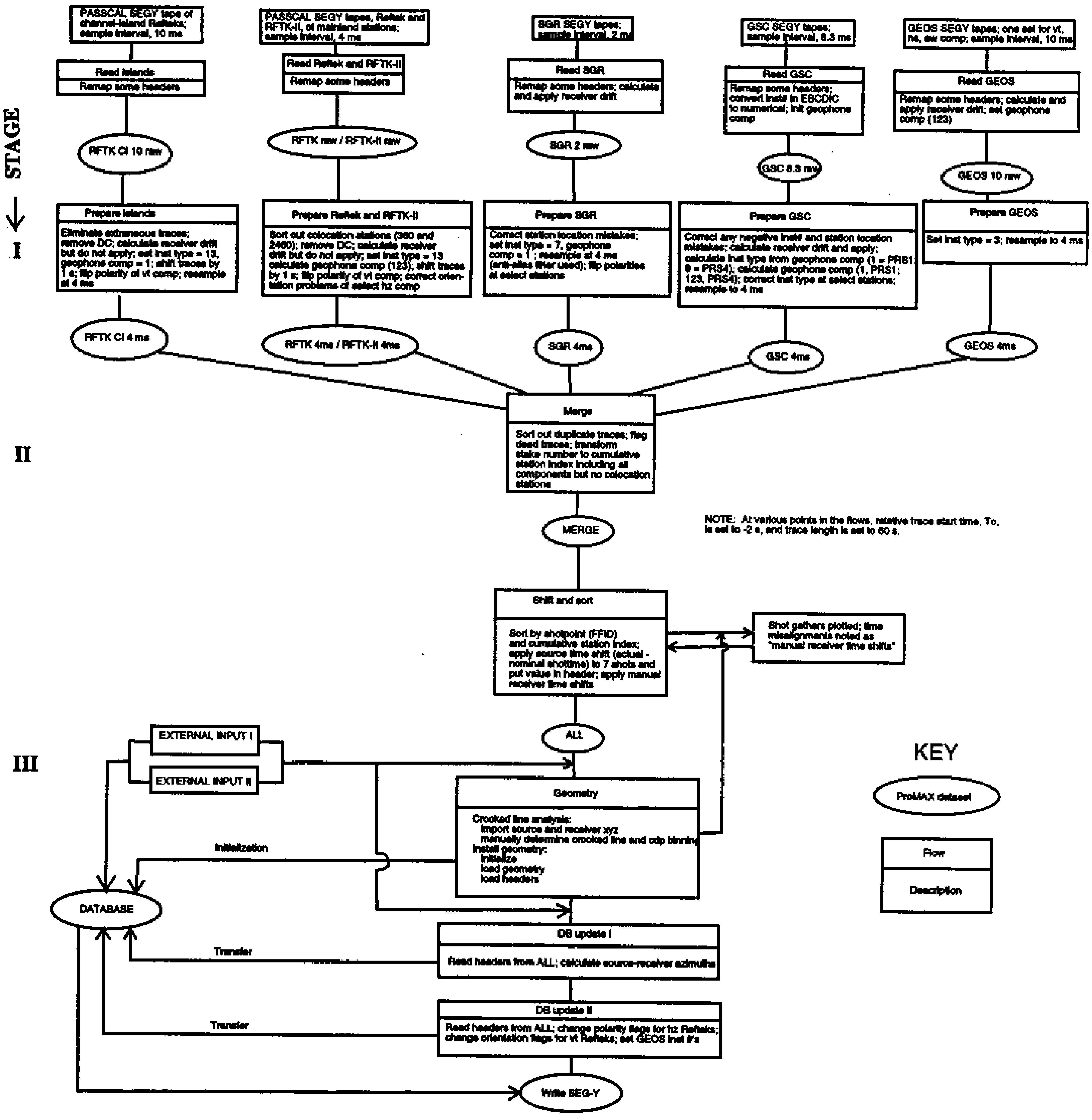


Figure 7. Flow diagrams for LARSE94 data processing. (a) Processing external to Promax; (b) ProMAX processing--main data set; (c) ProMAX processing--colocation sites

