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DATA REPORT FOR A SEISMIC STUDY OF THE *P* AND *S* WAVE VELOCITY STRUCTURE OF REDOUBT VOLCANO, ALASKA

by

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TABLE OF CONTENTS

TABLES

FIGURES

Summary

Between December 13, 1989 and April 21, 1990 Redoubt Volcano, Alaska erupted more than 20 times. During this period 14 lava domes were formed of which 13 were subsequently destroyed. The composite volume of the eruptions was estimated to be on the order of 0.15 cubic km. Economic losses (about $160 million) sustained during the eruptions prompted a number of studies of the volcano. The primary goals of these studies were to document the physical characteristics of the eruption and to address the reduction of hazards associated with the volcano. A special issue of the Journal of Volcanology and Geothermal Research (Miller and Chouet, 1994) has been devoted to the documentation of these eruptions, and should be referred to for further reading. This report describes the high-quality digital seismic data collected on Redoubt Volcano for three weeks during July, 1991. The data were collected to determine the velocity structure of the volcano and to provide insight into the dynamics of the eruptive sequence.

Introduction

Redoubt volcano is located on the northwest side of Cook Inlet, about 120 km southwest of Anchorage, Alaska. It is near the northeastern end of the Aleutian volcanic arc. The Quaternary stratovolcanoes of this arc are related to the northwestward subduction of the Pacific plate beneath southern Alaska. From a base elevation of 1500 m above sea level, underlain by Jurassic granodiorite of the Alaska-Aleutian Range batholith, Redoubt is a 1500 m high glacier-covered stratovolcano. The glaciers and volcanic deposits which mantle the volcano drape over the batholithic base to nearly sea level in adjoining glacially carved valleys.

The Quaternary history of the volcano extends back to about 0.9 Ma. At least 30 Holocene eruptions have been documented (Till et al., 1994), as well as lahars off all flanks of the volcano (Beget and Nye, 1994). Historic eruptions similar to the 1989-1990 sequence occurred in 1902, 1966, and 1968. The latest eruptive activity lasted about 6 months from December, 1989 until June, 1990.

The initial eruption of December 14, 1989 was preceded by an intense swarm of long-period seismicity which lasted for 23 hours. Following the initial eruption a lava dome began to form in the summit crater, sealing the vent. On December 26 long-period seismicity was again observed and increased in intensity until the dome was destroyed by another eruption on January 2, 1990. Repeated dome growth and destruction continued until April 21, 1990 when the thirteenth dome collapse occurred. The fourteenth and current dome was then emplaced and continued growing until about mid-June, 1990.

Instrumentation

PASSCAL (Program for Array Seismic Studies of the Continental Lithosphere) REF TEK® 72A digital recorders and geophones were provided for the experiment by IRIS

(Incorporated Research in Seismology) through the Lamont instrument center. A detailed description of the REF TEK® 72A portable seismic data acquisition system can be found in Refraction Technology, Inc. (1990). The recorder can collect up to 6 channels of data with sampling rates of 1 to 1,000 samples per seconds with 16 bit resolution. Mark Products three-component L-22-3D sensors (natural frequency of 2 Hz and sensitivity of 0.5 V/cm/s) were used. Data was written to 190 MB disk subsystems at 16 of the stations, and 600 MB disks were used at the remaining four stations.

The recorders were deployed in three semi-linear arrays across the volcano and in a diffuse pattern to fill gaps between the permanent network stations operated by the Alaskan Volcano Observatory (AVO). Figure 1 gives the array configuration and topography of Redoubt Volcano. Station names were derived from local place names and numbered consecutively along each array. The DR (Drift River) line trends N-S along the north-face of the volcano, the CR (Crescent River) line trends N-S along the south face, and the SE (south east) line trends NW-SE along the SE flank slope of the volcano. The SU station names are derived from their location about the summit of the volcano. Table 1 gives the station locations for the PASSCAL network and the local AVO network.

Timing

Because the internal clocks of each instrument drift independently, an Omega time clock was deployed with each station. At preset intervals, the internal clock was synchronized to the Omega time. Several of the stations had difficulty receiving the Omega satellite signal, in particular station N1, which never synchronized to the external signal and station E1 which had a systematic offset and drift rate. To compensate for this problem, we carried a USGS Master Clock II in the field and input a 1-Hz step function at a known minute mark to the PASSCAL instrument to provide an independent time-stamp.

Field Procedure

During July, 1991 the 20 digital seismic recorders were deployed on Redoubt Volcano. A total time limit of one month, including shipping to and from Alaska, and our desire to maximize the effective recording time required a multi-layered recording schedule. The schedule also had to reflect the fact that field work along the Cook Inlet during the summer was at the whim of prevailing fog patterns.

Our goal was to record local and regional seismic events, and four chemical explosions detonated around the volcano. Therefore, the recorders were programmed with eight separate data streams. The first stream continuously recorded the vertical component of ground velocity at 50 samples per second. The second stream recorded three components at 100 samples per second when a trigger threshold was met. The continuous recording was required because we had no opportunity to tune the trigger parameters for individual sites. To record the chemical explosions, a series of two-minute windows were programmed as data streams three through seven to record five times per day over a one week period. The entire experiment was supported by helicopter, economics required that we visit each site only for deployment, one disk swap, a site check, and instrument retrieval. Table 2 gives the data stream and trigger parameters used for the experiment .

Prior to shipping the equipment to the Drift River Oil Terminal for deployment, all of the instruments were deployed in a huddle test in Anchorage, Alaska for two days. This test revealed several damaged circuit boards (most likely from heavy handling during shipping to Alaska) which were repaired on the spot by an IRIS technician. This practical experiment revealed the damaged units and allowed for better instrument performance and data collection during the actual deployment on Redoubt Volcano.

The 190 MB capacity of the hard disks determined the amount of time each station could record, indicating at least one disk swap was required at 16 of the stations. Stations SU1-SU4 were the highest and most inaccessible sites so we deployed 600 MB disks at these sites and did not perform any maintenance or disk swaps at these stations. We calculated a conservative value for the amount of data expected to be collected and determined that the sites with 190 MB disks would run about 10-12 days before filling with data. We were equipped with 10 extra disks which meant that approximately one half of the array could be serviced with a disk swap on any given day. The filled disks were then flown to Anchorage where the data was archived to exabyte tape, the disks cleared and flown back to the volcano, then the remainder of the array serviced in the same manner. Fortunately, the weather cooperated and we were able to reach the sixteen sites over a three-day period and perform the required disk swap. Table 3 gives the performance of the stations. The average recording time for all stations was 15.5 days over a 24 day period.

Site Selection

Sites were selected on one primary basis - helicopter access. Since Redoubt Volcano is heavily glacier-clad, this meant that most of the stations were deployed along ridges of well-consolidated volcanic rocks or granitic basement. The only site with suspect underpinning was SU1, located next to the summit dome. An outcrop was found at the edge of the ice-crater surrounding the summit dome, but it was not clear if the outcrop extended through the glacier or was a large block carried in the glacier. Sites E2 and E3 were occupied for a few days, then moved to SE2 and SE4 respectively to provide a better profile for shot number 4. The disks were not reformatted so data from E2-SE2 and E3-SE4 occur on the same disk.

Instrument Failure

Several factors led to the loss of data at five of the stations. Cables at station W2 provided tempting to the local critters, but they were eventually satisfied that there was no nutritive value to the cables. New cables were installed during a quick visit to the site prior to the firing of the shots. Station SE2 was destroyed by a bear, resulting in a few day's loss of data. The antennae pole and bolts provided an ideal scratching post for the bear. The site was re-established prior to the detonation of the chemical explosions. The bear was not satisfied with his distance mark in shot-putting the lead-acid car batteries and decided to further his mark several days later. The disk swap at station DR5 failed. Stations E1 and N1 experienced difficulty receiving the Omega time signal as previously mentioned.

Active Experiment - Chemical Explosions

To help calibrate the network and to derive a well-constrained velocity model of the upper portion of the volcano, an active seismic experiment using chemical explosives was conducted. 1400 Kg of chemical explosives were transported to the Drift River Oil Terminal and, because of the proximity to large amounts of oil, uneasily stored by the terminal staff. The explosives were transported by external cargo net to three glacial kettles at the base of the volcano and to the summit crater. Each shot consisted of 350 Kg of explosives detonated at precise times on the hour. The recorders were programmed to turn on automatically during several windows per day to allow for contingencies such as bad weather. The recording times were set to begin on the hour and record for 120 seconds with an additional parameter programmed to record 10-s pre-event memory. The pre-event memory function turned out to not be implemented. Therefore, stations near the shot points have very little pre-event signal. Each shot was successful, due to the efforts of the personnel who valiantly performed under adverse conditions such as black flies and mosquitoes. Four team members spent 8 hours on the summit crater glacier adjacent to the steaming volcanic dome, loading explosives into a glacial crevasse, then detonating the shot from the seat of a partially flying helicopter. The said helicopter then took to immediate flight as large pieces of the surrounding hanging glaciers and substantial rockfall descended onto the summit glacier. Figure 2 shows record sections for the vertical component data for the four shots and Table 4 gives the shot schedule.

1-D Velocity Model

The shots were used to constrain the *ad hoc* 1-D velocity model used to locate seismicity recorded by the permanent network (Lahr, 1994). Two of the shots (numbers 2 and 3) and 10 of the recorders (the CR and DR lines) provided a reversed profile across the mountain. The traveltimes from these shots were used to constrain the shallow portion of the 1-D velocity model. Deeper velocities were determined by minimizing the root mean square travel time residuals of well recorded earthquakes in the 3-5 km depth range. The final 1-D velocity model is given in Table 5. The ultimate goal of this modelling was to accurately locate the seismicity occurring in a complex 3-D medium with a simple 1-D model. One test of the derived model is how well it relocates the shots. Using a modified version of the program HYPOELLIPSE (Lahr, 1989) in which the stations can be imbedded in the model, and P-wave arrivals from the PASSCAL network, the summit shot is relocated with an epicentral error of 30 m and a depth error of 70 m. Using P-wave arrivals from six stations of the permanent network the summit shot is located with an epicentral error of 40 m and a depth error of 90 m. The flank shots yield epicentral errors of 400 to 1750 m and depth errors of 660 to 1540 m.

3-D Velocity Model

P and *S* wave phase data from local seismic sources recorded by the PASSCAL and AVO networks were used to determine the three-dimensional velocity structure of Redoubt Volcano to depths of 7-8 km (Benz et al., 1996). 6219 *P* wave and 4008 *S* wave first arrival times were used. First-arrival times were calculated using a finite-difference technique and structure was determined using a nonlinear inversion procedure. The most prominent feature observed in both the P and S wave three-dimensional models is a relative low-velocity, near-vertical, pipelike structure approximately 1 km in diameter that extends from 1 to 6 km beneath sea level. This feature is aligned with the seismicity and is interpreted as a highly fractured and altered zone encompassing a magma conduit. No large low-velocity body suggestive of a magma chamber is resolved in the upper 7-8 km of the crust beneath the volcano.

Recorded Seismicity

During the three weeks the instruments were deployed approximately eight gigabytes of data were collected. Events recorded during the experiment include about 240 volcano-tectonic events; several hundred regional and Wadati-Benioff zone events; hundreds of glacier quakes; several teleseisms; and thousands of small microearthquakes associated with the cooling of the crater dome. Station SU1, located a few hundred meters from the dome, triggered over 14000 times in 21 days recording steam bursts, glacier quakes, and seismicity associated with the cooling of the dome. About one half of these triggers were observed at nearby stations. Figures 3-6 show examples of the seismicity recorded by the network.

P and *S*-wave phases were picked from the digital records of over 240 volcano-tectonic events and many of the regional events recorded by the PASSCAL network. The University of Alaska XPICK program coupled with Lahr's HYPOELLIPSE program was used to locate the events. Uncertainties in the arrival times range from 0.02 to 0.1 sec. During the experiment 24 local events triggered the local (AVO) network. The large discrepancy in the number of events observed by the two networks is due to the sensitivity of the triggering algorithms employed and array configuration. Because of the large station spacing of the permanent network, the small magnitude events observed by many of the PASSCAL instruments did not trigger on the permanent network. Table 6 gives the format of the HYPOELLIPSE summary data. Table 7 gives the local event locations.

The distribution of local earthquakes (Figure 8) is reminiscent of the long-term post-eruptive pattern described by Lahr et al (1994). Two prominent zones of seismicity are observed, the first directly beneath the crater dome extending from the crater floor to about 1.5 km depth. The second is offset to the north and west of the shallow seismicity by a few kilometers and extends from 3 to 7 km below the crater floor.

Data Archive

The data recorded by the PASSCAL recorders were downloaded to a SUN workstation in SEGY format. Trigger coincidence was determined with a 10 second maximum time difference between stations, and events recorded by more than three stations extracted from the data base and archived in AH format. Most of the coincident triggers which were obviously not correlated were removed from the final archive. In addition, the vertical component records from the continuous data stream were extracted for many of the local events when individual stations did not trigger on those events. Events were classified as local, regional, teleseismic, or glacial in origin based on visual characteristics.

The original Exabyte tapes (master data set) from disk dumps are available from the IRIS data center. The seismic data (in AH format) extracted from the master data set are preserved on Exabyte tape using the UNIX TAR facility. The extracted archive contains about 1.8 MB of data. Events are grouped into sub-directories by day and hour. Table 8 gives the data distribution structure. In addition, phase data and event locations are preserved in HYPOELLIPSE format in a separate sub-directory called "picks". Ancillary data such as the local network phase data and line files of topography are preserved in a sub-directory called "ancillary".

Acknowledgments

Numerous people contributed to the success of this experiment. For instrumentation, the staff of the Lamont PASSCAL instrument center provided guidance, computer advice, and technical help. Bob Busby of the instrument center directed our attention toward the details of the REF TEK® operation and Tom Jackson assisted with the preliminary tests of the equipment in Anchorage. Jim Fowler of IRIS made the logistical loan of the instruments and computers possible. The staff of AVO, including John Paskievitch and Inyo Ellersieck provided administrative and technical support. Our helicopter pilots Michael Wilton, Rick Farrish,, and Walt Woodrow performed amazing feats of high altitude mountain flying. The staff of the Cook Inlet Pipeline Company and the Drift River Oil Terminal including Don Gregor, Ron Green, and Larry Duncanson provided the critical task of helping us stage the experiment from the oil terminal.

