DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

National Earthquake Information Center Waveform Catalog October 1985

by

Madeleine D. Zirbes
Janna M. Lishner
Beverly J. Moon

U.S. Geological Survey
Denver, Colorado

Open-File Report 85-660J
1985

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

Contents

Introduction

This report provides a visual catalog of digitally recorded waveform data available from the event tapes produced by the United States Geological Survey's National Earthquake Information Center (NEIC). It is intended to provide the researcher with a quick index both to the availability of data and to the character of the data for each event (e.g., complexity and directionality).

The network-event tapes are a data service initiated by the NEIC in 1984. Currently, these tapes contain data from the Global Digital Seismograph Network (GDSN), the Regional Seismograph Test Network (RSTN), and the Glen Almond, Canada, SRO station. In the future, data from other high-quality stations and arrays, installed and operated by countries around the world, will be added to the event tapes as they are made available to us.

Network-event tapes contain digital data for earthquakes of magnitude 5.5 or greater in the NEIC network-day tape format. For this catalog, all available vertical component recordings in all period bands are shown, including those for stations that were saturated or nonoperational or that had some other difficulty during the event. Horizontal component records were omitted in order to minimize the size of this catalog. In general, one can expect them to be of approximately the same quality as the vertical component records at any particular time. Most of the available stations do not record short-period horizontal components. All stations that have intermediate-period recordings, however, record all three components in this band. Only long-period components are recorded continuously: short- and intermediate-period channels are recorded only when an event is detected. Horizontal components (where available) are recorded whenever the vertical component is, and never otherwise.

This report mainly consists of vertical component waveforms from all reporting stations, organized by event. The section for each event is prefaced by a station coverage map, in which stations and geography within 100° of the source are shown in an azimuthal equidistant projection centered at the epicenter. Following the coverage map, all short-period, vertical component waveforms are shown in order of increasing epicentral distance. Each short-period waveform is two minutes long and is identified by station code, start time, and epicentral distance, Δ, in degrees. The start time is chosen to be about 15 seconds before the earliest theoretical arrival time of interest (P, Pdiff, or PKPdf, depending on distance). The vertical scale is in microns of ground displacement at the dominant period of the instrument response, which is taken to be 1 second. Each page of waveforms is titled with the event origin date-time, the Flinn-Engdahl region name, and the component identifier (SPZ, LPZ or IPZ). Also, the depth of the event (h) in kilometers and its average body (m_b) and vertical surface wave (M_{SZ}) magnitudes are shown for convenience.

Following the short-period waveforms (SPZ), long-period vertical (LPZ) and finally intermediate-period vertical (IPZ) waveforms are shown. In each case, the format is the same as for the short-period waveforms. Fifty minutes of long-period data are shown beginning 1 minute before the theoretical first arrival, and the dominant period is taken to be 25 seconds. Four minutes of intermediate-period data are shown beginning 30 seconds before the theoretical first arrival, and the dominant period is assumed to be 1 second. Because (1) the event detection algorithm is not perfect, (2) only about half of the available stations have intermediate-period channels, and (3) one station (GAC) has no short-period recordings, it is not uncommon for stations with good long-period recordings to have no intermediate-period and perhaps no short-period recordings at all.

With the inclusion of the Network of Autonomously Registrating Stations (NARS) in September 1985, it was difficult to list the name of each station in the network on the station coverage map because of their close proximity. Instead, a new symbol (□) will be used to denote each station of the network, with the name NARS. When other networks are included with stations situated close together, a new symbol will be used to denote each station of each network. The name used will be the network name only.

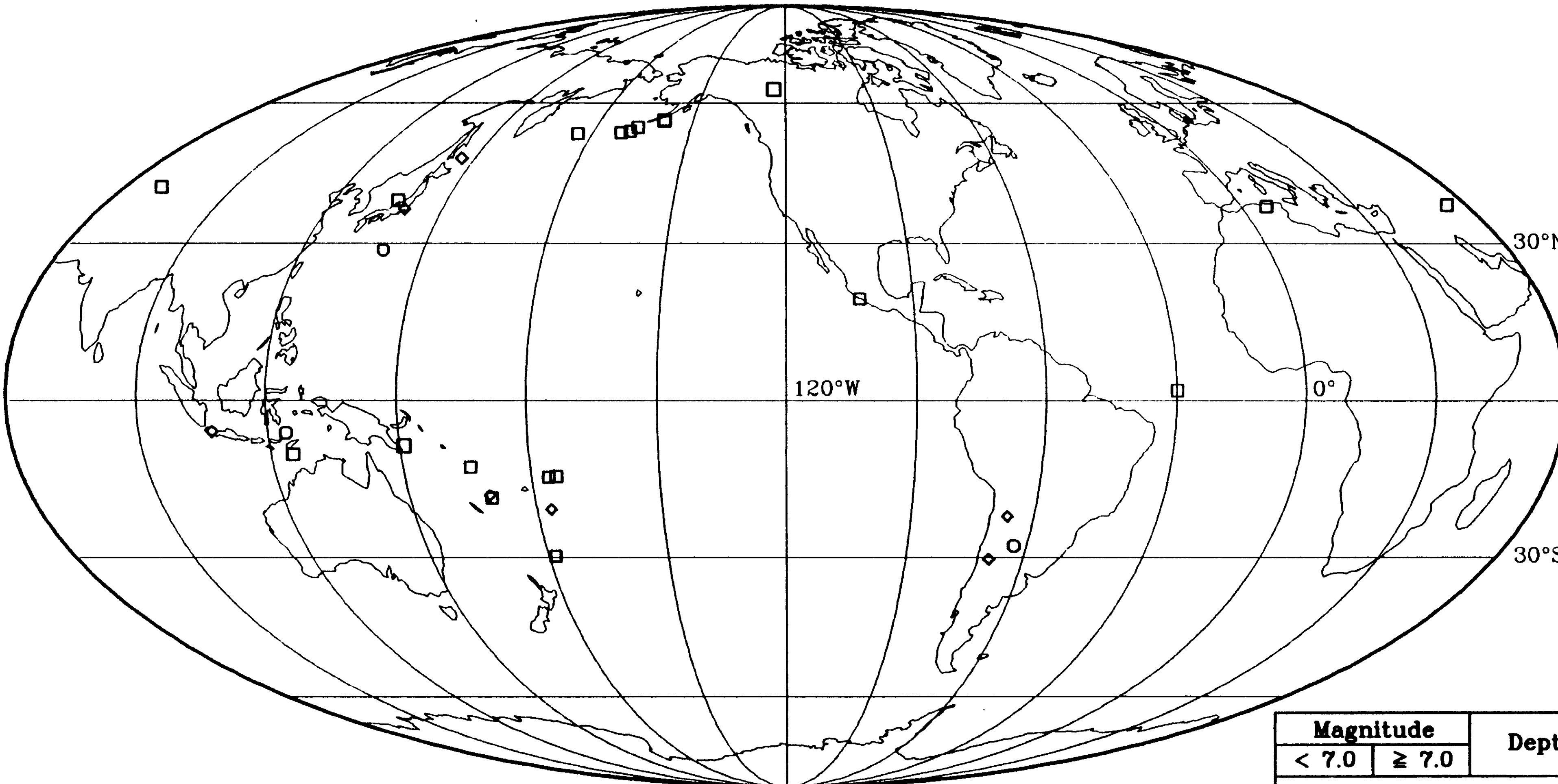
Table 1. Earthquakes for October 1985 with magnitudes ≥ 5.5

	Origin Time UTC	Latitude	Longitude	Depth (km)	Magnitude m_b	Magnitude M_{SZ}	Flinn-Engdahl Region Name
1.	1985 10 01 15:54:51.35	52.334° N	168.805° W	33.0	5.7	5.3	Fox Islands, Aleutian Islands
2.	1985 10 02 20:40:02.90	19.462° S	169.824° E	37.0	5.6	5.3	Vanuatu Islands
3.	1985 10 04 08:41:37.96	27.631° N	139.900° E	480.4	5.6		Bonin Islands Region
4.	1985 10 04 12:25:51.12	35.764° N	140.003° E	80.2	5.8		Near East Coast of Honshu, Japan
5.	1985 10 05 15:24:02.25	62.257° N	124.312° W	10.0	6.5	6.6	Northwest Territories, Canada
6.	1985 10 06 12:00:47.95	18.926° S	169.393° E	255.9	5.7		Vanuatu Islands
7.	1985 10 08 09:47:21.90	23.050° S	66.426° W	222.0	5.5		Jujuy Province, Argentina
8.	1985 10 09 01:15:05.09	6.887° S	107.100° E	158.4	5.9		Java
9.	1985 10 09 09:33:32.80	54.801° N	159.573° W	31.2	6.3	6.5	South of Alaska
10.	1985 10 11 19:29:46.14	30.729° S	178.284° W	28.3	5.6		Kermadec Islands
11.	1985 10 12 02:12:58.32	21.619° S	176.493° W	157.4	5.8		Fiji Islands Region
12.	1985 10 12 22:20:37.69	0.857° N	29.876° W	10.0	5.3	6.0	Central Mid-Atlantic Ridge
13.	1985 10 13 15:59:53.55	40.317° N	69.840° E	33.0	5.8	5.9	Tajik SSR
14.	1985 10 18 03:22:23.19	37.549° N	136.859° E	33.0	5.8	4.9	Near West Coast of Honshu, Japan
15.	1985 10 18 04:19:08.36	46.300° N	146.287° E	291.0	6.0		Northwest of Kuril Islands
16.	1985 10 21 02:36:11.44	13.555° S	166.020° E	46.3	5.5	5.0	Vanuatu Islands
17.	1985 10 23 00:49:13.92	11.150° S	125.116° E	33.0	6.0	5.3	Timor Sea
18.	1985 10 23 17:16:23.88	15.313° S	174.215° W	33.0	5.9		Tonga Islands
19.	1985 10 24 01:48:56.05	31.410° S	68.636° W	110.7	5.7		San Juan Province, Argentina
20.	1985 10 25 02:09:04.47	52.083° N	171.319° W	33.0	5.6	5.6	Fox Islands, Aleutian Islands
21.	1985 10 25 18:12:19.75	7.108° S	124.269° E	598.5	5.9		Banda Sea
22.	1985 10 26 15:59:36.17	54.857° N	159.467° W	33.0	5.6	4.6	South of Alaska
23.	1985 10 27 19:34:57.08	36.402° N	6.746° E	10.0	5.5	5.9	Algeria
24.	1985 10 28 12:52:31.24	15.431° S	175.941° W	33.0	5.5	5.7	Tonga Islands
25.	1985 10 29 13:13:42.79	36.720° N	54.805° E	33.0	6.0	5.9	Iran
26.	1985 10 29 14:10:39.53	9.564° S	150.992° E	10.0	6.0	6.7	East Papua New Guinea Region
27.	1985 10 29 15:02:27.15	18.168° N	102.549° W	33.0	5.6	5.4	Michoacan, Mexico
28.	1985 10 30 19:05:37.46	51.774° N	175.553° E	33.0	5.6	5.4	Rat Islands, Aleutian Islands
29.	1985 10 31 19:33:07.12	53.258° N	166.924° W	33.0	5.8	5.7	Fox Islands, Aleutian Islands
30.	1985 10 31 21:49:20.01	28.747° S	63.186° W	594.5	5.8		Santiago Del Estero Prov., Arg.

Table 2. Current network-event tape station list

Code	ID	Station	Latitude	Longitude	Elevation (m)	Type*
AFI	69	Afiamalu, Western Samoa	13.91° S	171.78° W	706.0	DWWSSN
ANMO	30	Albuquerque, New Mexico	34.95° N	106.46° W	1740.0	SRO
ANTO	31	Ankara, Turkey	39.87° N	32.79° E	883.0	SRO
BCAO	37	Bangui, Central African Republic	4.43° N	18.54° E	336.0	SRO
BDF	72	Brasilia, Brazil	15.66° S	47.90° W	1500.0	DWWSSN
CHTO	33	Chiang Mai, Thailand	18.79° N	98.98° E	316.0	SRO
COL	62	College, Alaska	64.90° N	147.79° W	320.0	DWWSSN
CTAO	50	Charters Towers, Australia	20.09° S	146.25° E	357.0	ASRO
GAC	43	Glen Almond, Quebec, Canada	45.70° N	75.48° W	620.0	SRO
GDH	70	Godhavn, Greenland	69.25° N	53.53° W	23.0	DWWSSN
GRA1	302	Haidhof, Germany	49.69° N	11.22° E	500.0	GRF
GRFO	39	Graefenberg, Germany	49.69° N	11.22° E	500.0	SRO
GUMO	35	Guam, Mariana Islands	13.59° N	144.87° E	14.0	SRO
HON	66	Honolulu, Hawaii	21.32° N	158.01° W	2.0	DWWSSN
JAS1	64	Jamestown, California	37.93° N	120.42° W	425.0	DWWSSN
KEV	67	Kevo, Finland	69.76° N	27.01° E	80.0	DWWSSN
KONO	54	Kongsberg, Norway	59.65° N	9.60° E	216.0	ASRO
LEM	76	Lembang, Indonesia	6.83° S	107.62° E	1247.0	DWWSSN
LON	63	Longmire, Washington	46.75° N	121.81° W	854.0	DWWSSN
MAJO	53	Matsushiro, Japan	36.54° N	138.21° E	422.0	ASRO
NE02	202	Monsted, Denmark	56.459° N	9.170° E	60.0	NARS
NE03	203	Logumkloster, Denmark	55.045° N	9.153° E	25.0	NARS
NE04	204	Witteveen, Netherlands	52.813° N	6.668° E	17.0	NARS
NE06	206	Dourbes, Belgium	50.097° N	4.595° E	225.0	NARS
NE07	207	Villiers-Adam, France	49.074° N	2.232° E	70.0	NARS
NE09	209	Les-Eyzies, France	44.852° N	0.981° E	160.0	NARS
NE10	210	Arette, France	43.086° N	0.699° W	480.0	NARS
NE11	211	Ainzon, France	41.814° N	1.517° W	440.0	NARS
NE13	213	Puertollano, Spain	38.685° N	4.091° W	700.0	NARS
NE14	214	Granada, Spain	37.190° N	3.595° W	774.0	NARS
NE15	215	Valkenburg, Netherlands	50.867° N	5.785° E	100.0	NARS
NE16	216	Clermont-Ferand, France	45.763° N	3.103° E	80.0	NARS
NE17	217	Toledo, Spain	39.881° N	4.049° W	480.0	NARS
NRA0	301	NORESS array site A0	60.735° N	11.541° E	302.0	NRSA
NWAO	38	Mundaring (Narrogin), Australia	32.93° S	117.24° E	265.0	SRO
RSCP	81	Cumberland Plateau, Tennessee,	35.60° N	85.57° W	481.0	RSTN
RSNT	82	Yellowknife, Northwest Territories	62.48° N	114.59° W	90.0	RSTN
RSNY	84	Adirondack, New York	44.55° N	74.53° W	351.0	RSTN
RSON	85	Red Lake, Ontario	50.86° N	93.70° W	302.0	RSTN
RSSD	83	Black Hills, South Dakota	44.12° N	104.04° W	1948.0	RSTN
SCP	61	State College, Pennsylvania	40.79° N	77.87° W	352.0	DWWSSN
SLR	71	Silverton, South Africa	25.73° S	28.28° E	1348.0	DWWSSN
SNZO	42	Wellington (South Karori), New Zealand	41.31° S	174.70° E	-12.0	SRO
TATO	41	Taipei, Taiwan	24.98° N	121.49° E	53.0	SRO
TAU	74	Hobart, Tasmania	42.91° S	147.32° E	132.0	DWWSSN
TOL	73	Toledo, Spain	39.88° N	4.05° W	480.0	DWWSSN
ZOBO	51	La Paz (Zongo), Bolivia	16.27° S	68.13° W	4450.0	ASRO

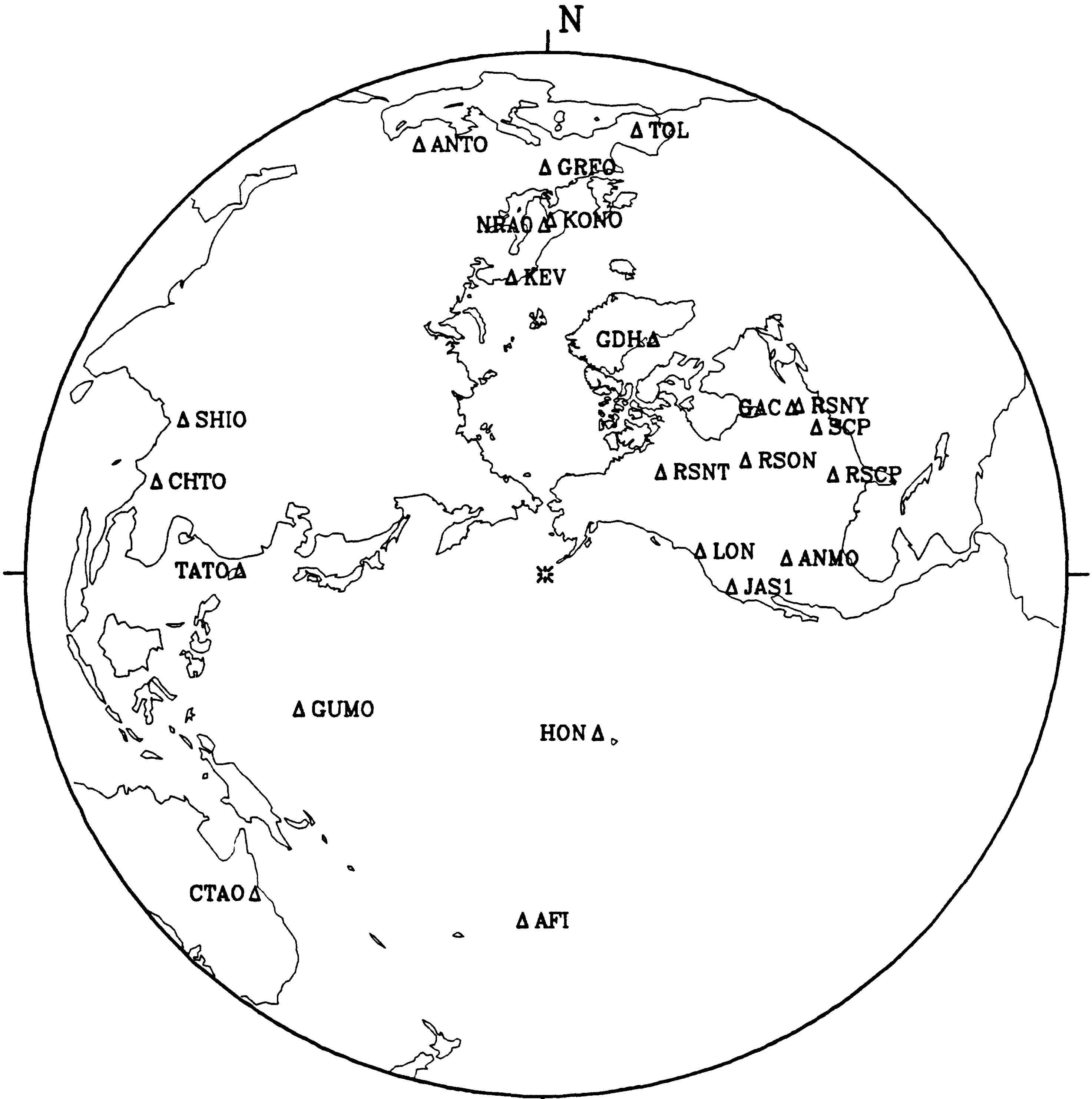
EARTHQUAKES – October 1985 – MAGNITUDE ≥ 5.5



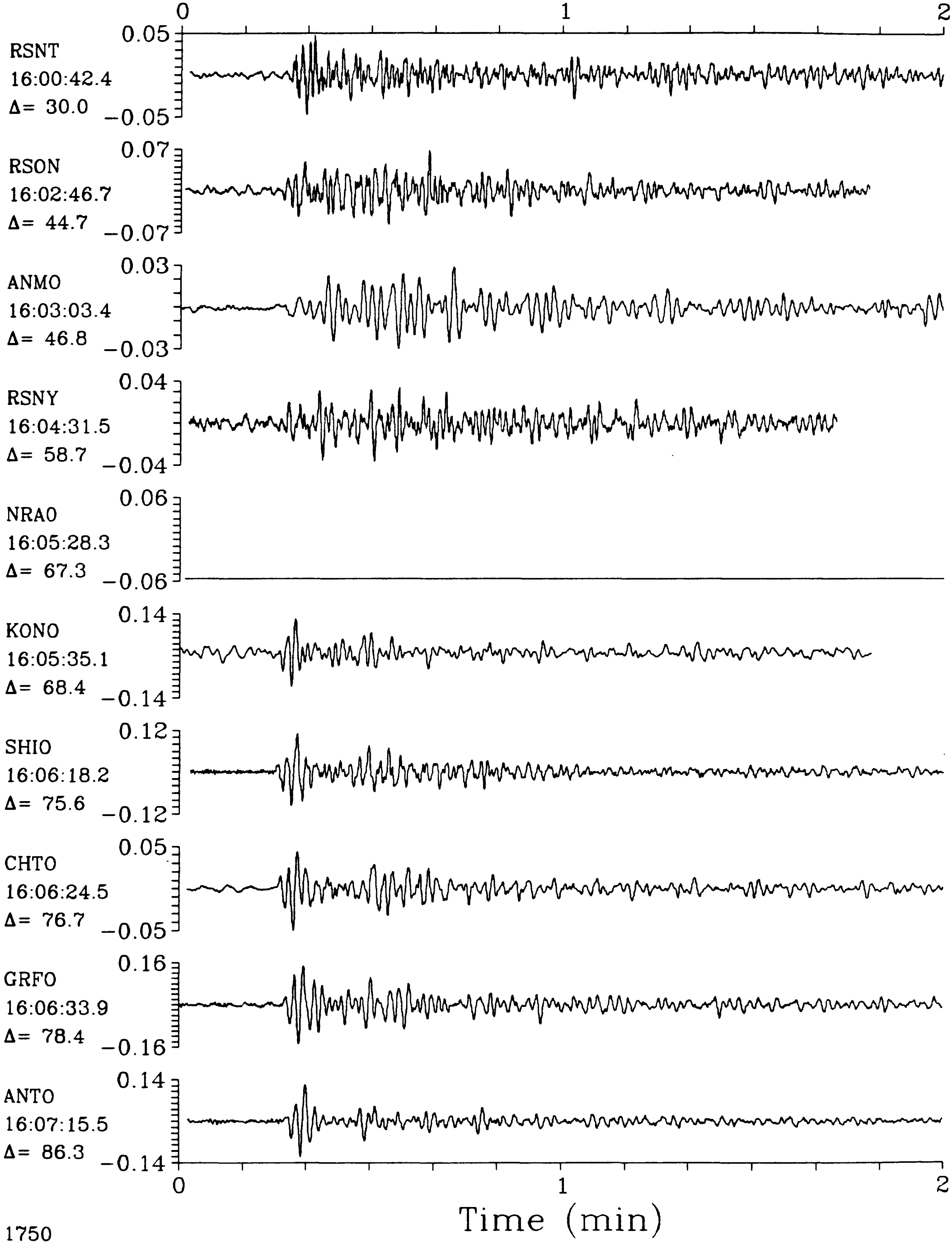
Magnitude < 7.0	Magnitude ≥ 7.0	Depth
□	⊞	0–70
◇	◈	71–300
○	⊕	301–800

01 October 1985 15:54:51.35

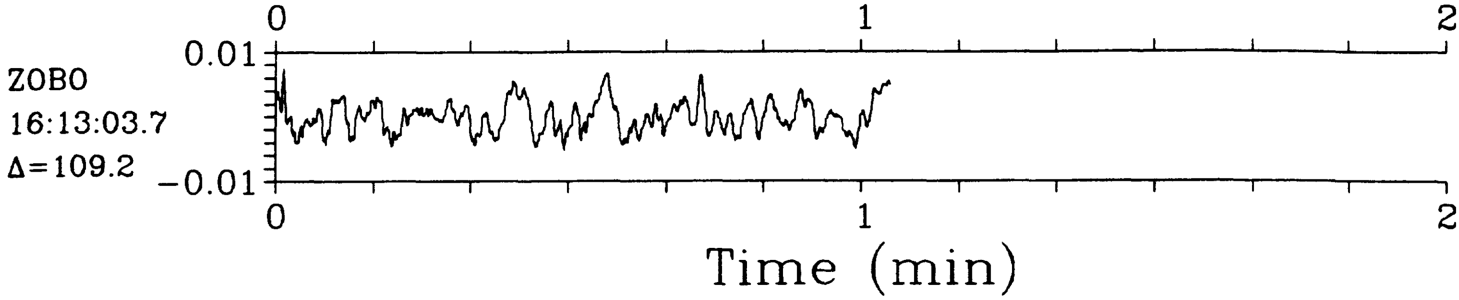
Fox Islands, Aleutian Islands



SPZ 01 October 1985 15:54:51.35 SPZ
Fox Islands, Aleutian Islands h=33.0 m_b=5.7 M_{SZ}=5.3

