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GEOLOGICAL SURVEY

Station Arrival Data for a Quarry Blast on
Santa Catalina Island, California

by

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

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INTRODUCTION

On November 8, 1981 a large blast was detonated on the southeast tip of Santa Catalina Island, one of the channel islands off the coast of southern California. Energy from the blast was recorded by a small array of portable seismometers on the island (figure 1) as well as by stations of the USGS-Cal Tech cooperative array on the mainland. Blasts the size of the one reported here are detonated only about once every 10 years on the island, therefore this blast offered a rare opportunity to gain seismic information about the crustal structure of California and the continental borderland.

No interpretation is offered in this report. The raw data is presented in the hope that it will be useful to other researchers in a variety of studies.

THE BLAST

The blast was located in a quarry that produces riprap for southern California coastal structures. A horizontal shaft was dug 55m into a cut face at a bearing of N45°E. Two horizontal shafts were extended from the end of the main shaft, forming a 'T'; one 15m to the left (N45°W) and the other 30m to the right (S45°E). The explosive (180,000 lb. of ammonium nitrate) was placed in five 'pockets' at intervals in the shaft. One pocket was placed at the end of each perpendicular shaft, a third at the junction of the 'T', and the remaining two in the main shaft at 15m and 30m from the entrance. The shaft was completely backfilled to the entrance.

The location of the adit was surveyed by quarry employees. All five pockets exploded simultaneously, therefore, the point of initiation is best approximated by the center of the pattern of pockets. The center of the blast was located at latitude 33° 19.06', longitude -118° 18.32' and at an elevation of 55m.

The origin time was to have been recorded by a geophone at the initiation point but the record was lost due to equipment failure. A backup record was obtained from a Ranger seismometer recording on a Kinometrics PS-1 seismograph at a distance of 400m. The arrival of blast energy on this record is preceded by a single impulsive spike. The spike is the result of a burst of radio frequency energy emitted by the detonator as it discharged. Therefore, the spike time represents the initiation time of 20:00:00.19 gmt.

The blast energy follows the spike by 0.16 seconds. Taking this as the travel time to the backup seismometer yields a seismic velocity in the quarry of 2.5 km/sec. This is a reasonable velocity for the site and serves to confirm that the spike truly represents the origin time.

NETWORK ARRIVALS

Blast arrivals in the USGS-Cal Tech cooperative seismograph network were recorded digitally on the Cal Tech Earthquake Detection and Recording (CEDAR) system (Johnson, 1979) and timed interactively by the first author using the Cal Tech-USGS Seismic Processing (CUSP) system. Each arrival is assigned a weight when it is picked. The weight consists of three parts. The first letter indicates whether the arrival is

impulsive (I) or emergent (E). Next, an estimate of the relative error of each pick is made (table 1). Absolute picking accuracy of the system is ± 0.02 seconds. Finally the first motion is given by a 'U' for compression ('+' if uncertain) or a 'D' for dilatation ('-' if uncertain).

All stations with distinguishable arrivals (P = first arrival, P' = second arrival) were timed (tables 2 & 3). Stations that were not timed were either too emergent, dead or received no energy.

TEMPORARY ARRAY

An array of nine portable seismometers was deployed along the length of Santa Catalina Island. Seven usable records were obtained. The instruments were Kinemetrics PS-1 smoked paper recorders with Ranger seismometers. Two of the recorders, WEND and HOWL, were equipped with WWVB receivers that produced continuous time ticks at one second intervals. The other recorders produced ticks at 20 second intervals produced by an internal clock. These records were corrected to true time by comparing the internally produced marks to WWVB recorded from an external radio at the beginning and end of each record.

Records were read using a 7x measuring magnifier. All arrivals were impulsive and could be read with an accuracy of ± 0.04 seconds (tables 4 & 5).

ACKNOWLEDGMENTS

We thank Steve Dickey who brought the blast to our attention and was invaluable in logistics. Both he and Gene Hawkins were instrumental in setting out the temporary array. We also wish to thank the owners and employees of the quarry and the residents of Santa Catalina Island.