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Table 1.
Station Locations

Station	Latitude (N)	Longitude (W)	Elevation (m)
PASSCAL Instruments			
CR2	60 26.792	152 49.535	931
CR3	60 27.682	152 48.576	1287
CR4	60 28.388	152 48.288	1839
DR2	60 32.386	152 46.136	651
DR3	60 31.663	152 46.429	1226
DR4	60 31.136	152 46.902	1449
DR5	60 30.548	152 46.768	1872
E1Z	60 31.881	152 37.208	1201
E2Z	60 27.668	152 38.832	853
E3Z	60 29.320	152 38.830	1318
N1Z	60 30.275	152 42.490	1682
SE2	60 26.798	152 38.717	659
SE3	60 27.354	152 40.038	994
SE4	60 27.533	152 41.394	1371
SE5	60 28.354	152 42.743	1792
SU1	60 29.354	152 45.877	2479
SU2	60 29.436	152 46.624	2743
SU3	60 30.010	152 46.920	2433
SU4	60 29.814	152 44.318	2492
SU6	60 28.766	152 47.285	2492
W1Z	60 32.204	152 51051	1014
W2Z	60 29.488	152 53842	1135
Permanent Network Stations			
DFR	60 35.51	152 41.16	1090
NCT	60 33.79	152 55.57	1079
RDN	60 31.37	152 44.26	1400
RDTE	60 34.39	152 24.32	930
RDTN	60 34.39	152 24.32	930
RDTZ	60 34.43	152 24.37	930
RDW	60 28.96	152 48.57	1813
RED	60 25.19	152 46.31	1064
REDE	60 25.19	152 46.31	1067
REDN	60 25.19	152 46.31	1067
REF	60 29.35	152 42.10	1801
RSO	60 27.73	152 45.23	1921
RS2	60 27.78	152 45.44	1953

Table 2.
Data Stream Parameters

Data Stream 1 CONTINUOUS
Channels 1
Sample rate 50 samples per second
Data Format 16
Filters
Trigger Type CON
Record Length (seconds) 600

Data Stream 2 TRIGGERS
Channels 123
Sample rate 100 samples per second
Data Format 16
Filters
Trigger Type EVT
Trigger Channels 123
Minimum Number of channels 1 Trigger Window (seconds)
Pretrigger Length (seconds) 10
Posttrigger Length (seconds)
Record Length (seconds) 60
STA (seconds) 0.5 LTA (seconds) 60
Mean Average Length
Trigger Ratio 5 Detrigger Ratio
LTA Hold Flag OFF

Data Stream 3 SHOT 1
Channels 123
Sample rate 100 samples per second
Data Format 16
Filters
Trigger Type TIM
Start Time : Year 1991 Day 188 0 :0 :0
Repeat Interval Days 1 0 :0 :0 Number of Repeats 6
Pretrigger Length (seconds) 10
Record Length (seconds) 120

Data Stream 4 SHOT 2
Channels 123
Sample rate 100 samples per second
Data Format 16
Filters
Trigger Type TIM
Start Time : Year 1991 Day 188 04:0 :0
Repeat Interval Days 1 0 :0 :0 Number of Repeats 6
Pretrigger Length (seconds) 10
Record Length (seconds) 120

Table 2 (cont.)

Data Stream 5 SHOT 3
Channels 123
Sample rate 100 samples per second
Data Format 16
Filters
Trigger Type TIM
Start Time : Year 1991 Day 188 06:0 :0
Repeat Interval Days 1 0 :0 :0 Number of Repeats 6
Pretrigger Length (seconds) 10
Record Length (seconds) 120

Data Stream 6 SHOT 4
Channels 123
Sample rate 100 samples per second
Data Format 16
Filters
Trigger Type TIM
Start Time : Year 1991 Day 188 18:0 :0
Repeat Interval Days 1 0 :0 :0 Number of Repeats 6
Pretrigger Length (seconds) 10
Record Length (seconds) 120

Data Stream 7 SHOT 5
Channels 123
Sample rate 100 samples per second
Data Format 16
Filters
Trigger Type TIM
Start Time : Year 1991 Day 188 21:0 :0
Repeat Interval Days 1 0 :0 :0 Number of Repeats 6
Pretrigger Length (seconds) 10
Record Length (seconds) 120

Data Stream 8 MINMARK
Channels 1
Sample rate 100 samples per second
Data Format 16
Filters
Trigger Type EXT
Pretrigger Length (seconds) 2
Record Length (seconds) 11

Calibration Definition 91:195:23:57:48:705 ST: 0386
Start time : Year Day : :
Repeat Interval Days : : Number of Repeats
Length of CAL (seconds)
Step OFF
Freq OFF
Noise OFF

Table 3.
Station Operation

Station	DR2	DR3	DR4	DR5	CR2	CR3	CR4	SE2	SE3	SE4	SE5	SU1	SU2	SU3	SU4	SU6	W1	W2	E1	N1
Inst. #	370	97	359	345	341	386	343	192	340	342	376	237	382	362	148	356	394	361	379	366
1991																				
184												=		=			=	=		
185					=	=						│	=	│			│	│	=	
186	=	=	=		│	│	=					│	│	│			│	│	│	=
187	│	│	│		│	│	│				=	│	│	│			│	│	│	│
188	│	│	│		│	│	│	=		=	│	│	│	│	=	=	│	│	│	=
189	│	│	│	=	│	│	│	│		│	│	│	│	│	│	│	│	│	│	
190	│	│	│	│	│	│	│	│	=	│	│	│	│	│	│	│	│	│	│	
191	│	│	│	│	│	│	=	│	│	│	│	│	│	│	│	│	│	=	│	
192	│	=	=	│	│	│		│	│	│	│	│	│	│	│	│	│		│	
193	│			│	=	│		│	│	│	=	│	│	│	│	│	│		│	
194	│			=	│	│		│	│	=	│	│	│	│	│	│	│		=	
195	=	=	=		│	=		│	│		│	│	│	│	│	│	=	=	=	
196	│	│	│		│	=	=	=	│		│	│	│	│	│	=	│	│	│	=
197	│	│	│		│		│	│	=	=	│	│	│	│	=	│	│	│	│	│
198	│	=	│		│		│	│	│	│	│	│	│	│		│	│	│	│	│
199	│		│		│		│	│	│	│	│	│	│	│		│	│	│	│	│
200	│		│		│		│	│	│	│	│	│	=	│		│	│	│	│	│
201	│		│		│		│	│	│	│	│	│		│		│	│	│	│	=
202	│		│		│		│	│	│	│	│	│		│		│	│	│	│	
203	│		│		│		│	│	=	│	=	=		=		=	│	│	│	
204	│		=		│		=	=		│							│	│	│	
205	│				│					│							│	│	│	
206	│				│					=							│	│	│	
207	=				=												=	=	=	

Table 4.
Shot Schedule

Shot Number	Date	Latitude (N)	Longitude (W)	Elevation (m)	Shot Time (GMT)	Size (kg)
1	7/10/91	60 29.34	152 45.19	2430	04:00:00.01	350
2	7/10/91	60 33.19	152 46.49	400	06:00:00.13	350
3	7/11/91	60 26.17	152 49.91	600	00:00:00.01	350
4	7/11/91	60 26.62	152 37.47	320	04:00:00.01	350

Table 5.
Velocity Model

Velocity (km/s)	Depth (km)
2.9	-3.0
5.1	-1.7
6.5	1.5

Table 6.
HYPOELLIPSE Summary Record Format

To save space no decimal points are used. Use the format for reading given below.

Item	Col.	Nos.	Format for Reading
Origin Time:			
KDATE - year, month, day	1 -	6	I6
KHRMN - hour, minute	7 -	10	I4
seconds	11	14	F4.2
LAT degrees	15 -	16	I2
N or S		17	A1
LAT minutes	18 -	21	F4.2
LON degrees	22 -	24	I3
E or W		25	A1
LON minutes	26 -	29	F4.2
DEPTH (km)	30 -	34	F5.2
PREFERRED MAGNITUDE	35 -	36	F2.1
NO - Number of P, S, and S-P readings used in the solution	37 -	39	I3
GAP - Largest azimuthal separation in degrees between stations as seen from the epicenter (deg).	40 -	42	I3
D1 - Distance to closest station used in solution (km)	43 -	45	F3.0
RMS (sec)	46 -	49	F4.2
Azimuth of axis 1 of error ellipsoid (deg)	50 -	52	I3
Dip of axis 1 (deg)	53 -	54	I2
SE - Length of ellipsoid semi-axis 1 (km)	55 -	58	F4.2
Azimuth of axis 2 of error ellipsoid (deg)	59 -	61	I3
Dip of axis 2 (deg)	62 -	63	I2
SE - Length of ellipsoid semi-axis 2 (km)	64 -	67	F4.2
Average XMAG	68 -	69	F2.1
Average FMAG	70 -	71	F2.1
Processing state (not used by HYPOELLIPSE) * - More data available to be added P - Preliminary, but location not finalized F - Final location determined G - NEIS solution A - NEIS solution obtained from AEIC I - Insufficient data to determine a hypocenter N - Not of principal interest		72	A1
SE - Length of ellipsoid semi-axis 3 (km)	73 -	76	F4.2
Quality - Either error ellipsoid quality or HYPO quality depending upon QUALITY OPTION record		77	A1

Table 6 (cont.)

Item	Col. Nos.	Format for Reading
MAGTYP - F, X, A, or K to indicate which type of magnitude is entered in columns 35-36	78	A1
NSWT - Number of S-phase arrivals used in solution	79 - 80	I2
/ or \	81	A1
[The primary SUMMARY record is always first and has a / in column 81. If an archive file has more than one SUMMARY record, the second and subsequent records will have a \ in column 81]		
First 4 characters of INSTRUCTION record	82 - 85	A4
Month data was run	86 - 87	I2
Year data was run	88 - 89	I2
Event type:	90	A1
E or blank — local or regional earthquake		
T — teleseism		
R — regional		
N — nuclear explosion		
G — glacial event		
X — emergent, low frequency, near volcano		
Q — quarry shot		
S — artificial source		
O — other non-earthquake (eg sonic boom)		
C — calibration signal		
a — volcano-tectonic		
B — volcano long-period		
+ — continuation of previous event		
F — false trigger		
Fixed location indicator, from column 19 of INSTRUCTION record or imposed by SELECT DELAY option	91	I1
Sequence number	92 - 96	A5
S-P time at closest station used in solution. Blank if either P or S is not used. Set to 9999 if S-P .GE. 100.	97 - 100	F4.2
ZUP - Computed with GLOBAL OPTION	101 - 102	F2.0
ZDN - Computed with GLOBAL OPTION	103 - 104	F2.0
Vp/Vs - Computed slope of Ts vs Tp. Only computed if TEST(49) is not equal to 0.	105 - 108	F4.2
Number of readings weighted out due to Jeffrey's, truncation, or boxcar weighting.	109 - 110	I2
DEPTH (km)	111 - 115	F5.2

Table 7.
Listing of Local Events in HYPOELLIPSE Format

```
910704035005686 0N3137152W4828  355    21208  3    8315 7  4121939   60     F 106A 14/      493a         95.3.5     0
910704050757536 0N3060152W4424  428    21277  3    6350 6  5425542   79     F  96A 14/      493a           .5.4     0
910704093324076 0N3111152W4568  473    20251  2    6344 2  50 7528   85     P  71A 13/      493a           .4.4     0
910705082228916 0N3064152W4403  367    17205  3    5 41 6  60132 8   33     P  91A 12/      493a           .4.5     0
910705083413846 0N3024152W4567  428 6  27161  1    5237 2  3914611   25    6P  56AF18/      493a           .3.3     0
910705094208006 0N2957152W4535 -135    11257  1    6336 2  3324526   98     P  20A  6/      493B           .1.1     0
910705142750646 0N2947152W4636  -62    13125  0    8190 2  26 9843  122     P  52A  5/      493B           .0.3     0
910706010820526 0N3014152W4494  266    26144  2    7183 7  26 9115   63     P  50A 15/      493a           .0.2 184 0
910706070142536 0N3054152W4455  449    29158  2    6 69 1  44159 3   33     P  88A 17/      493a        124.4.5 135 0
910706083920476 0N2973152W4546 -141    13236  1    5340 3  40250 8   71     P  21A  8/      493X           .1.1     0
910706104534916 0N2950152W4629 -147 8  13127  0   12335 5  27 6613   57    8P  17AF 6/      493B           .0.1     0
910706140101096 0N3045152W4539  382    23141  2    717512  34 8118   59     P  91A 16/      493a        113.3.5     0
910706161510696 0N2943152W4450  236    24137  2    9333 2  35 6426   45        80A 16/      493            .1.4     0
910706212534716 0N3124152W4944  418    33 94  2    6106 2  3519720   26     P  55A 21/      493a           .2.2 203 0
910706212738186 0N3116152W4941  388    23141  2    530117  5620322   32     P  94A 14/      493a           .5.5 165 0
910707032643726 0N2938152W4563 -117     9107  0    4 16 5  5728415   63     P  20A  2/      493B           .2.1     0
910707043137246 0N3136152W4862  43510  39105  2    524016  3814224   30   10P  58AF26/      493a           .3.2     0
910707061633856 0N3127152W5008  441    29107  2    8 9714  3719325   31     P  66A 18/      493a         80.3.3 169 0
910707065007986 0N3012152W4494  253    26119  2    9 4216  3513717   22     P  76A 17/      493a           .0.2     0
910707083810116 0N3067152W4649  344    35104  1    7110 5  3020118   31     P  61A 23/      493a           .2.3     0
910707091207506 0N2951152W4588 -124    13187  0    4252 2  5234324   29     P  13A  7/      493a           .1.0     0
910707091411416 0N3053152W4653  315    32102  1    5240 7  2414814   19     P  61A 22/      493a         74.3.4     0
910707101224486 0N2973152W4469  229    20113  2    6228 1  31138 9   29     P  86A 14/      493a           .1.3     0
910707102842856 0N3039152W4509  433 7  40124  2    5 59 1  30149 7   21    7P  52AF26/      493a           .3.3     0
910707103249296 0N3059152W4470  455    20135  2    9 71 7  4816314   38     P  94A 14/      493a           .5.5     0
910707164016416 0N2998152W4608  209    15101  1    416510  3026441  102     P  60A 10/      493a           .2.3     0
910707164914786 0N2984152W4497  154    17112  3    4140 4  22 4917   48     P 105A 12/      493a           .3.6     0
910707175631506 0N2958152W4478  151    29108  2    8133 2  21 43 8   33     P  64A 18/      493a           .1.3     0
910707194253036 0N2900152W4087  621    34109  2    829613  3520122   48     P  62A 21/      493a           .3.3     0
910707194522126 0N3074152W4529  375    28128  2    6270 6  4417720   31     P  66A 17/      493a           .3.4     0
910707202456246 0N3065152W4535  414    30125  2    6247 8  3415420   25     P  61A 17/      493a           .2.2     0
910707202907506 0N3057152W4552  383    31120  2    7268 1  4017813   30     P  54A 21/      493a           .3.3     0
910707213310846 0N3052152W4645  288    33103  1    6171 7  2626315   37     P  56A 18/      493a           .2.2     0
910707235951476 0N3091152W4581  295    25121  1    4 81 2  4317115   28     P  51A 14/      493a         72.3.3 179 0
910708045150986 0N3038152W4428  425    22136  3    4119 8  30 2619   64     P  82A 13/      493a           .5.4 151 0
910708063112406 0N2918152W4530 -188     9249  1   20  2 4  8127030  166     P  22A  1/      493B         20.2.0     0
910708074421116 0N2964152W4548 -185    12240  1    735120  20 9940   50     P 148A  6/      493B           .4.2     0
910708095812796 0N2957152W4642 -184     7138  1    321521  5931626   23     P 104A  2/      493B           .5.2     0
```

Table 7 (cont.)