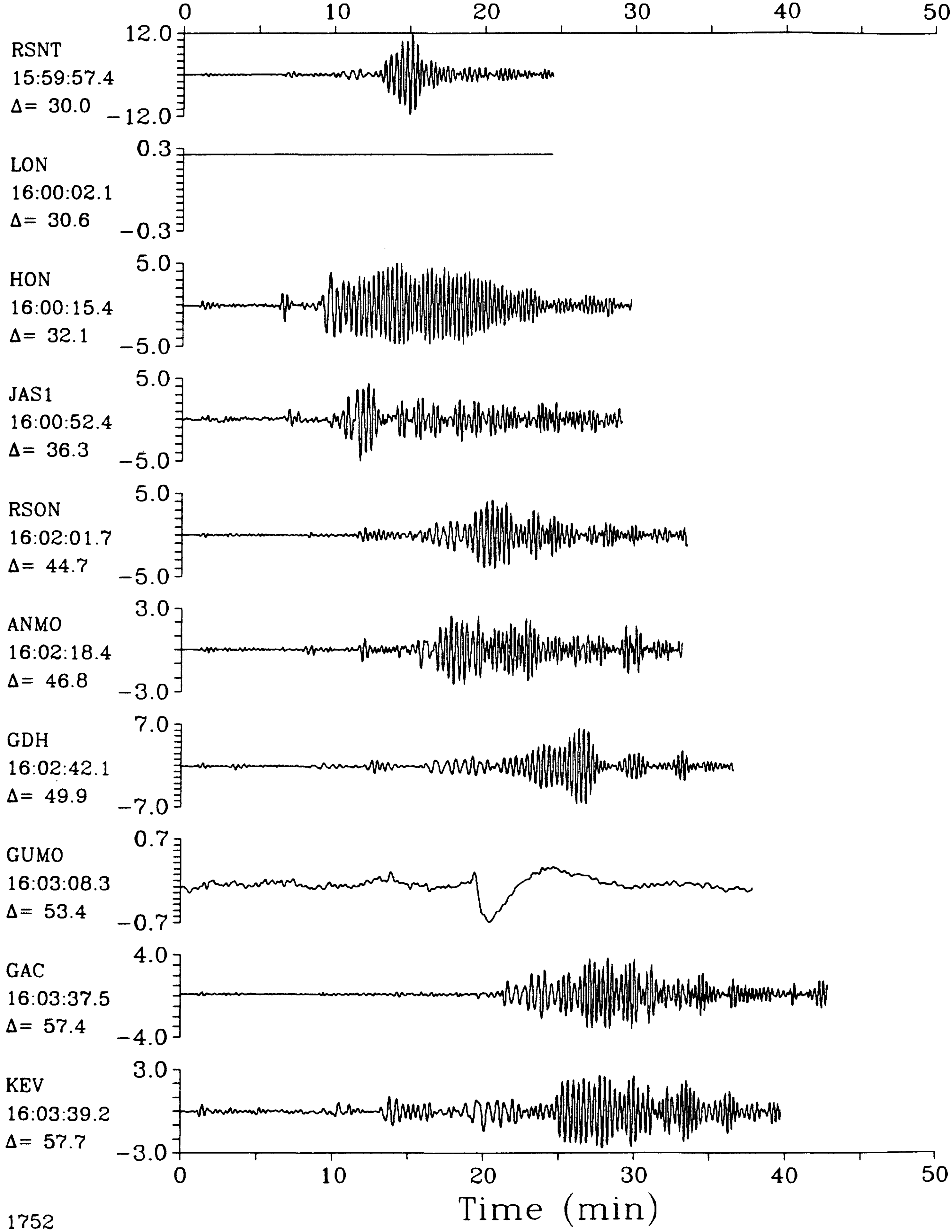


Fox Islands, Aleutian Islands h=33.0 m_b=5.7 M_{SZ}=5.3



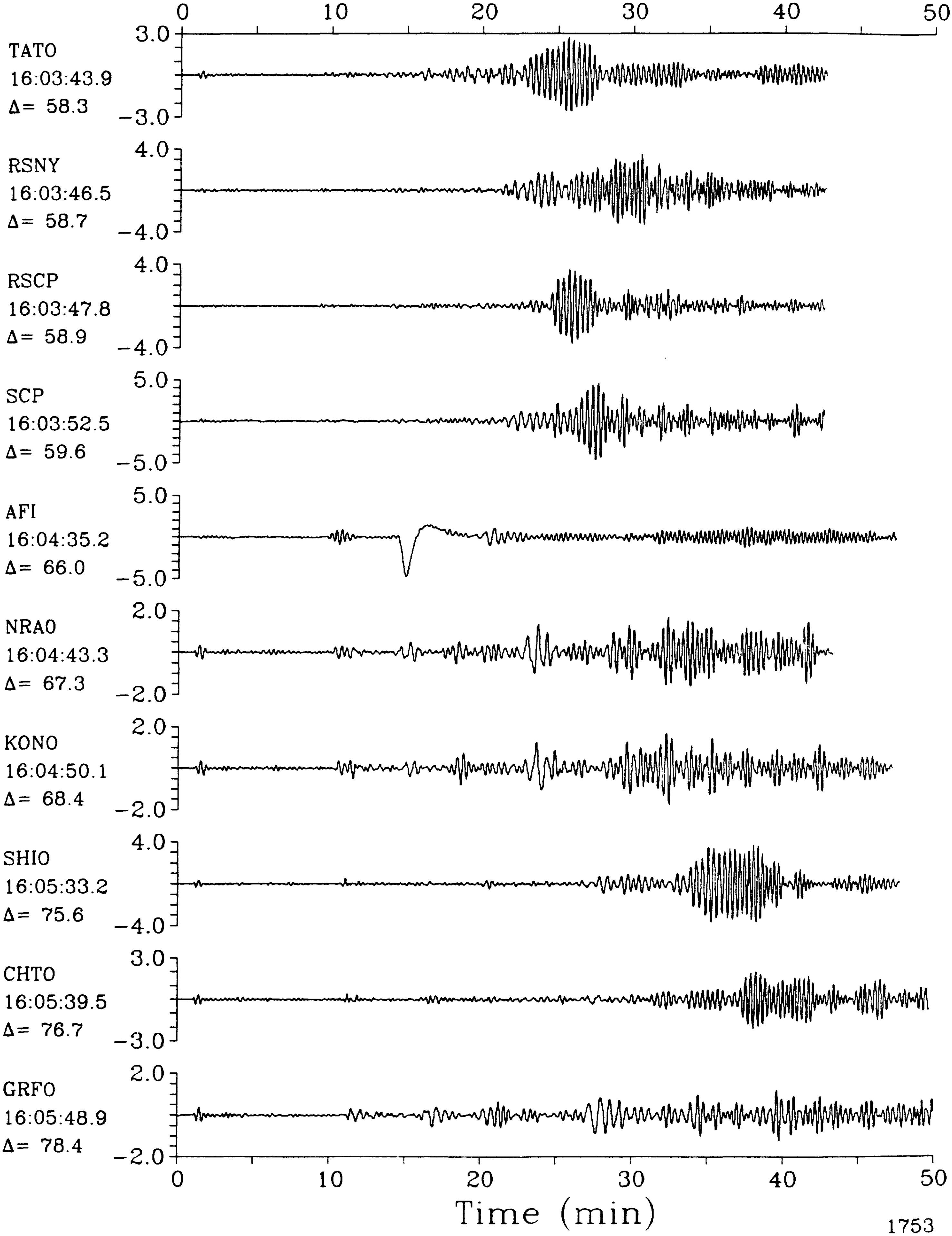
LPZ 01 October 1985 15:54:51.35 LPZ

Fox Islands, Aleutian Islands h=33.0 m_b=5.7 M_{SZ}=5.3



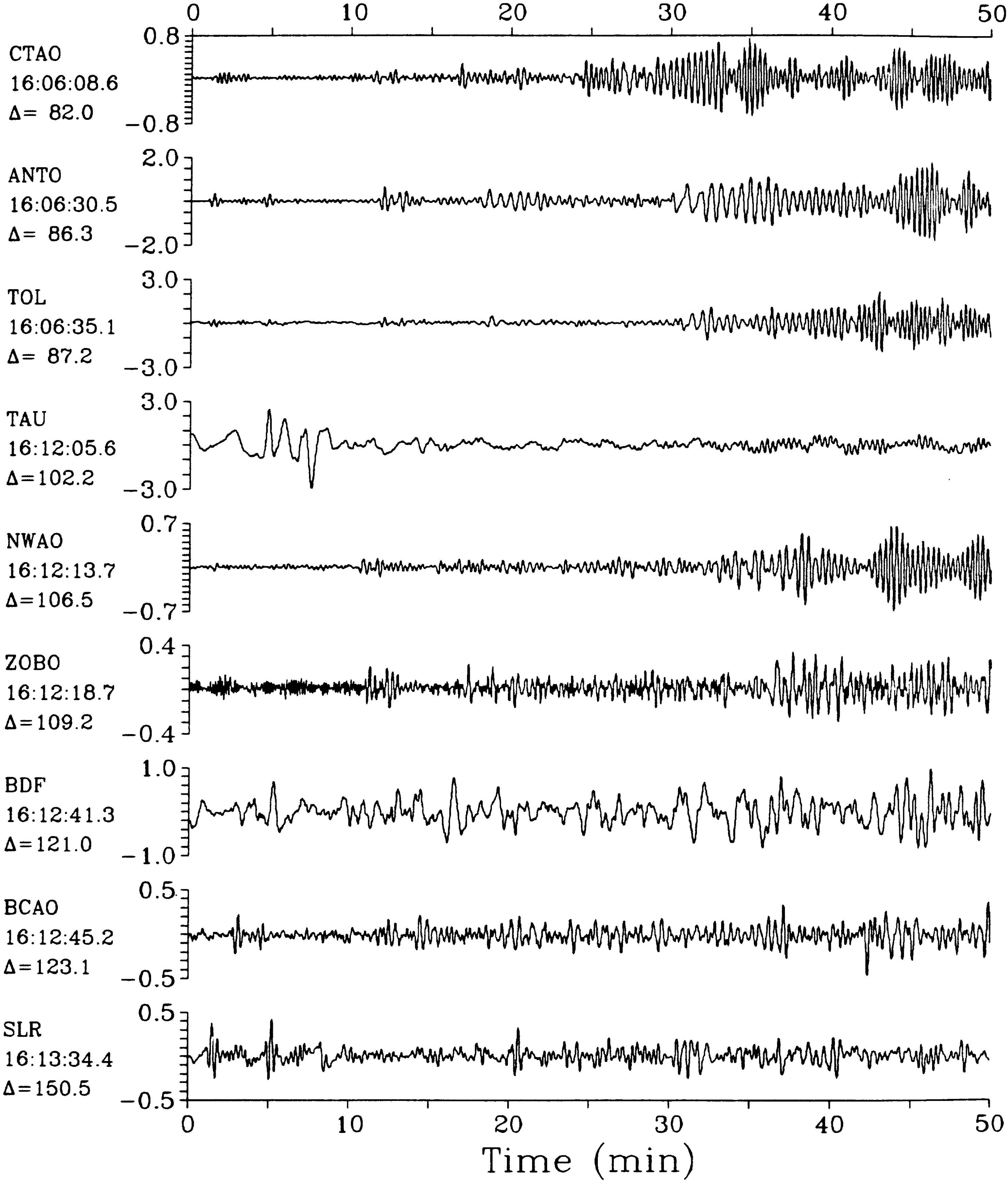
LPZ **01 October 1985 15:54:51.35** LPZ

Fox Islands, Aleutian Islands h=33.0 m_b=5.7 M_{SZ}=5.3



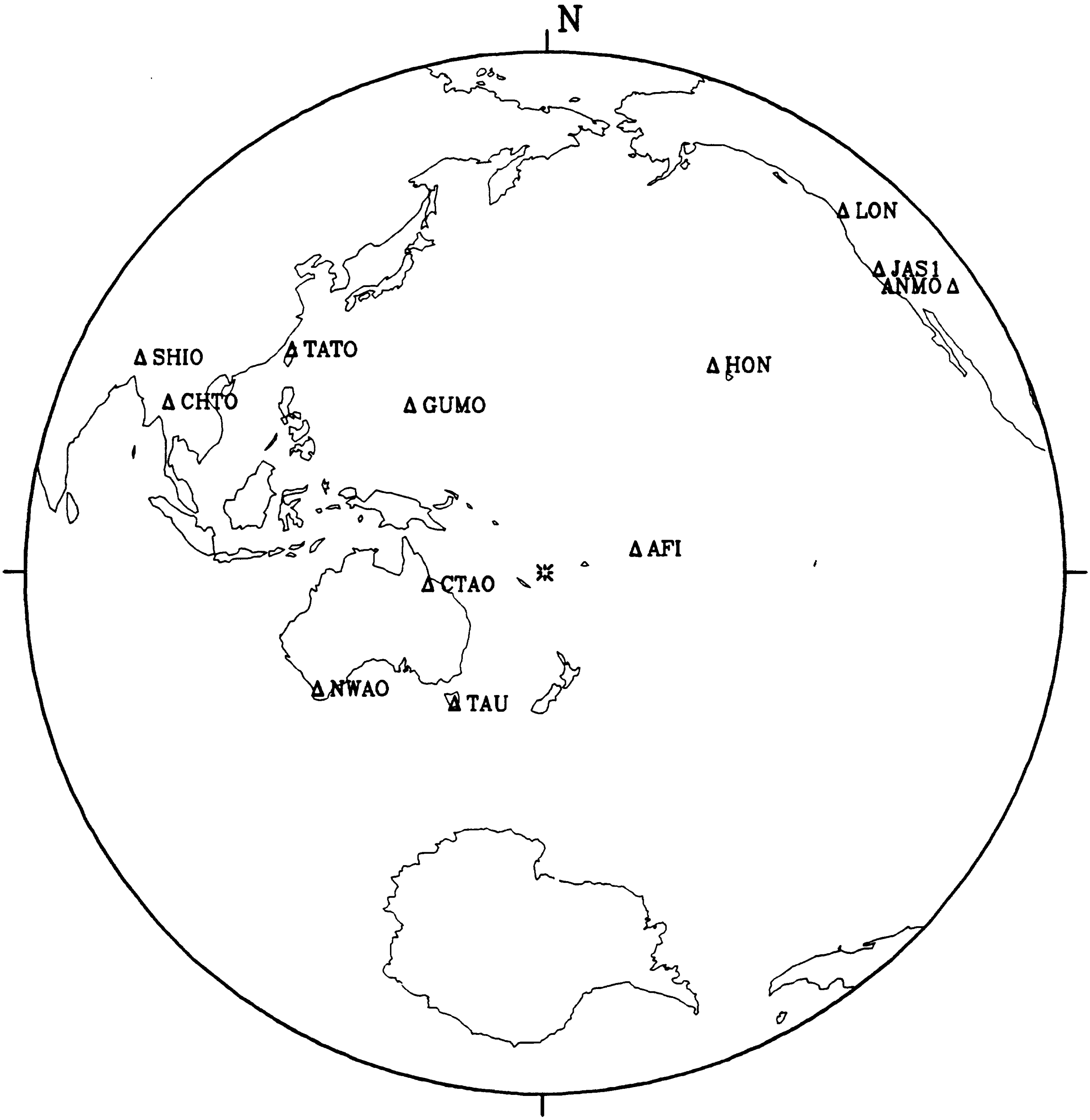
LPZ 01 October 1985 15:54:51.35 LPZ

Fox Islands, Aleutian Islands h=33.0 m_b=5.7 M_{SZ}=5.3



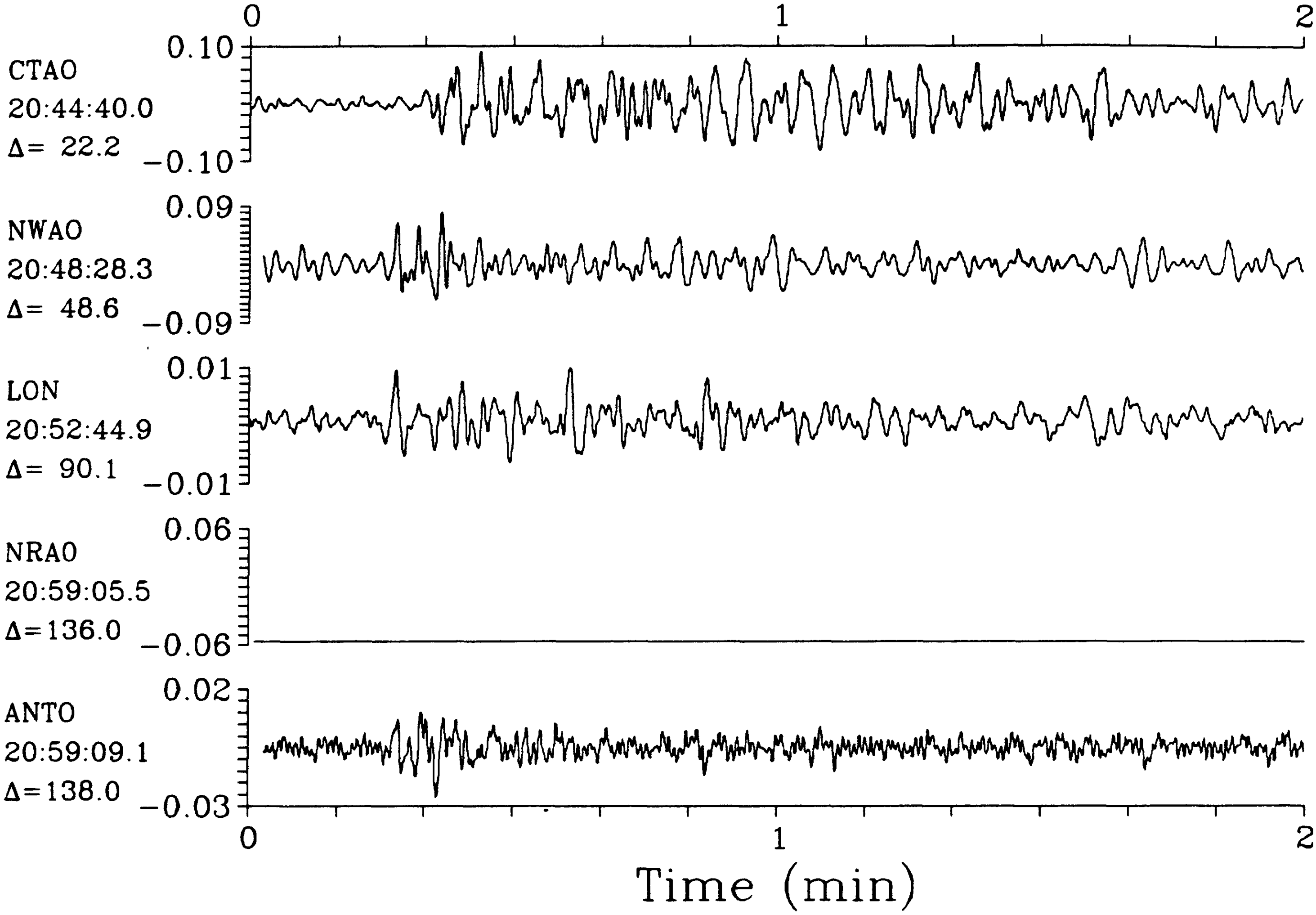
02 October 1985 20:40:02.90

Vanuatu Islands



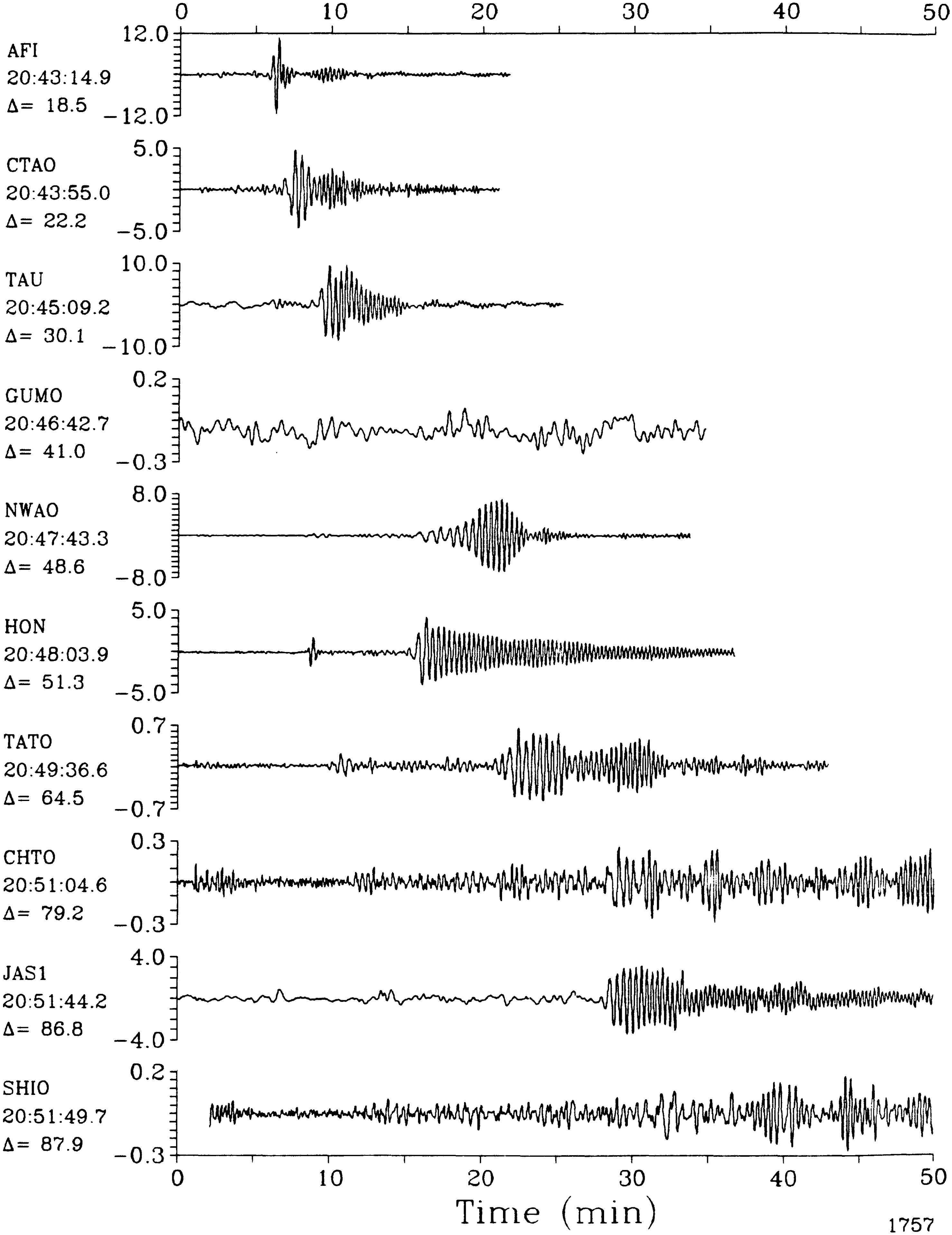
SPZ 02 October 1985 20:40:02.90 SPZ

Vanuatu Islands h=37.0 m_b=5.6 M_{SZ}=5.3



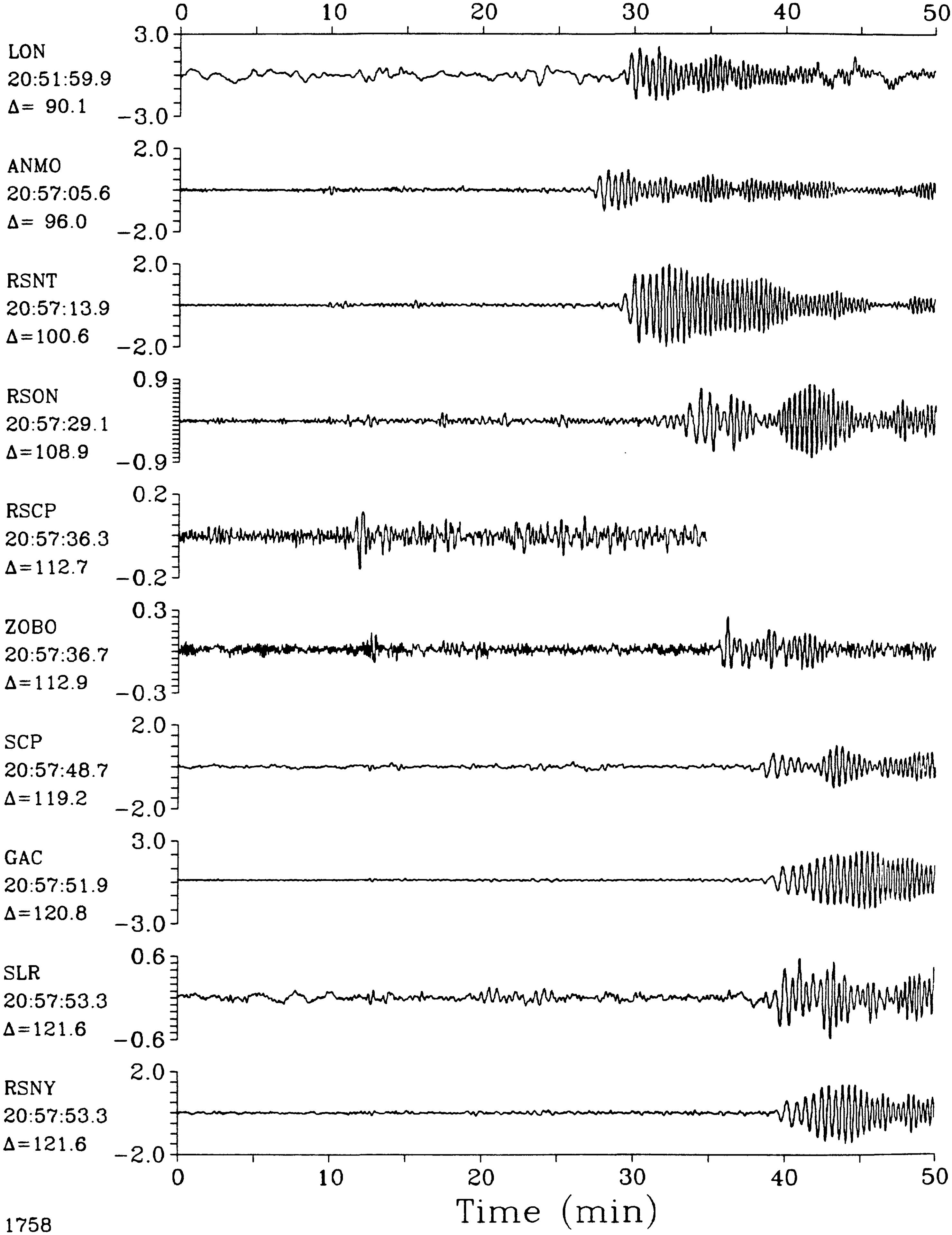
LPZ 02 October 1985 20:40:02.90 LPZ

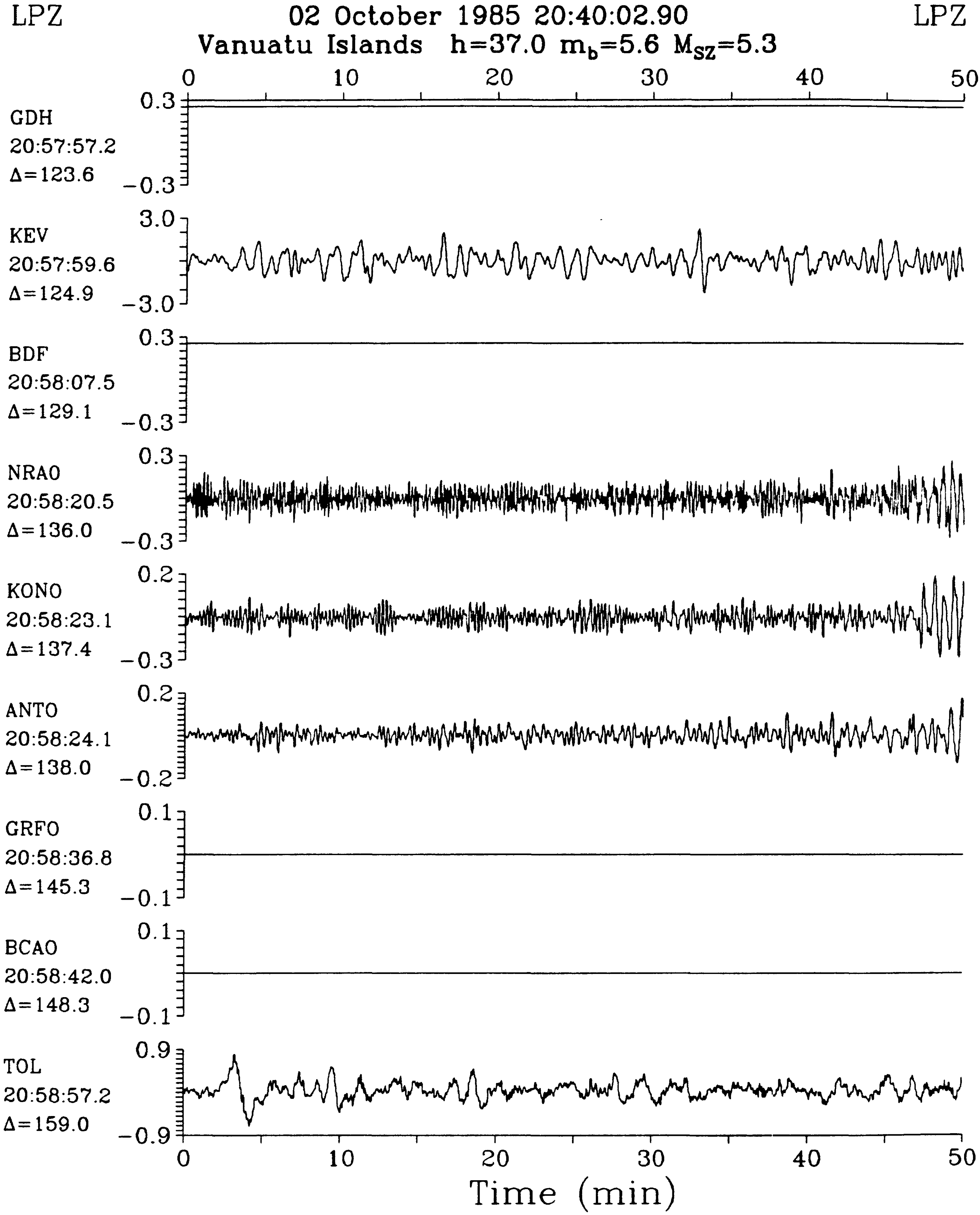
Vanuatu Islands h=37.0 m_b=5.6 M_{SZ}=5.3



LPZ 02 October 1985 20:40:02.90 LPZ

Vanuatu Islands h=37.0 m_b=5.6 M_{SZ}=5.3

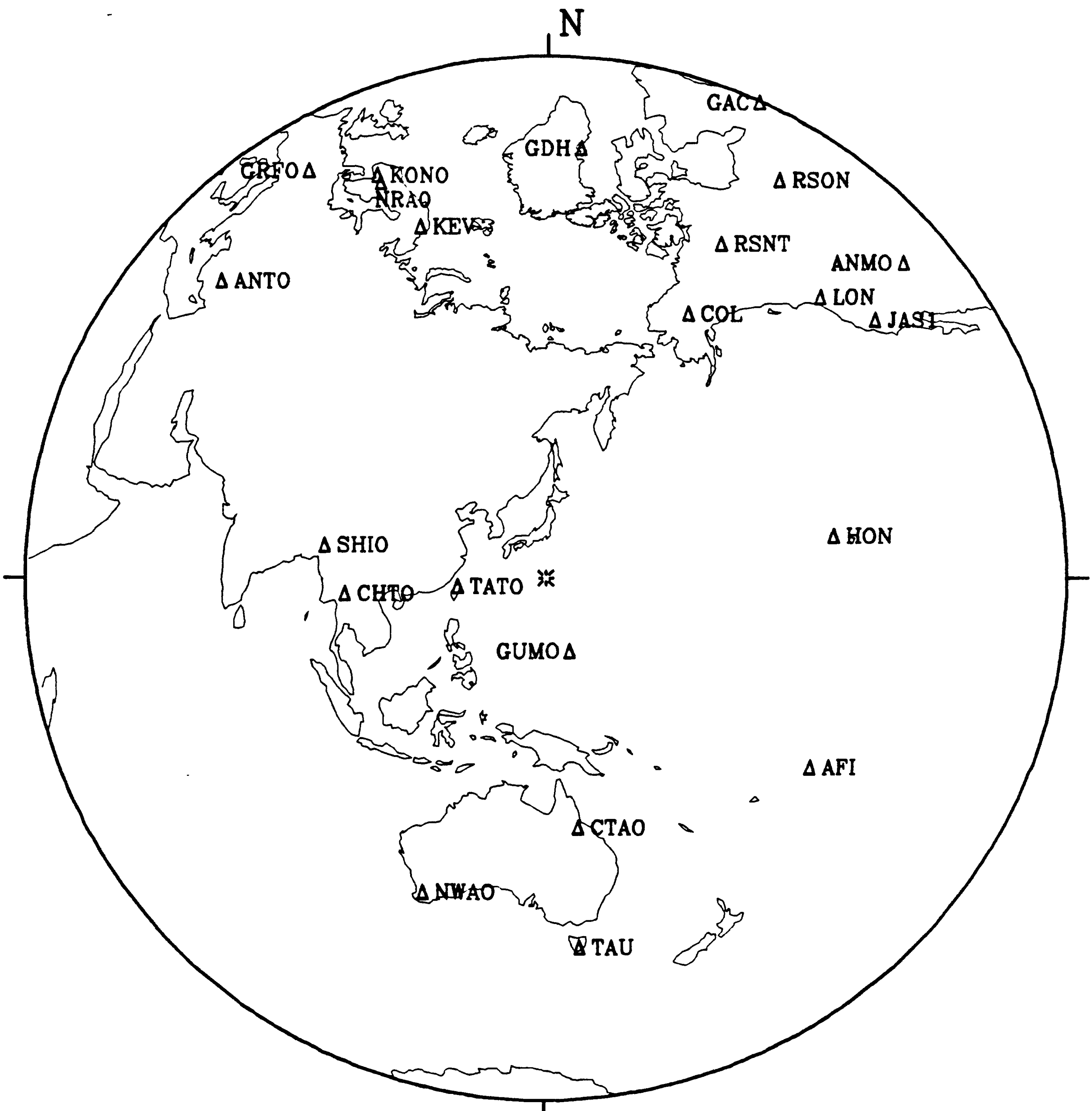


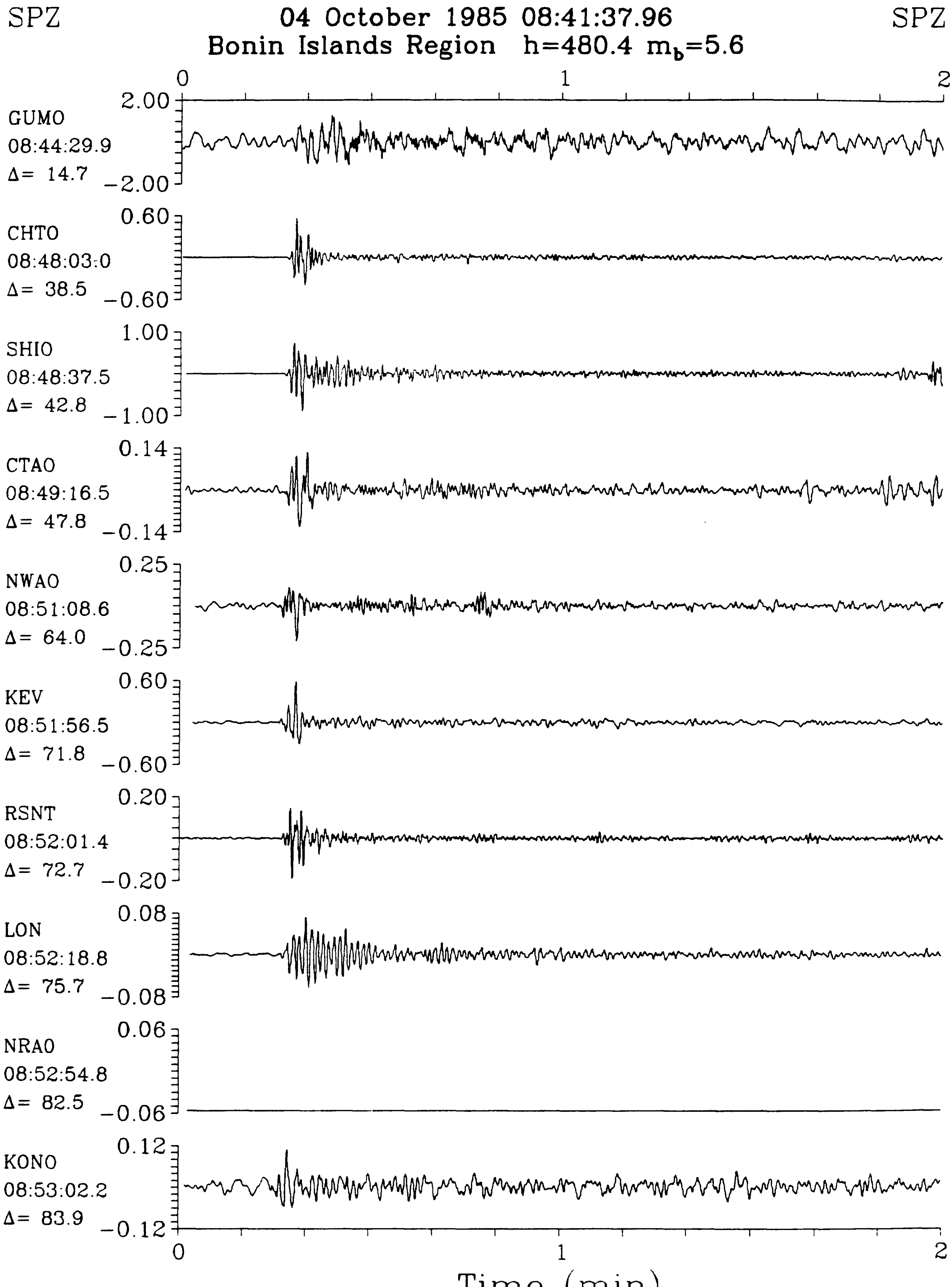


LPZ
02 October 1985 20:40:02.90
Vanuatu Islands h=37.0 m_b=5.6 M_SZ=5.3
LPZ
GDH
20:57:57.2
Δ=123.6
KEV
20:57:59.6
Δ=124.9
BDF
20:58:07.5
Δ=129.1
NRAO
20:58:20.5
Δ=136.0
KONO
20:58:23.1
Δ=137.4
ANTO
20:58:24.1
Δ=138.0
GRFO
20:58:36.8
Δ=145.3
BCAO
20:58:42.0
Δ=148.3
TOL
20:58:57.2
Δ=159.0
Time (min)