REFERENCE

- Johnson, C. E., 1979, CEDAR -- an approach to the computer automation of short-period local seismic networks: Ph.D. thesis (Part I), Calif. Inst. of Technol., Pasadena, 121 p.

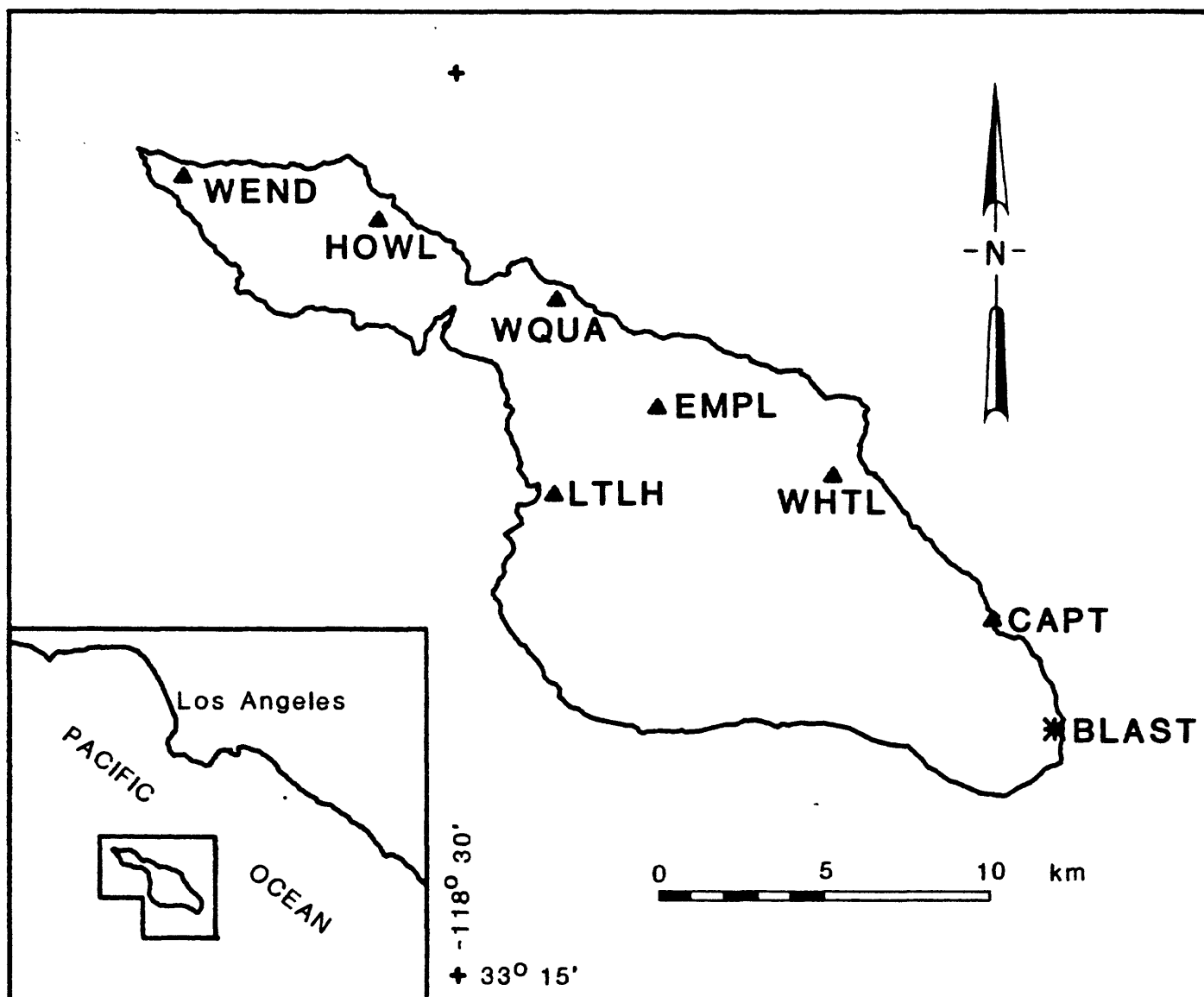


Figure 1. Temporary array of stations deployed on Santa Catalina Island to monitor the quarry blast of November 8, 1981.