9107081306364660N2959152W4655	-162	5132	0	634911	6425324	138	P	170A	0/	493B	.4.5		0
9107081318425360N2870152W4653	355	25113	1	513114	43 3716	32	P	76A	16/	493a	83.4.3	239	0
9107081326401060N2953152W4603	-165	10141	0	5 69 1	65159 5	42	P	27A	3/	493B	.2.1		0
9107081401065060N2759152W5139	1968	8197	2	2326 8	504 5710	335	P	8821D	0/	493E	699		0
9107081407138260N2691152W4699	1680	12185	2	4286 3	131 1714	259	P	1229D	0/	493E	3 9		0
9107081507353360N2950152W4679	-171	11139	0	11 7818	3117521	27	P	23A	2/	493B	.1.1		0
9107081509465560N2513152W5004	1975	13271	3	4109 3	137 1824	194	P	1235D	0/	493E	4 9		0
9107081634417960N3414152W3751	460	22294	9	10132 6	93 4016	82	P	272B	14/	493a	1.1.		0
9107081703152260N2724152W5017	688	31176	1	913518	48 3527	39	P	56A	20/	493a	.3.1	138	0
9107081740075560N2938152W4578	-230	7254	0	4 23 0	2311312	71	P	335B	2/	493B	0.1		0
9107081912157260N2906152W4668	-139	8177	1	4306 1	66 3714	48	P	18A	2/	493B	.1.1		0
9107082013521560N2946152W4512	-230	5170	1	11113 5	25 23 7	66	P	906C	0/	493B	0.2		0
9107082309327660N3042152W4702	-115	10167	0	3 8 8	23 99 9	153	P	13A	2/	493B	.1.1		0
9107082312348560N3060152W4624	271	20108	0	5 63 2	5815536	40		94A	12/	493	.4.5		0
9107090248380960N2936152W4585	-229	7171	0	19320 4	39 51 6	21	P	166A	1/	493B	51.0.0		0
9107090549515960N3106152W4499	-11	5215	2	7157 2	103247 4	194	P	2176D	0/	493G	.499		0
9107090552396960N3021152W4468	404	19180	1	313722	4323927	163	P	75A	12/	493a	.5.5		0
9107090632488060N2946152W4587	-90	18 72	0	11335 0	20 65 5	29	P	67A	6/	493B	.0.1		0
9107090636530460N2941152W4595	-230	10 83	0	21 25 1	25116 2	19	P	195A	2/	493B	.0.0		0
9107090719468660N2937152W4605	-230	11122	0	11266 0	15356 0	27	P	2964D	6/	493a	.0.1		0
9107090918485760N2937152W4521	-230	7110	1	9 4 0	26 94 3	20	P	214A	0/	493B	.0.0		0
9107090958495360N3114152W4954	461	52 93	2	7 91 3	2918321	26	P	46A	34/	493a	.2.3		0
9107091114183960N2948152W4577	-203	12139	0	5 8818	3735122	20	P	45A	4/	493B	.3.2		0
9107091332021960N3123152W4530	414	32172	1	517923	3328026	55	P	64A	17/	493a	.3.3	209	0
9107091430305360N2492152W5377	4226	18284	5	21113 3	418 2310	630		252C	2/	493	1.1.		0
9107091450386660N2939152W4594	-165	15 89	0	7107 4	3820142	28	P	17A	6/	493B	.0.1		0
9107091612006960N3169152W4044	847	31262	5	813110	6522836	140	P	72A	19/	493a	161.6.3	173	0
9107091641041060N2987152W4470	-112	13131	0	1214310	40 5016	50	P	20A	2/	493G	.0.1		0
9107092207096160N2947152W4524	-133	12102	1	4328 4	3223716	21	P	16A	3/	493B	.1.0		0
9107100014598360N3020152W4473	-90	14171	1	821614	8331015	52	P	245A	0/	493E	.1.6		0
9107100017576060N3026152W4791	412	46 66	1	7150 8	23241 8	33	P	46A	30/	493a	.2.2	223	0
9107100051409660N3022152W4780	408	39 65	1	8263 8	2617210	22	P	47A	26/	493a	96.1.3	246	0
9107100237372360N2987152W4459	264	30129	0	614511	22 5120	50	P	65A	19/	493a	97.0.2	180	0
9107100308444360N2956152W4549	-230	16157	1	6 56 1	16326 6	22	P	201A	10/	493X	.0.1		0
9107100359599460N2940152W4511	-138	16 86	1	5174 2	3626423	45	P	20A	0/	493A	.1.1		0
9107100600000460N3275152W4623	143	25119	1	5152 6	32 5831	29	P	39A	0/	493Q	.1.3		0
9107100609435360N2891152W4444	686	23164	2	5 52 2	195142 7	33	P	70A	14/	493a	147.4.4	270	0
9107100726593560N2950152W4490	-124	9196	1	214114	89 4715	36	P	18A	4/	493X	.6.1		0
9107101032285760N3012152W4562	349	30122	1	5324 2	23 5539	63	P	54A	20/	493a	.3.3	213	0

Table 7 (cont.)

910710104132226 0N2980152W4570	-146	16102	1	832813	14 6426	19	P	25A	8/	493a	.0.1		0
910710105031996 0N2947152W4522	-162	8103	1	833216	3522940	29	P	21A	0/	493B	.1.1		0
910710105122246 0N2958152W4551	-100	15 92	1	5 69 2	27338 9	35	P	110A	7/	493B	.1.3		0
910710105807066 0N2963152W4556	-89	15136	1	7 66 7	3333419	53	P	204A	7/	493B	.2.1		0
910710121845806 0N2941152W4531	-101	6186	1	2247 3	78156 9	151	P	25A	0/	493B	.8 6		0
910710122051856 0N2949152W4567	-111	20 90	0	7 76 3	2016716	35	P	11A	11/	493B	.0.1		0
910710145041876 0N2967152W4659	129	16236	1	4256 0	13216613	68	P	72A	10/	493a	.2.4		0
910710155346756 0N3005152W4562	462	44116	1	6144 4	2323623	40	P	50A	30/	493a	.2.2		0
910710161420586 0N3073152W4567	360	39148	1	715011	1924418	30	P	38A	25/	493a	.2.1	196	0
910710161903376 0N2948152W4475	-157	7208	1	514520	10424321	36	P	56A	0/	493B	.3.1		0
910710173816696 0N2942152W4518	-153	11 88	1	523713	2633426	44	P	19A	0/	493B	.1.1		0
910710183606756 0N3103152W4901	451	21 87	2	4310 6	4021634	57	P	91A	14/	493a	.5.4		0
910710192630526 0N3113152W5026	430	43165	2	626313	4116822	26	P	56A	28/	493a	.2.3		0
910710202716786 0N2967152W4540	-172	6141	1	4238 1	5032814	59	P	246A	0/	493B	.6.6		0
910710205918526 0N2835152W4477	-121	11134	2	8 2219	13528033	86	P	55A	0/	493B	.6 3		0
910710211402906 0N2946152W4482	-179	10103	1	730820	2220630	32	P	24A	1/	493B	.1.1		0
910710212506186 0N2956152W4546	-162	8 93	1	311110	47 1534	31	P	59A	0/	493B	.2.3		0
910710225752806 0N2946152W4558	-220	8102	0	4 60 5	2532916	73	P	149A	0/	493B	.1.3		0
910711000000086 0N2683152W4939	29	23108	0	7317 1	29 4744	39	P	55A	0/	493Q0	.1.3		0
910711024853366 0N2935152W4584	-230	5172	0	6256 0	43346 0	134	P9900D		0/	493B	0 2		0
910711025124156 0N2878152W4443	-100	12153	2	7303 0	35 33 0	83	P9900D		5/	493G	40.3.2		0
910711052250046 0N2967152W4538	-230	6113	1	10 62 3	38332 4	51	P	422B	0/	493B	0.1		0
910711055853306 0N2949152W4530	-132	7101	1	2344 9	3824930	30	P	22A	0/	493B	.2.1		0
910711074150456 0N2948152W4573	-230	6144	0	14 15 0	38285 0	83	P9900D		1/	493B	.0.1		0
910711083728826 0N3096152W4624	341	41138	1	714214	1923618	27	P	53A	25/	493a	.3.3		0
910711091636126 0N3144152W4618	386	41142	0	624311	3614917	20	P	41A	27/	493a	.2.2		0
910711093935306 0N2932152W4588	-230	5175	0	7 36 0	27306 0	54	P9900D		0/	493X	.01.		0
910711100437756 0N2959152W4573	221	17310	1	727211	13017726	70	P	41A	11/	493a	.2.2		0
910711100514126 0N2968152W4488	269	36 81	1	7142 1	1723230	47	P	38A	23/	493a	.0.2		0
910711102057386 0N3085152W4527	-129	14189	1	724919	5514926	36	P	18A	4/	493G	.4.1	129	0
910711105117416 0N2959152W4539	-230	7103	1	6254 0	28344 1	48	P	346B	0/	493B	.0.1		0
910711151029506 0N2780152W4482	253	37146	2	8296 3	17 27 7	29	P	56A	25/	493a	.0.3		0
910711152630376 0N2935152W4586	-230	8171	0	4 73 1	35343 2	70	P	727C	2/	493B	.0.2		0
910711181524146 0N3062152W4549	-144	12169	1	6304 2	3821241	89	P	23A	4/	493G	.5.2		0
910711182433326 0N2923152W4559	-230	9119	0	7116 3	18206 3	37	P	339B	2/	493B	0.2		0
910711182658456 0N2945152W4544	-230	9104	0	6302 1	59 32 5	29	P	393B	2/	493B	0.2		0
910711185218136 0N2936152W4579	-230	6173	0	4 59 1	39329 2	69	P	721C	0/	493B	0.4		0
910711185443196 0N2937152W4557	-220	9109	0	7341 3	66 7213	32	P	145A	2/	493B	.1.1		0
910711185829296 0N3039152W4438	44111	40168	1	5146 3	25 56 4	43	11P	60AF	26/	493a	.3.3		0

Table 7 (cont.)

910711200508536ON2937152W4569	-206	7175	0	417120	10127739	67	P	32A 2/	493B	.2.2		0
9107112137428760N2935152W4574	-179	10176	0	3253 0	1834317	39	P	81A 4/	493B	.5.3		0
9107112158143860N3090152W4640	357 2	38132	1	614412	2123712	34	2P	52AF25/	493a	.3.3		0
9107112245309660N2986152W4671	259-4	18190	0	9149 4	3223912	91	-4P	53AF12/	493a	.0.2		0
9107112326240760N2970152W4508	-193	9118	1	3257 5	1835034	47	P	30A 2/	493B	.4.1		0
9107120001348160N3038152W4636	308 4	29131	0	514710	1923914	38	4P	43AF18/	493a	.2.2		0
9107120415407960N2639152W4526	849	13211	4	730311	97 3718	121	P	535C 0/	493E	2 4		0
9107120607310660N3062152W4551	333 1	30150	1	8 64 2	3415513	21	1P	52AF19/	493a	.3.3		0
9107120624497560N2944152W4503	-207	8195	1	3326 8	77 5711	28	P	169A 2/	493B	.2.2		0
9107120807033760N3002152W4538	246-1	19120	1	5151 2	4124228	104	-1P	48AF12/	493a	.1.3		0
9107120853452760N2989152W4584	-139	17131	1	5333 5	15 6410	21	P	43A 11/	493B	.1.1		0
9107120903321760N2981152W4550	-109	12130	1	3253 1	2116224	73	P	17A 6/	493B	.4.4		0
9107121217496060N2969152W4558	-174	18124	1	629211	17 2413	15	P	54A 12/	493a	.2.2		0
9107121305503660N2981152W4548	-114 2	18131	1	6 74 7	2016511	35	2P	16AF12/	493a	.2.1		0
9107121438435460N2961152W4557	-230	5139	1	4 56 3	40326 3	54	P	197A 0/	493B	0.3		0
9107121937161060N2955152W4541	-187	8166	1	2 4814	2231224	34	P	123A 2/	493B	.4.3		0
9107121938562660N2965152W4532	-106 0	17151	1	515910	31 6811	18	0P	12AF11/	493a	.1.2		0
9107122056249660N3080152W4625	340 1	29134	1	614712	31 5032	50	1P	54AF18/	493a	.3.3		0
9107130002183960N3101152W4793	455 5	28122	1	614514	34 4729	66	5P	56AF17/	493a	.3.3-262		0
9107130416418460N3064152W4359	639 3	26188	2	712811	4522531	106	3P	57AF17/	493a	.4.4		0
9107131021357060N3070152W4640	313 4	30126	0	5172 6	3226840	53	4P	54AF20/	493a	.3.3		0
9107131234342560N3031152W4532	289 1	21146	1	6 7615	4934116	28	1P	50AF14/	493a	102.3.3	83	0
9107131316237360N3477152W4691	1285 5	23297	4	832616	9122924	195	5P	78AF16/	493a	.5.6		0
9107131623242360N2940152W4575	-210	9171	0	6263 0	4335321	26	P	90A 3/	493G	.2.4		0
9107131657586060N3010152W4568	256 1	23119	1	832514	2823115	51	1P	42AF15/	493a	80.0.2		0
9107131746023260N3011152W4571	267 1	28119	1	535910	2326423	42	1P	51AF18/	493a	.0.2		0
9107131951247260N2947152W4541	-230	5175	0	2237 0	62327 0	146	P9900D 0/		493B	0 9		0
9107132313548360N2895152W4564	-44	12138	1	7252 0	3916223	73	P	114A 6/	493B	.1.5		0
9107132324009860N2946152W4532	-230	7180	1	2243 0	17333 0	70	P9900D 2/		493B	.0.2		0
9107140253420460N2939152W4593	-230	6100	0	8 29 0	43299 2	24	P1506D 1/		493B	.0.2		0
9107141158385860N3019152W4676	195 2	19109	0	8250 6	33341 9	21	2P	52AF12/	493a	.0.4	687	0
9107141604155460N2989152W4540	414 3	22107	1	8326 9	25 6438	45	3P	55AF14/	493a	.3.3		0
9107141750214560N2761152W4446	363 2	17213	3	11303 6	25212 8	108	2P	76AF11/	493a	.4.3		0
9107141930055160N3061152W4442	405 8	15210	1	8129 2	4222034	136	8P	77AF 9/	493a	.6.5		0
9107142149172060N2651152W4685	1141	9279	4	733218	224 7330	462	P2894D 0/		493E	1.99		0
9107150431036460N2988152W4556	398-1	18103	1	5347 6	5125521	105	-1P	80AF11/	493a	100.4.5	136	0
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Table 7 (cont.)

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9107161103504660N2960152W4564 -115     6216  0   425113 10615716  55    P  22A  0/    493B        .6.4      0
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Table 7 (cont.)

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Table 7 (cont.)

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Table 8.
Data Archive Format

Data Directories (Julian Day, 1991)									Phase Data Directory	Ancillary Directory
185	186	187	188	---	204	205	206	207	picks	ancillary

Hourly sub-directories for each day												Phase data files	Line Files etc.
00	01	02	03	04	05	06	07	08	09	10	11	188135225p	3000ft.red
12	13	14	15	16	17	18	19	20	21	22	23	188135225q	6000ft.red

Event sub-directories for 188J, hour 13

188130716	188130817	188131244	188131352	188131642
188131705	188132858	188133239	188133749	188134610
188135225				

Listing of event sub-directory 188/13/188135225

Horizontal (E)	Horizontal (N)	Vertical *50 samples/s from the continuous data stream
cr2E_she.188135232	cr2N_shn.188135232	cr2_shz.188135232
		cr3_shz.188135225*
cr4E_she.188135232	cr4N_shn.188135232	cr4_shz.188135232
dr2E_she.188135232	dr2N_shn.188135232	dr2_shz.188135232
dr3E_she.188135231	dr3N_shn.188135231	dr3_shz.188135231
		dr4_shz.188135225*
e1E_she.188135230	e1N_shn.188135230	e1Z_shz.188135230
e2E_she.188135231	e2N_shn.188135231	e2Z_shz.188135231
e3E_she.188135225	e3N_shn.188135225	e3Z_shz.188135225
se5E_she.188135230	se5N_shn.188135230	se5_shz.188135230
		su1_shz.188135225*
		su2_shz.188135225*
su3E_she.188135232	su3N_shn.188135232	su3_shz.188135232
		w1Z_shz.188135225*
w2E_she.188135231	w2N_shn.188135231	w2Z_shz.188135231

Figure Captions

Figure 1. Map of station locations. Inset shows the location of Redoubt Volcano, Alaska with a star. Filled squares indicate the AVO network stations. Filled circles indicate the PASSCAL station locations. Shot points are indicated by open stars. Contours are at 3000, 6000, and 9000 feet. Note that stations E2 and E3 were moved to sites SE2 and SE4 after running for about 2 days.

Figure 2. Record sections of the vertical components of the PASSCAL network for a) shot 1, b) shot 2, c) shot 3, and d) shot 4.

Figure 3. Example of a deep volcano-tectonic event which occurred epicenterally between stations W1 and DR2 at a depth of 4.6 km. Stations are aligned by first arrival time. Start time of record is indicated by date and time at the top left corner of the figure. Station names are indicated on the left and amplitude values in counts on the right. a) Vertical components, b) and c), the horizontal north and east components. Note that the timing for station E1 is not correct - it was not recoverable. Station SU3 did not trigger on this event, but the vertical component was recovered from the continuous 50 samples/s data stream.