04 October 1985 08:41:37.96

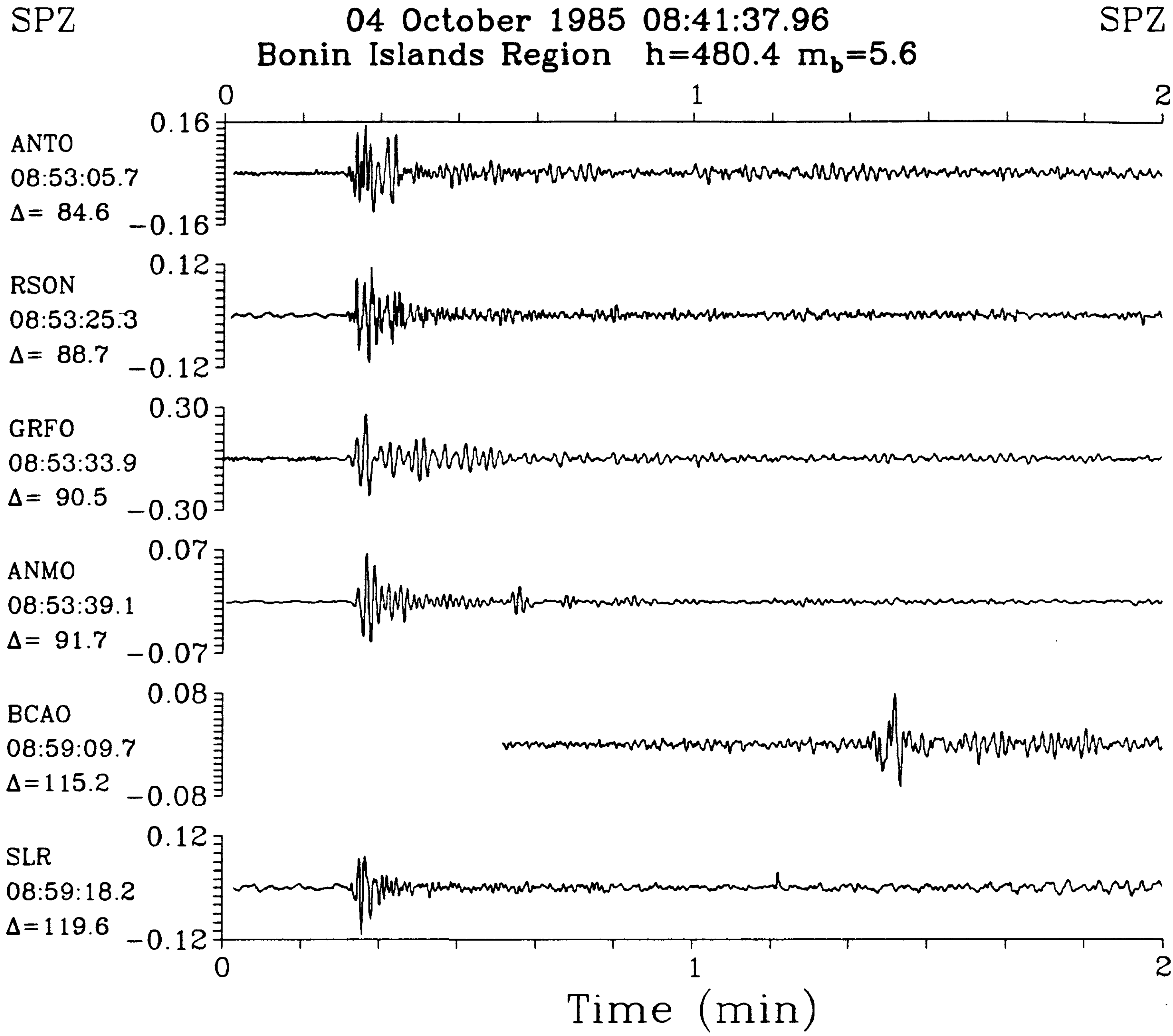
Bonin Islands Region





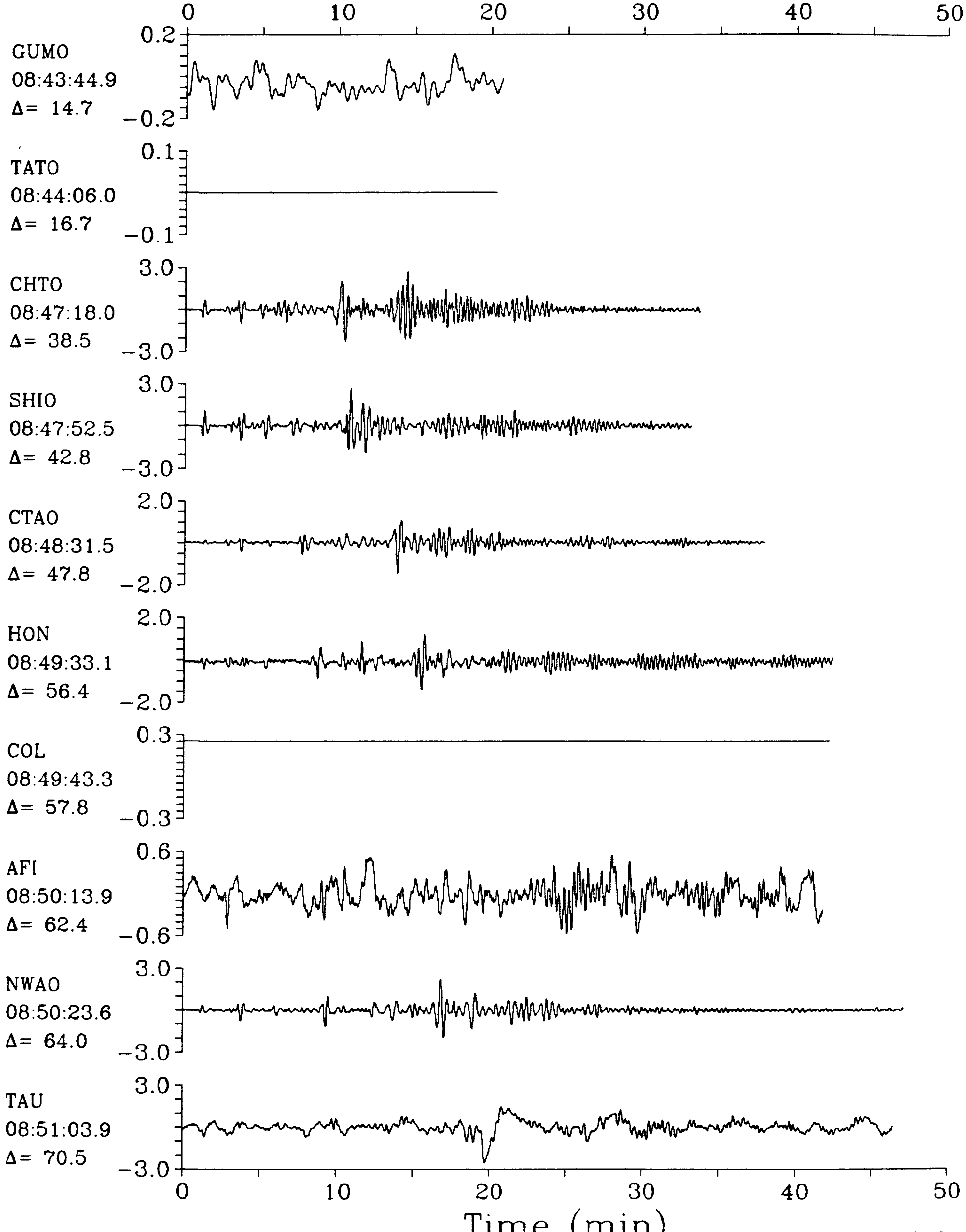
SPZ
04 October 1985 08:41:37.96
Bonin Islands Region h=480.4 m_b=5.6
SPZ
GUMO
08:44:29.9
Δ= 14.7
2.00
−2.00
CHTO
08:48:03.0
Δ= 38.5
0.60
−0.60
SHIO
08:48:37.5
Δ= 42.8
1.00
−1.00
CTAO
08:49:16.5
Δ= 47.8
0.14
−0.14
NWAO
08:51:08.6
Δ= 64.0
0.25
−0.25
KEV
08:51:56.5
Δ= 71.8
0.60
−0.60
RSNT
08:52:01.4
Δ= 72.7
0.20
−0.20
LON
08:52:18.8
Δ= 75.7
0.08
−0.08
NRAO
08:52:54.8
Δ= 82.5
0.06
−0.06
KONO
08:53:02.2
Δ= 83.9
0.12
−0.12
0
1
2
Time (min)

1761


SPZ
04 October 1985 08:41:37.96
Bonin Islands Region h=480.4 m_b=5.6
SPZ
ANTO
08:53:05.7
Δ= 84.6
RSON
08:53:25.3
Δ= 88.7
GRFO
08:53:33.9
Δ= 90.5
ANMO
08:53:39.1
Δ= 91.7
BCAO
08:59:09.7
Δ=115.2
SLR
08:59:18.2
Δ=119.6
0.16
−0.16
0.12
−0.12
0.30
−0.30
0.07
−0.07
0.08
−0.08
0.12
−0.12
0
1
2
Time (min)

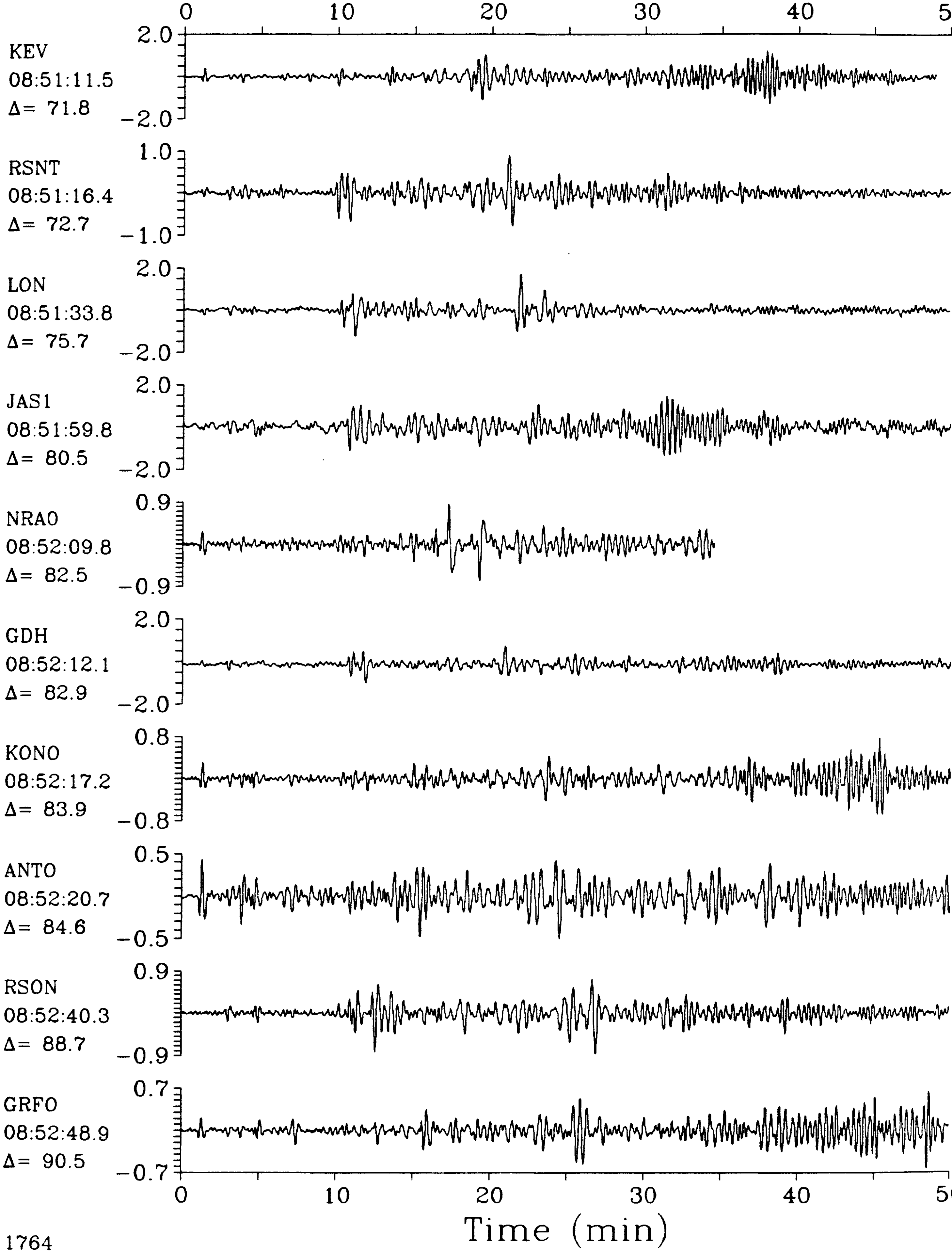
LPZ 04 October 1985 08:41:37.96 LPZ

Bonin Islands Region h=480.4 m_b=5.6



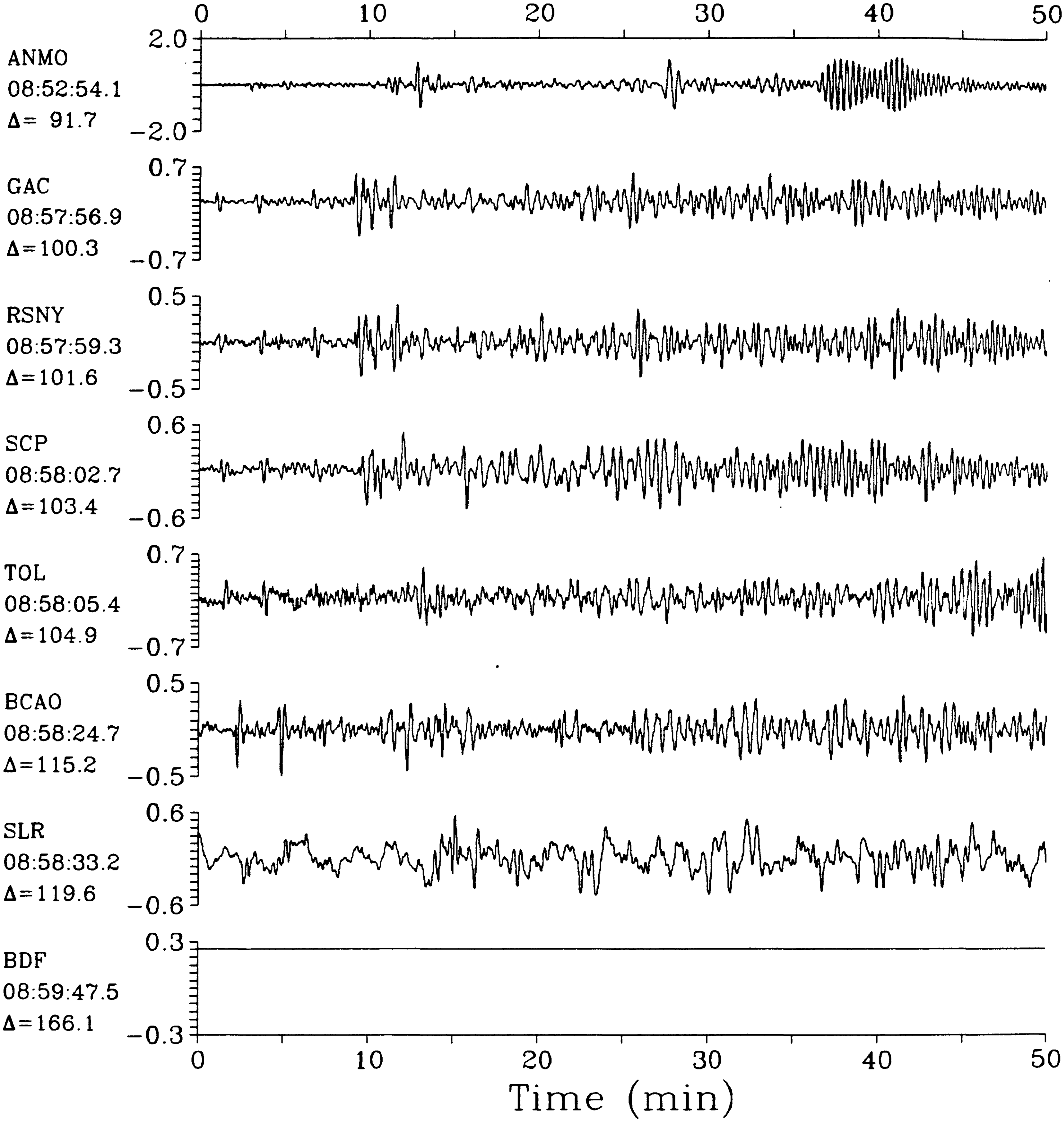
LPZ 04 October 1985 08:41:37.96 LPZ

Bonin Islands Region h=480.4 m_b=5.6



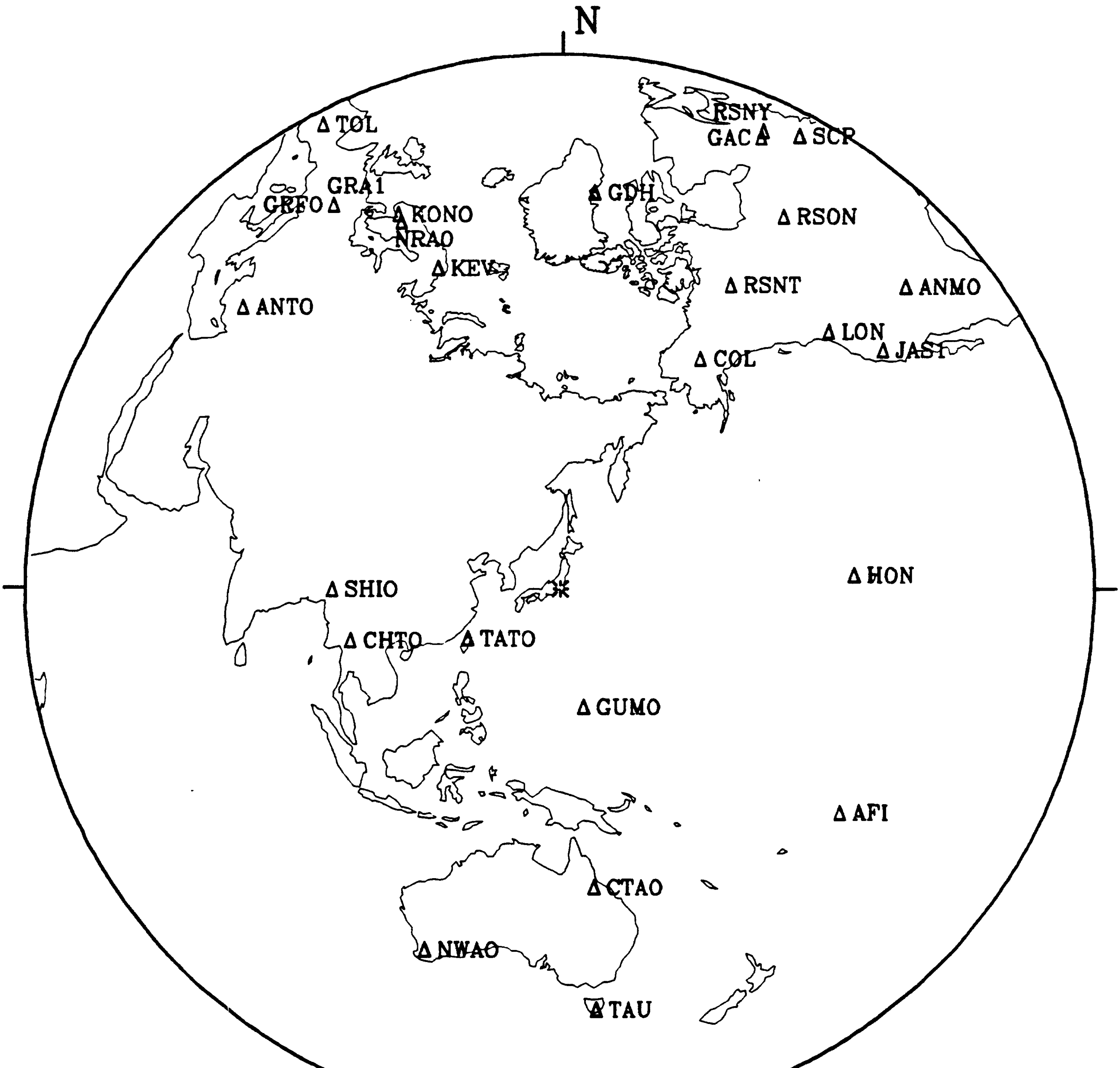
LPZ 04 October 1985 08:41:37.96 LPZ

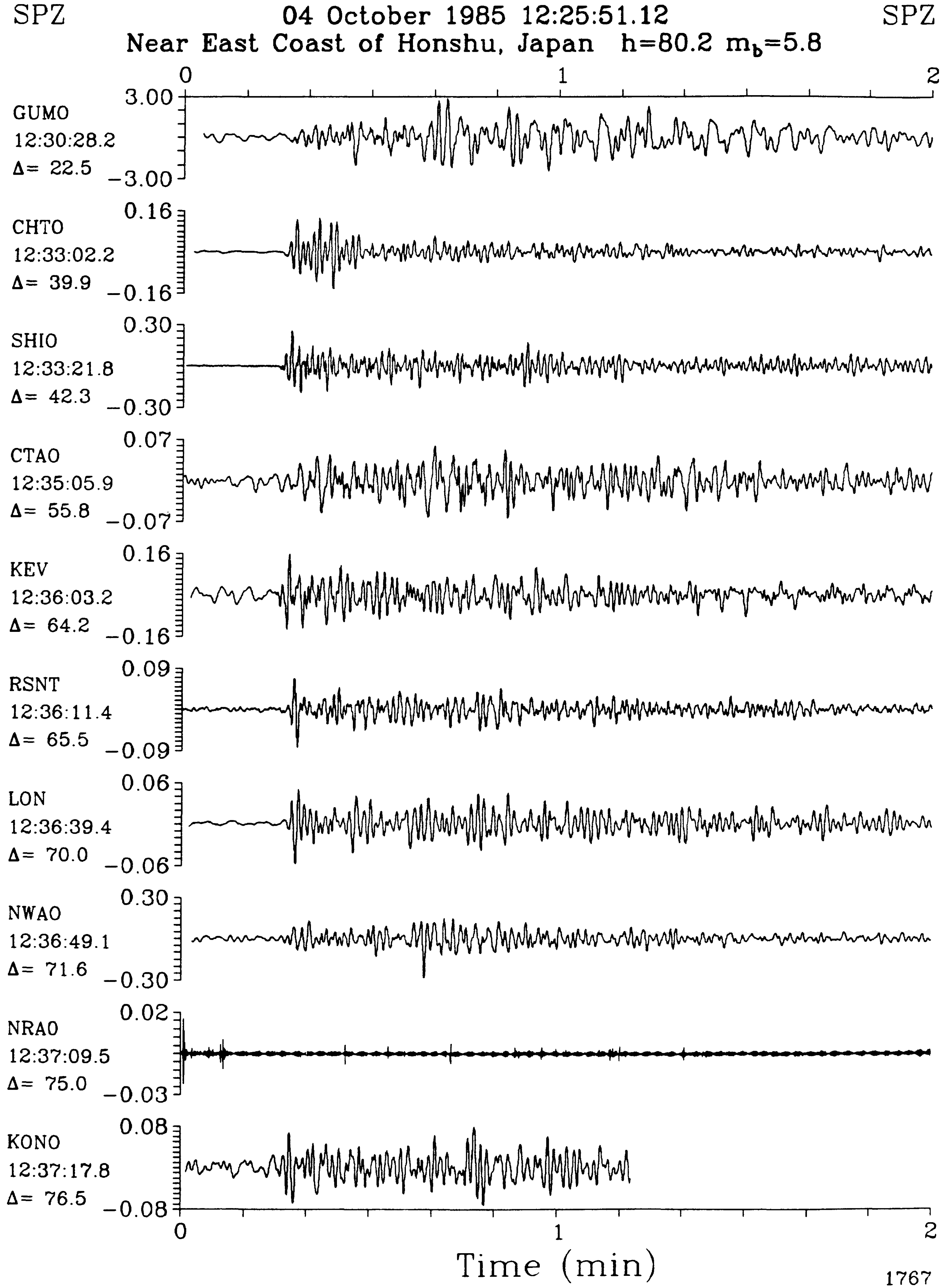
Bonin Islands Region h=480.4 m_b=5.6



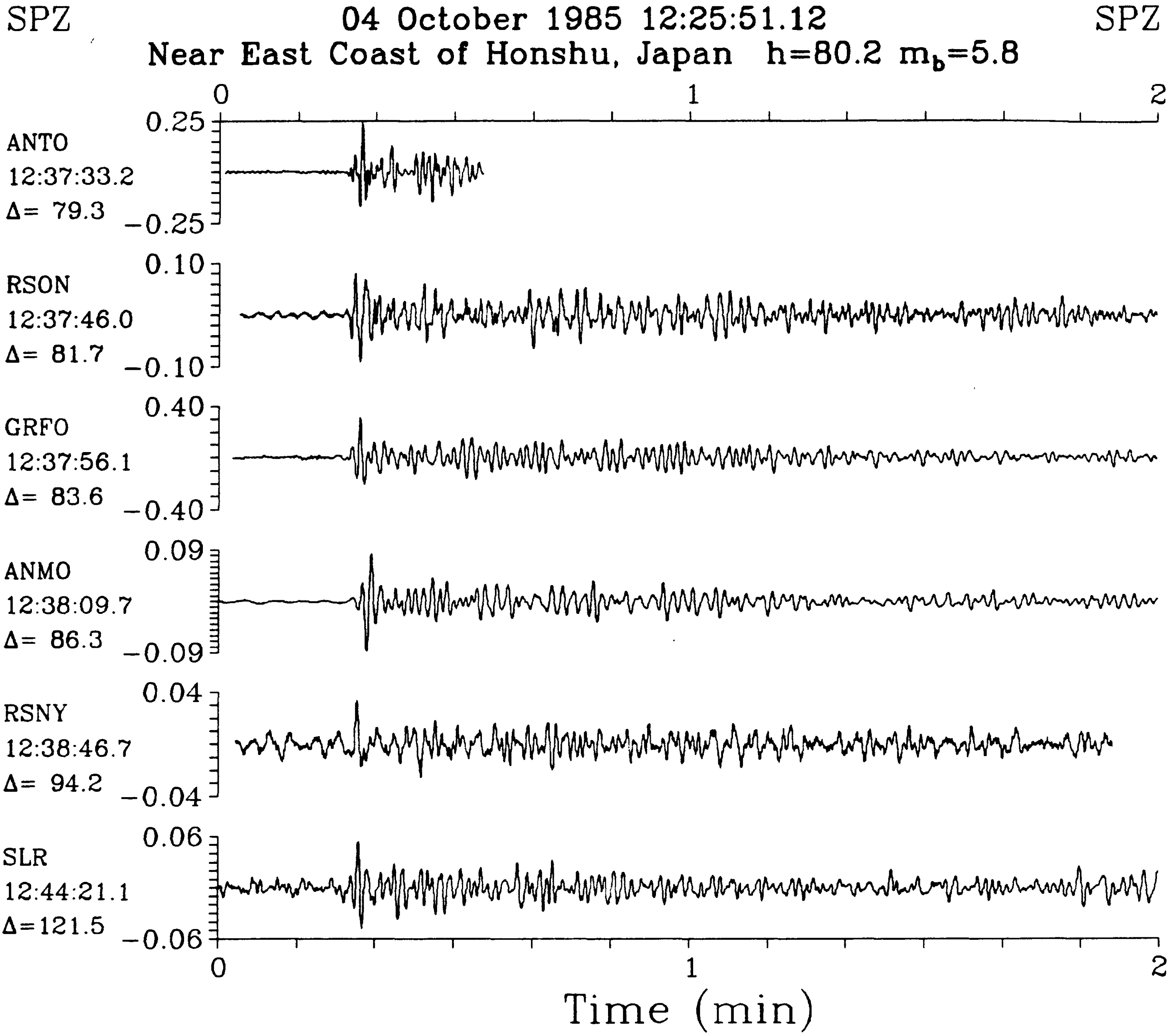
04 October 1985 12:25:51.12

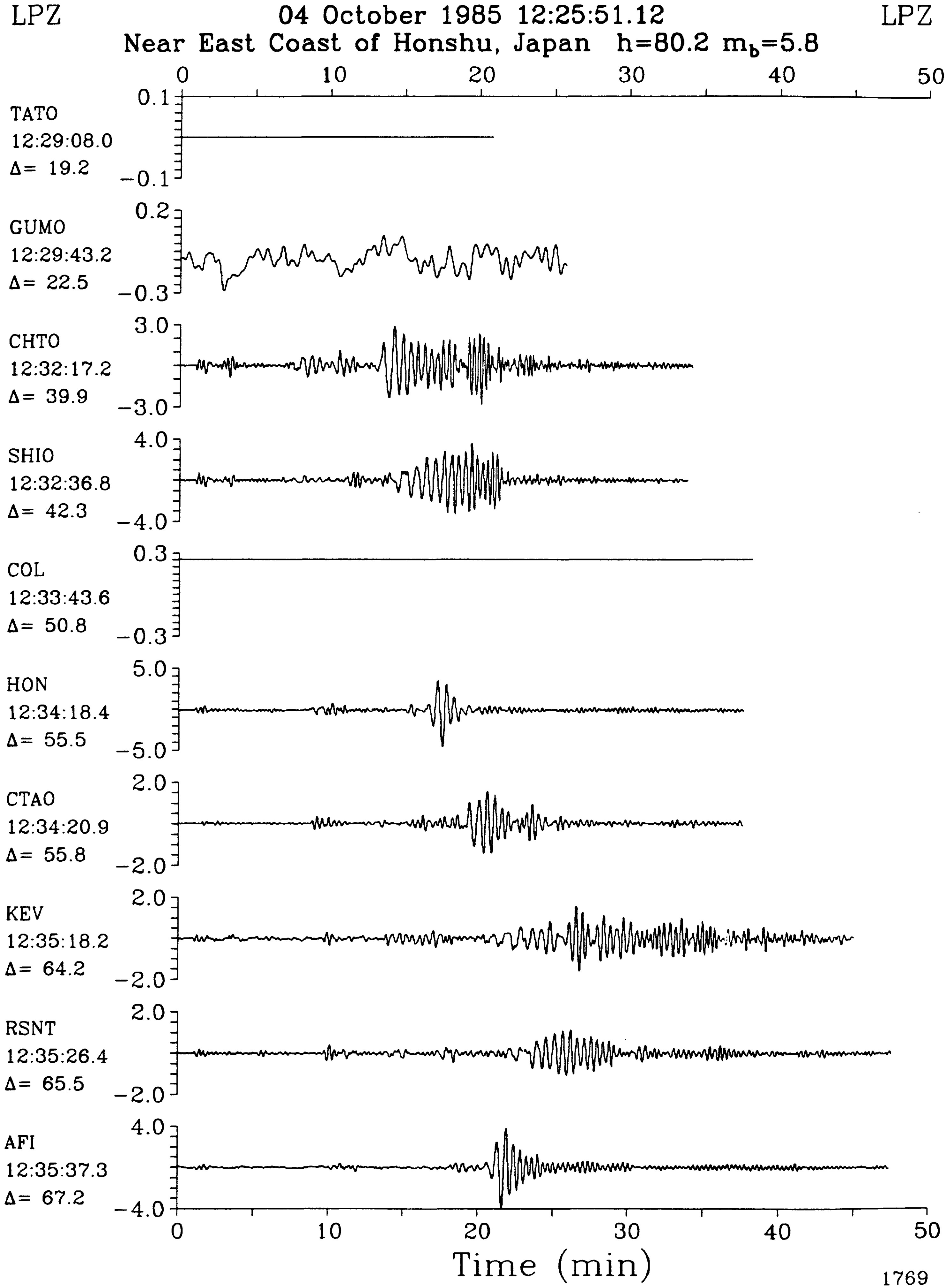
Near East Coast of Honshu, Japan




SPZ
04 October 1985 12:25:51.12
SPZ
Near East Coast of Honshu, Japan h=80.2 m_b=5.8
0
1
2
GUMO
12:30:28.2
Δ= 22.5
3.00
−3.00
CHTO
12:33:02.2
Δ= 39.9
0.16
−0.16
SHIO
12:33:21.8
Δ= 42.3
0.30
−0.30
CTAO
12:35:05.9
Δ= 55.8
0.07
−0.07
KEV
12:36:03.2
Δ= 64.2
0.16
−0.16
RSNT
12:36:11.4
Δ= 65.5
0.09
−0.09
LON
12:36:39.4
Δ= 70.0
0.06
−0.06
NWAO
12:36:49.1
Δ= 71.6
0.30
−0.30
NRAO
12:37:09.5
Δ= 75.0
0.02
−0.03
KONO
12:37:17.8
Δ= 76.5
0.08
−0.08
Time (min)