TABLE 1. -- PHASE PICK ERROR ESTIMATES

<u>WEIGHT</u>	<u>MAXIMUM ERROR</u>
0	± 0.02
1	± 0.05
2	± 0.10
3	± 0.30
4	> 0.30

TABLE 2. -- CATALINA BLAST STATION ARRIVAL TIMES
[seconds after 20:00 GMT]

STATION	PICK	WT.	TIME (sec.)	DIST. (km)	STATION	PICK	WT.	TIME (sec.)	DIST. (km)
CIS	P	IOU	2.90	13.4	MDA	P	E3-	23.36	138.1
CIW	P	IOU	5.34	28.1		P'	E4-	24.36	
SCI	P	IOU	8.58	43.6	SBSC	P	E2-	23.40	144.2
LCL	P	E3-	10.68	58.2		P'	I1D	24.22	
SBI	P	I1U	12.10	69.6	PYR	P	IOU	23.82	144.4
SNS	P	IOU	12.90	71.7	ECF	P	I1U	24.18	145.8
VPD	P	IOU	13.02	74.9	LJBE	P	E2	24.78	147.5
SCY	P	E4	15.32	88.6		P'	E3	25.60	
PTD	P	I1D	15.68	89.2	LJB	P	IOU	24.38	147.5
SAD	P	IOU	16.02	91.0		P'	E4-	25.36	
PAS	P	I1U	16.66	93.1	VG2	P	I1U	24.68	150.3
PCF	P	E3	16.48	94.6	LHU	P	E2-	24.76	150.5
VST	P	E2+	16.72	101.7		P'	E2+	26.28	
	P'	E4	17.68		CAH	P	IOU	23.76	151.0
KYP	P	IOU	17.46	102.0		P'	I1U	24.88	
PEM	P	E2-	17.74	102.6	SBCD	P	E3+	24.64	151.1
	P'	E4	18.82			P'	E2-	26.58	
MWC	P	E2+	18.22	103.1	MLL	P	E2+	25.58	153.3
SME	P	E2-	17.30	104.6	SYS	P	I1U	23.52	153.9
	P'	E3-	17.98			P'	E2+	25.28	
GAV	P	E2-	18.36	107.4	KEE	P	I1-	25.46	157.7
	P'	E4	18.78		SBB	P	E2+	25.92	158.4
SIP	P	IOU	18.40	108.4		P'	I1D	27.10	
	P'	I1U	18.92		RDM	P	E3+	26.02	158.7
SBSN	P	IOU	18.22	112.1	BTL	P	E2-	26.20	159.4
	P'	E4-	19.36			P'	E4	26.96	
SBLG	P	I1U	18.88	112.9	RAY	P	I1D	26.26	159.9
SUN	P	I1U	19.42	114.2		P'	I2D	27.30	
RVR	P	IOU	19.62	114.4	HOT	P	E2-	25.60	160.6
CFL	P	E2-	19.46	115.7		P'	E2-	25.56	
IRC	P	E2	20.32	119.3	JUL	P	IOD	24.80	160.7
	P'	E2-	20.78			P'	E4-	26.04	
CAM	P	E2+	21.08	123.8	BAR	P	E2-	25.70	168.3
SS2	P	E2-	21.12	123.8		P'	I1U	27.38	
	P'	E2+	21.60		WWR	P	E2+	27.88	170.4
PEC	P	E2+	20.62	124.0		P'	E4	28.80	
	P'	E2-	21.00		PSP	P	E4+	27.62	171.5
DB2	P	IOU	20.48	124.5	SMO	P	E2+	27.48	173.3
	P'	I4-	20.76			P'	I1D	29.28	
JNH	P	E2+	21.68	129.5	RYS	P	I1U	27.94	176.0
	P'	E2+	22.28			P'	E2-	30.22	
BLU	P	I1D	22.06	132.2	SIL	P	E2-	28.92	178.4
	P'	E4-	22.96		FTC	P	E3	28.16	180.6
PLM	P	E2+	21.58	134.5	SDW	P	E3+	29.32	183.0
	P'	E4-	22.46		YAQ	P	E2+	28.58	183.1
POB	P	E2+	22.02	134.9		P'	E3-	30.22	
CFT	P	E2+	23.28	136.5	MRV	P	E3	29.52	183.1
	P'	E3+	23.78			P'	E2+	30.90	184.5
LRR	P	E2-	22.96	136.5	SBLC	P	I1D	28.36	184.5
	P'	E3-	23.76			P'	E4	31.78	