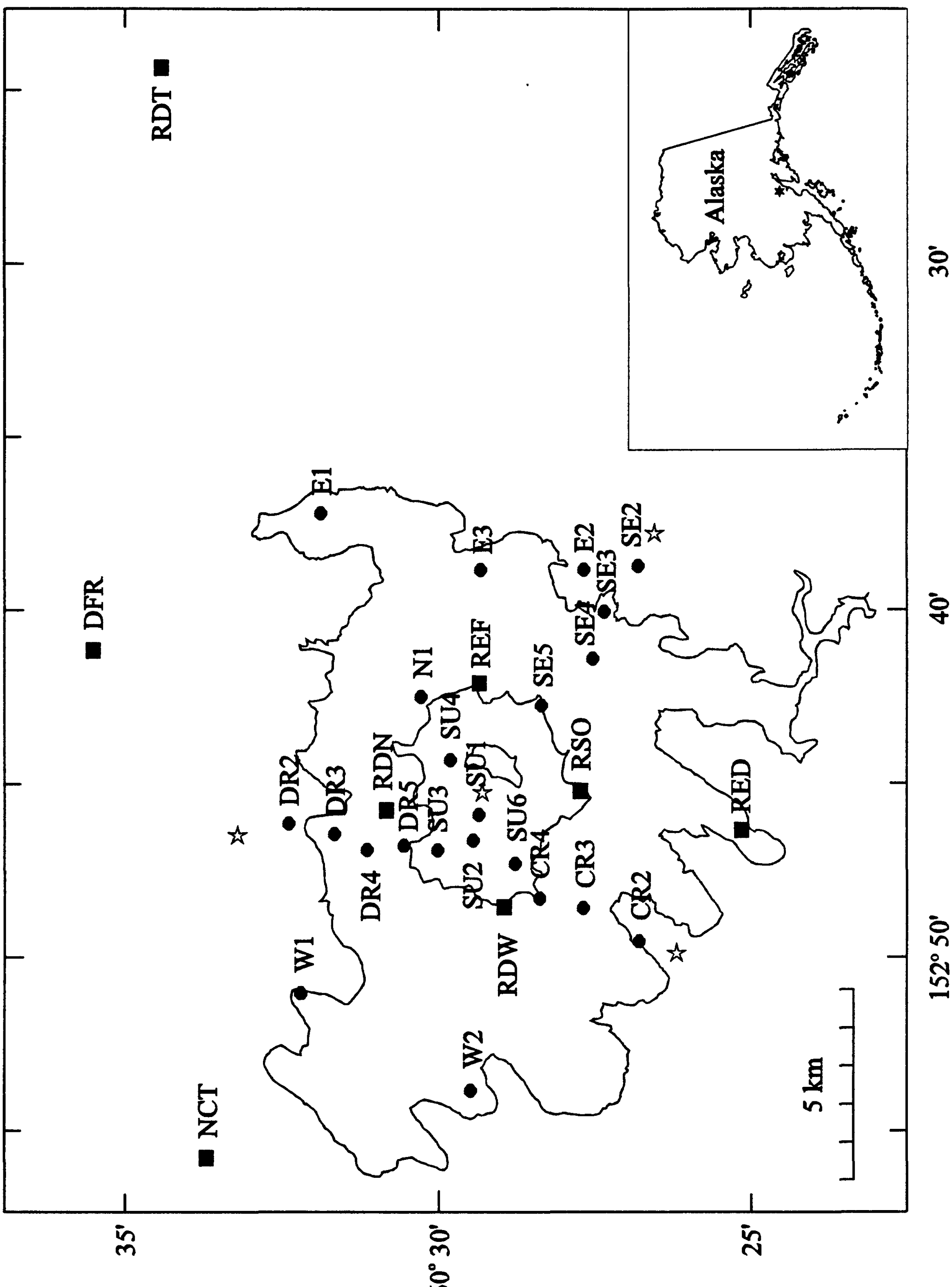
Figure 4. Example of a regional event which occurred about 150 km S of Redoubt Volcano at a depth of 70 km. a) vertical, b) north, and c) east components.

Figure 5. Example of a shallow event associated with the summit crater dome. Vertical components only are shown. Thousands of these events were observed at station SU1.

Figure 6. Example of a steam burst occurring near the summit crater. Note the high amplitude observed at station SU1. a) vertical, b) north, and c) east components.

Figure 7. Example of a glacier quake which occurred in the main body of the Drift River glacier, just north of station DR2. a) vertical, b) north, and c) east components.

Figure 8. Map and N-S vertical cross-section of the local seismicity which occurred between 3 July and 26 July, 1991. Depth in the vertical section is plotted at two times the horizontal scale. Stations are shown as open triangles.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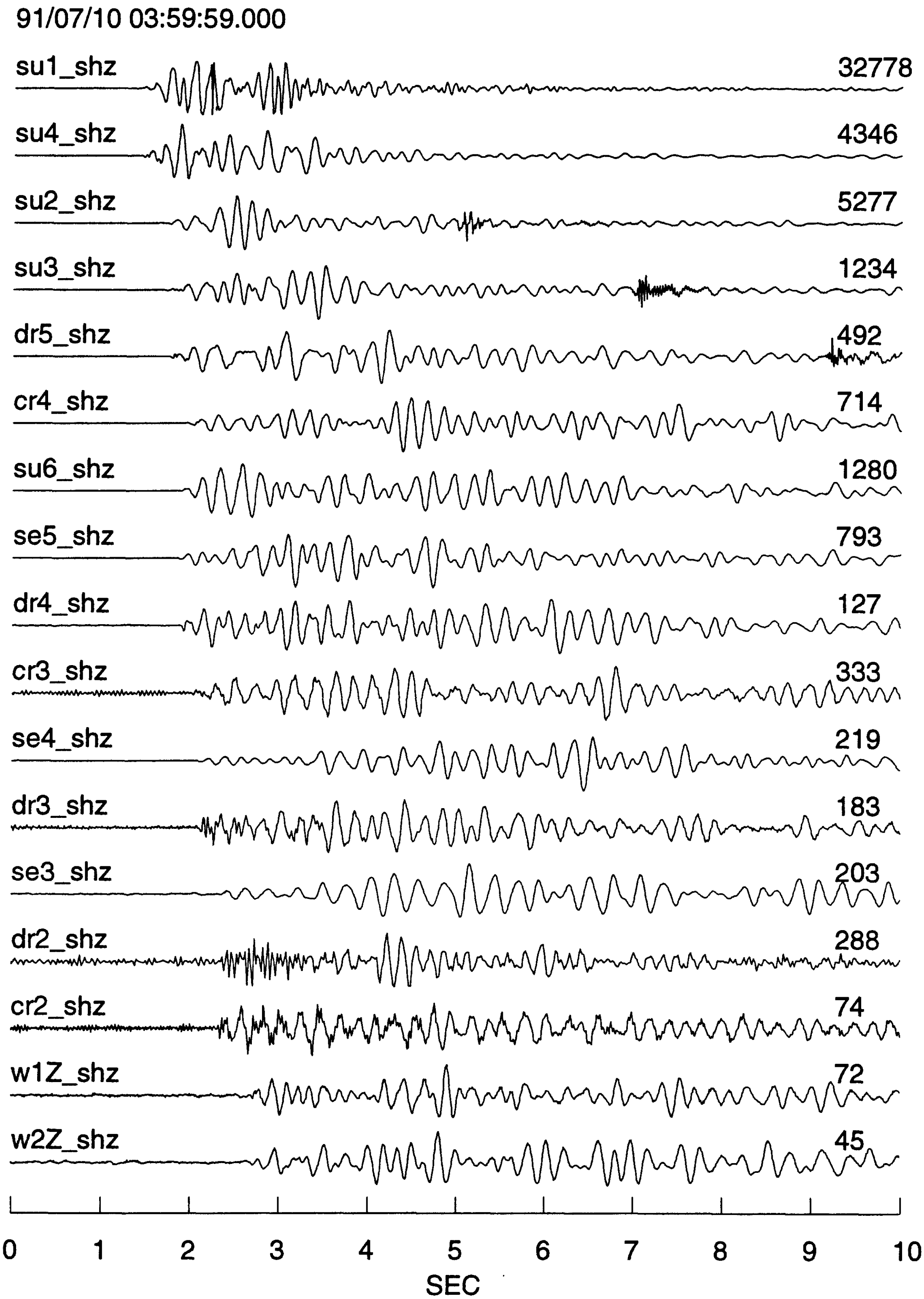
NCT
E1
E2
E3
SE2
SE3
SE4
SE5
N1
REF
SU1
SU2
SU3
SU4
SU6
RDN
RSO
DR2
DR3
DR4
DR5
CR2
CR3
CR4
RDW
RED
W1
W2
5 km
Alaska
35'
60° 30'
25'
30'
40'
152° 50'

Figure 1.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cr4_shz
714
su6_shz
1280
se5_shz
793
dr4_shz
127
cr3_shz
333
se4_shz
219
dr3_shz
183
se3_shz
203
dr2_shz
288
cr2_shz
74
w1Z_shz
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2
3
4
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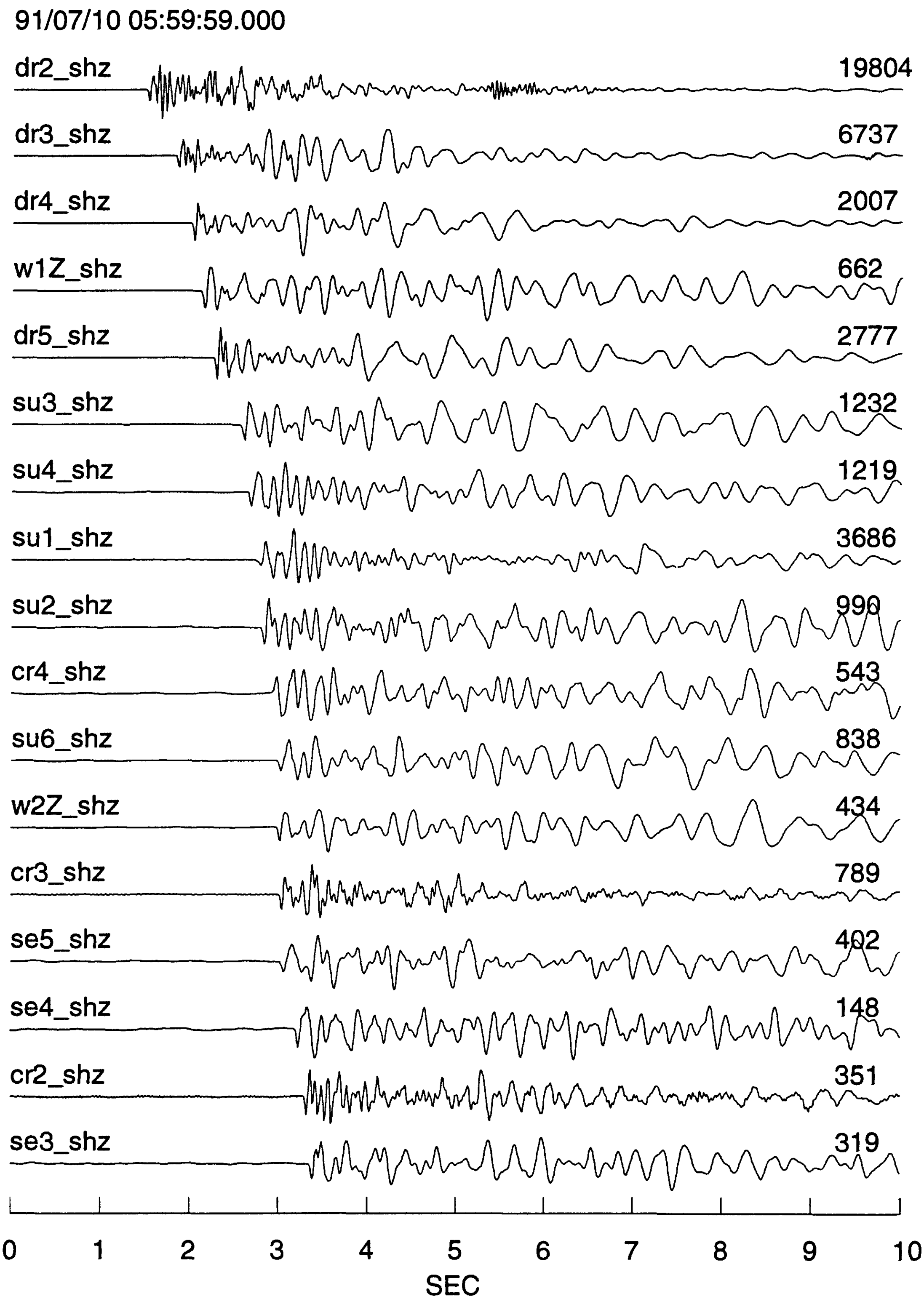
6
7
8
9
10
SEC

Figure 2a.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2777
su3_shz
1232
su4_shz
1219
su1_shz
3686
su2_shz
990
cr4_shz
543
su6_shz
838
w2Z_shz
434
cr3_shz
789
se5_shz
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se4_shz
148
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6
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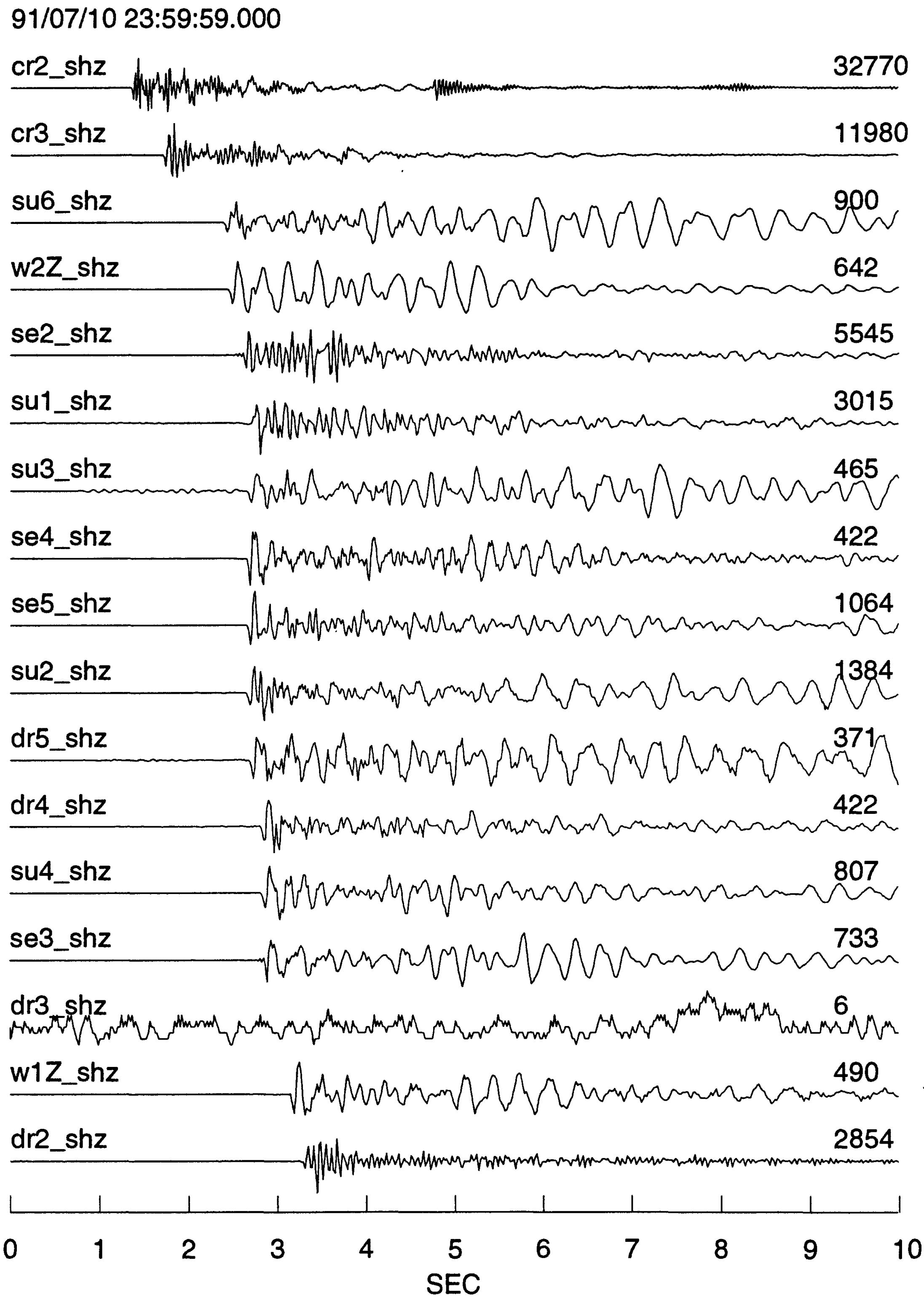
8
9
10
SEC