1767

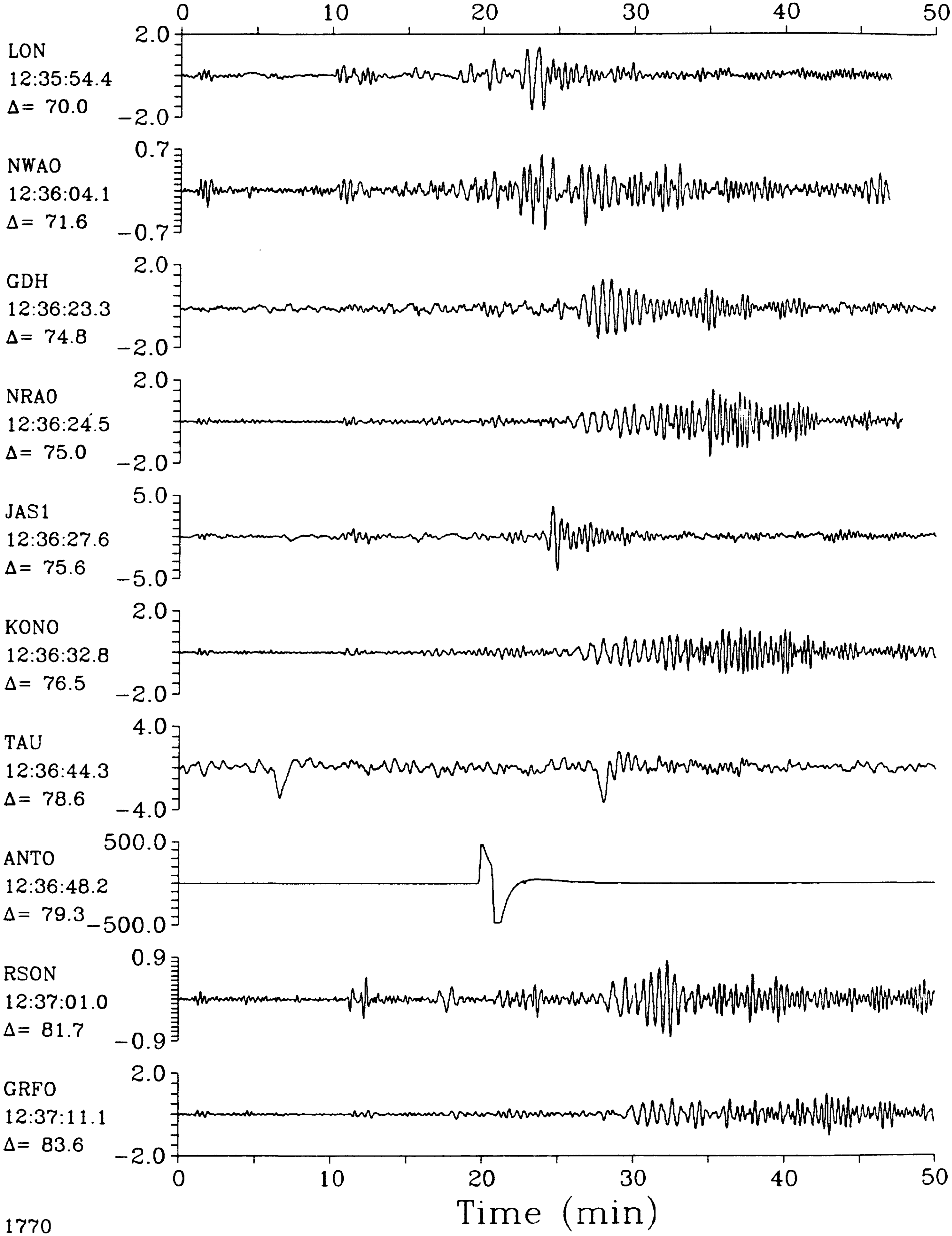

SPZ
04 October 1985 12:25:51.12
SPZ
Near East Coast of Honshu, Japan h=80.2 mb=5.8
ANTO
12:37:33.2
Δ= 79.3
RSON
12:37:46.0
Δ= 81.7
GRFO
12:37:56.1
Δ= 83.6
ANMO
12:38:09.7
Δ= 86.3
RSNY
12:38:46.7
Δ= 94.2
SLR
12:44:21.1
Δ=121.5
0.25
-0.25
0.10
-0.10
0.40
-0.40
0.09
-0.09
0.04
-0.04
0.06
-0.06
0
1
2
Time (min)



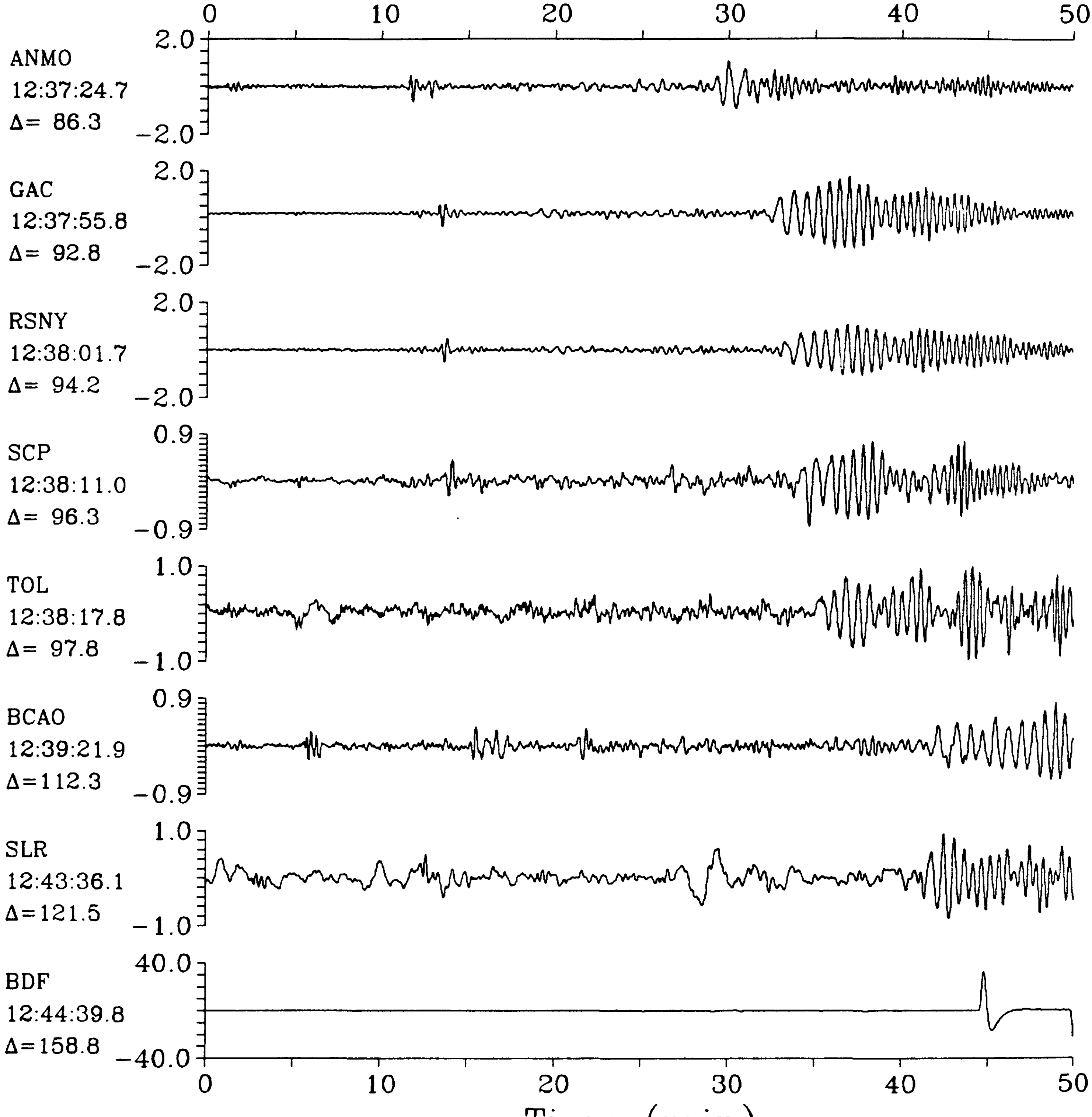
LPZ
04 October 1985 12:25:51.12
LPZ
Near East Coast of Honshu, Japan h=80.2 m_b=5.8
TATO
12:29:08.0
Δ= 19.2
GUMO
12:29:43.2
Δ= 22.5
CHTO
12:32:17.2
Δ= 39.9
SHIO
12:32:36.8
Δ= 42.3
COL
12:33:43.6
Δ= 50.8
HON
12:34:18.4
Δ= 55.5
CTAO
12:34:20.9
Δ= 55.8
KEV
12:35:18.2
Δ= 64.2
RSNT
12:35:26.4
Δ= 65.5
AFI
12:35:37.3
Δ= 67.2
Time (min)

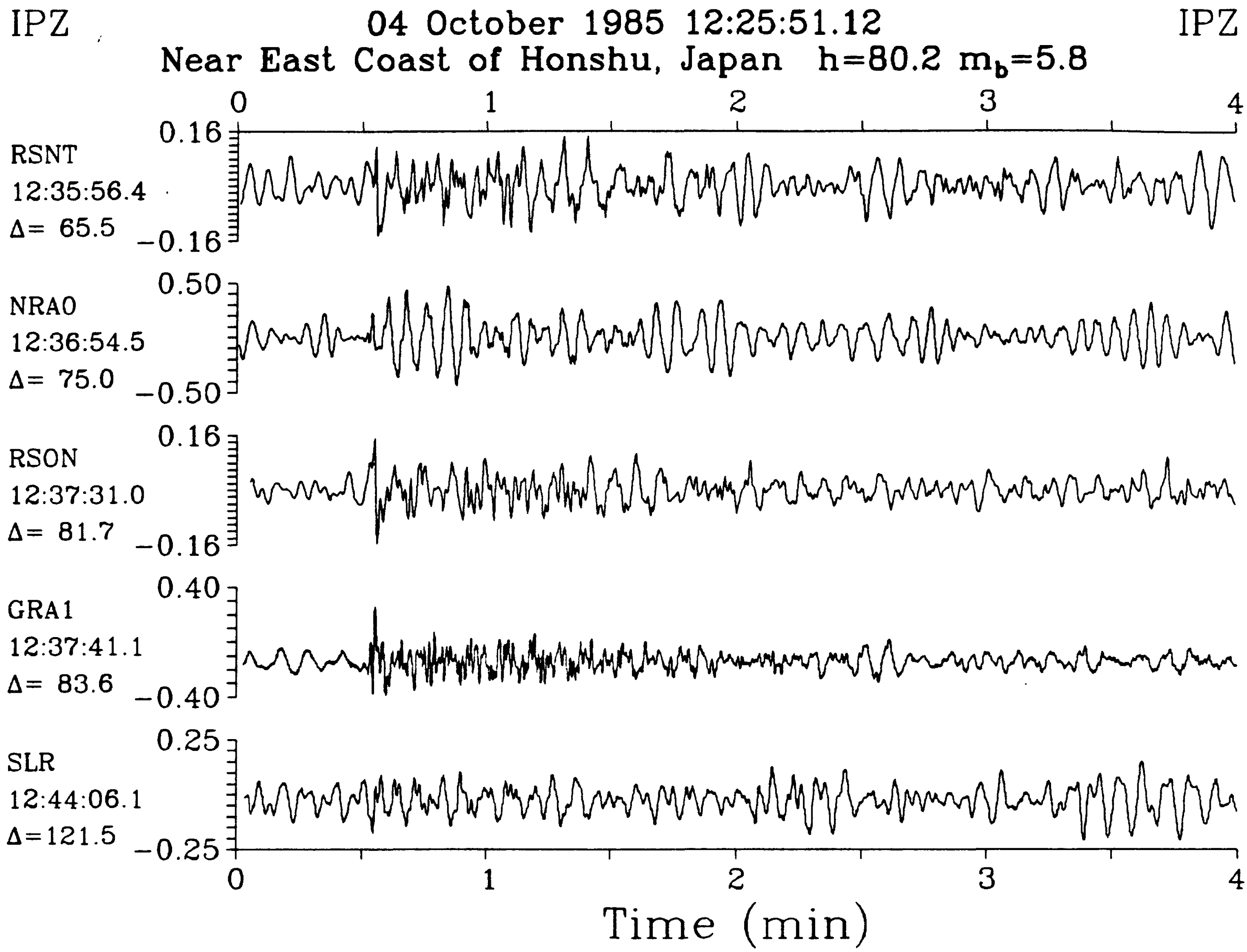
LPZ 04 October 1985 12:25:51.12 LPZ

Near East Coast of Honshu, Japan h=80.2 m_b=5.8



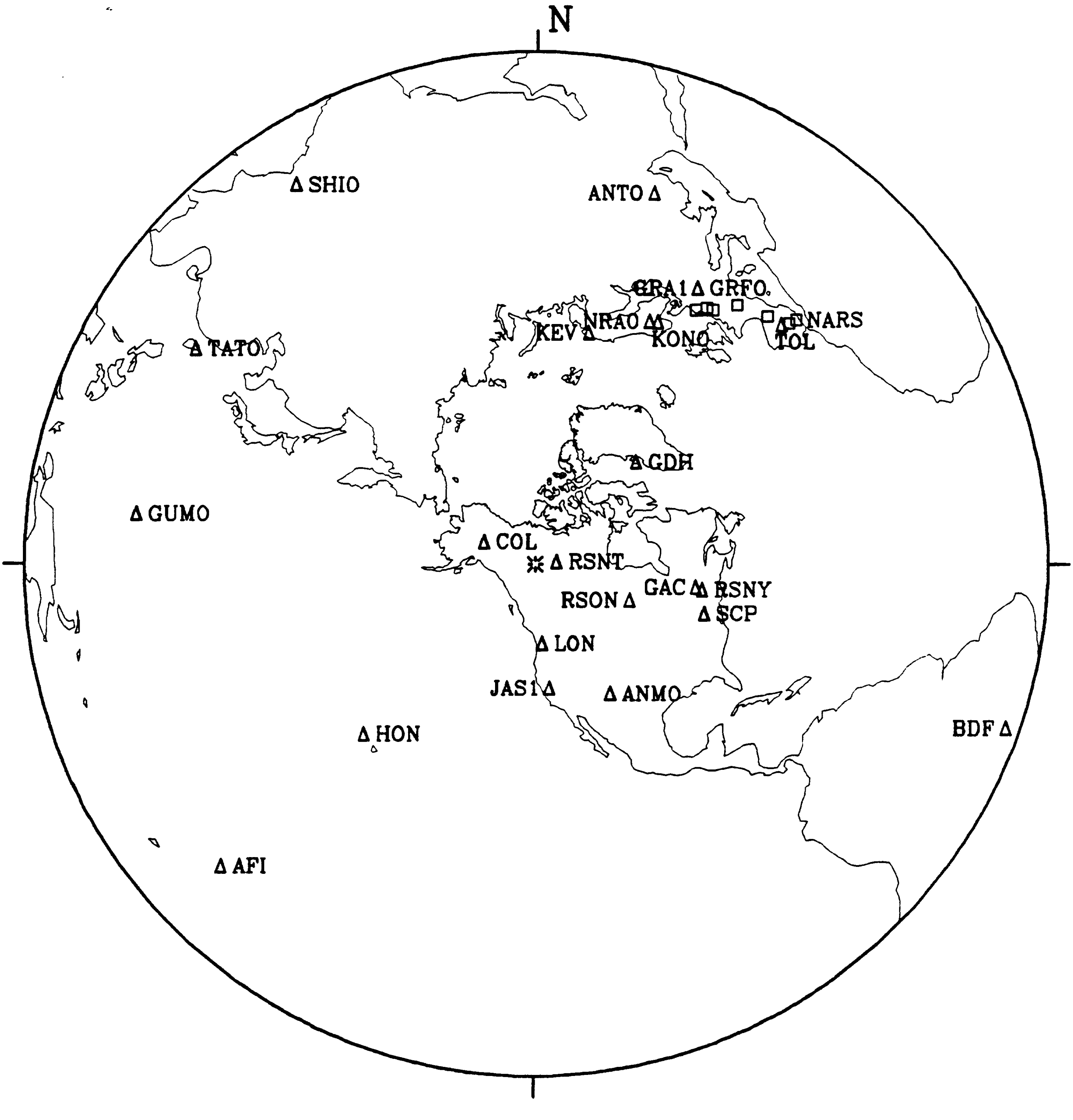
04 October 1985 12:25:51.12
Near East Coast of Honshu, Japan h=80.2 m_b=5.8

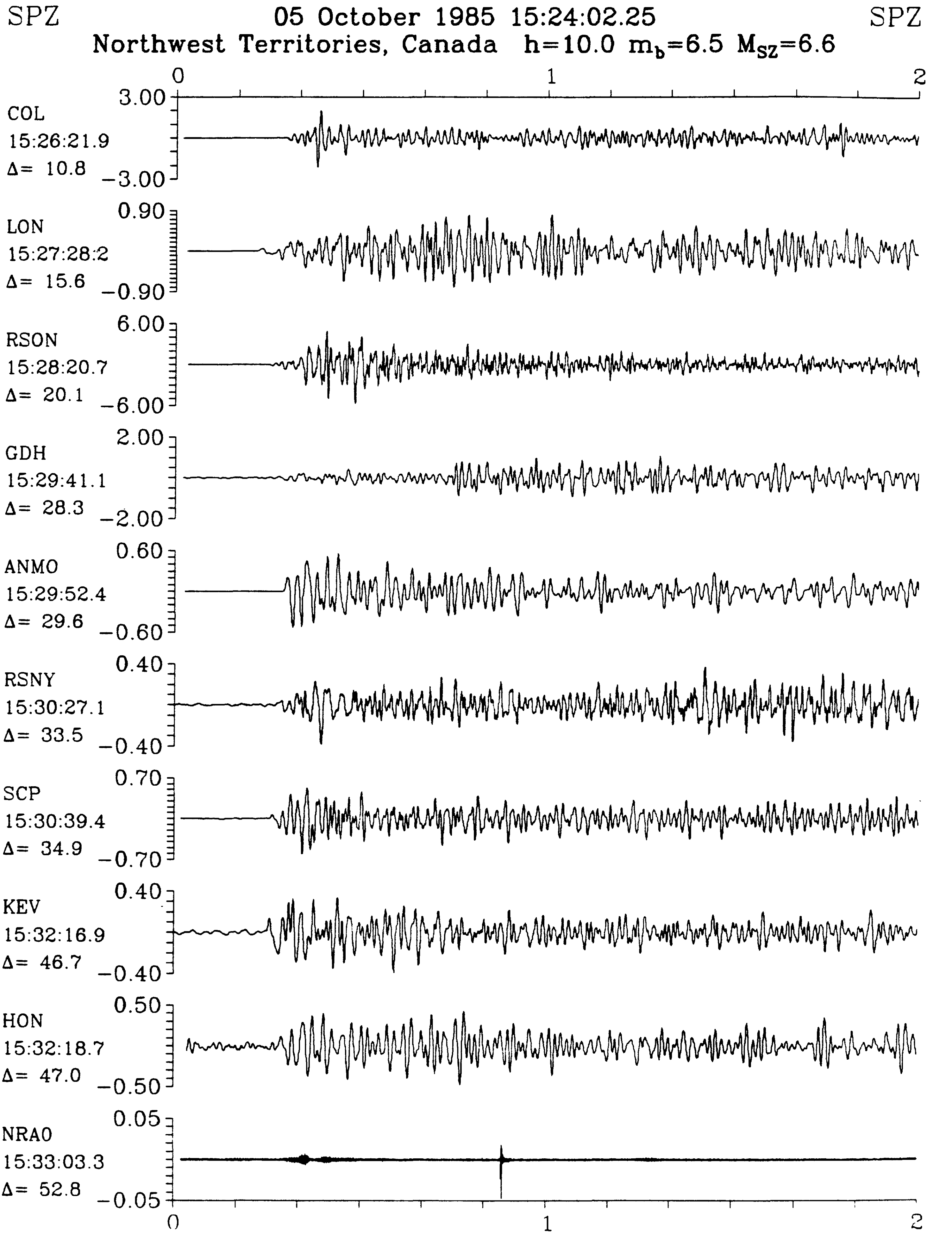



IPZ
04 October 1985 12:25:51.12
IPZ
Near East Coast of Honshu, Japan h=80.2 mb=5.8
RSNT
12:35:56.4
Δ= 65.5
NRA0
12:36:54.5
Δ= 75.0
RSON
12:37:31.0
Δ= 81.7
GRA1
12:37:41.1
Δ= 83.6
SLR
12:44:06.1
Δ=121.5
0.16
−0.16
0.50
−0.50
0.16
−0.16
0.40
−0.40
0.25
−0.25
0
1
2
3
4
Time (min)

05 October 1985 15:24:02.25

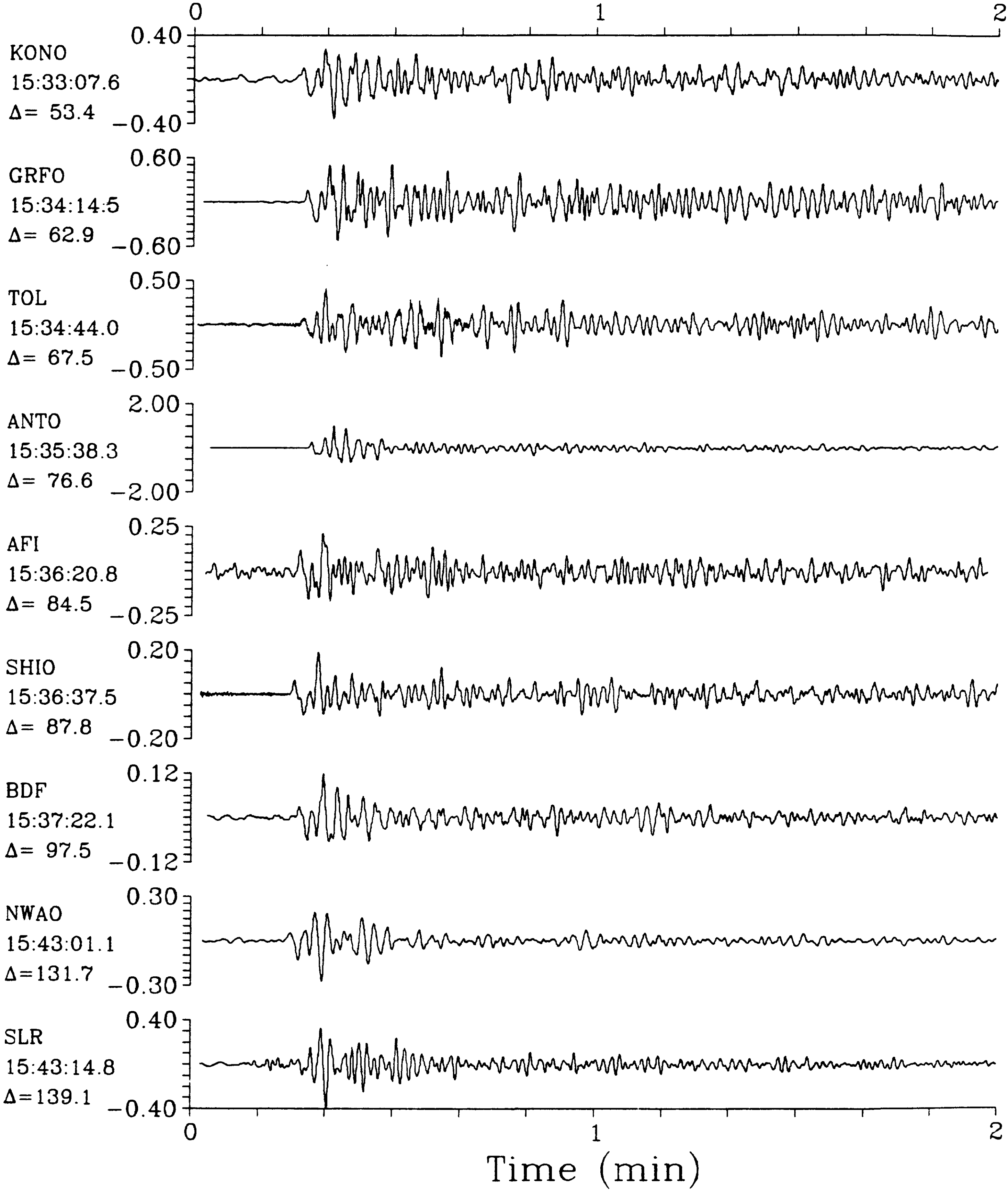
Northwest Territories, Canada

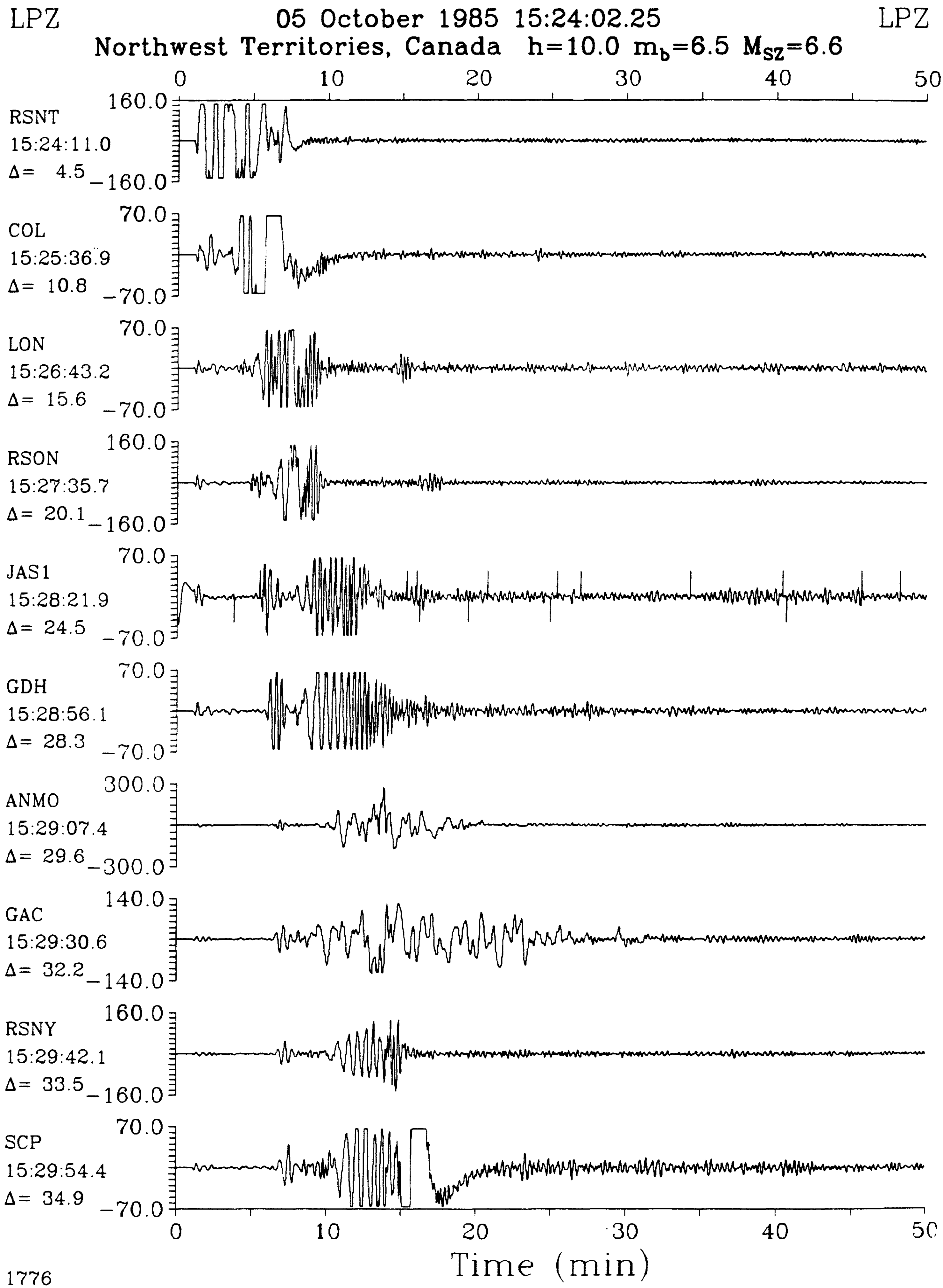



SPZ
05 October 1985 15:24:02.25
Northwest Territories, Canada h=10.0 m_b=6.5 M_SZ=6.6
SPZ
COL
15:26:21.9
Δ= 10.8
3.00
-3.00
LON
15:27:28:2
Δ= 15.6
0.90
-0.90
RSON
15:28:20.7
Δ= 20.1
6.00
-6.00
GDH
15:29:41.1
Δ= 28.3
2.00
-2.00
ANMO
15:29:52.4
Δ= 29.6
0.60
-0.60
RSNY
15:30:27.1
Δ= 33.5
0.40
-0.40
SCP
15:30:39.4
Δ= 34.9
0.70
-0.70
KEV
15:32:16.9
Δ= 46.7
0.40
-0.40
HON
15:32:18.7
Δ= 47.0
0.50
-0.50
NRAO
15:33:03.3
Δ= 52.8
0.05
-0.05
0
1
2
Time (min)