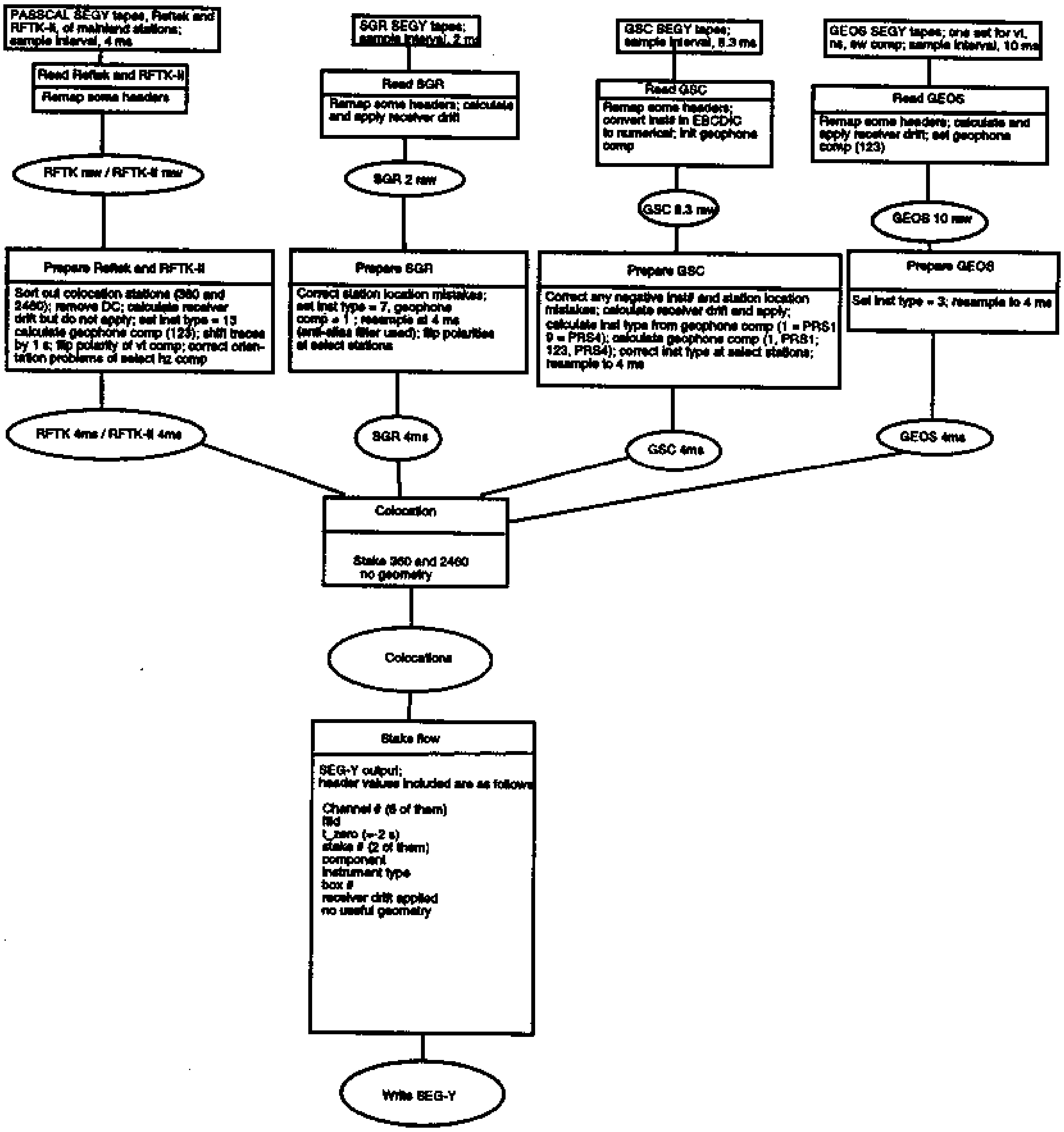
ProMAX DATA PROCESSING FLOWS--MAIN DATA SET b



NOTE: At various points in the flows, relative trace start time, To, is set to -2 s, and trace length is set to 60 s.