Figure 2b.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5545
su1_shz
3015
su3_shz
465
se4_shz
422
se5_shz
1064
su2_shz
1384
dr5_shz
371
dr4_shz
422
su4_shz
807
se3_shz
733
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6
w1Z_shz
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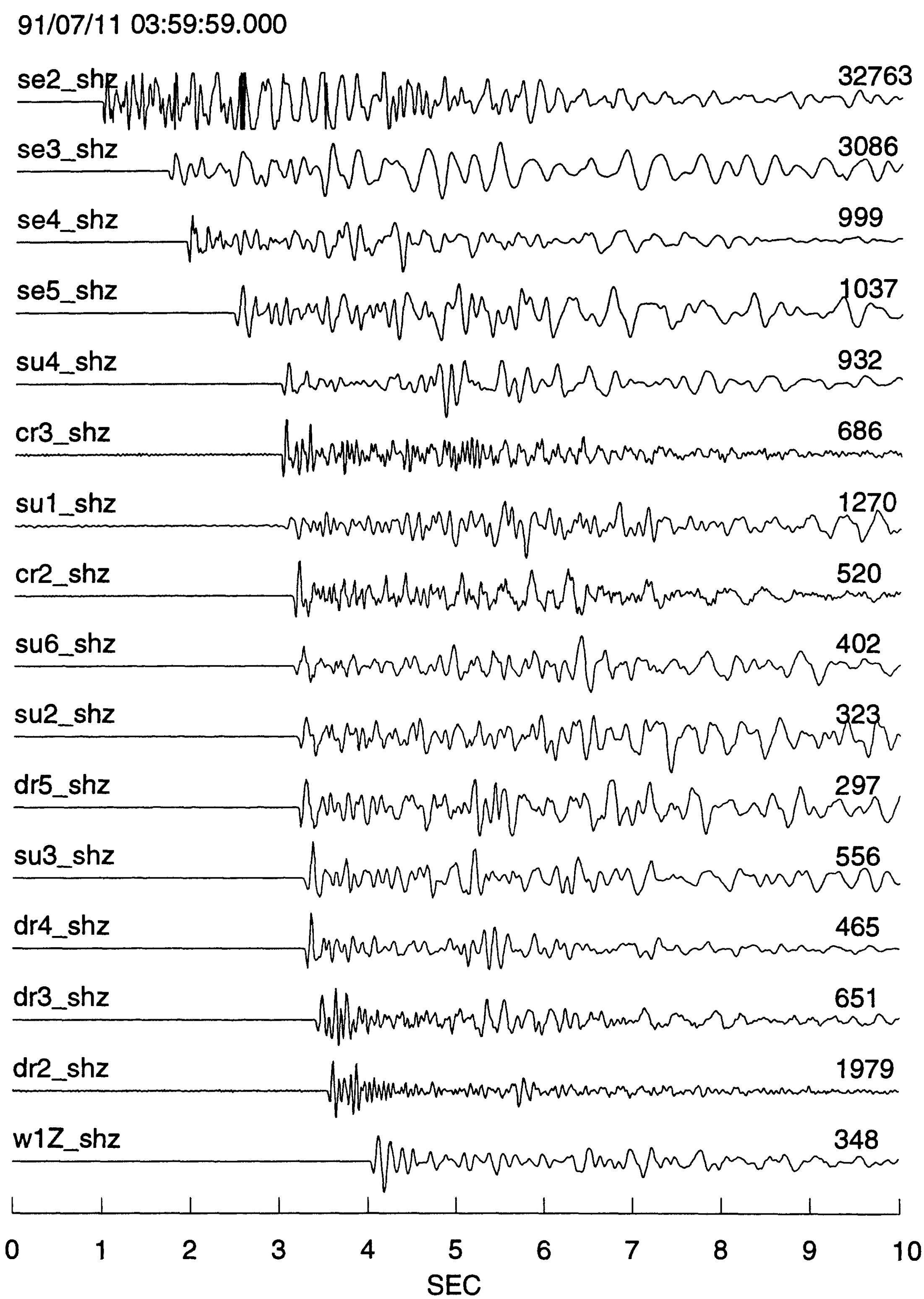
10
SEC

Figure 2c.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1270
cr2_shz
520
su6_shz
402
su2_shz
323
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297
su3_shz
556
dr4_shz
465
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7
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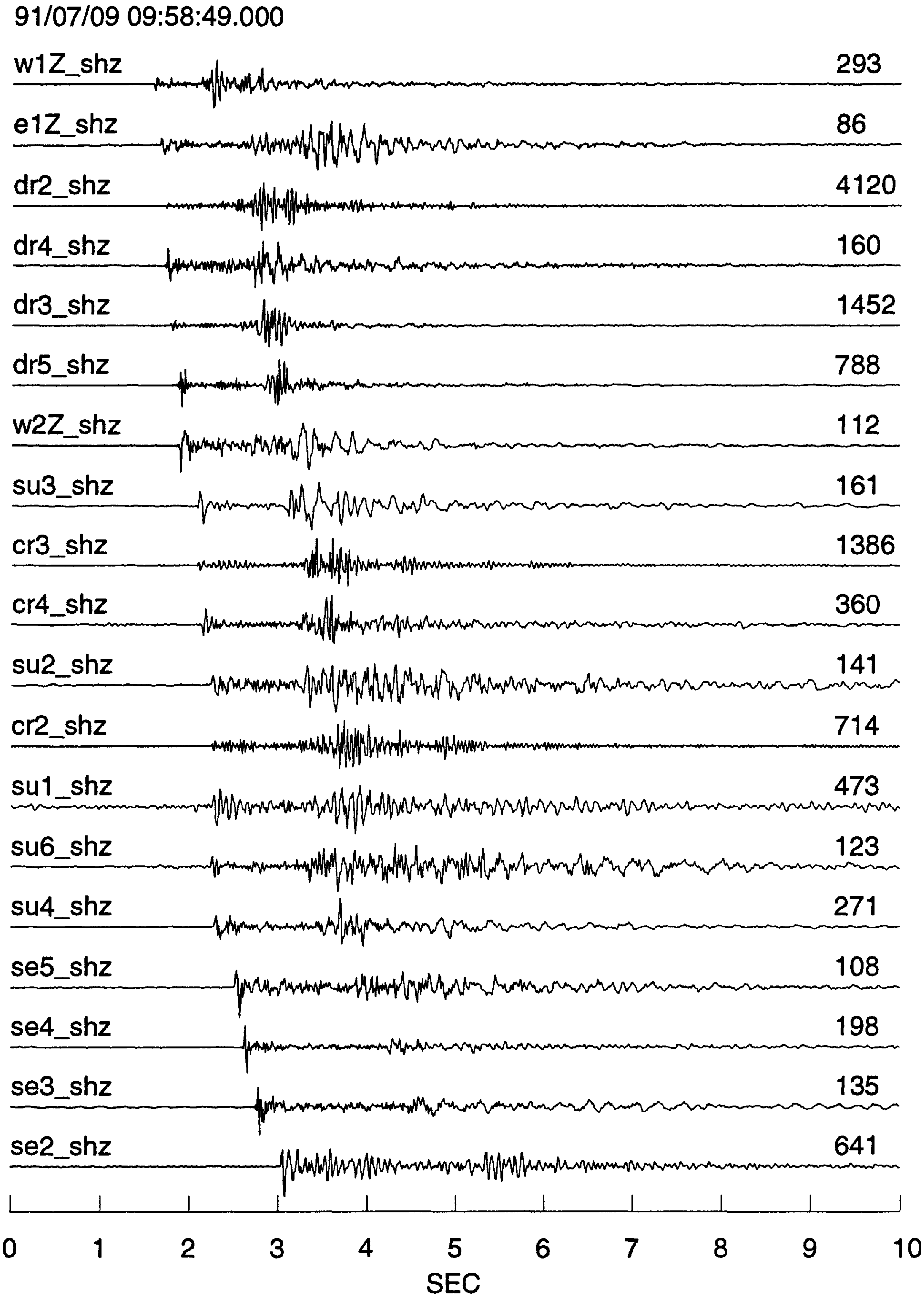
9
10
SEC

Figure 2d.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1386
cr4_shz
360
su2_shz
141
cr2_shz
714
su1_shz
473
su6_shz
123
su4_shz
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se5_shz
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se4_shz
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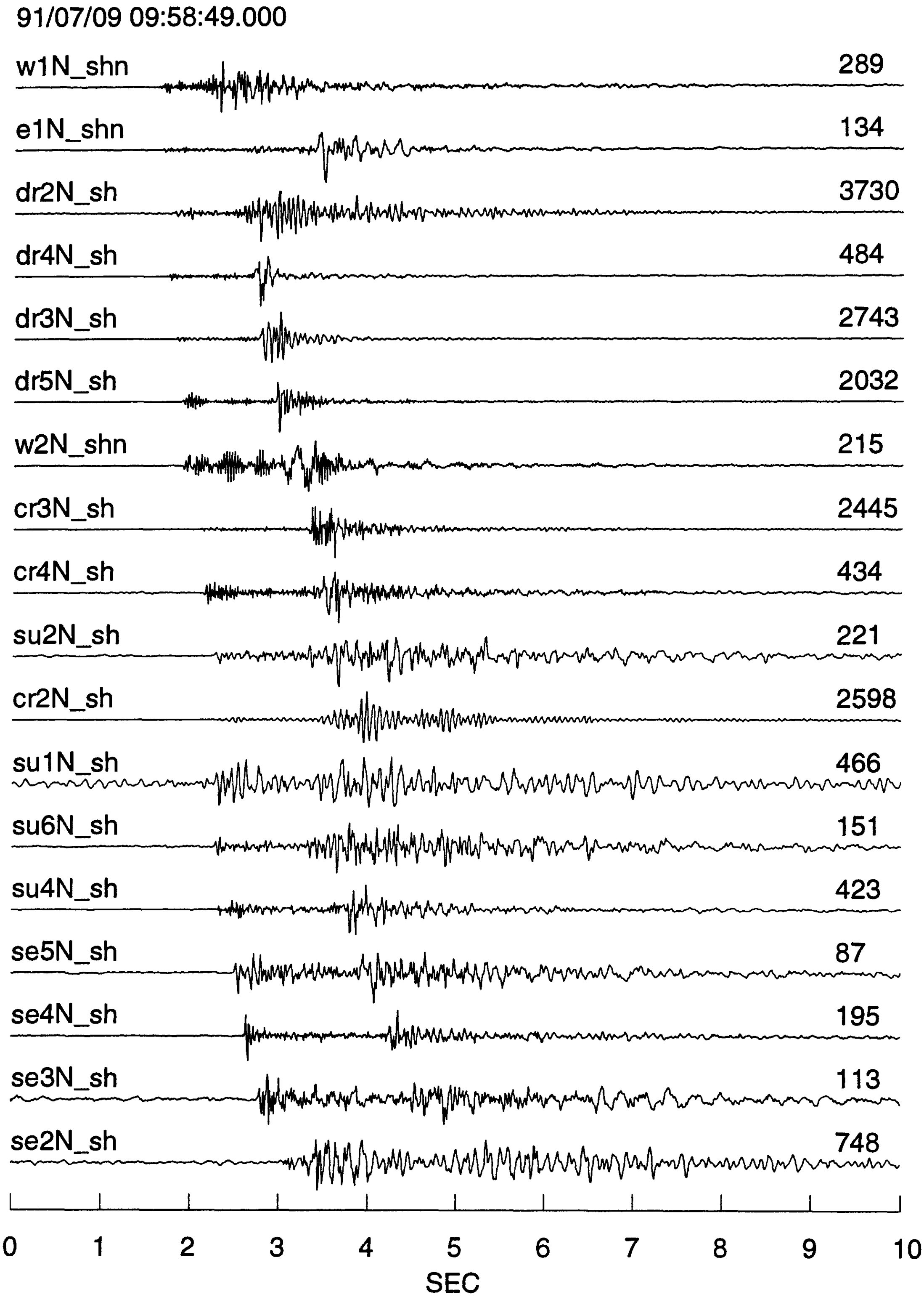
SEC

Figure 3a.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1
2
3
4
5
6
7
8
9
10
SEC

Figure 3b.

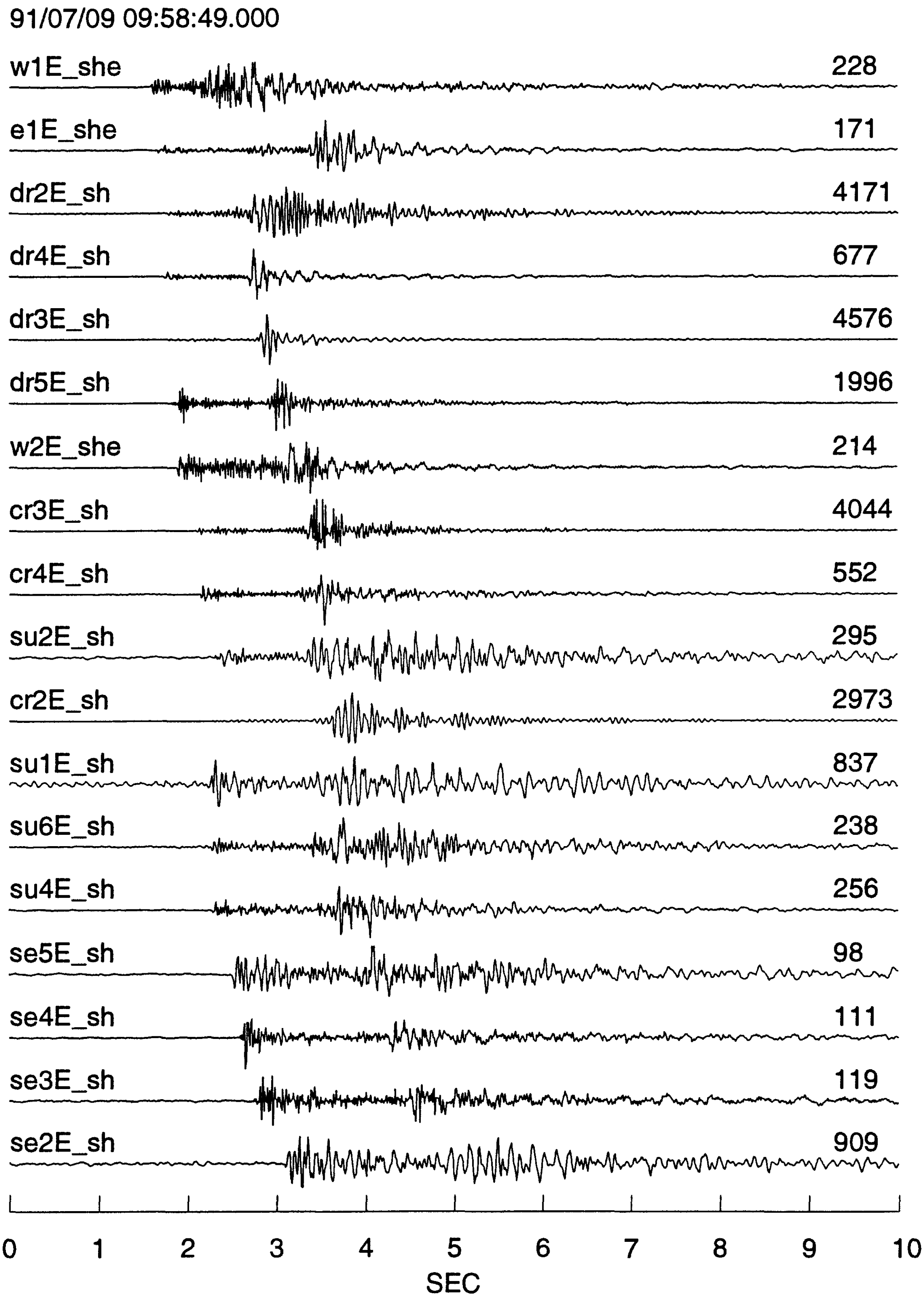
91/07/09 09:58:49.000
w1E_she
228
e1E_she
171
dr2E_sh
4171
dr4E_sh
677
dr3E_sh
4576
dr5E_sh
1996
w2E_she
214
cr3E_sh
4044
cr4E_sh
552
su2E_sh
295
cr2E_sh
2973
su1E_sh
837
su6E_sh
238
su4E_sh
256
se5E_sh
98
se4E_sh
111
se3E_sh
119
se2E_sh
909
0
1
2
3
4
5
6
7
8
9
10
SEC

Figure 3c.