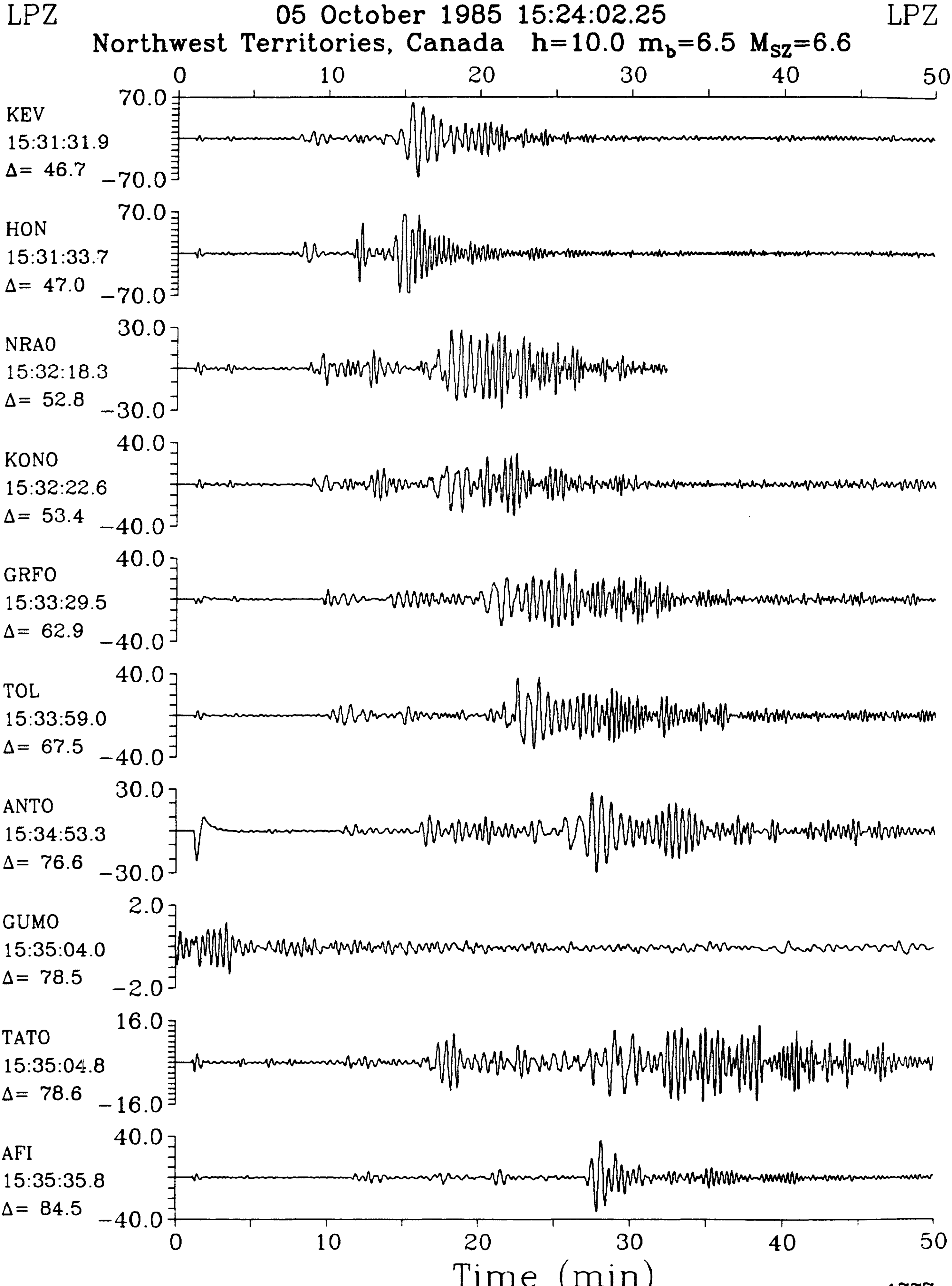
SPZ 05 October 1985 15:24:02.25 SPZ

Northwest Territories, Canada h=10.0 m_b=6.5 M_{SZ}=6.6





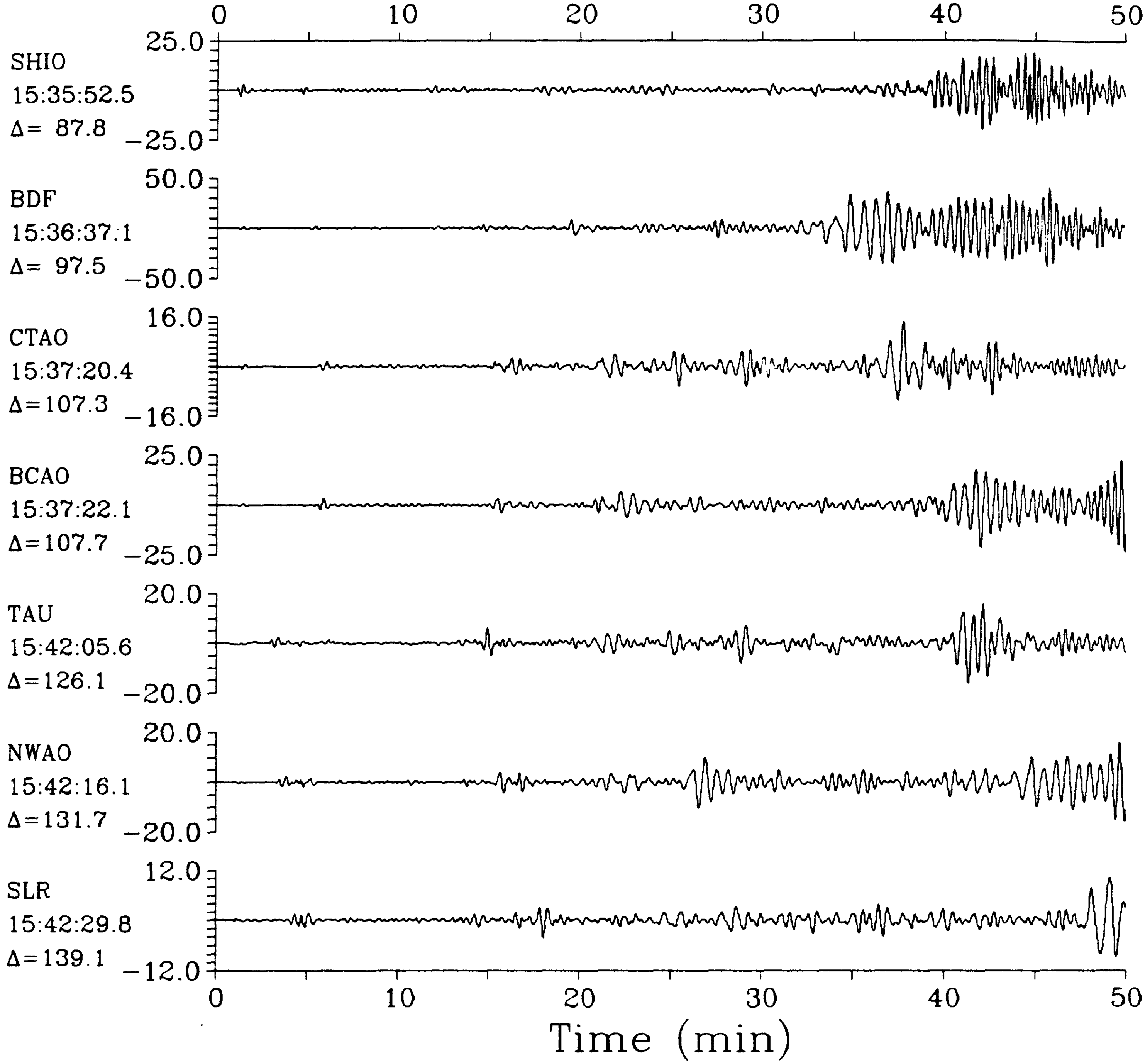
LPZ
05 October 1985 15:24:02.25
Northwest Territories, Canada h=10.0 m_b=6.5 M_{SZ}=6.6
LPZ
RSNT
15:24:11.0
Δ= 4.5
COL
15:25:36.9
Δ= 10.8
LON
15:26:43.2
Δ= 15.6
RSON
15:27:35.7
Δ= 20.1
JAS1
15:28:21.9
Δ= 24.5
GDH
15:28:56.1
Δ= 28.3
ANMO
15:29:07.4
Δ= 29.6
GAC
15:29:30.6
Δ= 32.2
RSNY
15:29:42.1
Δ= 33.5
SCP
15:29:54.4
Δ= 34.9
Time (min)

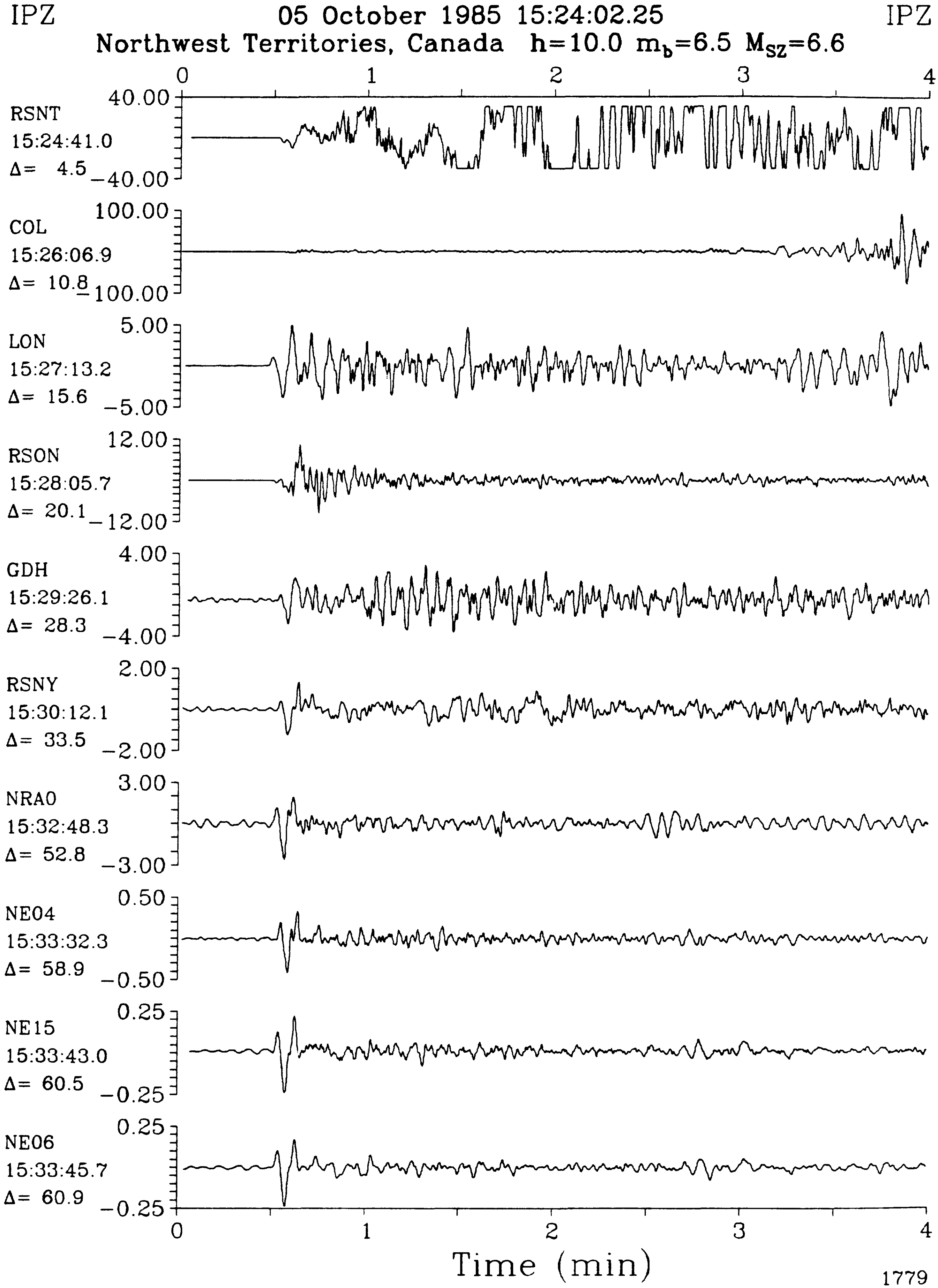

LPZ
05 October 1985 15:24:02.25
LPZ
Northwest Territories, Canada h=10.0 m_b=6.5 M_{SZ}=6.6
KEV
15:31:31.9
Δ= 46.7
HON
15:31:33.7
Δ= 47.0
NRAO
15:32:18.3
Δ= 52.8
KONO
15:32:22.6
Δ= 53.4
GRFO
15:33:29.5
Δ= 62.9
TOL
15:33:59.0
Δ= 67.5
ANTO
15:34:53.3
Δ= 76.6
GUMO
15:35:04.0
Δ= 78.5
TATO
15:35:04.8
Δ= 78.6
AFI
15:35:35.8
Δ= 84.5
Time (min)

1777

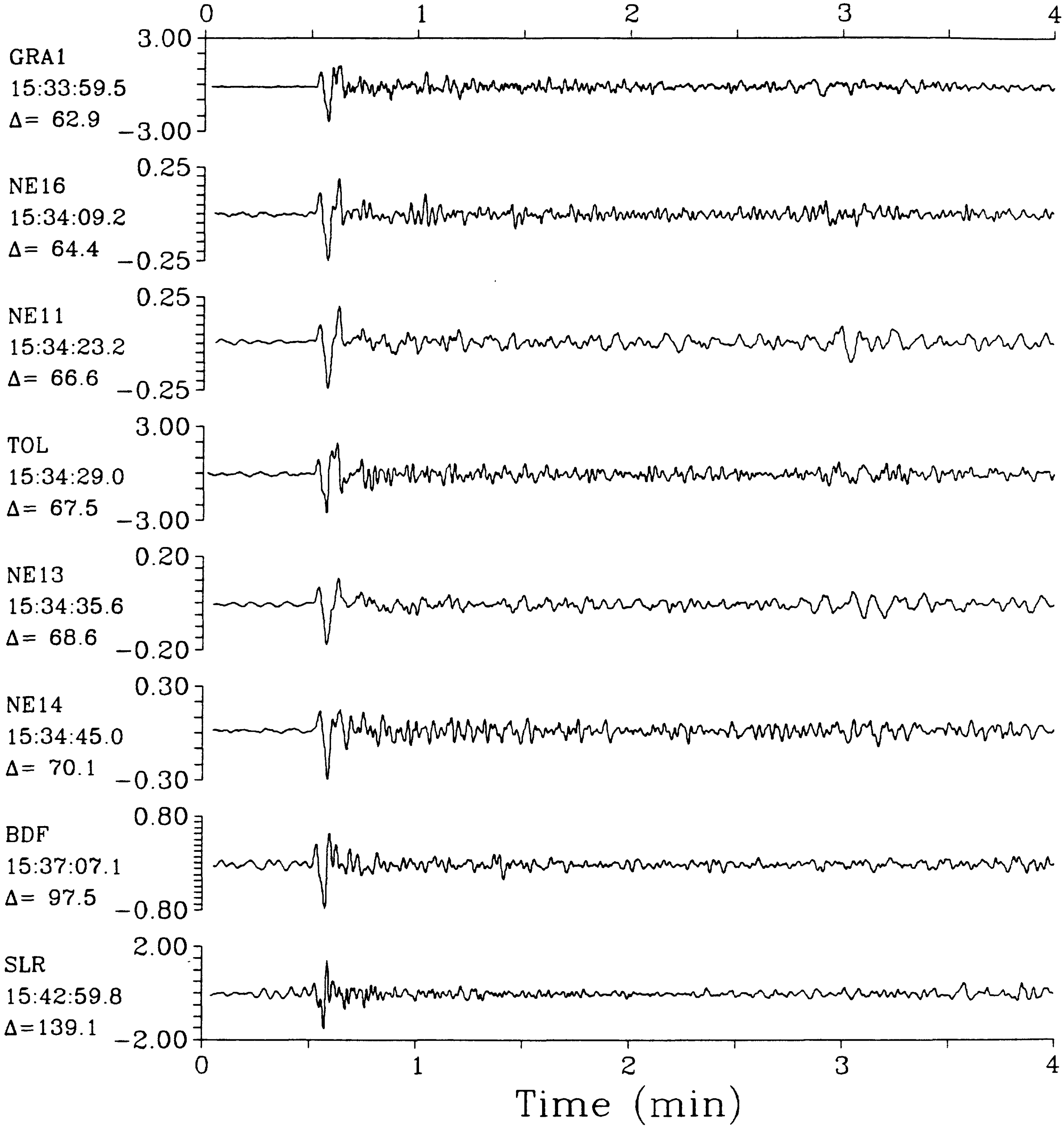
LPZ 05 October 1985 15:24:02.25 LPZ

Northwest Territories, Canada h=10.0 m_b=6.5 M_{SZ}=6.6



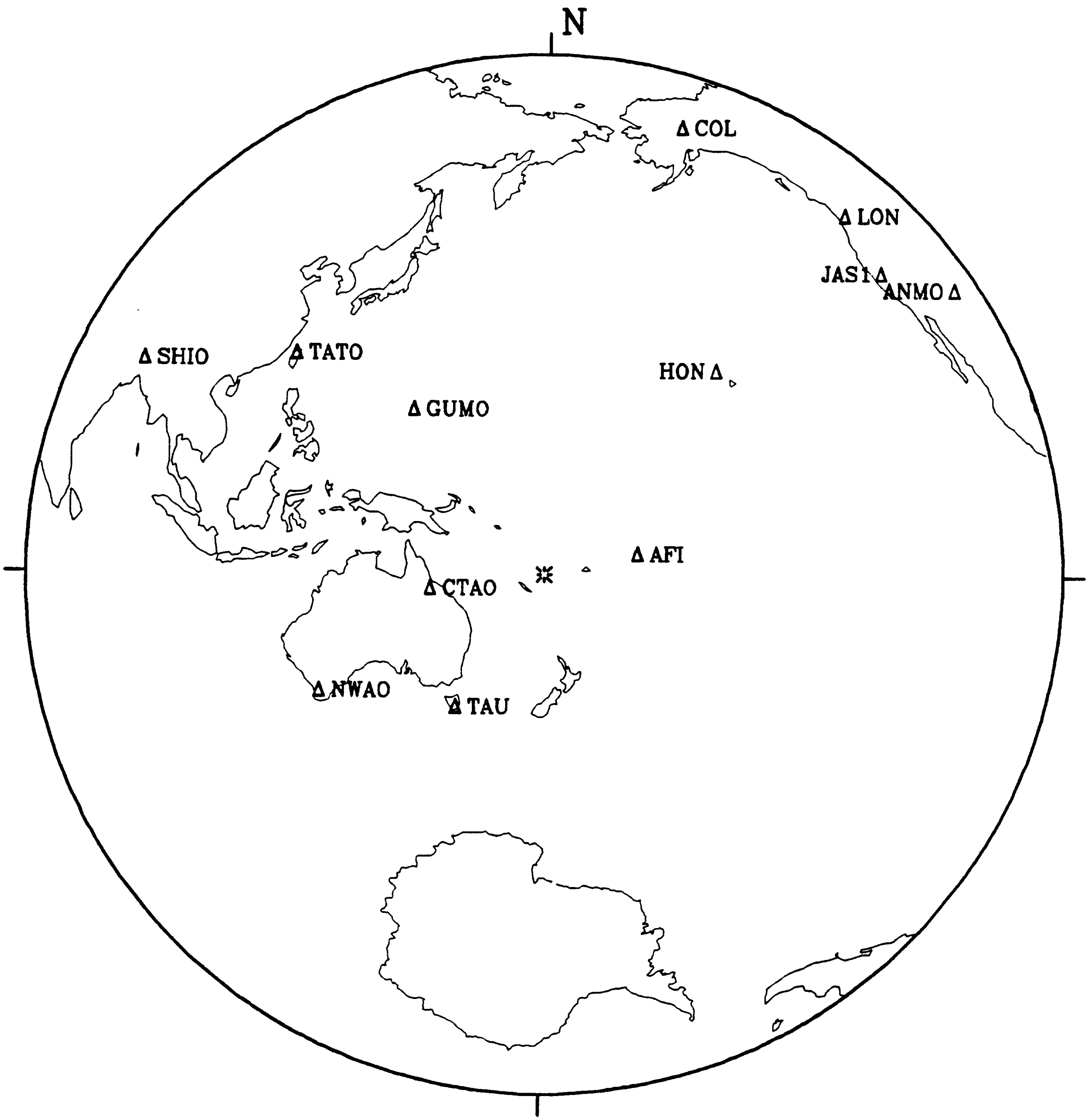

IPZ
05 October 1985 15:24:02.25
IPZ
Northwest Territories, Canada h=10.0 m_b=6.5 M_SZ=6.6
0
1
2
3
4
RSNT
15:24:41.0
Δ= 4.5
40.00
−40.00
COL
15:26:06.9
Δ= 10.8
100.00
−100.00
LON
15:27:13.2
Δ= 15.6
5.00
−5.00
RSON
15:28:05.7
Δ= 20.1
12.00
−12.00
GDH
15:29:26.1
Δ= 28.3
4.00
−4.00
RSNY
15:30:12.1
Δ= 33.5
2.00
−2.00
NRA0
15:32:48.3
Δ= 52.8
3.00
−3.00
NE04
15:33:32.3
Δ= 58.9
0.50
−0.50
NE15
15:33:43.0
Δ= 60.5
0.25
−0.25
NE06
15:33:45.7
Δ= 60.9
0.25
−0.25
Time (min)
1779