TABLE 2. -- CATALINA BLAST STATION ARRIVAL TIMES (cont.)
[seconds after 20:00 GMT]

STATION	PICK	WT.	TIME (sec.)	DIST. (km)	STATION	PICK	WT.	TIME (sec.)	DIST. (km)
COY	P	E3+	29.08	185.9	ISA	P	E4+	39.18	260.7
	P'	E4-	30.94		SHH	P	E3+	39.50	264.0
RMR	P	E4-	30.24	188.6		P'	E4+	43.40	
ABL	P	I1U	29.64	189.9	BCH	P	E3+	39.18	264.1
	P'	E3-	32.46		BC2	P	E4	39.20	267.1
EWC	P	E4	30.14	191.4		P'	E4+	43.80	
LAQ	P	E2-	30.04	191.5	WWP	P	E4-	39.96	269.0
	P'	E2+	31.48		CH2	P'	E4	45.00	276.6
BRG	P	E4-	31.20	199.4	YEG	P	E2-	41.56	279.9
	P'	E2-	33.04		CO2	P'	E3-	45.72	281.1
BMT	P	E2+	31.78	203.5	AMS	P	E4-	42.76	285.1
	P'	E3+	34.42		WCH	P'	E4+	48.82	285.4
SYP	P	E2+	31.08	204.7	SPM	P	E3+	43.92	297.5
	P'	E2+	34.00			P'	E2+	48.94	
SBSM	P	E3+	31.28	205.7	WRC	P	E3+	45.60	298.3
MIR	P	E4	32.48	207.4		P'	E4+	51.50	
	P'	E2+	33.92		GRP	P	E4	43.90	299.0
INS	P	E3-	34.16	207.6		P'	E4+	48.94	
RCH	P	E4-	33.36	211.8	LTC	P	E4	45.50	301.6
	P'	I2+	35.12			P'	E4+	51.46	
MEC	P'	E4	35.70	214.6	WCS	P	E2-	44.68	304.5
CPM	P	E4	33.56	216.4		P'	E3-	52.08	
	P'	E4-	35.86		GLA	P	E4	49.02	325.8
FLS	P	E2-	33.76	217.5	TTM	P	E4-	49.30	341.2
IKP	P	E2+	33.18	218.4	GWV	P'	E4+	59.52	351.7
SLT	P'	E3+	36.60	222.0	RVS	P'	E4-	59.36	360.2
HDG	P'	I2D	36.72	222.4	NOP	P	E4	52.54	368.6
CRR	P	E4+	33.40	223.4		P'	E4-	63.24	
PKM	P	E2+	33.84	223.9	RVM	P'	E4	63.52	392.3
TMB	P	E4-	35.36	226.6					
TPC	P	E4-	34.98	226.8					
	P'	E4-	37.48						
CTW	P'	E2-	37.98	229.8					
JFS	P	E2-	37.00	233.0					
	P'	E4	39.60						
SUP	P'	I2D	38.12	235.1					
SBLP	P	E4	35.20	237.6					
PNM	P'	E3-	39.86	243.7					
NW2	P'	E4	42.16	245.0					
LAV	P'	E3	40.50	246.2					
COK	P'	E4	40.56	246.3					
FRK	P	E4	35.64	248.6					
	P'	E3-	40.76						
SBCC	P	E3-	36.86	249.0					
CRG	P	E4-	37.94	250.2					
	P'	E4	44.40						
SGL	P	E2+	36.98	252.3					
	P'	E2-	41.16						
LED	P'	E3+	41.96	253.6					
GSC	P	E3+	39.18	259.9					