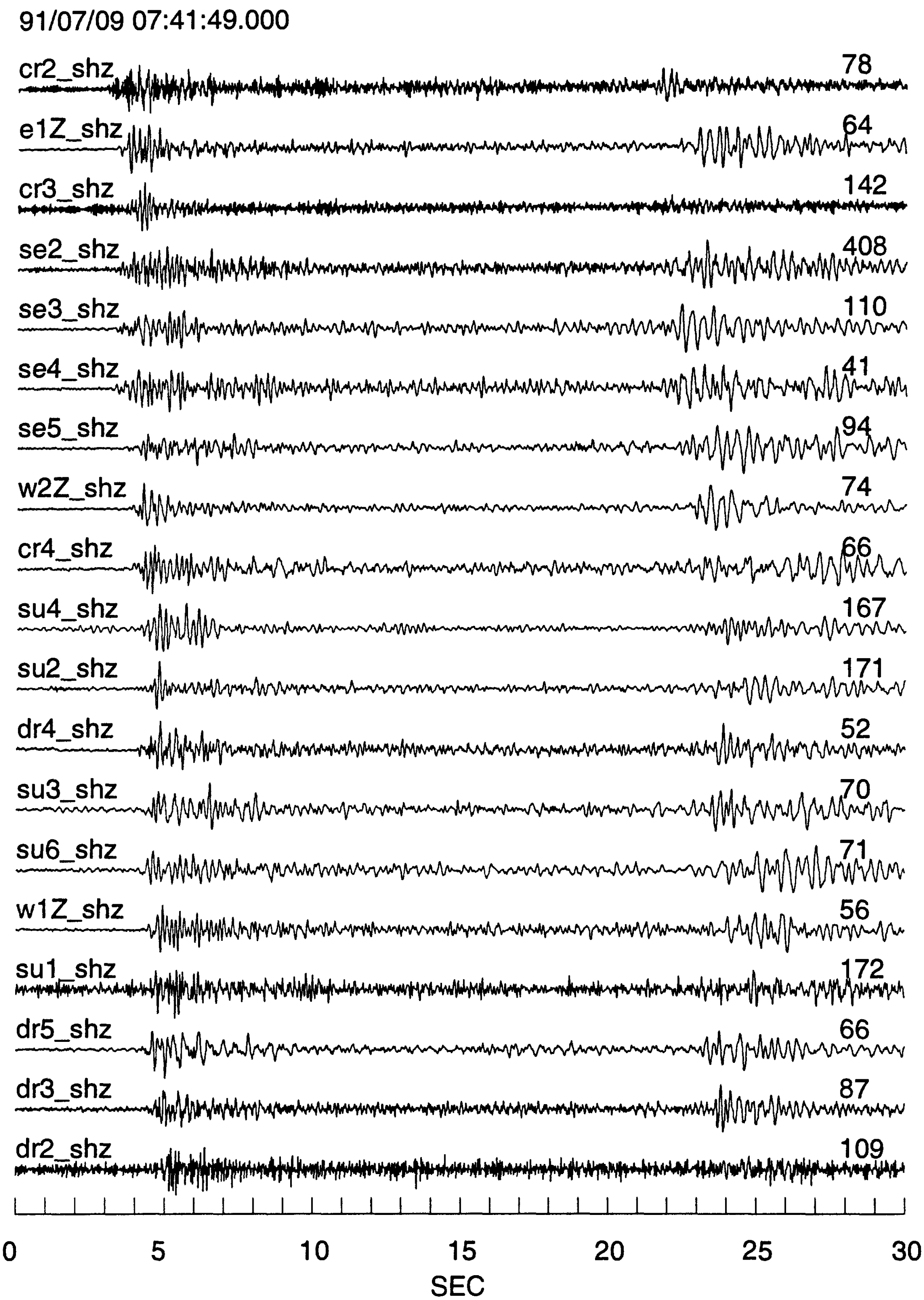
91/07/09 07:41:49.000
cr2_shz
78
e1Z_shz
64
cr3_shz
142
se2_shz
408
se3_shz
110
se4_shz
41
se5_shz
94
w2Z_shz
74
cr4_shz
66
su4_shz
167
su2_shz
171
dr4_shz
52
su3_shz
70
su6_shz
71
w1Z_shz
56
su1_shz
172
dr5_shz
66
dr3_shz
87
dr2_shz
109
0
5
10
15
20
25
30
SEC

Figure 4a.

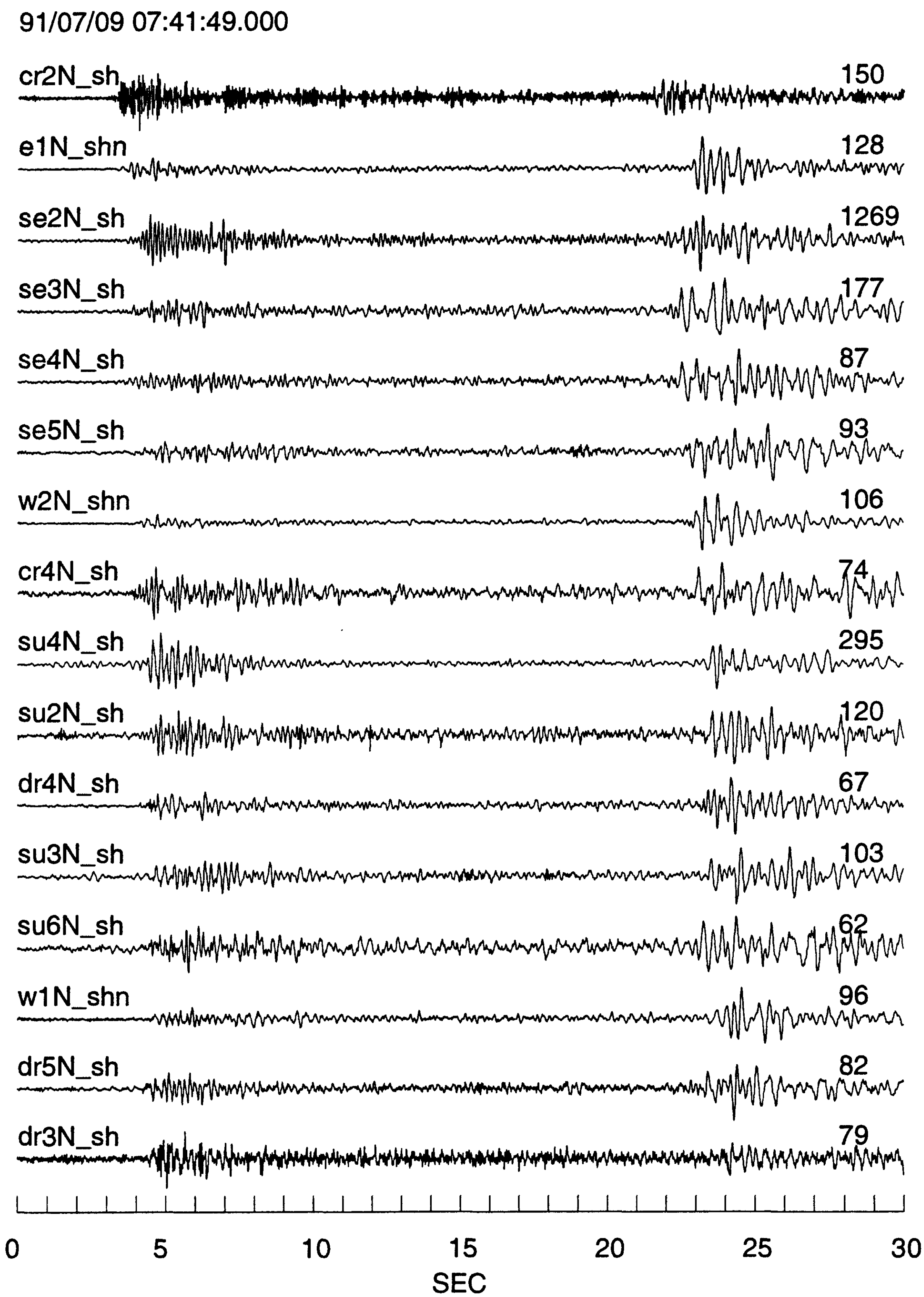
91/07/09 07:41:49.000
cr2N_sh
150
e1N_shn
128
se2N_sh
1269
se3N_sh
177
se4N_sh
87
se5N_sh
93
w2N_shn
106
cr4N_sh
74
su4N_sh
295
su2N_sh
120
dr4N_sh
67
su3N_sh
103
su6N_sh
62
w1N_shn
96
dr5N_sh
82
dr3N_sh
79
0
5
10
15
20
25
30
SEC

Figure 4b.

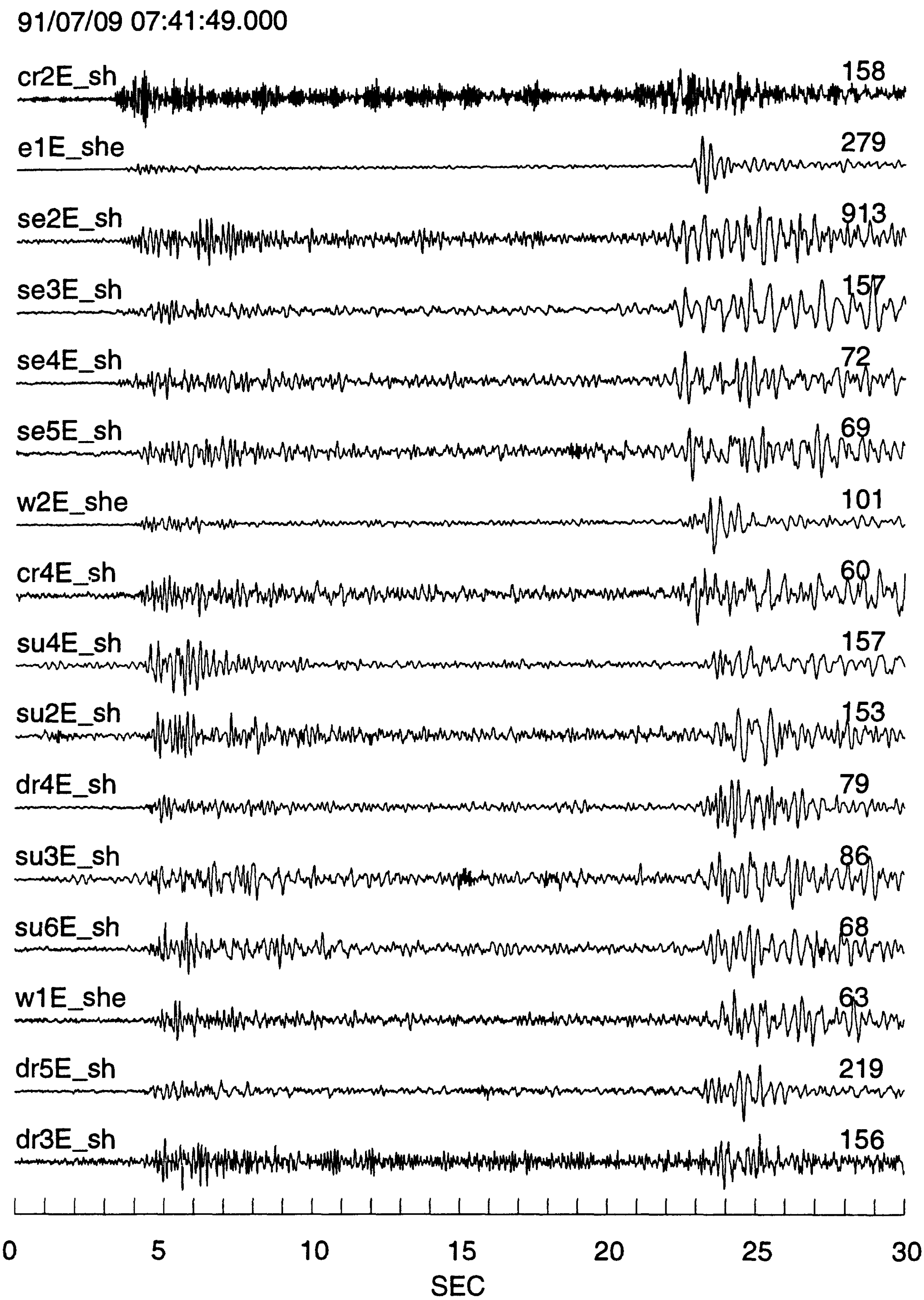
91/07/09 07:41:49.000
cr2E_sh
158
e1E_she
279
se2E_sh
913
se3E_sh
157
se4E_sh
72
se5E_sh
69
w2E_she
101
cr4E_sh
60
su4E_sh
157
su2E_sh
153
dr4E_sh
79
su3E_sh
86
su6E_sh
68
w1E_she
63
dr5E_sh
219
dr3E_sh
156
0
5
10
15
20
25
30
SEC

Figure 4c.