05 October 1985 15:24:02.25
Northwest Territories, Canada h=10.0 m_b=6.5 M_{SZ}=6.6



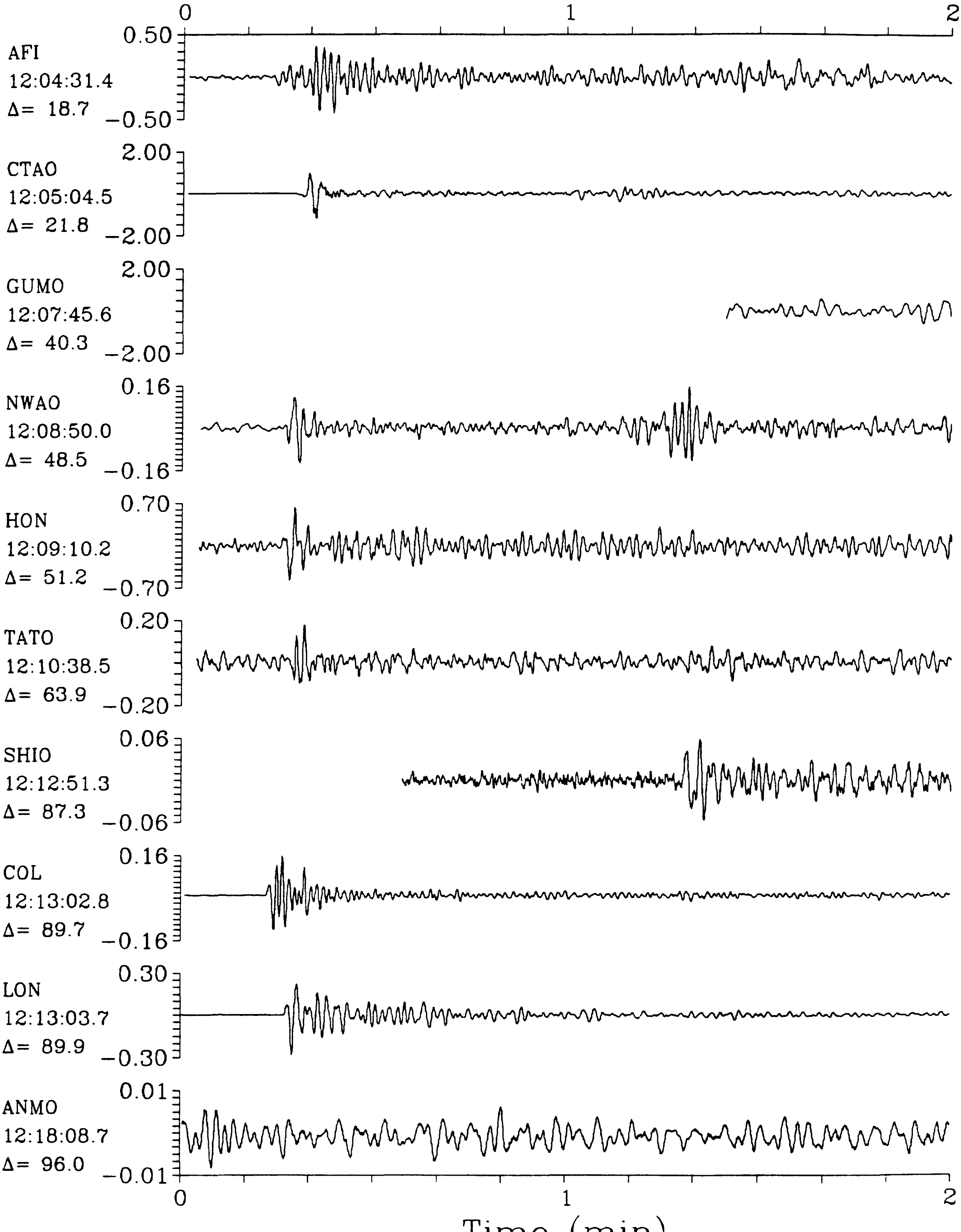
06 October 1985 12:00:47.95

Vanuatu Islands

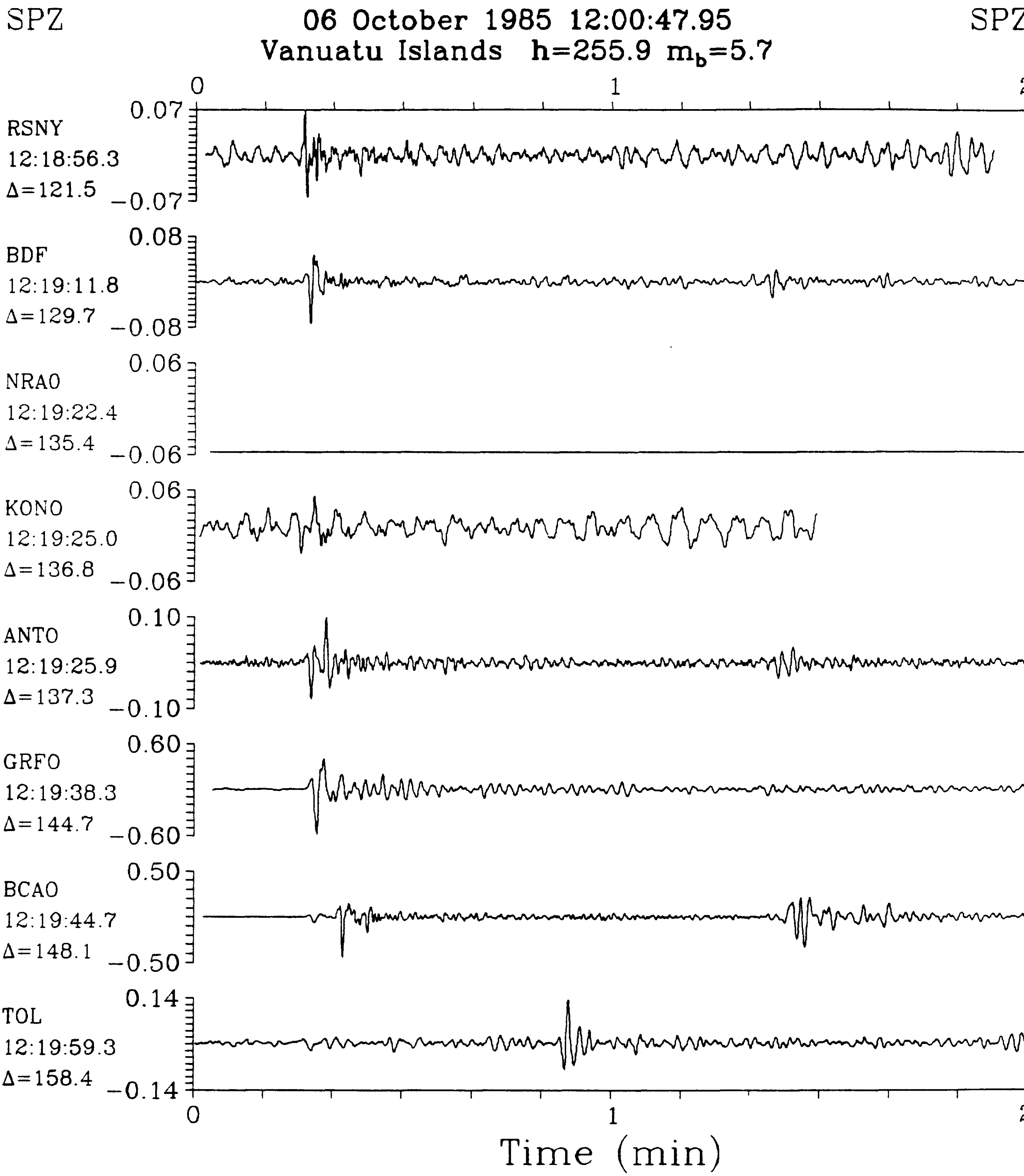


SPZ 06 October 1985 12:00:47.95 SPZ

Vanuatu Islands h=255.9 m_b=5.7

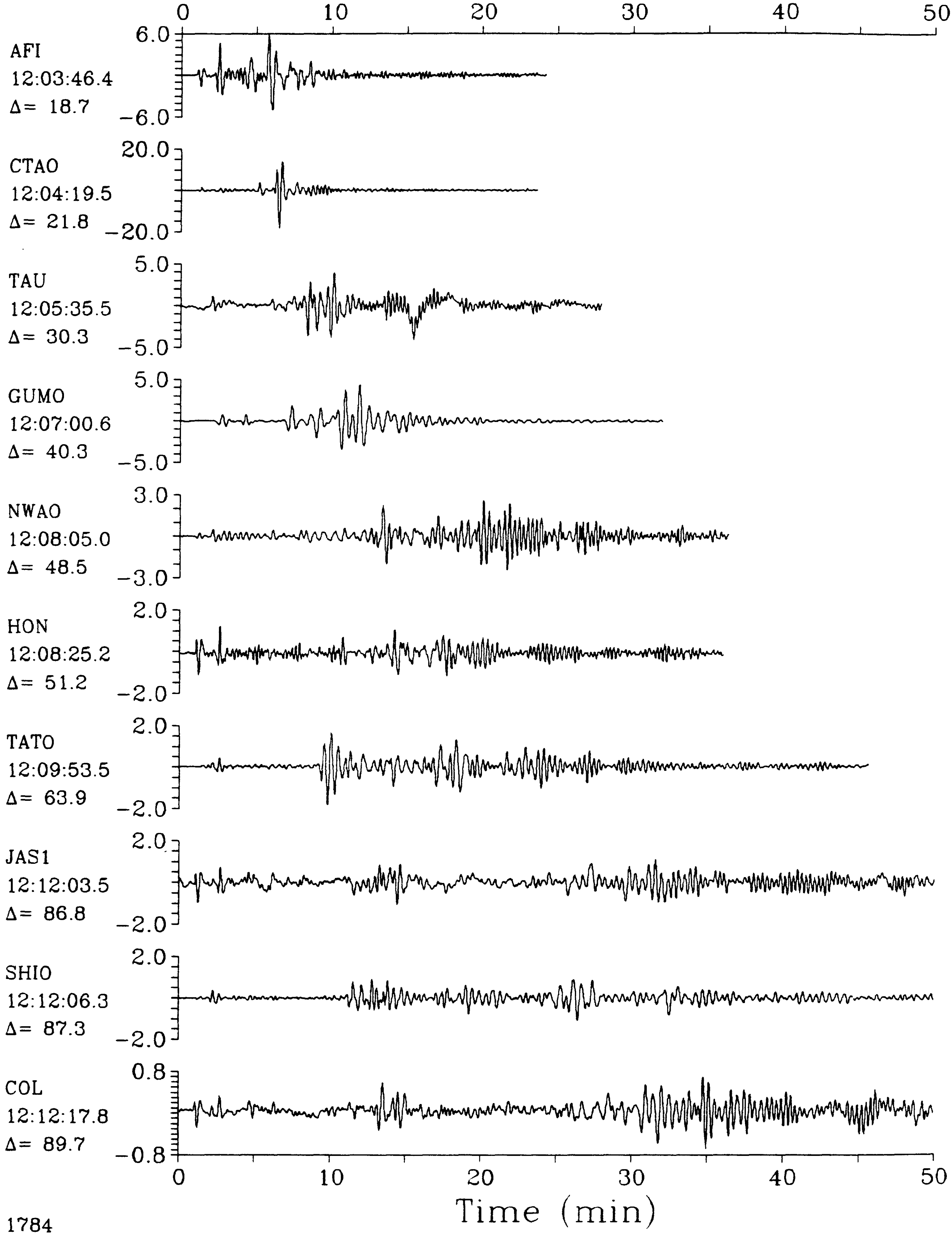


1782

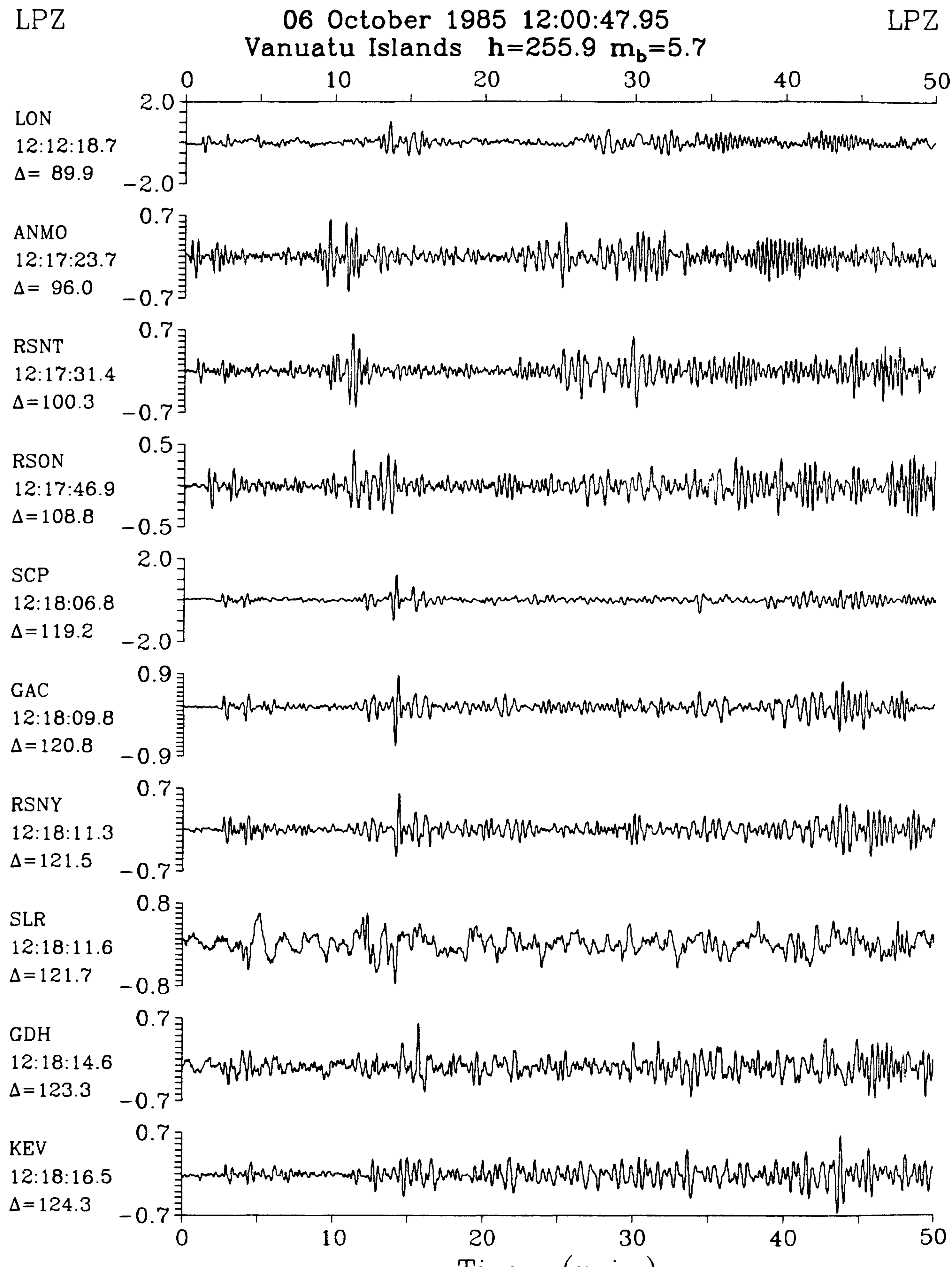

SPZ
06 October 1985 12:00:47.95
Vanuatu Islands h=255.9 m_b=5.7
SPZ
RSNY
12:18:56.3
Δ=121.5
0.07
−0.07
BDF
12:19:11.8
Δ=129.7
0.08
−0.08
NRAO
12:19:22.4
Δ=135.4
0.06
−0.06
KONO
12:19:25.0
Δ=136.8
0.06
−0.06
ANTO
12:19:25.9
Δ=137.3
0.10
−0.10
GRFO
12:19:38.3
Δ=144.7
0.60
−0.60
BCAO
12:19:44.7
Δ=148.1
0.50
−0.50
TOL
12:19:59.3
Δ=158.4
0.14
−0.14
0
1
2
Time (min)

LPZ 06 October 1985 12:00:47.95 LPZ

Vanuatu Islands $h=255.9$ $m_b=5.7$



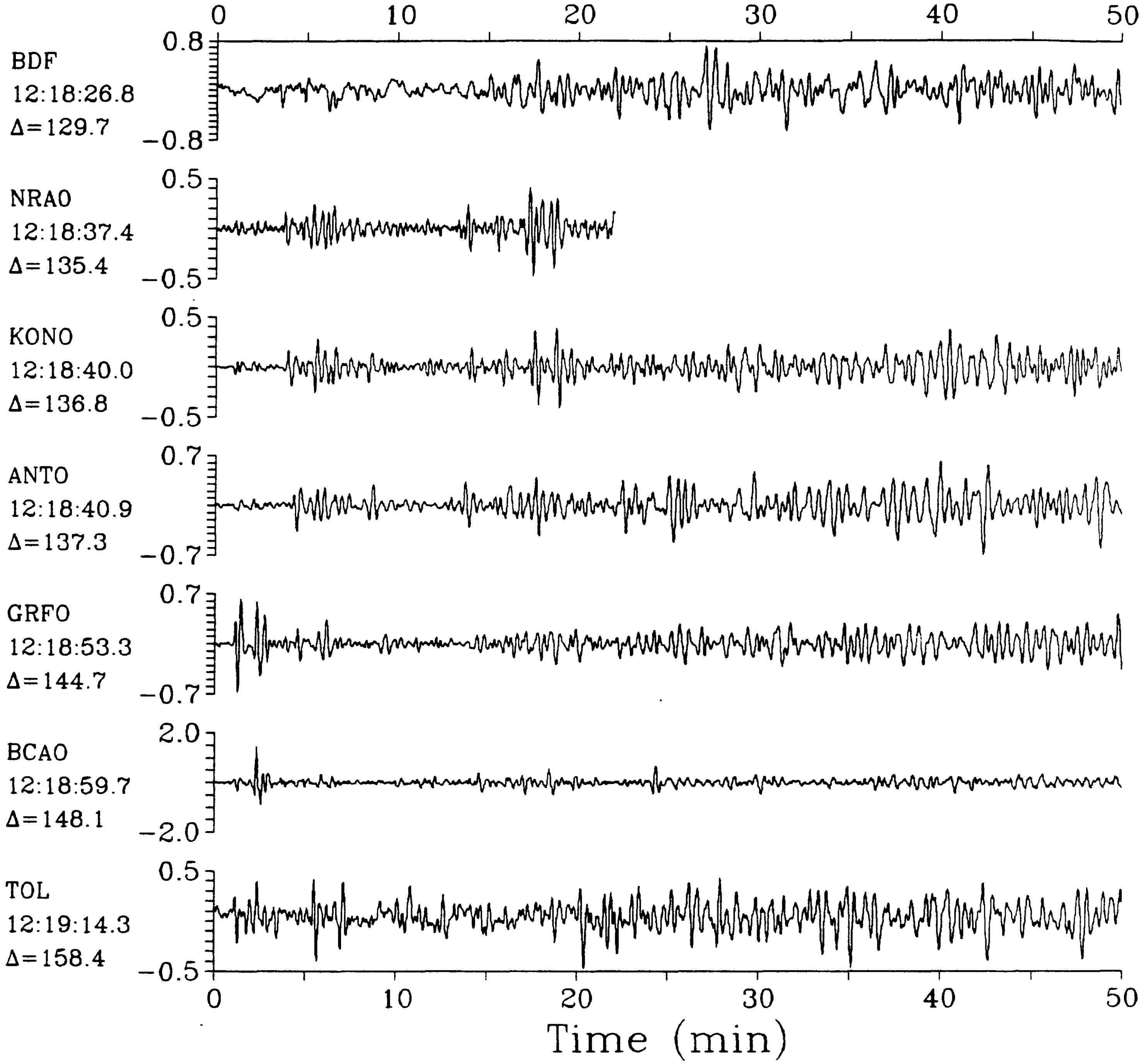
1784


LPZ
06 October 1985 12:00:47.95
Vanuatu Islands h=255.9 m_b=5.7
LPZ
LON
12:12:18.7
Δ= 89.9
2.0
-2.0
ANMO
12:17:23.7
Δ= 96.0
0.7
-0.7
RSNT
12:17:31.4
Δ=100.3
0.7
-0.7
RSON
12:17:46.9
Δ=108.8
0.5
-0.5
SCP
12:18:06.8
Δ=119.2
2.0
-2.0
GAC
12:18:09.8
Δ=120.8
0.9
-0.9
RSNY
12:18:11.3
Δ=121.5
0.7
-0.7
SLR
12:18:11.6
Δ=121.7
0.8
-0.8
GDH
12:18:14.6
Δ=123.3
0.7
-0.7
KEV
12:18:16.5
Δ=124.3
0.7
-0.7
0
10
20
30
40
50
Time (min)

1785

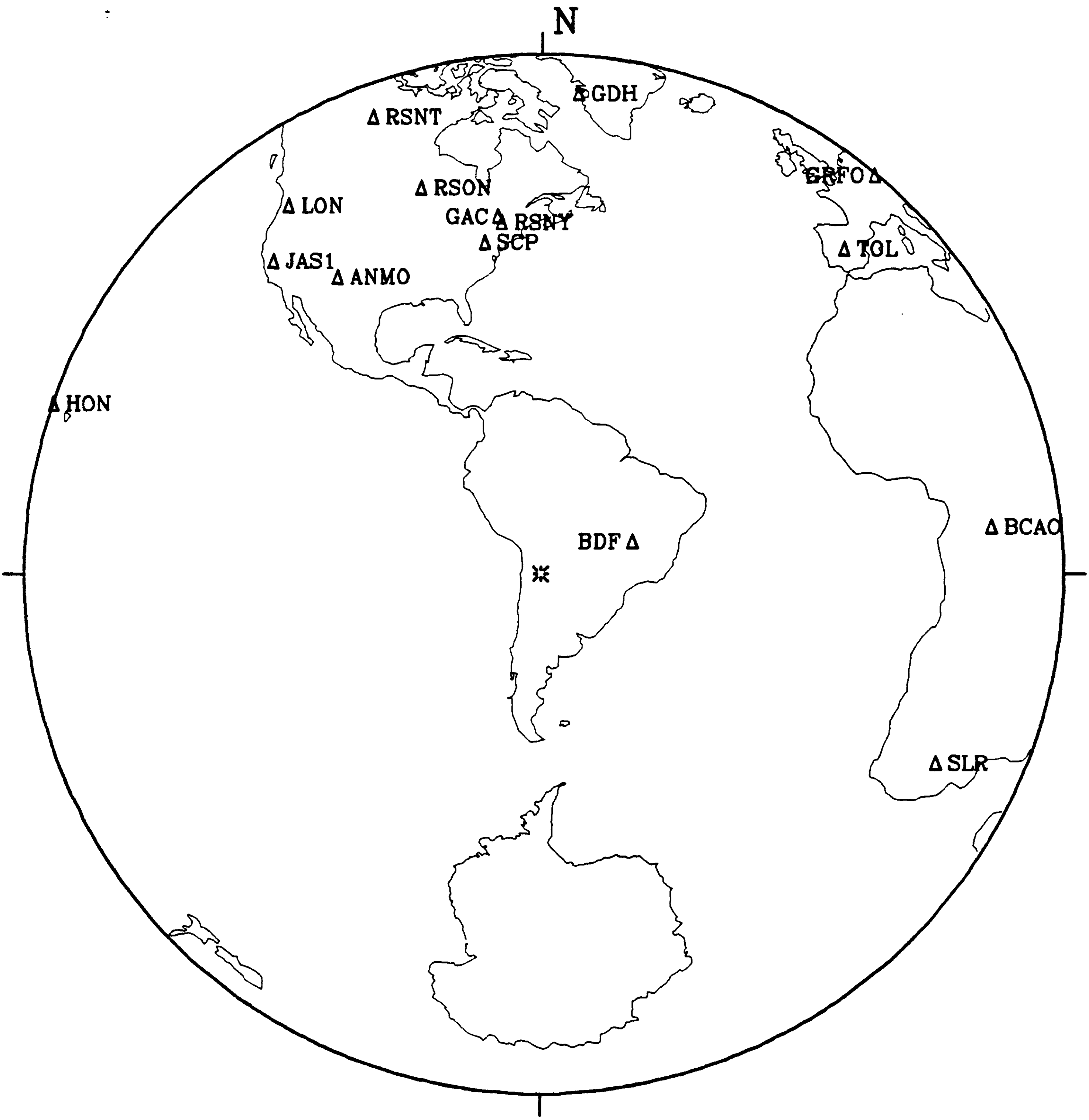
LPZ 06 October 1985 12:00:47.95 LPZ

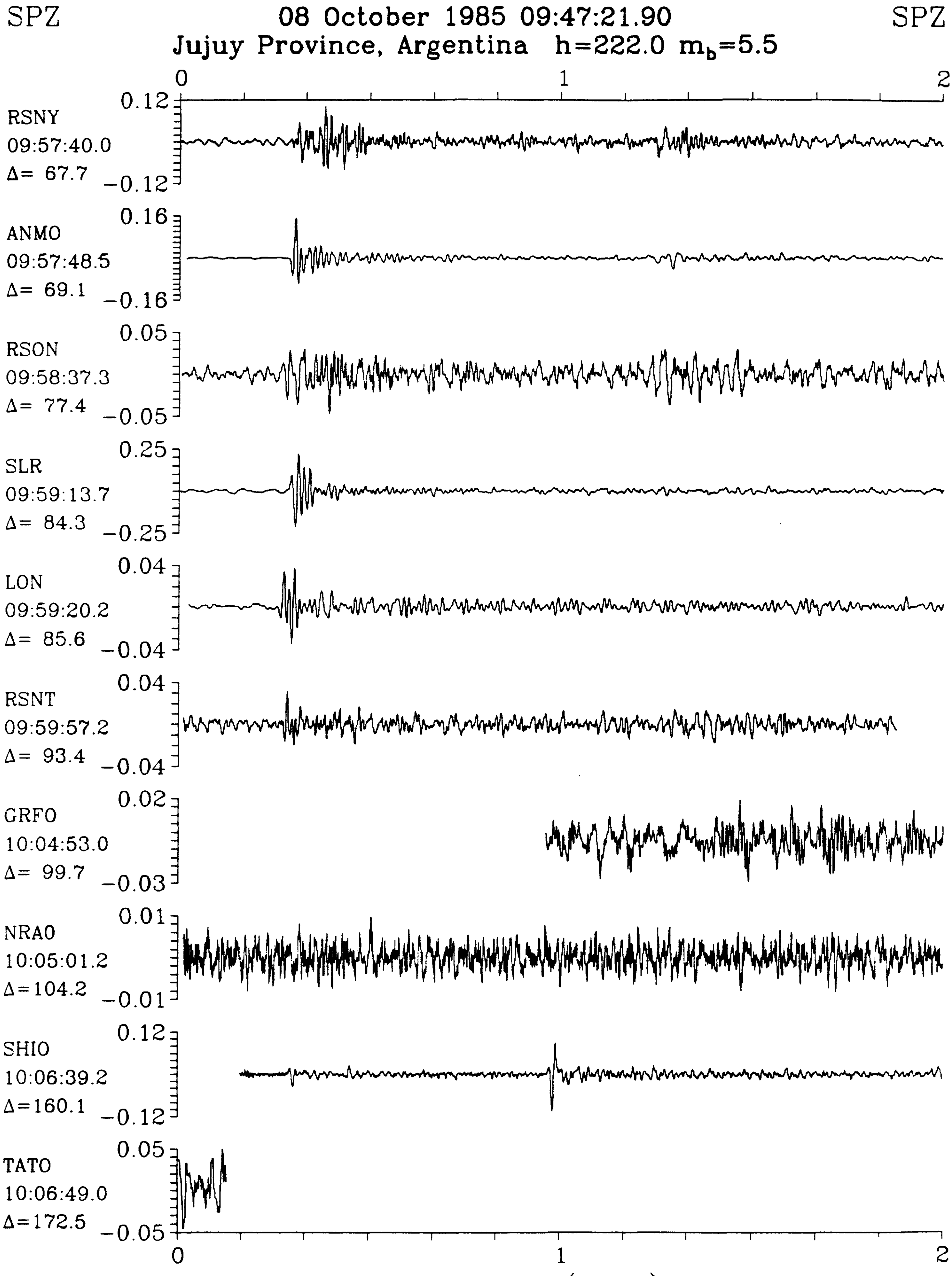
Vanuatu Islands h=255.9 m_b=5.7



08 October 1985 09:47:21.90

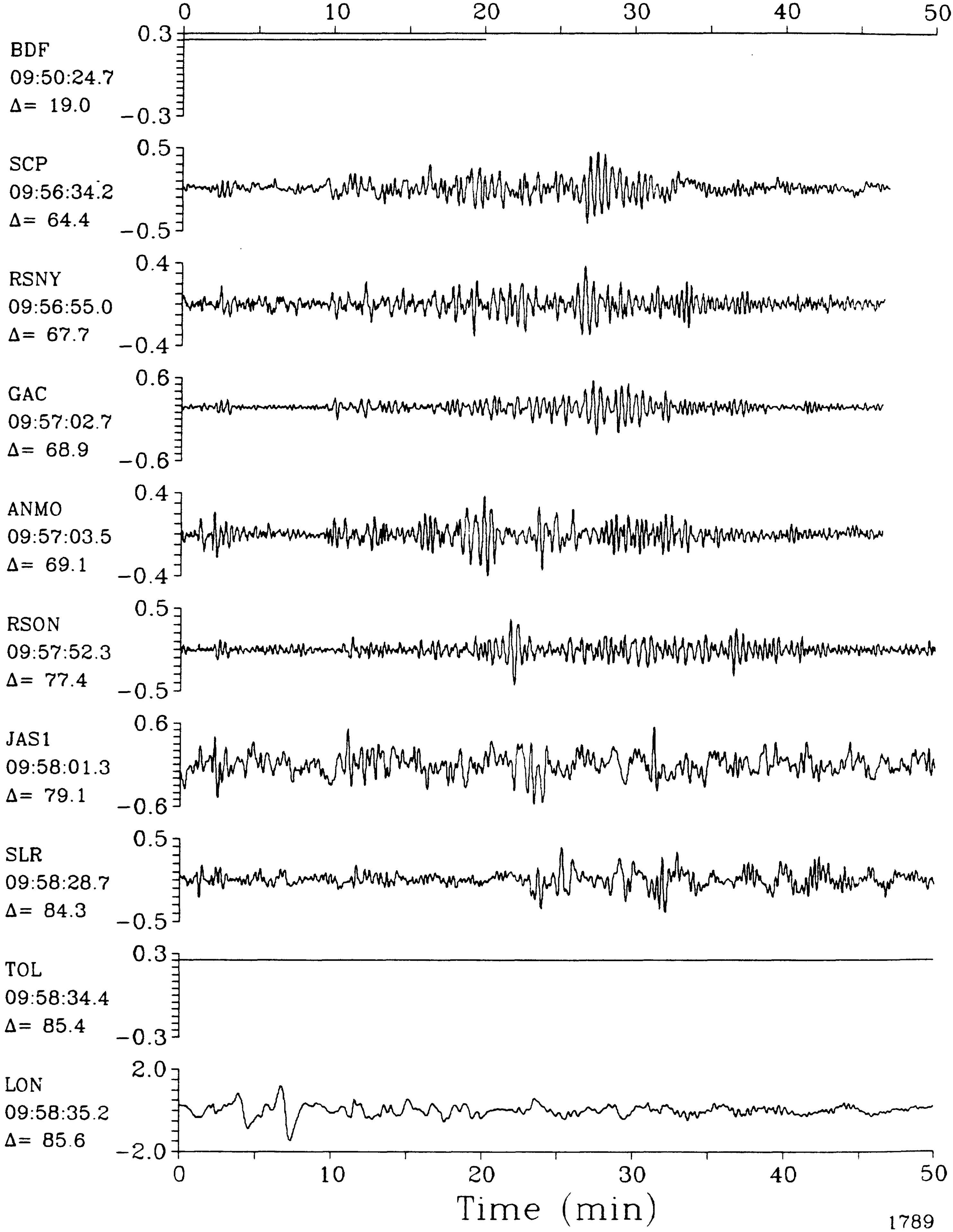
Jujuy Province, Argentina



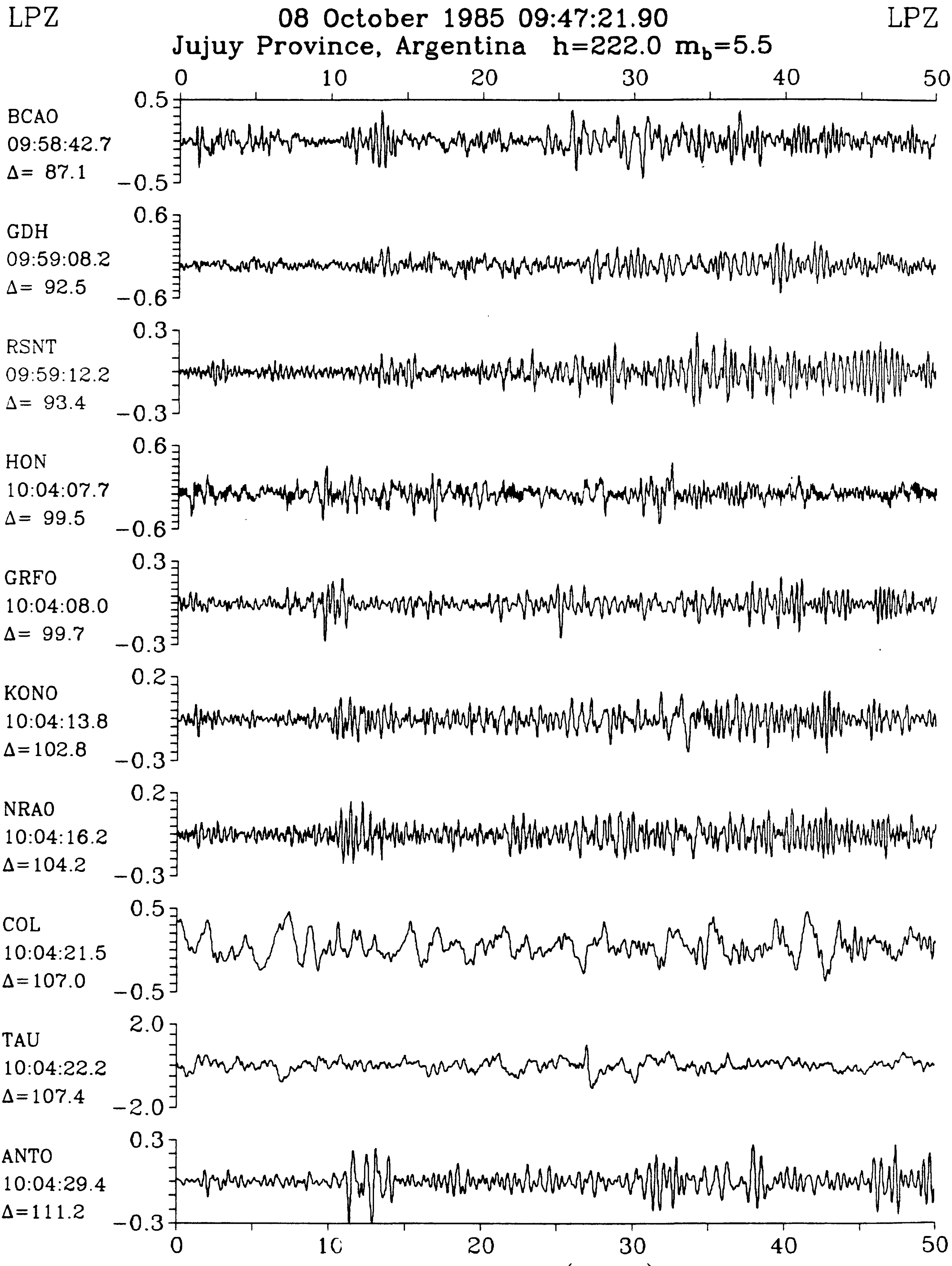

SPZ
08 October 1985 09:47:21.90
Jujuy Province, Argentina h=222.0 m_b=5.5
SPZ
RSNY
09:57:40.0
Δ= 67.7
ANMO
09:57:48.5
Δ= 69.1
RSON
09:58:37.3
Δ= 77.4
SLR
09:59:13.7
Δ= 84.3
LON
09:59:20.2
Δ= 85.6
RSNT
09:59:57.2
Δ= 93.4
GRFO
10:04:53.0
Δ= 99.7
NRAO
10:05:01.2
Δ=104.2
SHIO
10:06:39.2
Δ=160.1
TATO
10:06:49.0
Δ=172.5
Time (min)

LPZ 08 October 1985 09:47:21.90 LPZ

Jujuy Province, Argentina h=222.0 m_b=5.5



1789

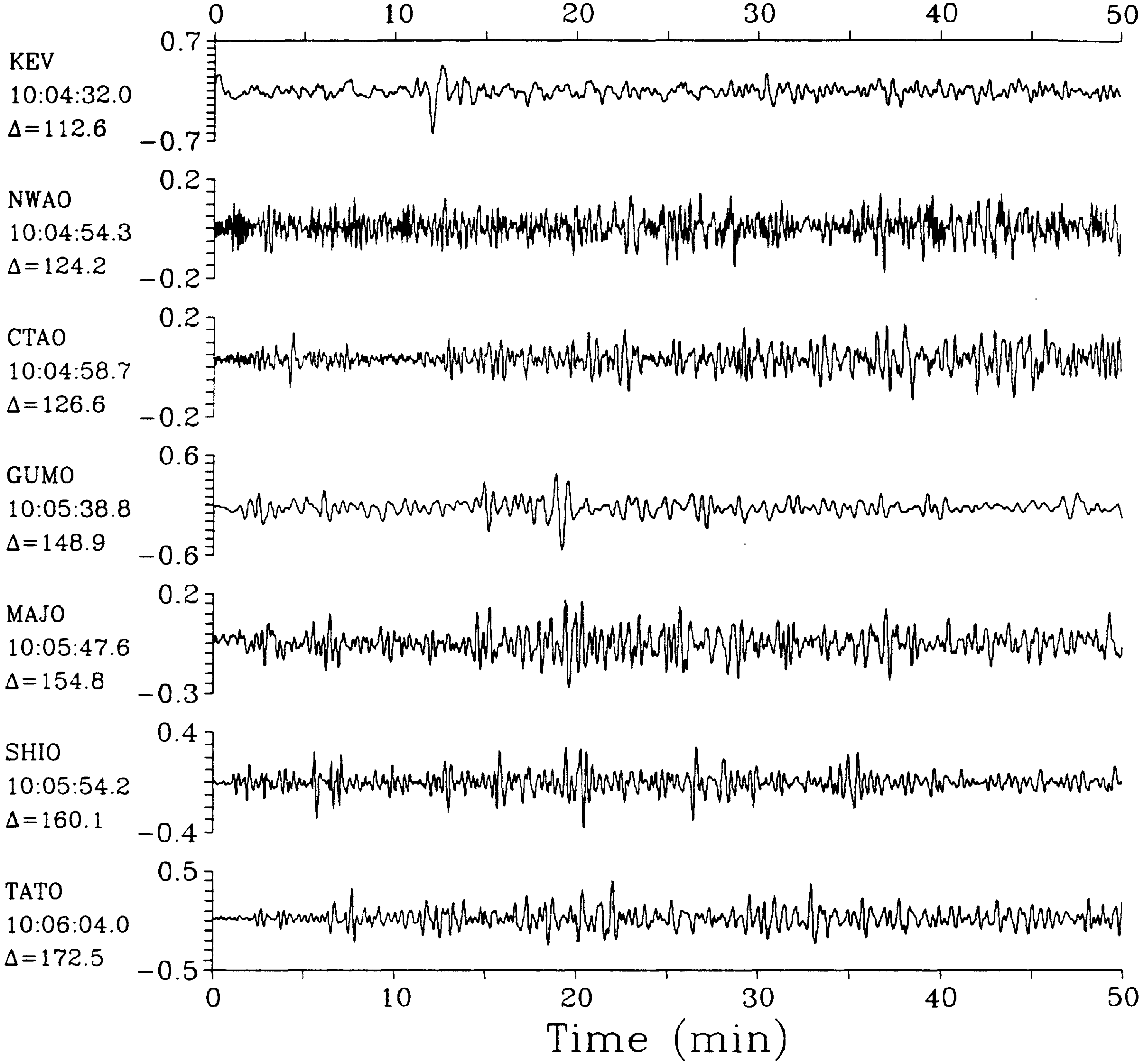


LPZ
08 October 1985 09:47:21.90
Jujuy Province, Argentina h=222.0 m_b=5.5
LPZ
BCAO
09:58:42.7
Δ= 87.1
GDH
09:59:08.2
Δ= 92.5
RSNT
09:59:12.2
Δ= 93.4
HON
10:04:07.7
Δ= 99.5
GRFO
10:04:08.0
Δ= 99.7
KONO
10:04:13.8
Δ=102.8
NRAO
10:04:16.2
Δ=104.2
COL
10:04:21.5
Δ=107.0
TAU
10:04:22.2
Δ=107.4
ANTO
10:04:29.4
Δ=111.2
0.5
−0.5
0.6
−0.6
0.3
−0.3
0.2
2.0
−2.0
0
10
20
30
40
50
Time (min)