ProMAX DATA PROCESSING FLOWS--COLOCATION SITES

C



Stage I

Each of the different instrument systems produced raw SEG-Y tapes with different predefined trace headers. Certain key variables, including shotpoint index, the shotpoint name or number, the station name or number, and geophone component number, were used to define a consistent set of major trace headers: SHOT (shot-gather index, from 1-64, assigned by geographic order, south to north; bytes 9-12), SP (shotpoint name or field number; bytes 17-20), STAKE (station name or number--field stake number), and COMPONENT (north-south, etc.; bytes 179-180) (see TABLE 5). In addition, INSTRUMENT TYPE (bytes 215-216) and GEOPHONE TYPE trace header (bytes 221-222) were defined (TABLE 5).

Stage II

During the second stage, the reformatted data from each instrument system were merged and sorted into shot gathers. At this stage, geometry, timing information, and other miscellaneous information were loaded into the headers. A geographically ordered site number was defined, SITE INDEX (1-664, south to north; bytes 169-170), as well as a cumulative station-trace index, CHANNEL (3 per station, 1-1992, south to north; bytes 13-16). For CHANNEL, sites that had vertical-component instruments only, have two unused channels associated with them. Receiver timing corrections were applied and shot gathers were plotted. Each shot gather was carefully examined for apparent timing problems. In general, only timing problems exceeding 50 ms were noted for correction. The RefTek data contributed the great majority of timing problems. Nearly 20 percent of the Reftek seismograms showed misalignment when compared with seismograms from neighboring recorders (generally, SGR's). The amount of misalignment was measured and these receiver time drifts were subtracted and recorded in the headers. (The origin of the RefTek problem is a faulty program for logging GPS time information and calculating drift). In stage II, TRACEID (bytes 29-30) was set to 1 (seismic data), as is required by SEG-Y format and MST (bytes 181-184) was set to 0. A complete description of the header values is given in Table 5. They are compatible with the IASPEI SEG-Y format.

Stage III

In the third and final stage of processing, the final header parameters were written to the database, and the shot-ordered data were written in SEG-Y format to six 8-mm tapes. Each tape has an EBCDIC reel header. The data collected in 1994 were written and plotted as shot gathers in geographic order from south to north with a sample rate of 4 msec and a trace length of 60 seconds. The Santa Catalina Island quarry blast data, collected in 1995, were written as a shot gather, also in geographic order from south to north, but with a sample rate of 8 msec and a trace length of 80 seconds. Tape 1 contains shot indices 1-22, tape 2 contains shots indices 23-44, tape 3 contains shot indices 45-64, tape 4 contains shot index 65, a quarry blast on Santa Catalina Island, and tape 5 and 6 contains the collocation shot gathers discussed below.

Collocation sites

The collocation sites and the type of instrument LOCATED at these sites are listed in TABLE 4. These data were processed and sorted into shot gathers for each of the two sites. The data were corrected for shot drifts but no other error checking was done. Traces have header values consistent with the rest of the 1994 data set. For each shot, a separate channel was assigned for every trace at a site.

TABLE 4

COLLOCATION SEISMOGRAPHS

Collocation Site	Seismograph types present	Tape
Stake 2460	3,7,9	5
Stake 360	1,13	6

Seismograph types
1=PRS1
3=GEOS
7=SGR
9=PRS4
13=RefTek

TABLE 5

ARCHIVE DATA TAPE FORMAT

Archive data tapes are written in standard SEG-Y 32-bit IBM floating point format (Barry et al., 1975). 8 mm tapes have been used for distribution; each tape has the standard SEG-Y EBCDIC reel header. Minor modifications to the trace headers have been made to allow the archived data to be adequately described. A list of the header fields used for these data is shown below.