TABLE 3. -- COORDINATES OF TIMED STATIONS

CODE	STATION NAME	LATITUDE	LONGITUDE	ELEVATION
ABL	MOUNT ABEL	34°51.05'	119°13.25'	1981m
AMS	AMOS	33° 8.48'	115°15.25'	140m
BAR	BARRETT DAM	32°40.80'	116°40.30'	510m
BC2	BIG CHUCKWALLA MOUNTAINS	33°39.42'	115°27.67'	1185m
BCH	BRANCH MOUNTAIN	35°11.10'	120° 5.05'	1140m
BLU	BLUE RIDGE	34°24.40'	117°43.61'	1880m
BMT	BEAR MOUNTAIN	35° 8.15'	118°35.81'	1237m
BRG	BORREGO MOUNTAIN	33°10.27'	116°10.44'	219m
BTL	BUTLER PEAK	34°15.43'	117° 0.29'	2526m
CAH	CAHUILLA VALLEY	33°30.22'	116°41.91'	1219m
CAM	CAMARILLO HILLS	34°15.27'	119° 2.00'	268m
CFL	CHILAO FLAT	34°19.97'	118° 1.38'	1586m
CFT	CRAFTON HILLS	34° 2.11'	117° 6.66'	671m
CH2	CHOCOLATE MOUNTAIN	33°17.77'	115°20.17'	347m
CIS	SANTA CATALINA ISLAND	33°24.40'	118°24.20'	485m
CIW	SANTA CATALINA ISLAND WEST	33°27.92'	118°33.10'	50m
CO2	COXCOMB MOUNTAINS	33°50.83'	115°20.68'	276m
COK	COOK RANCH	32°50.95'	115°43.61'	-15m
COY	COYOTE MOUNTAIN	33°21.63'	116°18.56'	232m
CPM	COPPER MOUNTAIN	34° 9.14'	116°11.48'	937m
CRG	CROCKER GRADE	35°14.53'	119°43.40'	1204m
CRR	CARRIZO	32°53.18'	115°58.10'	98m
CTW	COTTONWOOD MOUNTAINS	33°40.78'	115°52.31'	561m
DB2	DOUBLE BUTTE	33°44.10'	117° 3.72'	625m
ECF	ECHO FALLS	34°27.48'	119° 5.44'	1000m
EWC	EAST WIDE CANYON	33°56.24'	116°22.86'	512m

TABLE 3. — COORDINATES OF TIMED STATIONS (cont.)

CODE	STATION NAME	LATITUDE	LONGITUDE	ELEVATION
FLS	FLASH 2 PEAK	34°58.13'	117° 2.19'	3300m
FRK	FRINK	33°24.05'	115°38.21'	91m
FTC	FORT TEJON	34°52.25'	118°53.51'	924m
GAV	GLEN AVON	34° 1.21'	117°30.44'	186m
GLA	GLAMIS	33° 3.10'	114°49.60'	627m
GRP	GRANITE PASS	34°48.26'	115°36.27'	1238m
GSC	GOLDSTONE	35°18.10'	116°48.30'	990m
GWV	GREENWATER VALLEY	36°11.20'	116°40.23'	1540m
HDG	HIDALGO MOUNTAIN	34°25.73'	116°18.30'	1347m
HOT	HOT SPRINGS MOUNTAIN	33°18.85'	116°34.90'	1963m
IKP	INKOPAH	32°38.93'	116° 6.48'	957m
INS	INSPIRATION	33°56.14'	116°11.66'	1700m
IRC	IRON CANYON	34°23.31'	118°24.09'	579m
ISA	ISABELLA	35°39.80'	118°28.40'	835m
JFS	JOSEPH F. STATEN	35°21.05'	117°40.20'	1433m
JNH	JUNIPER HILLS	34°26.85'	117°57.27'	1317m
JUL	JULIAN	33° 2.90'	116°36.77'	1292m
KEE	KEEN CAMP	33°38.30'	116°39.19'	1366m
KYP	KEY POINT	34° 6.11'	118°52.77'	700m
LAQ	LA QUINTA	33°37.68'	116°16.78'	49m
LAV	LAVIC	34°45.95'	116°17.19'	902m
LCL	RANCHO CERRITOS	33°50.00'	118°11.55'	8m
LED	LEAD MOUNTAIN	34°28.06'	115°56.19'	853m
LHU	LAKE HUGHES	34°40.30'	118°24.70'	1036m
LJB	LOVEJOY BUTTE	34°35.47'	117°50.88'	899m
LJBE	LOVEJOY BUTTE	34°35.47'	117°50.88'	899m

TABLE 3. — COORDINATES OF TIMED STATIONS (cont.)