1790

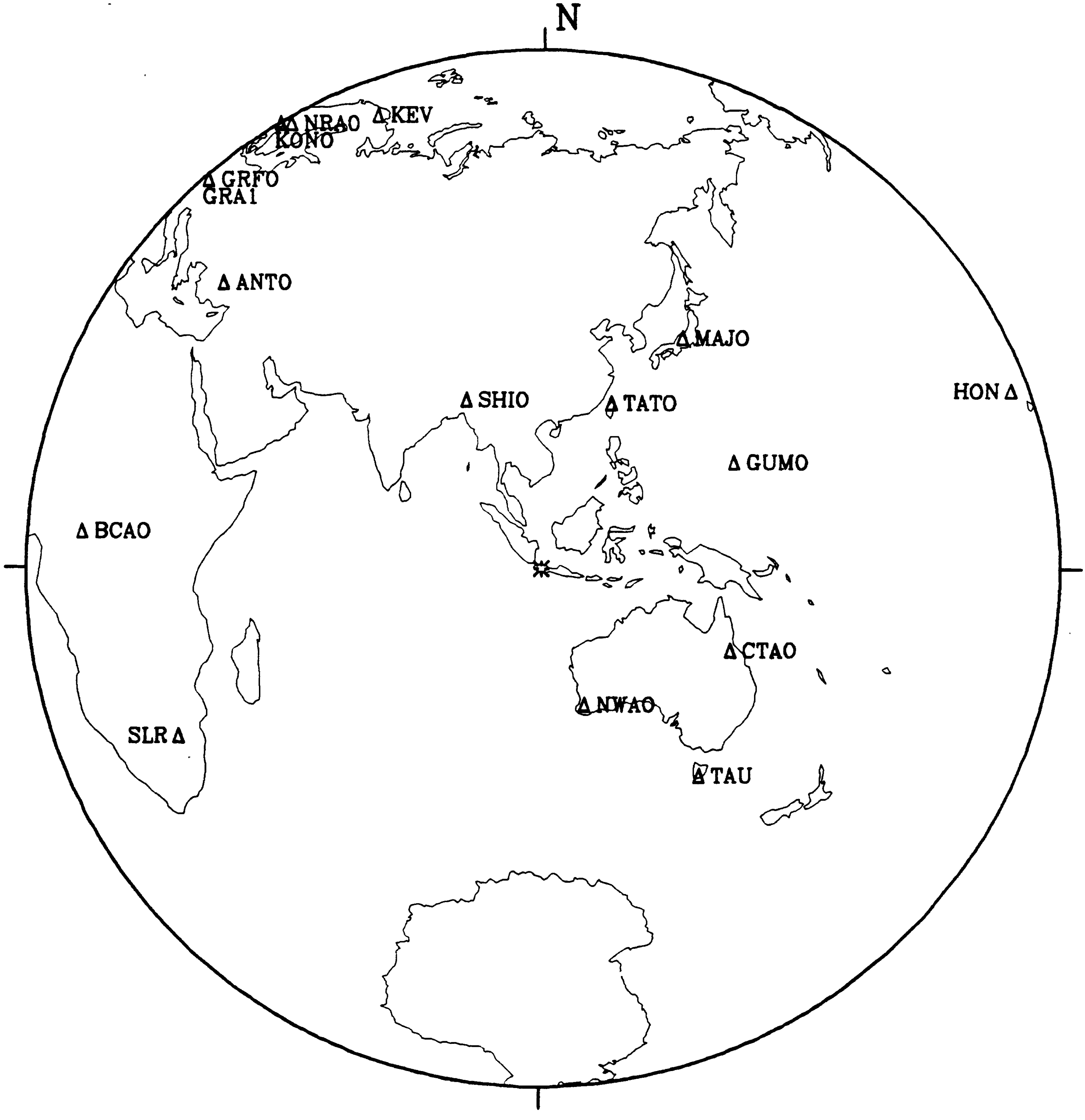
LPZ 08 October 1985 09:47:21.90 LPZ

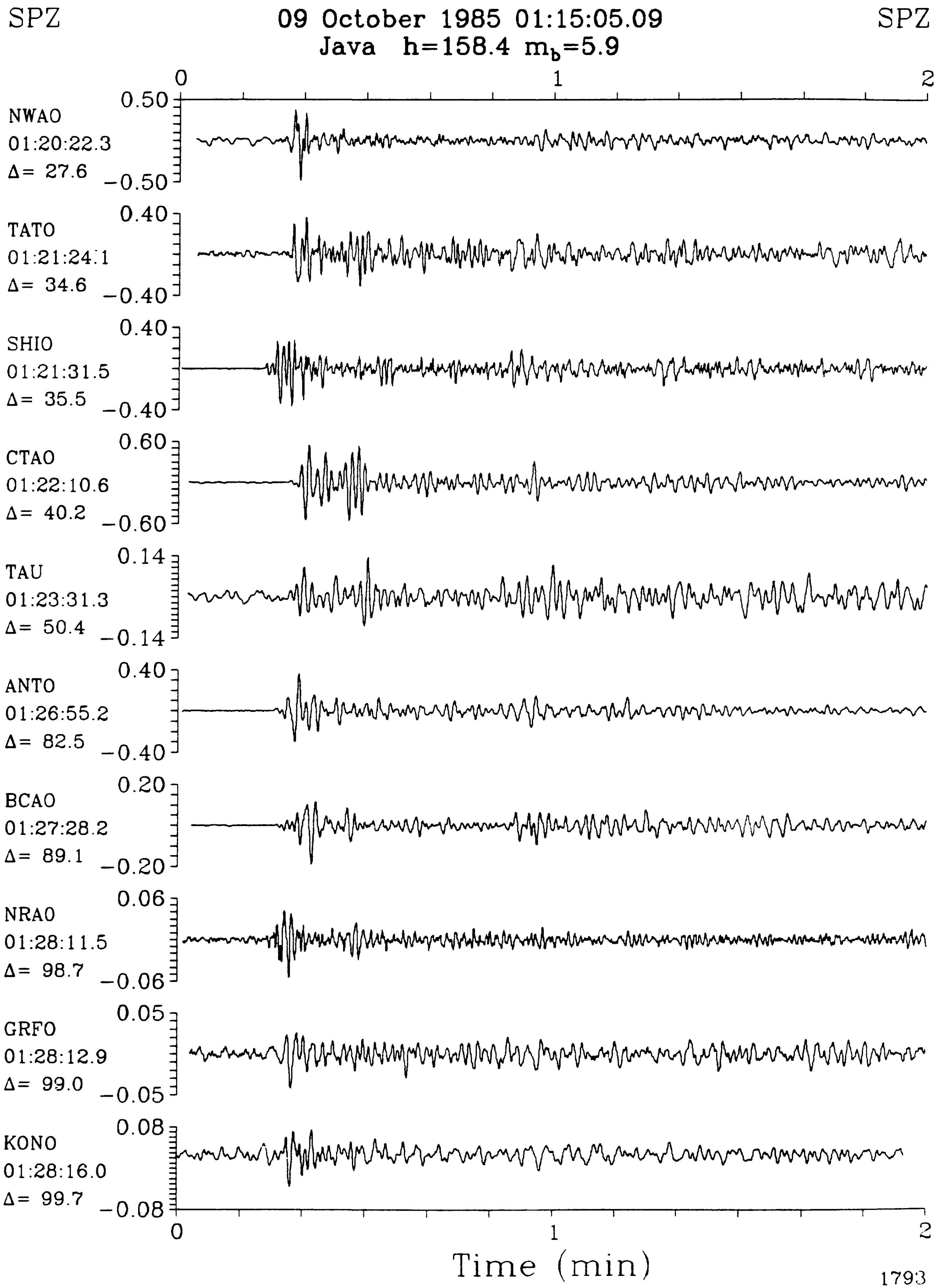
Jujuy Province, Argentina $h=222.0$ $m_b=5.5$

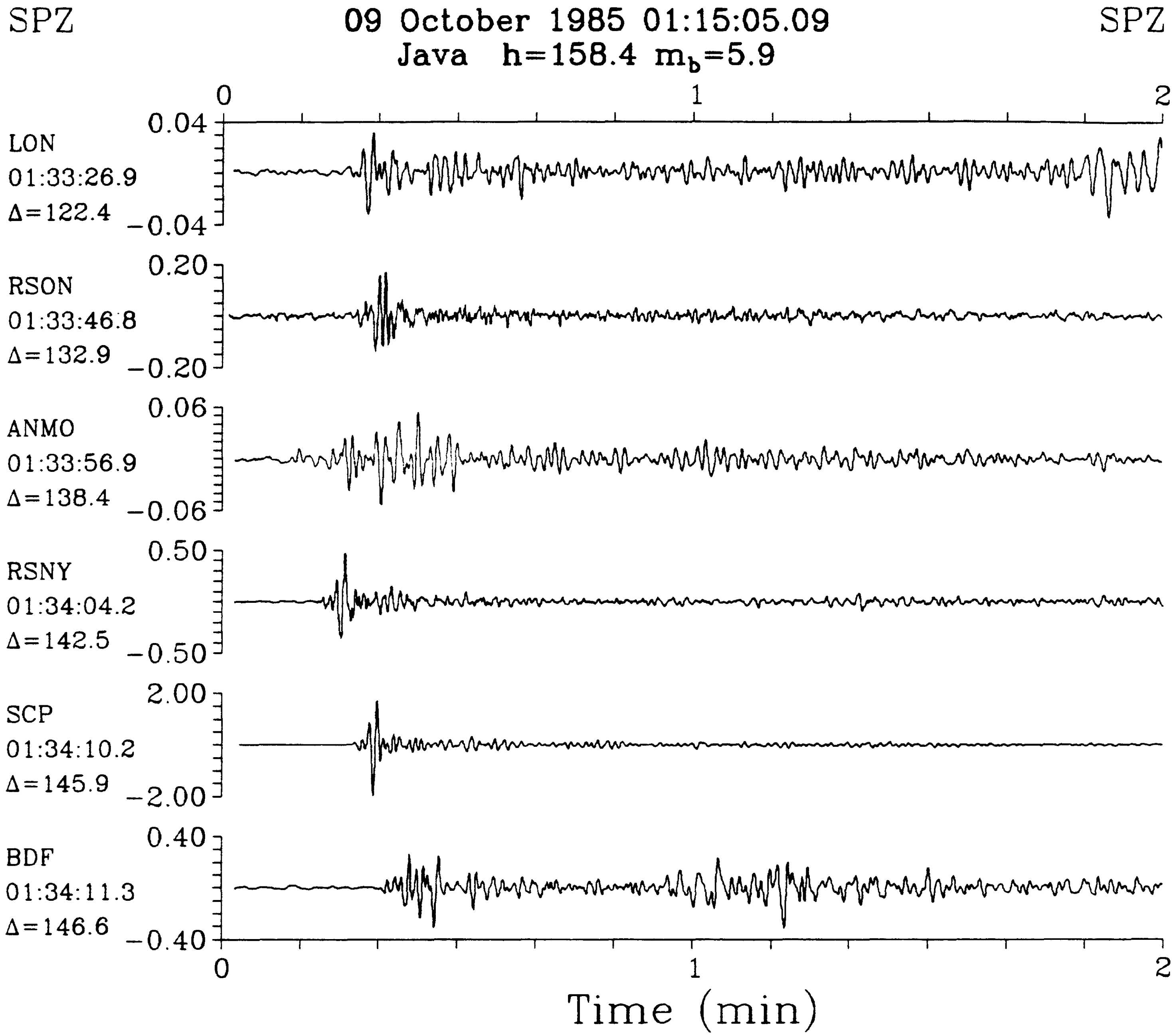


09 October 1985 01:15:05.09

Java

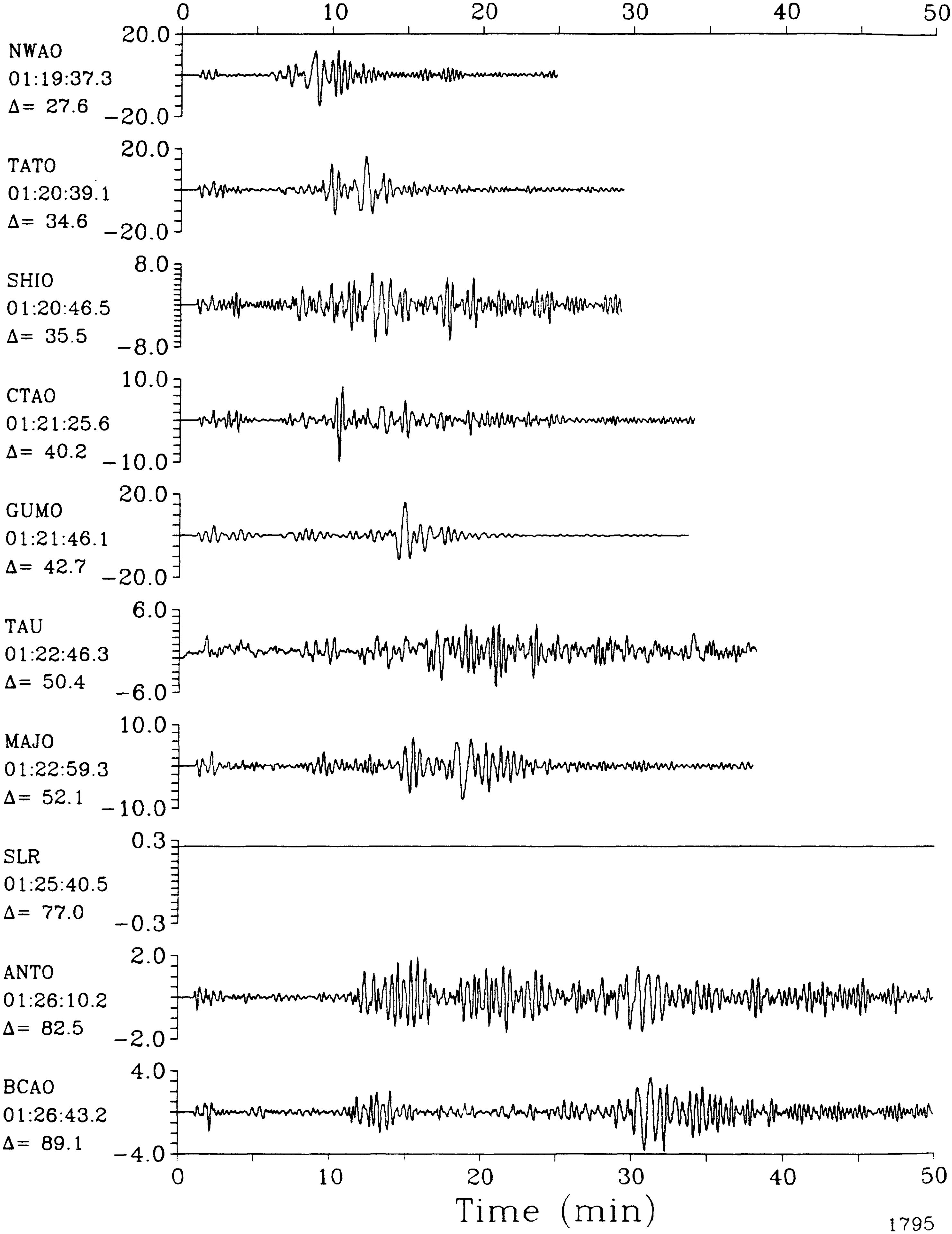



SPZ
09 October 1985 01:15:05.09
Java h=158.4 m_b=5.9
SPZ
NWAO
01:20:22.3
Δ= 27.6
0.50
−0.50
TATO
01:21:24.1
Δ= 34.6
0.40
−0.40
SHIO
01:21:31.5
Δ= 35.5
0.40
−0.40
CTAO
01:22:10.6
Δ= 40.2
0.60
−0.60
TAU
01:23:31.3
Δ= 50.4
0.14
−0.14
ANTO
01:26:55.2
Δ= 82.5
0.40
−0.40
BCAO
01:27:28.2
Δ= 89.1
0.20
−0.20
NRAO
01:28:11.5
Δ= 98.7
0.06
−0.06
GRFO
01:28:12.9
Δ= 99.0
0.05
−0.05
KONO
01:28:16.0
Δ= 99.7
0.08
−0.08
0
1
2
Time (min)
1793

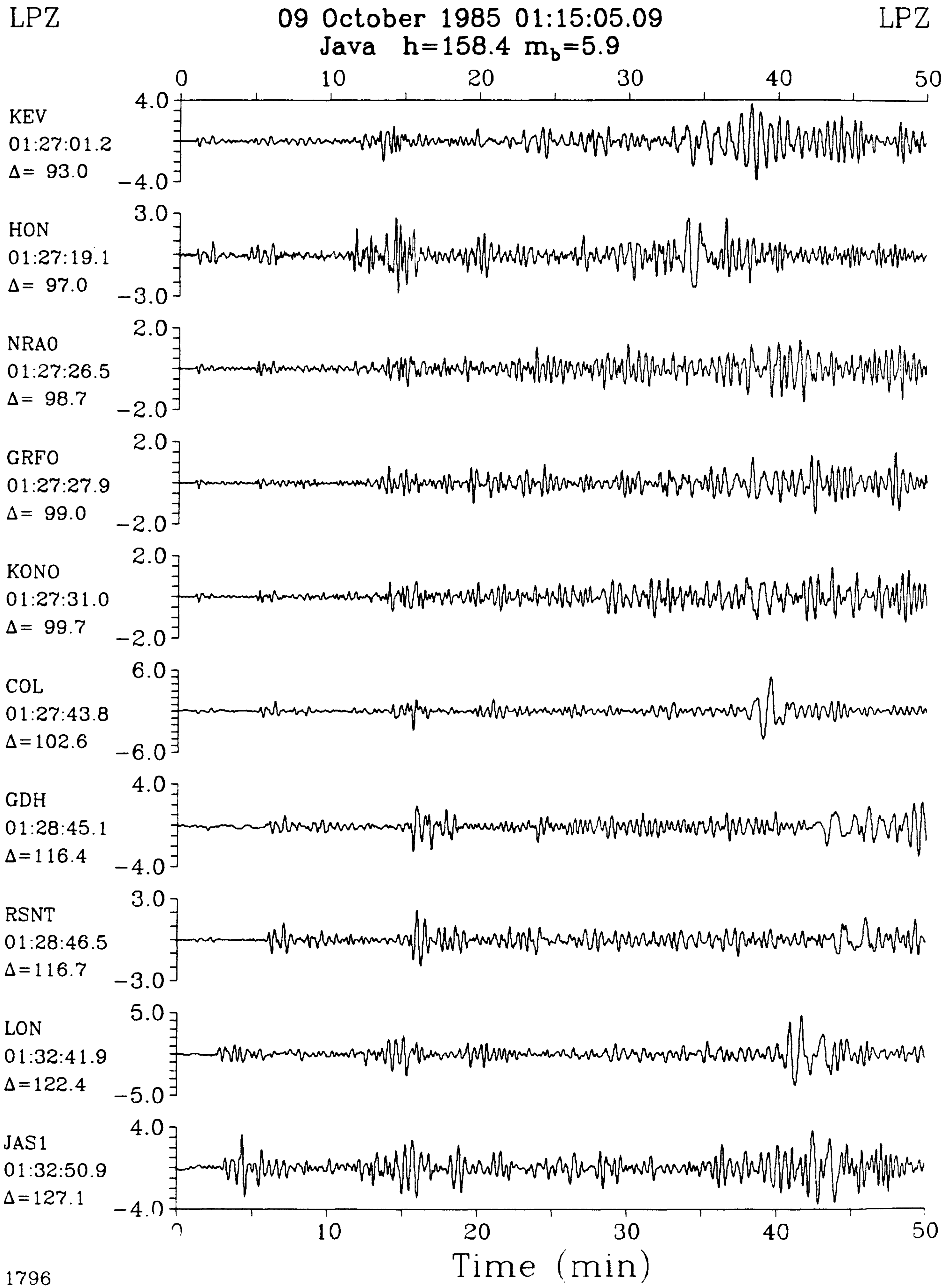

SPZ
09 October 1985 01:15:05.09
Java h=158.4 m_b=5.9
SPZ
LON
01:33:26.9
Δ=122.4
RSON
01:33:46.8
Δ=132.9
ANMO
01:33:56.9
Δ=138.4
RSNY
01:34:04.2
Δ=142.5
SCP
01:34:10.2
Δ=145.9
BDF
01:34:11.3
Δ=146.6
0.04
−0.04
0.20
−0.20
0.06
−0.06
0.50
−0.50
2.00
−2.00
0.40
−0.40
0
1
2
Time (min)

LPZ 09 October 1985 01:15:05.09 LPZ

Java h=158.4 m_b=5.9

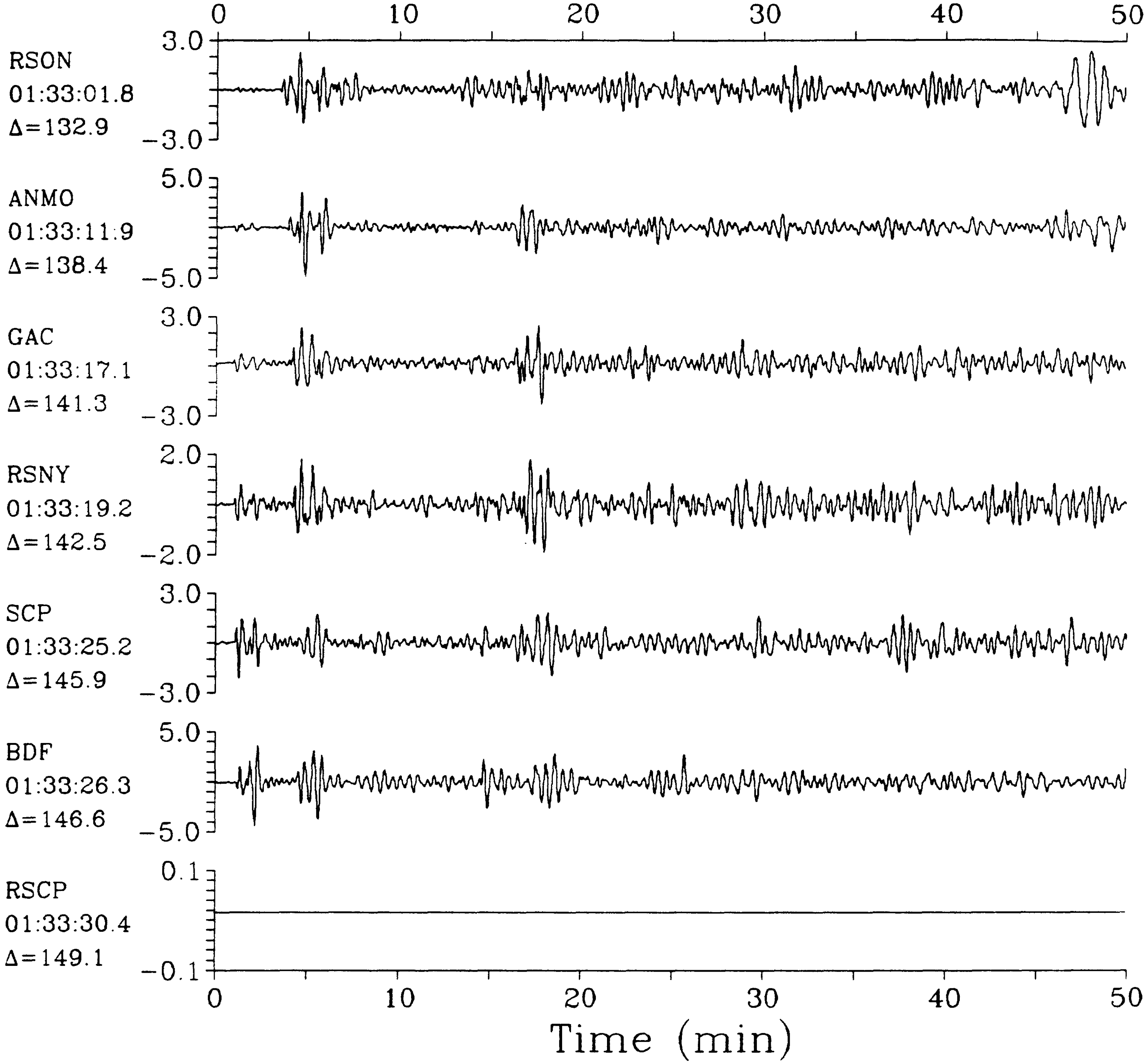


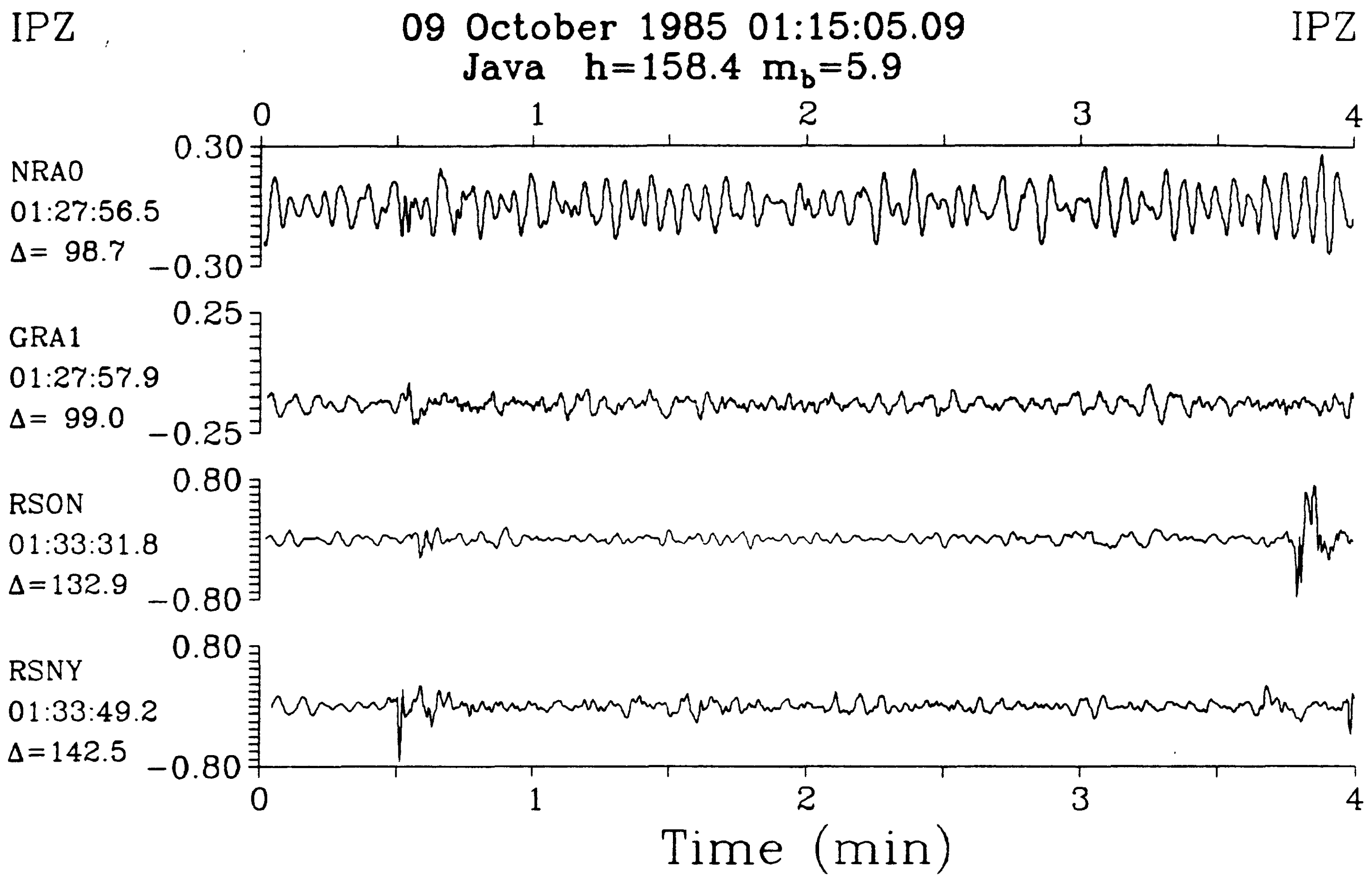
1795


LPZ
09 October 1985 01:15:05.09
Java h=158.4 m_b=5.9
LPZ
KEV
01:27:01.2
Δ= 93.0
HON
01:27:19.1
Δ= 97.0
NRAO
01:27:26.5
Δ= 98.7
GRFO
01:27:27.9
Δ= 99.0
KONO
01:27:31.0
Δ= 99.7
COL
01:27:43.8
Δ=102.6
GDH
01:28:45.1
Δ=116.4
RSNT
01:28:46.5
Δ=116.7
LON
01:32:41.9
Δ=122.4
JAS1
01:32:50.9
Δ=127.1
Time (min)