Trace Identification Header (total of 240 bytes)

size	bytes	LARSE-Explosion
long	1- 4	*L0: Sequence number within line*
long	5- 8	*L0: Sequence number within reel*
long	9- 12	**L1: Shot gather index number: [1-64; geographic order; S to N]**
long	13- 16	**L1: Shot gather trace number: [1-1992; 3 traces/stake (or site): vertical component plus 2 horizontal components or 2 zero traces; cumulative from S to N; no colocation sites]**
long	17- 20	L1: SP name (e.g., 8170)
long	21- 24	CDP number (empty)
long	25- 28	CDP trace number (empty)
short	29- 30	L0: Trace ID code (SET = 1)
short	31- 32	No. vertically summed traces (empty)
short	33- 34	No. horz summed traces (empty)
short	35- 36	1 = production, 2 = test (SET = 1)
long	37- 40	L1: Source-receiver offset (signed)
long	41- 44	L1: Receiver elevation
long	45- 48	L1: Source elevation
long	49- 52	L1: Source depth (meters): (total depth - depth to top of explosive)/2
long	53- 56	Datum elevation at receiver (empty)
long	57- 60	Datum elevation at source (empty)
long	61- 64	Water depth at source (empty)
long	65- 68	Water depth at receiver (empty)
short	69- 70	L0: should be (SET = 1)
short	71- 72	L0: (SET = -10)
long	73- 76	L1: Source long deci-sec of arc (/36000.)
long	77- 80	L1: Source lat deci-sec of arc (/36000.)

long	81- 84	L1: Receiver long deci-sec of arc (/36000.)
long	85- 88	L1: Receiver lat deci-sec of arc (/36000.)
short	89- 90	L1: Coordinate units (SET = 2 = DEGREES)
short	91- 92	Weathering velocity (empty)
short	93- 94	Sub-weathering vel. (empty)
short	95- 96	L2: Polarity flag: 0--data has NOT been modified; the convention indicated in 111 applies 1--data has NOT been modified; the convention indicated in 111 does not apply -1--data HAS been modified; the convention indicated in 111 applies
short	97- 98	L2: Orientation flag: (same description as for polarity flag)
short	99-100	L1: Source static (msec) (NOT USED)
short	101-102	L1: Receiver static (msec) (NOT USED)
short	103-104	L1: Total static applied (msec) (NOT USED)
short	105-106	L2: Manual time shift applied ("hand static")
short	107-108	L2: Actual - nominal shot time (msec)
short	109-110	L1: Relative time of first sample (msec): T_0 = -2000)
short	111-112	L2: Polarity convention (SET = 1): The convention used is POSITIVE DEFLECTION = GROUND UP, NORTH, OR EAST
short	113-114	L2: Orientation convention: Channel 1 (vertical component) (SET = 0) Channels 2 and 3 (horizontal components): 0--North arrow on geophone points North 1--North arrow on geophone points West 2--North arrow on geophone points East In the last two cases, changes to the data include interchange of channels and appropriate polarity changes. In the case where the North arrow on the geophone points South, a polarity change is made and indicated under the polarity flag. 99--unknown orientation
short	115-116	L1: number Samples if <2^15; else=32767 (see 229-232)
short	117-118	L1: Sampling interval in microsec
short	119-120	Gain type (empty)
short	121-122	L1: Instrument gain constant (NOT USED)
short	123-124	instrument inital gain in dB (empty)
long	125-128	M4: UTM source X
long	129-132	M4: UTM source Y
long	133-136	M4: UTM receiver X