CODE	STATION NAME	LATITUDE	LONGITUDE	ELEVATION
LRR	LITTLE ROCK RESERVOIR	34°31.56'	118° 1.66'	908m
LTM	LITTLE MARIA MOUNTAINS	33°54.90'	114°55.10'	744m
MDA	MOUNT DAVIS	33°54.78'	116°59.97'	845m
MEC	MECCA HILLS	33°38.12'	116° 1.71'	495m
MIR	MARTINEZ INDIAN RESERVATION	33°24.97'	116° 4.86'	91m
MLL	MILL CREEK	34° 5.48'	116°56.18'	1513m
MRV	MORONGO VALLEY	34° 3.68'	116°32.58'	981m
MWC	MOUNT WILSON	34°13.40'	118° 3.50'	1730m
NOP	NOPAH RANGE	36° 7.68'	116° 9.17'	970m
NW2	NEW RIVER	33° 5.43'	115°41.54'	-68m
PAS	PASADENA	34° 8.95'	118°10.29'	308m
PCF	POMONA	34° 3.19'	117°47.44'	163m
PEC	PERRIS	33°53.51'	117° 9.60'	616m
PEM	PINE MOUNTAIN	34°10.04'	117°52.18'	500m
PKM	PEAK MOUNTAIN	34°53.75'	119°49.13'	1704m
PLM	PALOMAR	33°21.20'	116°51.70'	1692m
PNM	PINTO MOUNTAINS	33°58.64'	115°48.05'	1147m
POB	POLLY BUTTE	33°41.20'	116°55.40'	1003m
PSP	PALM SPRINGS	33°47.63'	116°32.93'	195m
PTD	POINT DUME	34° 0.25'	118°48.38'	40m
PYR	PYRAMID	34°34.08'	118°44.50'	1247m
RAY	RAYWOOD FLAT	34° 2.18'	116°48.67'	2342m
RCH	RECHE MOUNTAIN	34°18.44'	116°21.03'	841m
RDM	ROUND MOUNTAIN	34°24.00'	117°11.10'	1426m
RMR	RIMROCK	34°12.77'	116°34.52'	1702m
RVM	RIO VISTA MINE	34°10.81'	114°12.02'	243m

TABLE 3. -- COORDINATES OF TIMED STATIONS (cont.)

CODE	STATION NAME	LATITUDE	LONGITUDE	ELEVATION
RVR	RIVERSIDE	33°59.60'	117°22.50'	260m
RVS	RIVERSIDE MOUNTAINS	34° 2.08'	114°31.08'	677m
RYS	REYES PEAK	34°38.60'	119°21.10'	1841m
SAD	SADDLE PEAK	34° 4.86'	118°39.90'	732m
SBB	SADDLEBACK BUTTE	34°41.30'	117°49.50'	850m
SBCC	COLSON CANYON	34°56.38'	120°10.32'	610m
SBCD	CASITAS DAM	34°22.12'	119°20.63'	213m
SBI	SANTA BARBARA ISLAND	33°28.84'	119° 1.72'	6m
SBLC	LA CUMBRE PEAK	34°29.79'	119°42.81'	1190m
SBLG	LAGUNA PEAK	34° 6.87'	119° 3.85'	415m
SBLP	LOMPOC	34°33.57'	120°24.02'	134m
SBSC	SANTA CRUZ ISLAND	33°59.68'	119°37.99'	457m
SBSM	SAN MIGUEL ISLAND	34° 2.24'	120°21.01'	172m
SBSN	SAN NICOLAS ISLAND	33°14.68'	119°30.38'	259m
SCI	SAN CLEMENTE ISLAND	32°58.80'	118°32.80'	219m
SCY	STONE CANYON RESERVOIR	34° 6.37'	118°27.25'	287m
SDW	SIDEWINDER MINE	34°36.55'	117° 4.45'	1184m
SGL	SIGNAL MOUNTAIN	32°38.95'	115°43.52'	110m
SHH	SHEEPHOLE MOUNTAINS	34°11.26'	115°39.27'	1122m
SIL	SILVER PEAK	34°20.87'	116°49.60'	1730m
SIP	SIMI PEAK	34°12.24'	118°47.94'	700m
SLT	SALTON SEA TEST BASE	33°15.89'	115°55.39'	-50m
SME	SANTA ROSA MINE	33°49.36'	117°21.32'	494m
SMO	SANTA ROSA MOUNTAIN	33°32.15'	116°27.70'	2437m
SNS	SAN ONOFRE	33°25.90'	117°32.90'	190m
SPM	SHIP MOUNTAINS	34°28.32'	115°24.16'	915m