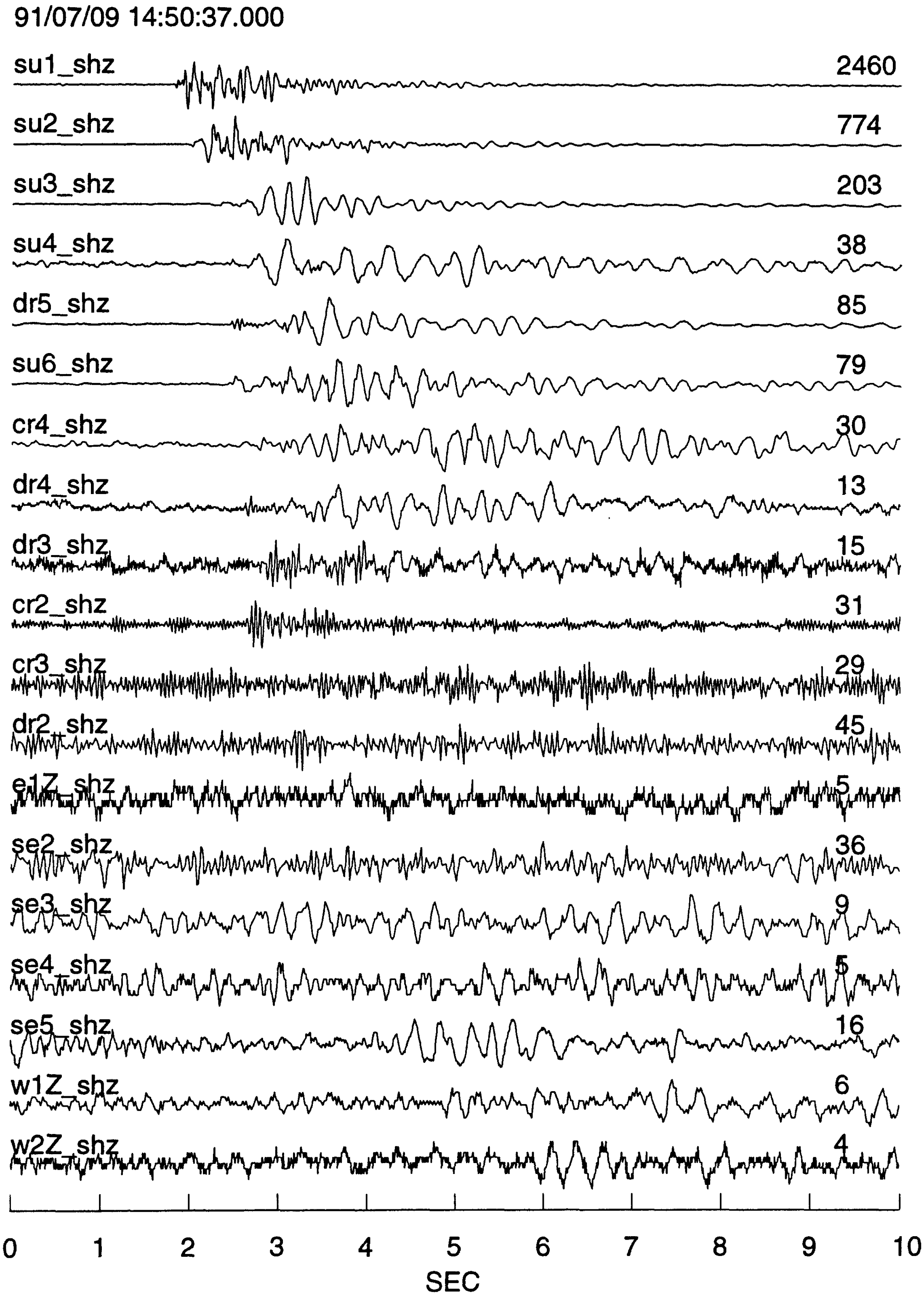
91/07/09 14:50:37.000
su1_shz 2460
su2_shz 774
su3_shz 203
su4_shz 38
dr5_shz 85
su6_shz 79
cr4_shz 30
dr4_shz 13
dr3_shz 15
cr2_shz 31
cr3_shz 29
dr2_shz 45
e1Z_shz 5
se2_shz 36
se3_shz 9
se4_shz 5
se5_shz 16
w1Z_shz 6
w2Z_shz 4
0 1 2 3 4 5 6 7 8 9 10
SEC

Figure 5.

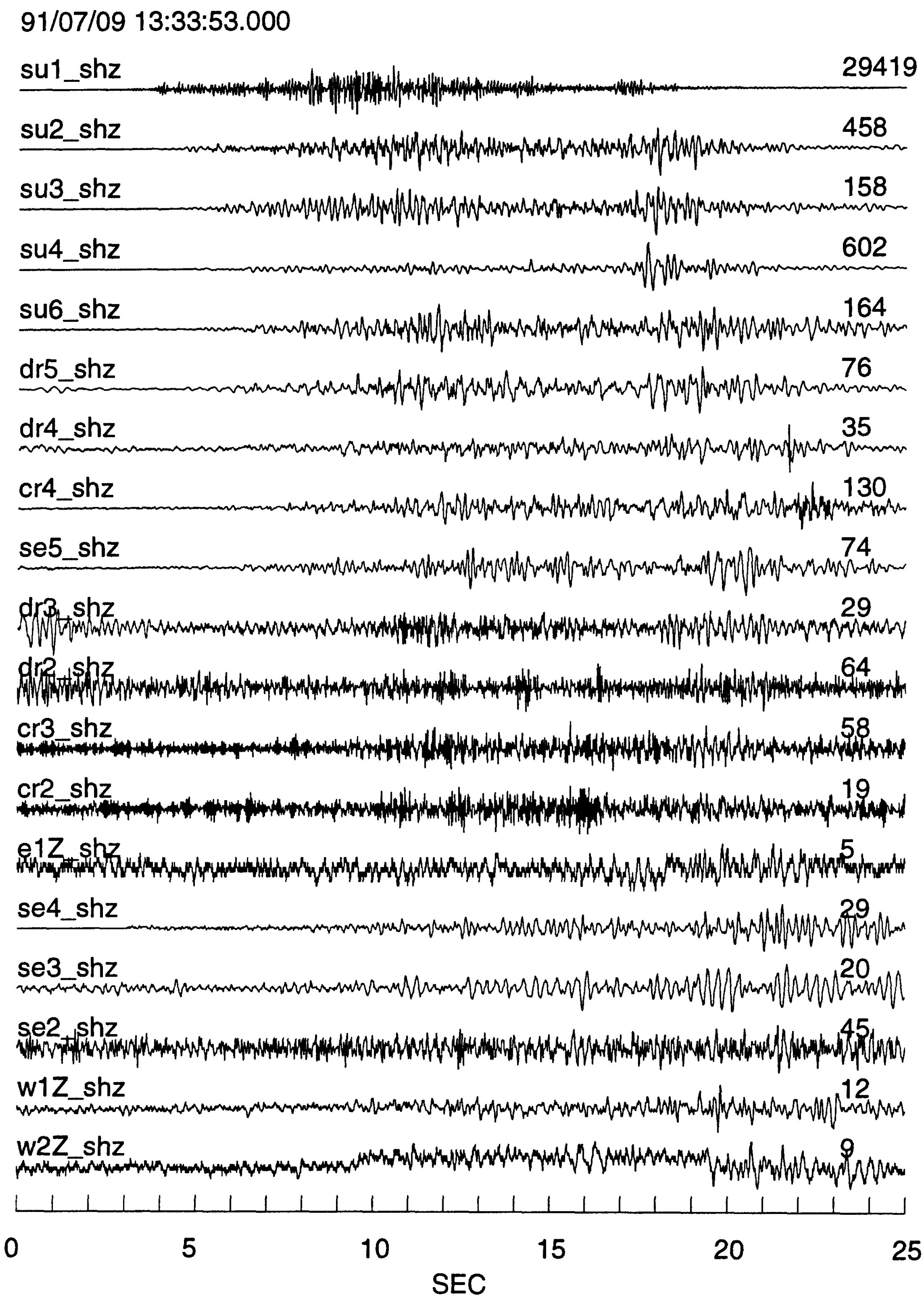
91/07/09 13:33:53.000
su1_shz 29419
su2_shz 458
su3_shz 158
su4_shz 602
su6_shz 164
dr5_shz 76
dr4_shz 35
cr4_shz 130
se5_shz 74
dr3_shz 29
dr2_shz 64
cr3_shz 58
cr2_shz 19
e1Z_shz 5
se4_shz 29
se3_shz 20
se2_shz 45
w1Z_shz 12
w2Z_shz 9
0 5 10 15 20 25
SEC

Figure 6a.

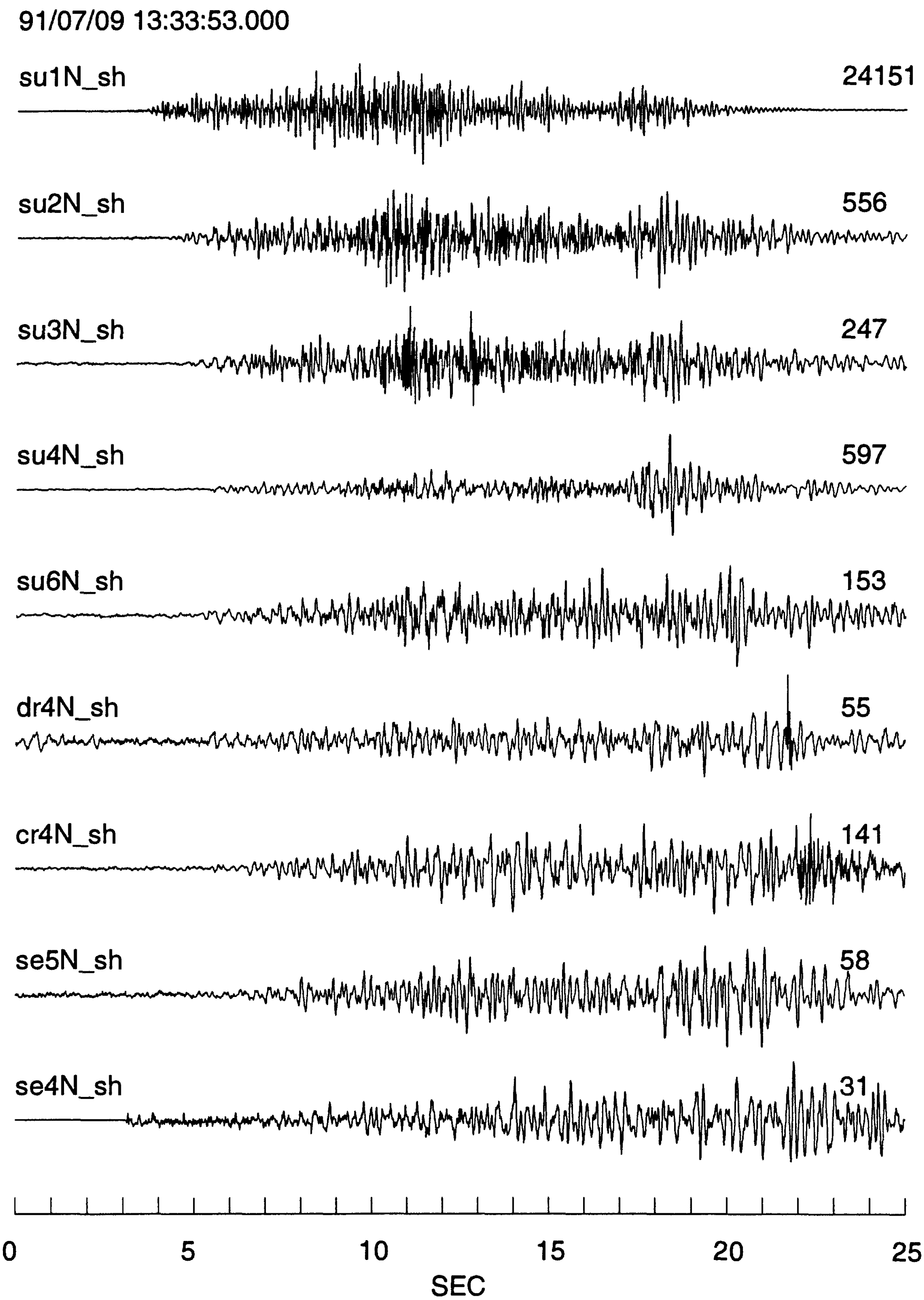
91/07/09 13:33:53.000
su1N_sh
24151
su2N_sh
556
su3N_sh
247
su4N_sh
597
su6N_sh
153
dr4N_sh
55
cr4N_sh
141
se5N_sh
58
se4N_sh
31
0
5
10
15
20
25
SEC

Figure 6b.

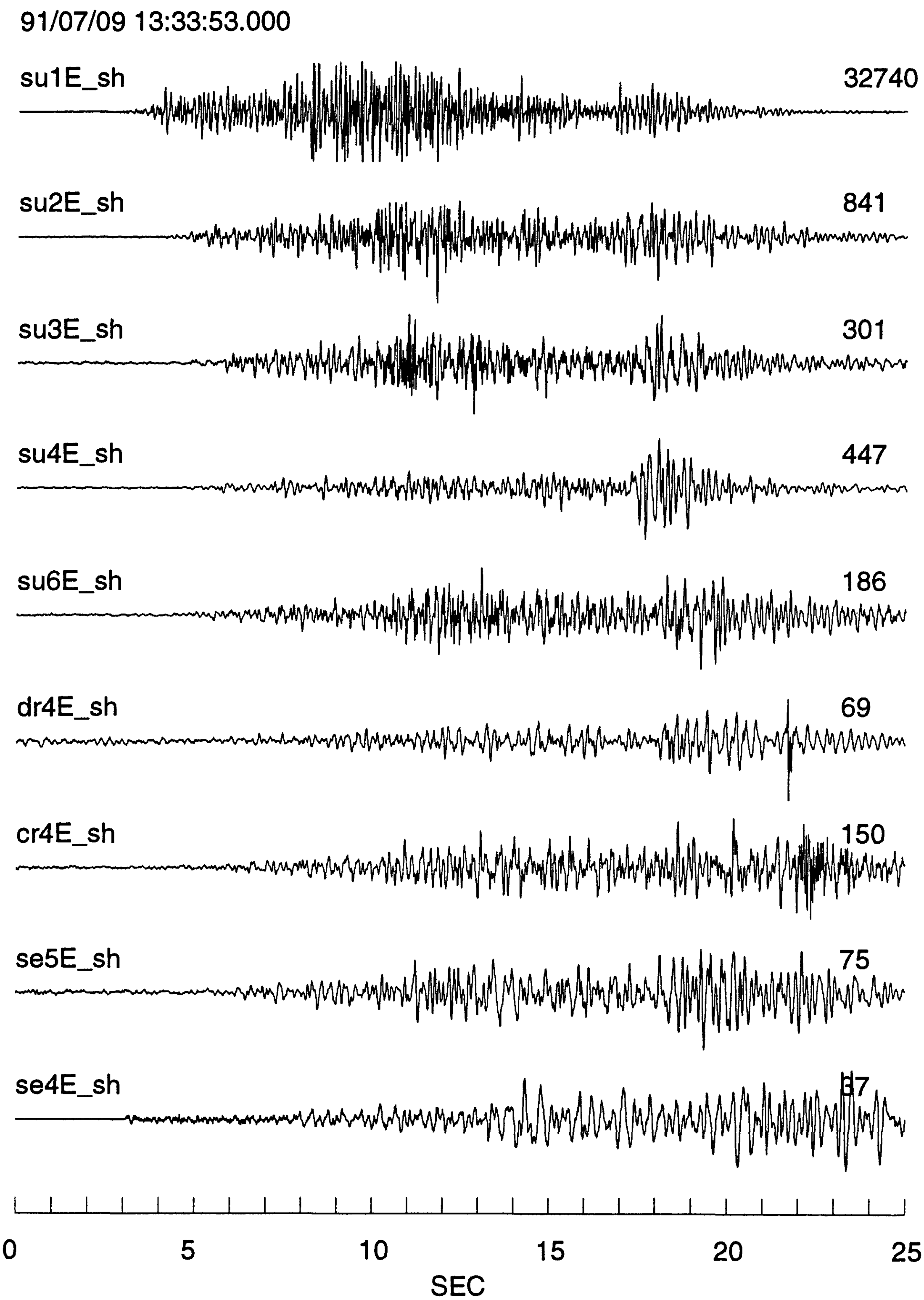
91/07/09 13:33:53.000
su1E_sh
32740
su2E_sh
841
su3E_sh
301
su4E_sh
447
su6E_sh
186
dr4E_sh
69
cr4E_sh
150
se5E_sh
75
se4E_sh
0
5
10
15
20
25
SEC

Figure 6c.