long	137-140	M4: UTM receiver Y
short	141-142	L2: Colocation site (0=N; 1=Y) (See tape 2 for data from all colocated intruments. Only data from one instrument is shown in tape 1)
short	143-144	alias filter slope (empty)
short	145-146	notch filter frequency (empty)
short	147-148	notch filter slope (empty)
short	149-150	low-cutoff frequency (empty)
short	151-152	L2: Deployment number (shot night: 1,2,3)
short	153-154	Source line (empty)
short	155-156	L1: Instrument channel number (NOT USED)
short	157-158	L1: Time of first sample year
short	159-160	L1: Time of first sample day
short	161-162	L1: Time of first sample hour
short	163-164	L1: Time of first sample minute
short	165-166	L1: Time of first sample sec
short	167-168	L1: Time code [GMT=2]
short	169-170	L2: Site index (1-664; S to N)
short	171-172	L2: Site index w/ colocated inst. (NOT USED)
short	173-174	M0: PASSCAL: Field stake (or site) number
short	175-176	[empty]
short	177-178	[empty]
short	179-180	L2: Component (Z=1, N-S=2, E-W=3)
long	181-184	I: Microsec trace start time
short	185-186	I: Charge size (kg) or airgun size (cu in)
short	187-188	I: Shot/trigger time - year
short	189-190	I: Shot/trigger time- Julian day
short	191-192	I: Shot/trigger time - hour
short	193-194	I: Shot/trigger time - minute
short	195-196	I: Shot/trigger time - second
long	197-200	I: Shot/trigger time - microsec
long	201-204	I: Override for sample interval (SET = 0)
short	205-206	I: Azimuth of sensor orient axis (NOT USED)
short	207-208	I: Geophone inclination (NOT USED)
long	209-212	I: LMO static (x/v) (ms) (NOT USED)
short	213-214	I: LMO flag: (0=Y, 1=N) (SET = 1)
short	215-216	I: Instrument type: 1--PRS1 3--GEOS 7--SGR 9--PRS4 13--Reftek (all types included)
short	217-218	I: correction to be applied: (SET=0)
short	219-220	I: Azimuth of source-receiver (min of arc)

short	221-222	Geophone type: 1--L28 (PASSCAL)(4.5 Hz) 2--L22 (2 Hz) 3--L10B (8 Hz) 4--L4 1 Hz 5--L4 2 Hz 6--FBA 7--TDC-10 (4.5 Hz) 8--L28 (GSC) 9--LRS1033 (4.5 HZ) 99--unknown
short	223-224	Geophone number (NOT USED)
short	225-226	Inst. ID number
short	227-228	(MUST BE EMPTY)
long	229-232	Number of samples if > 2^15 (see 115-116)
long	233-236	M2: Reftek amplitude bias removed (NOT USED)
short	237-238	M1: Receiver clock drift removed (Negative means the trace was shifted (i.e., moved) to earlier time)
short	239-240	blank

L0: needed for SEGY format
L1: experiment description
L2: overrides definition

Italicized type = SEGY standard def. that is USED
Bold type = OVERWRITE of SEGY standard def.
Regular type = SEGY standard def. that is NOT USED

ACKNOWLEDGMENTS

We are indebted to the following persons and institutions for supplying seismographs and/or field hands: James Fowler, Marcos Alvarez, Steven Michnik and William Koperwhats of IRIS/PASSCAL; Isa Asudeh and Tim Cartwright of the Geological Survey of Canada; Roger Borcherdt of the USGS; Kate Miller of the University of Texas at El Paso; Michael Fehler of the Los Alamos National Laboratory; Claus Prodehl of the University of Karlsruhe, Germany; Elizabeth Ambos of the California State University at Long Beach; Edward Bender of Orange Coast College; and John Louie of the University of Nevada at Reno. Lamont-Doherty Earth Observatory operated the *R.V. Ewing;* James Gardner, Ray Sliter and Jock Keene of the USGS and Jonn McRaney of SCEC assisted with air-gun data acquisition. Thomas Burdette of the USGS assisted in supervising shotpoint permitting, loading, and shooting; Brian Laird of the USGS and Katrin Hafner of SCEC assisted in surveying. We thank RLA Communications for providing the base station data used to calculate accurate positions from our GPS rover data. Numerous people assisted in the deployment of seismographs (TABLE 2). We thank the U.S. Forest Service, U.S. Bureau of Land Management, U.S. Army Corps of Engineers, U.S. Naval Weapons Station Seal Beach, Caltrans, Metropolitan Water District of Southern California, County of Los Angeles, CalMat, Rose Hills Cemetery, Chevron, U.S. Borax Co., and numerous private citizens of the Los Angeles region for permission to operate on lands under their jurisdiction or ownership. The National Earthquake Hazards Reduction Program and the National Science Foundation funded this experiment. We thank Rufus Catchings for a review of this report.

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