TABLE 3. -- COORDINATES OF TIMED STATIONS (cont.)

CODE	STATION NAME	LATITUDE	LONGITUDE	ELEVATION
SS2	SAN SEVAINE	34°12.46'	117°29.98'	1609m
SUN	SUNSET PEAK	34°12.64'	117°41.58'	1683m
SUP	SUPERSTITION MOUNTAIN	32°57.31'	115°49.43'	219m
SYP	SAN YNEZ PEAK	34°31.63'	119°58.67'	1305m
SYS	SAN YSIDRO	32°34.78'	116°54.69'	277m
TMB	TEMBLOR RANGE SE	35° 5.24'	119°32.08'	1021m
TPC	TWENTYNINE PALMS	34° 6.35'	116° 2.92'	761m
TTM	TURTLE MOUNTAIN	34°20.12'	114°49.65'	1098m
VG2	VISTA GRANDE	33°49.91'	116°48.55'	1484m
VPD	VILLA PARK DAM	33°48.90'	117°45.70'	183m
VST	VISTA	33° 9.40'	117°13.90'	112m
WCH	CHIMNEY PEAK	35°52.98'	118° 4.48'	2475m
WCS	COSO HOT SPRINGS	36° 1.58'	117°46.01'	1143m
WRC	RENEGADE CANYON	35°57.04'	117°38.89'	945m
WWP	WALKER PASS	35°44.13'	118° 5.22'	1151m
WWR	WHITEWATER	33°59.51'	116°39.36'	702m
YAQ	YAQUI MEADOWS	33°10.08'	116°21.00'	441m
YEG	YEGUAS MOUNTAIN	35°26.18'	119°57.56'	939m

TABLE 4. -- PORTABLE STATION ARRIVAL TIMES
[seconds after 20:00 GMT]

<u>STATION</u>	<u>PHASE</u>	<u>WEIGHT</u>	<u>TIME(sec)</u>	<u>DIST.(km)</u>
CAPT	P	IUO	1.01	3.8
WHLT	P	IUO	2.31	10.3
EMPL	P	IUO	3.27	15.5
LTLH	P	IUO	3.33	16.7
WQUA	P	IUO	4.09	20.1
HOWL	P	IUO	4.95	25.8
WEND	P	IUO	5.84	31.5

TABLE 5. -- PORTABLE STATION LOCATIONS

<u>CODE</u>	<u>STATION NAME</u>	<u>LATITUDE</u>	<u>LONGITUDE</u>	<u>ELEVATION</u>
CAPT	CASINO POINT	33°20.88'	118°19.49'	6m
WHTL	WHITE'S LANDING	33°23.29'	118°22.64'	46m
EMPL	EMPIRE LANDING	33°24.43'	118°26.02'	439m
LTLH	LITTLE HARBOR	33°22.98'	118°28.05'	42m
WQUA	WEST QUARRY	33°26.23'	118°28.03'	220m
HOWL	HOWLAND'S LANDING	33°27.53'	118°31.58'	30m
WEND	WEST END	33°28.23'	118°35.41'	130m