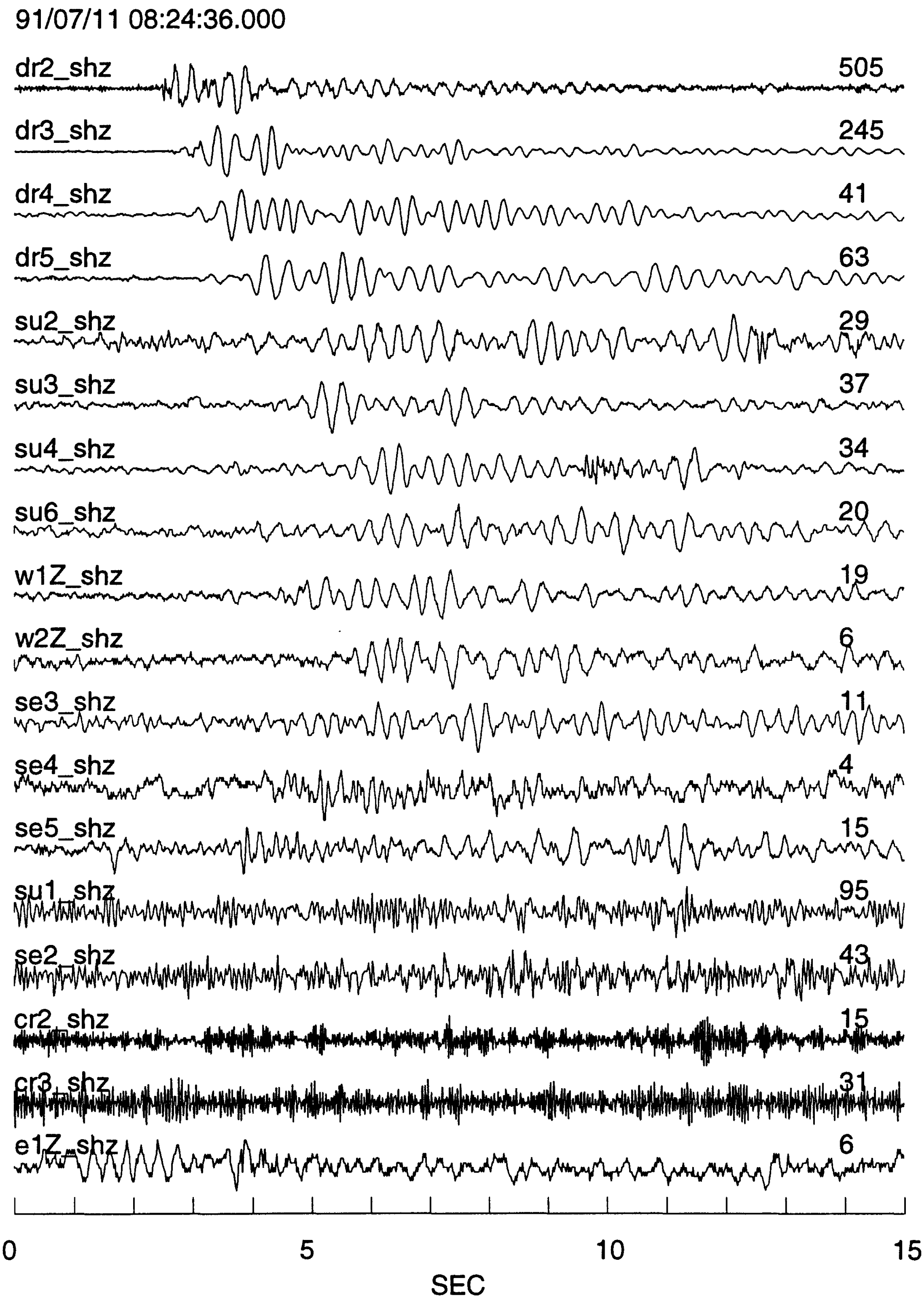
91/07/11 08:24:36.000
dr2_shz 505
dr3_shz 245
dr4_shz 41
dr5_shz 63
su2_shz 29
su3_shz 37
su4_shz 34
su6_shz 20
w1Z_shz 19
w2Z_shz 6
se3_shz 11
se4_shz 4
se5_shz 15
su1_shz 95
se2_shz 43
cr2_shz 15
cr3_shz 31
e1Z_shz 6
0
5
10
15
SEC

Figure 7a.

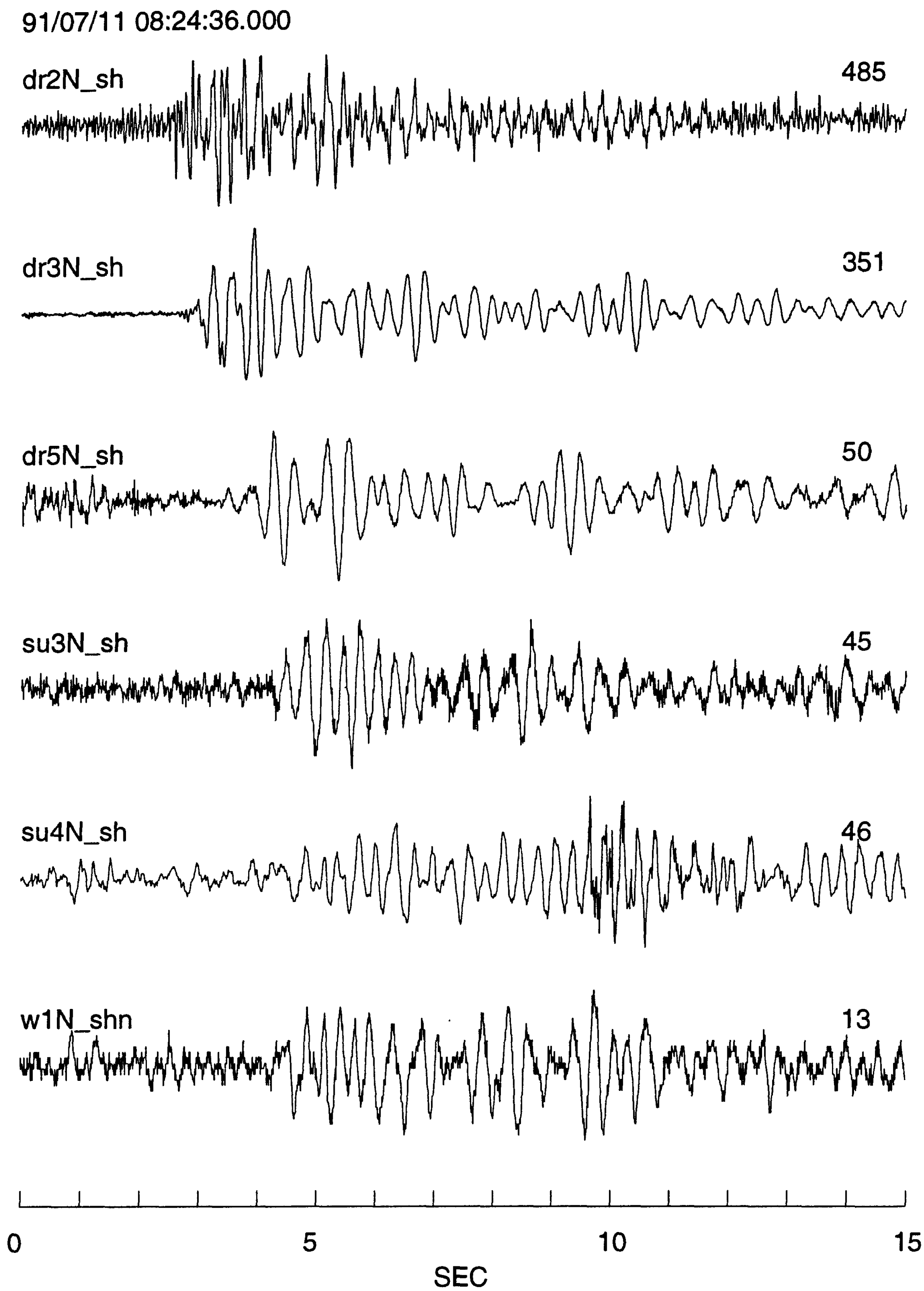
91/07/11 08:24:36.000
dr2N_sh
485
dr3N_sh
351
dr5N_sh
50
su3N_sh
45
su4N_sh
46
w1N_shn
13
0
5
10
15
SEC

Figure 7b.

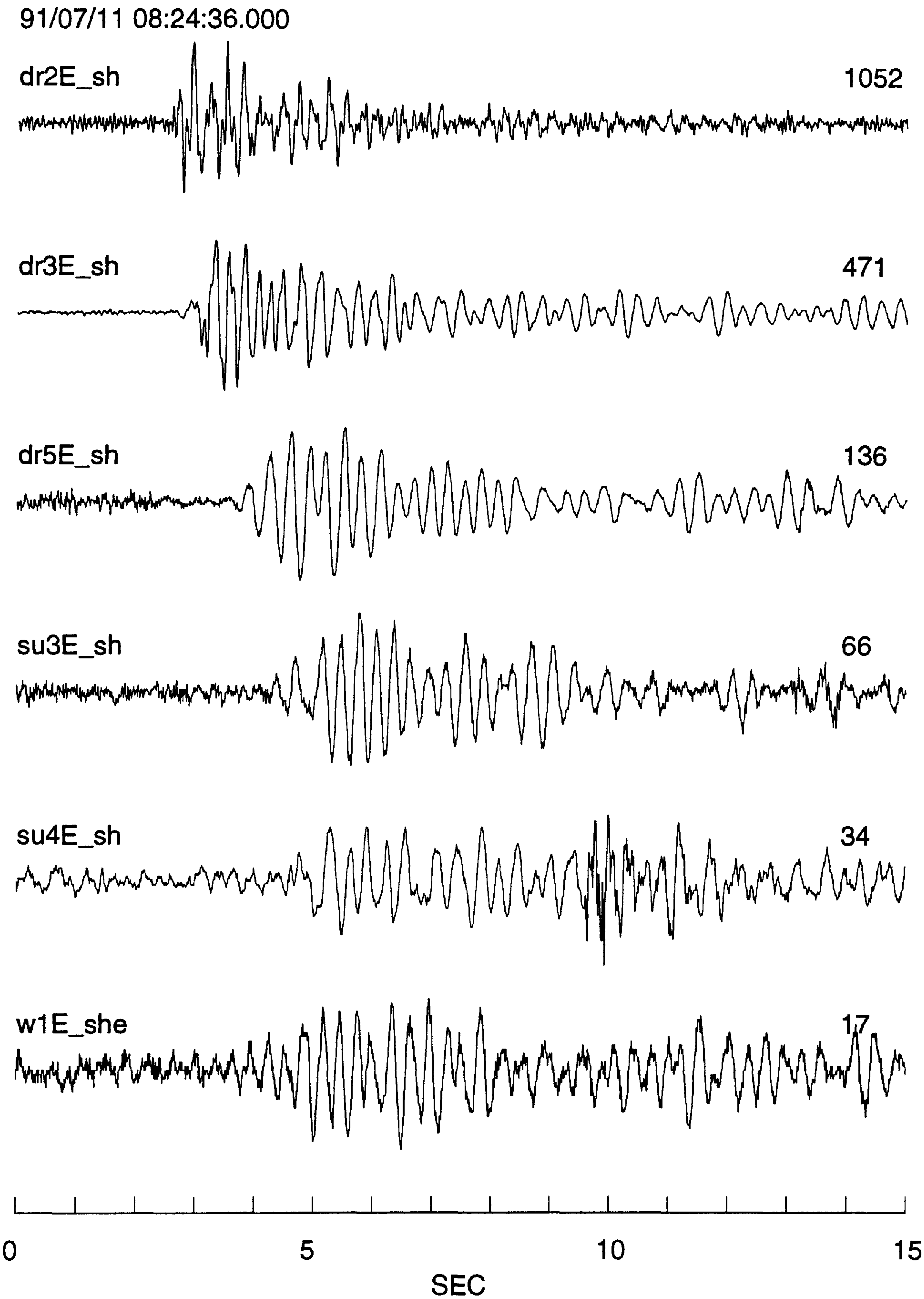
91/07/11 08:24:36.000
dr2E_sh
1052
dr3E_sh
471
dr5E_sh
136
su3E_sh
66
su4E_sh
34
w1E_she
17
0
5
10
15
SEC

Figure 7c.

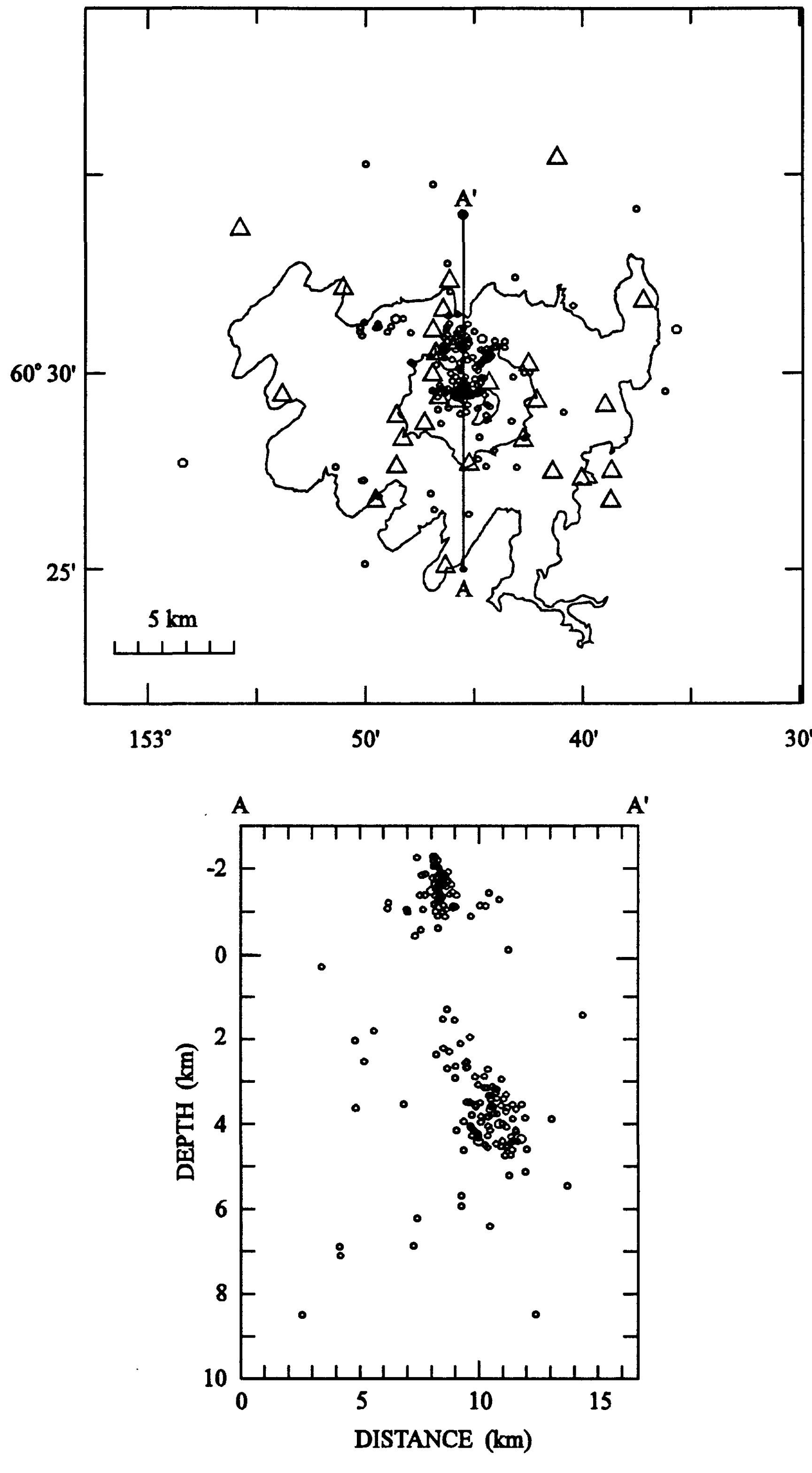
A'
A
60° 30'
25'
5 km
153°
50'
40'
30'
A
A'
-2
0
2
4
6
8
10
DEPTH (km)
0
5
10
15
DISTANCE (km)

Figure 8.