LPZ 09 October 1985 01:15:05.09 LPZ

Java h=158.4 m_b=5.9

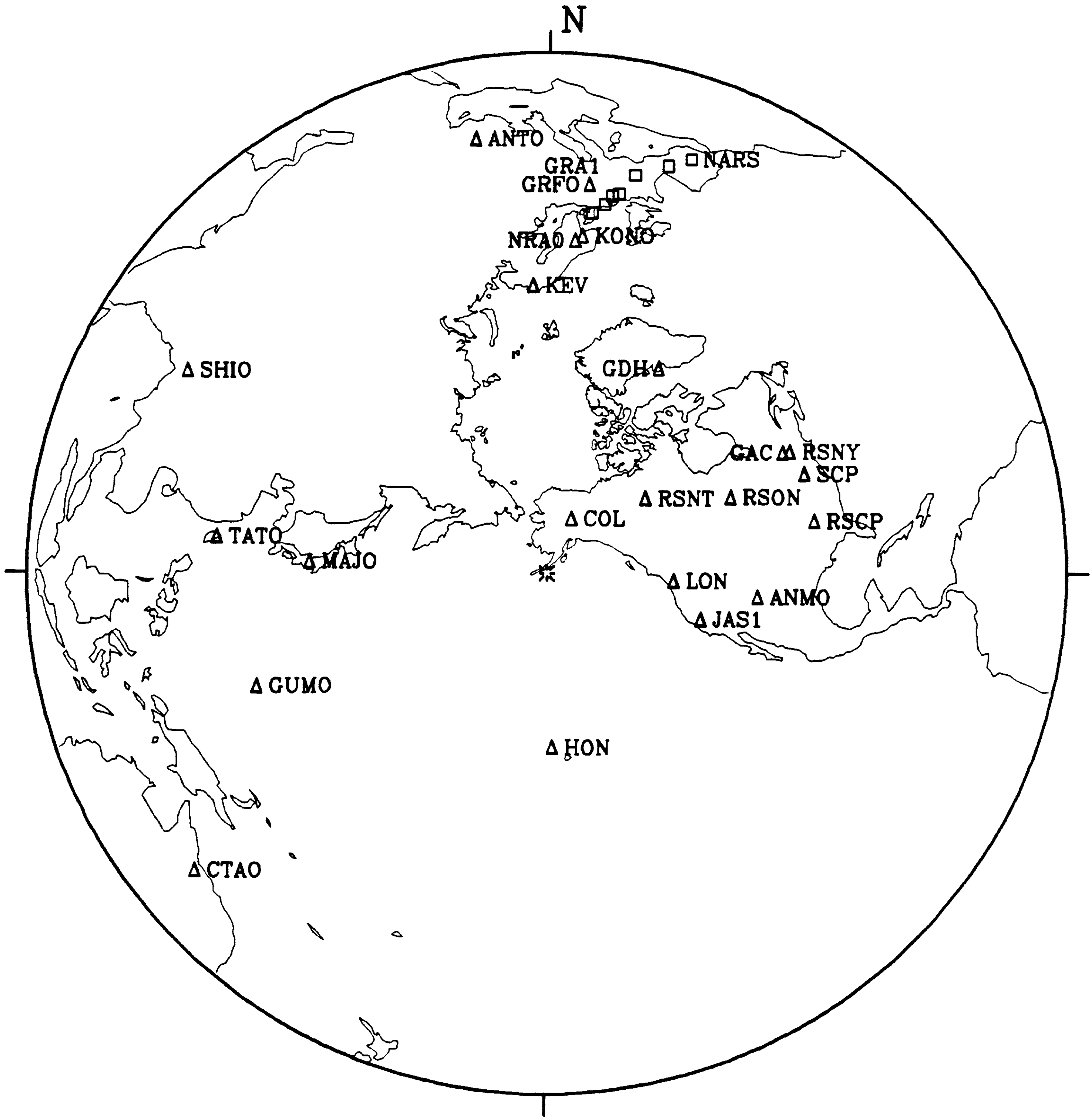




IPZ
09 October 1985 01:15:05.09
Java h=158.4 m_b=5.9
IPZ
NRA0
01:27:56.5
Δ= 98.7
GRA1
01:27:57.9
Δ= 99.0
RSON
01:33:31.8
Δ=132.9
RSNY
01:33:49.2
Δ=142.5
0.30
−0.30
0.25
−0.25
0.80
−0.80
0.80
−0.80
0
1
2
3
4
Time (min)

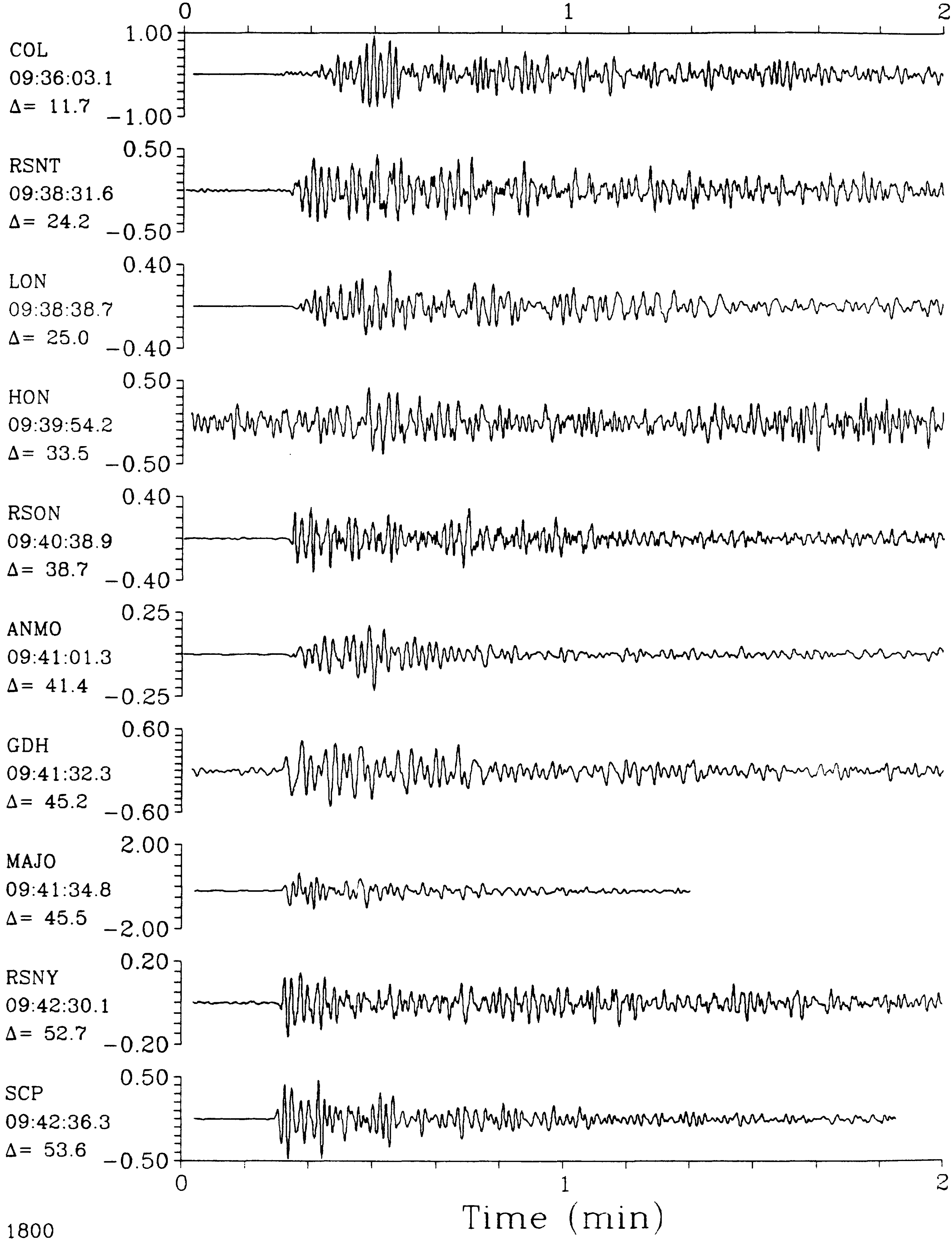
09 October 1985 09:33:32.80

South of Alaska



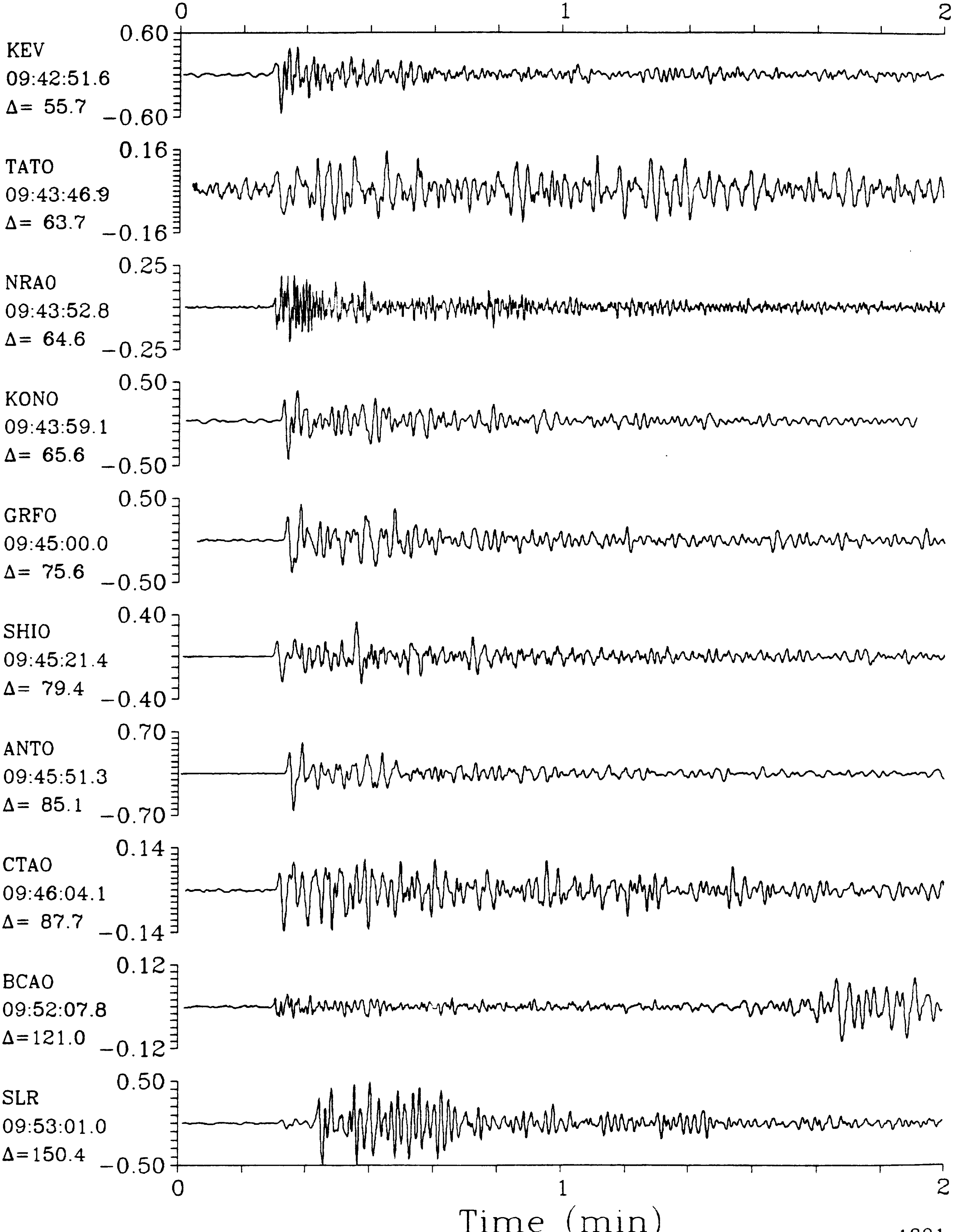
SPZ 09 October 1985 09:33:32.80 SPZ

South of Alaska h=31.2 m_b=6.3 M_{SZ}=6.5

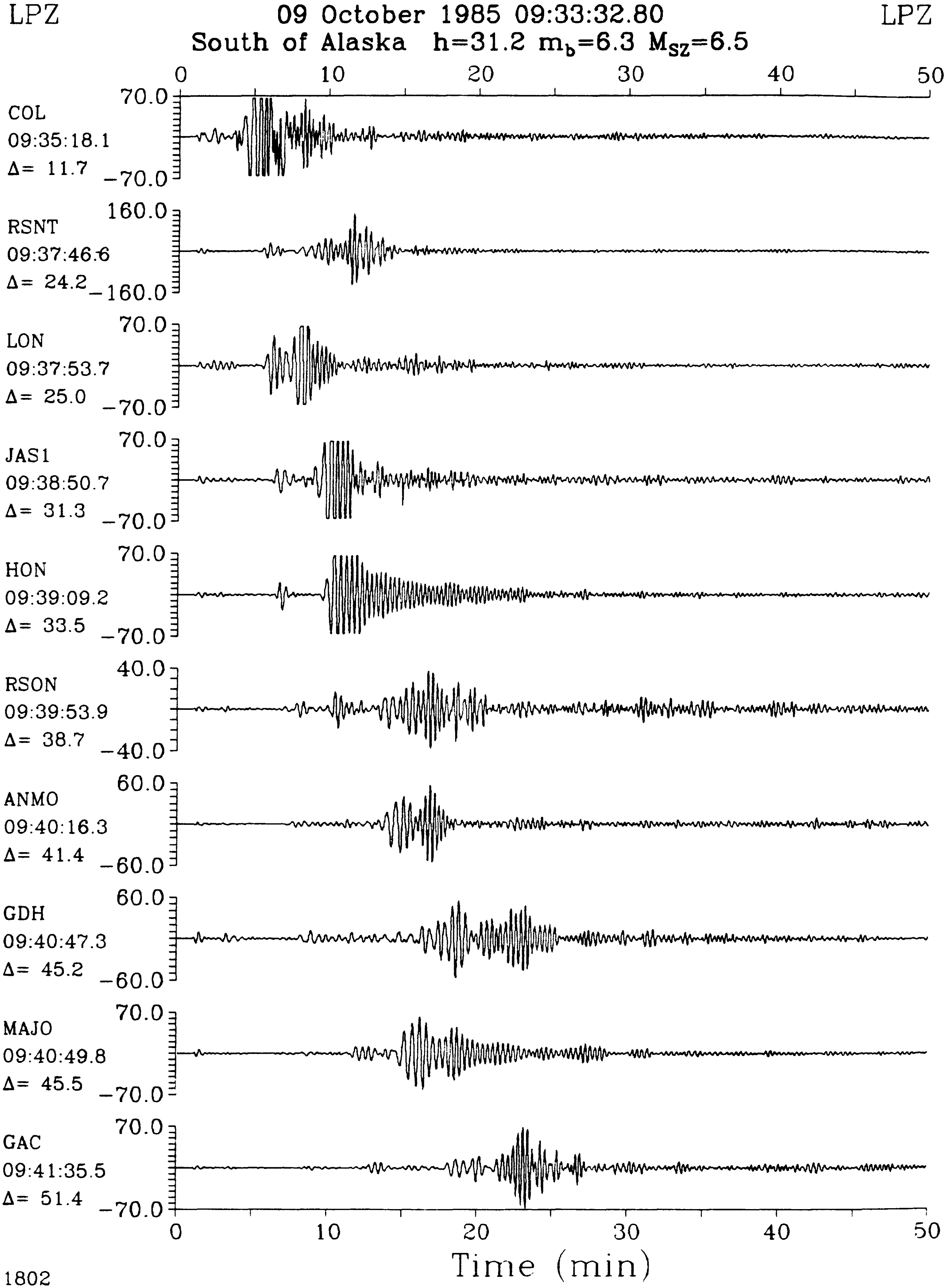


SPZ 09 October 1985 09:33:32.80 SPZ

South of Alaska h=31.2 m_b=6.3 M_{SZ}=6.5

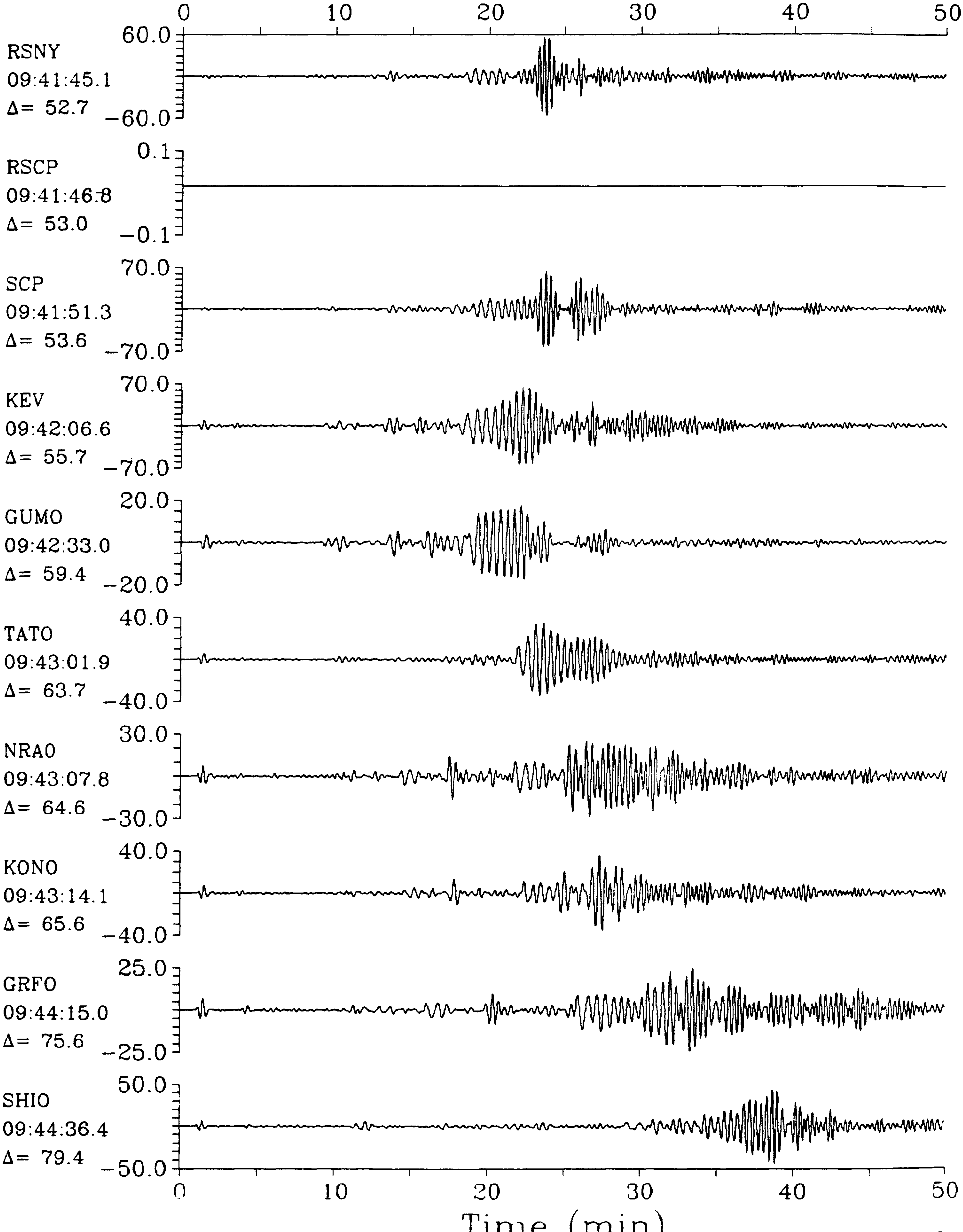


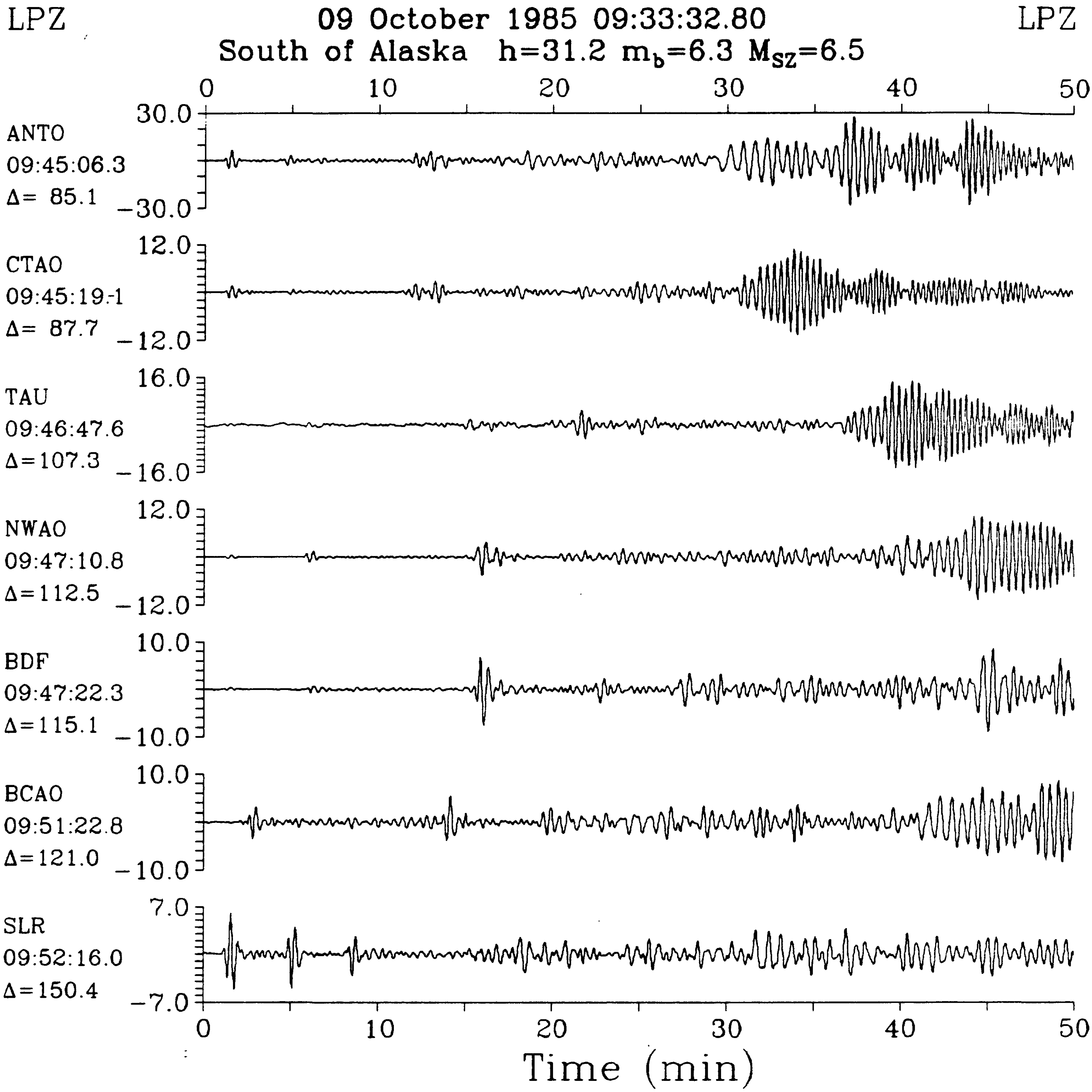
1801


LPZ
09 October 1985 09:33:32.80
LPZ
South of Alaska h=31.2 m_b=6.3 M_{SZ}=6.5
COL
09:35:18.1
Δ= 11.7
RSNT
09:37:46.6
Δ= 24.2
LON
09:37:53.7
Δ= 25.0
JAS1
09:38:50.7
Δ= 31.3
HON
09:39:09.2
Δ= 33.5
RSON
09:39:53.9
Δ= 38.7
ANMO
09:40:16.3
Δ= 41.4
GDH
09:40:47.3
Δ= 45.2
MAJO
09:40:49.8
Δ= 45.5
GAC
09:41:35.5
Δ= 51.4
70.0
-70.0
160.0
-160.0
40.0
-40.0
60.0
-60.0
0
10
20
30
40
50
Time (min)

LPZ 09 October 1985 09:33:32.80 LPZ

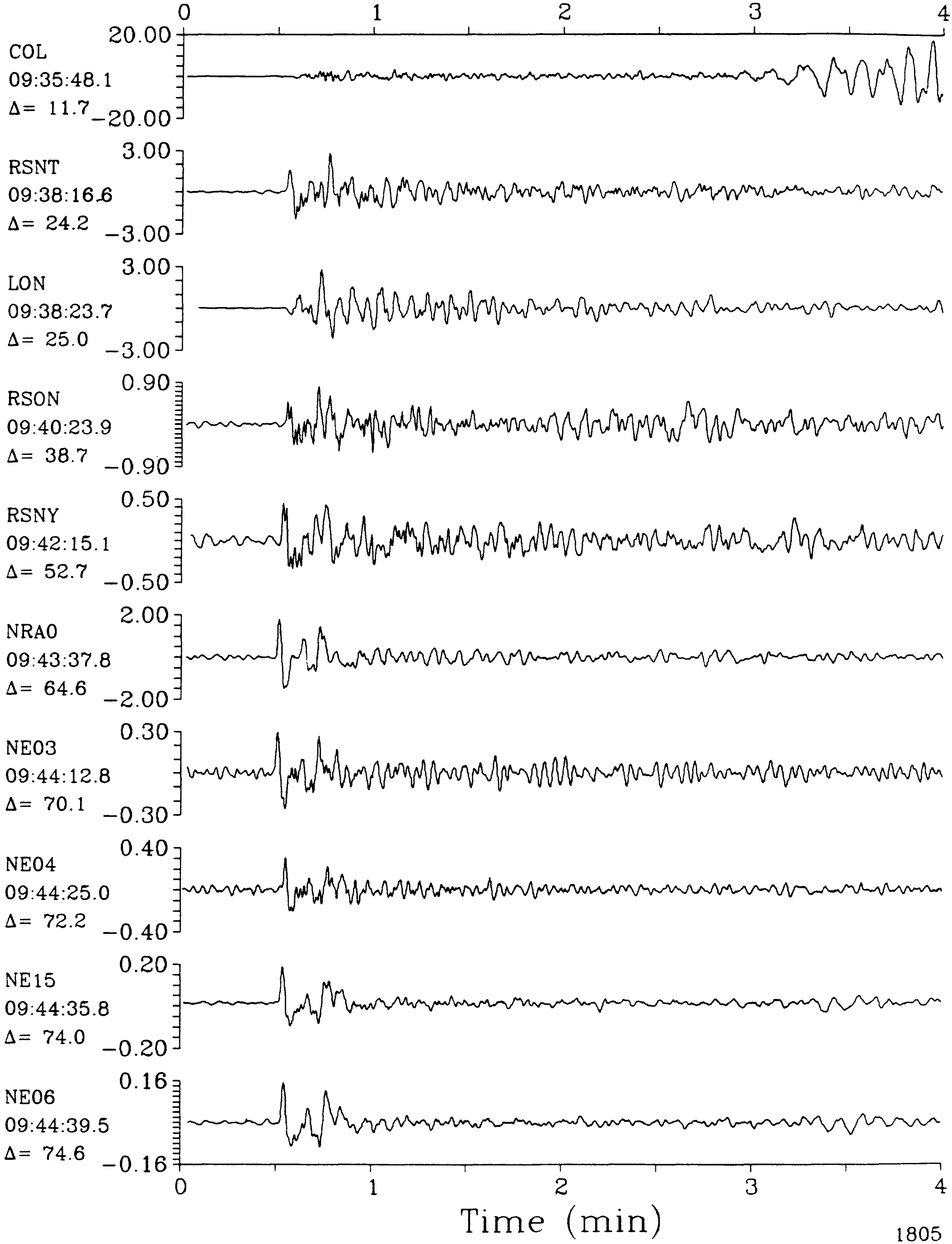
South of Alaska h=31.2 m_b=6.3 M_{SZ}=6.5




LPZ
09 October 1985 09:33:32.80
South of Alaska h=31.2 m_b=6.3 M_{SZ}=6.5
LPZ
ANTO
09:45:06.3
Δ= 85.1
CTAO
09:45:19.1
Δ= 87.7
TAU
09:46:47.6
Δ=107.3
NWAO
09:47:10.8
Δ=112.5
BDF
09:47:22.3
Δ=115.1
BCAO
09:51:22.8
Δ=121.0
SLR
09:52:16.0
Δ=150.4
Time (min)

IPZ 09 October 1985 09:33:32.80 IPZ

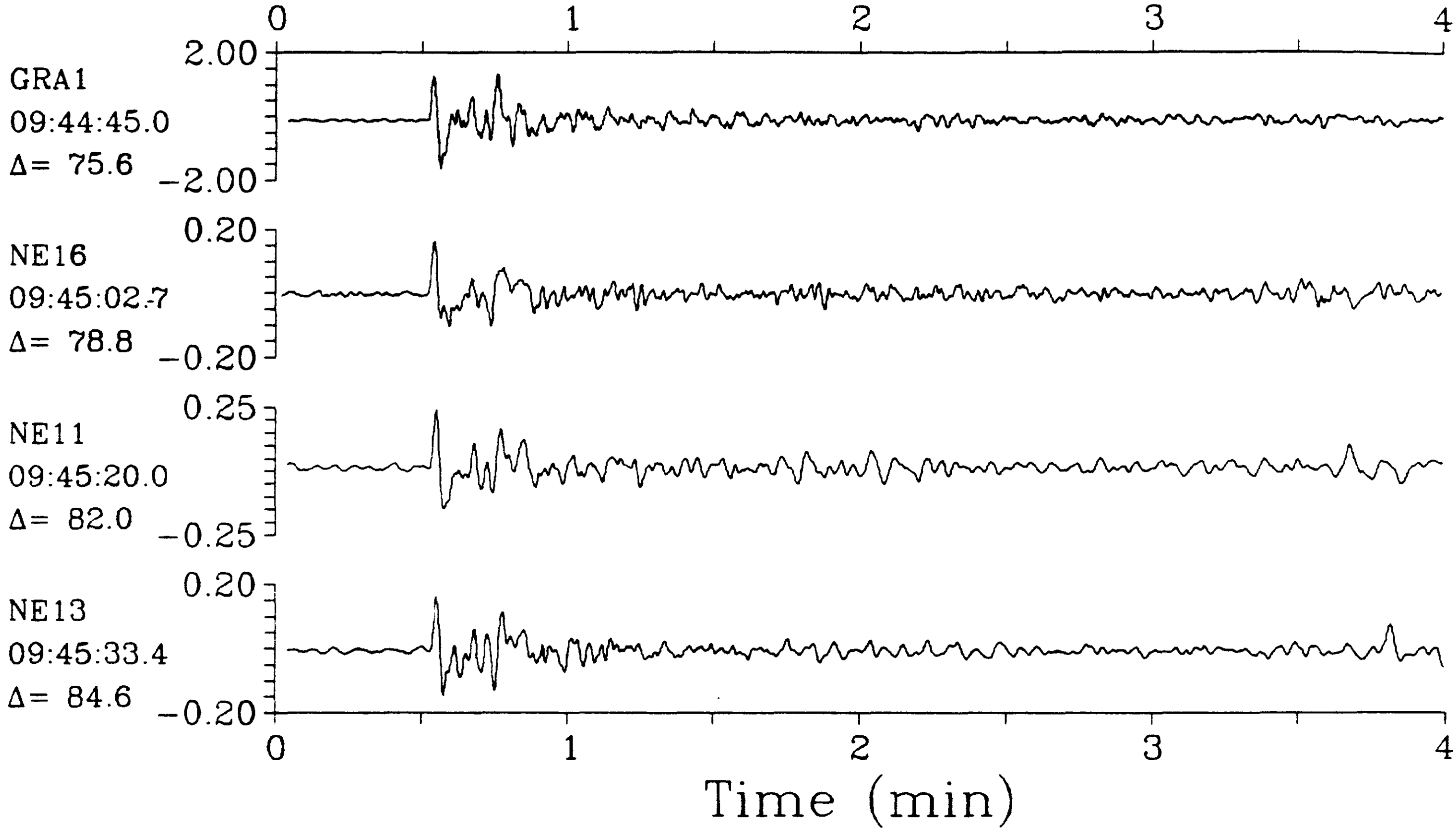
South of Alaska h=31.2 m_b=6.3 M_{SZ}=6.5



1805

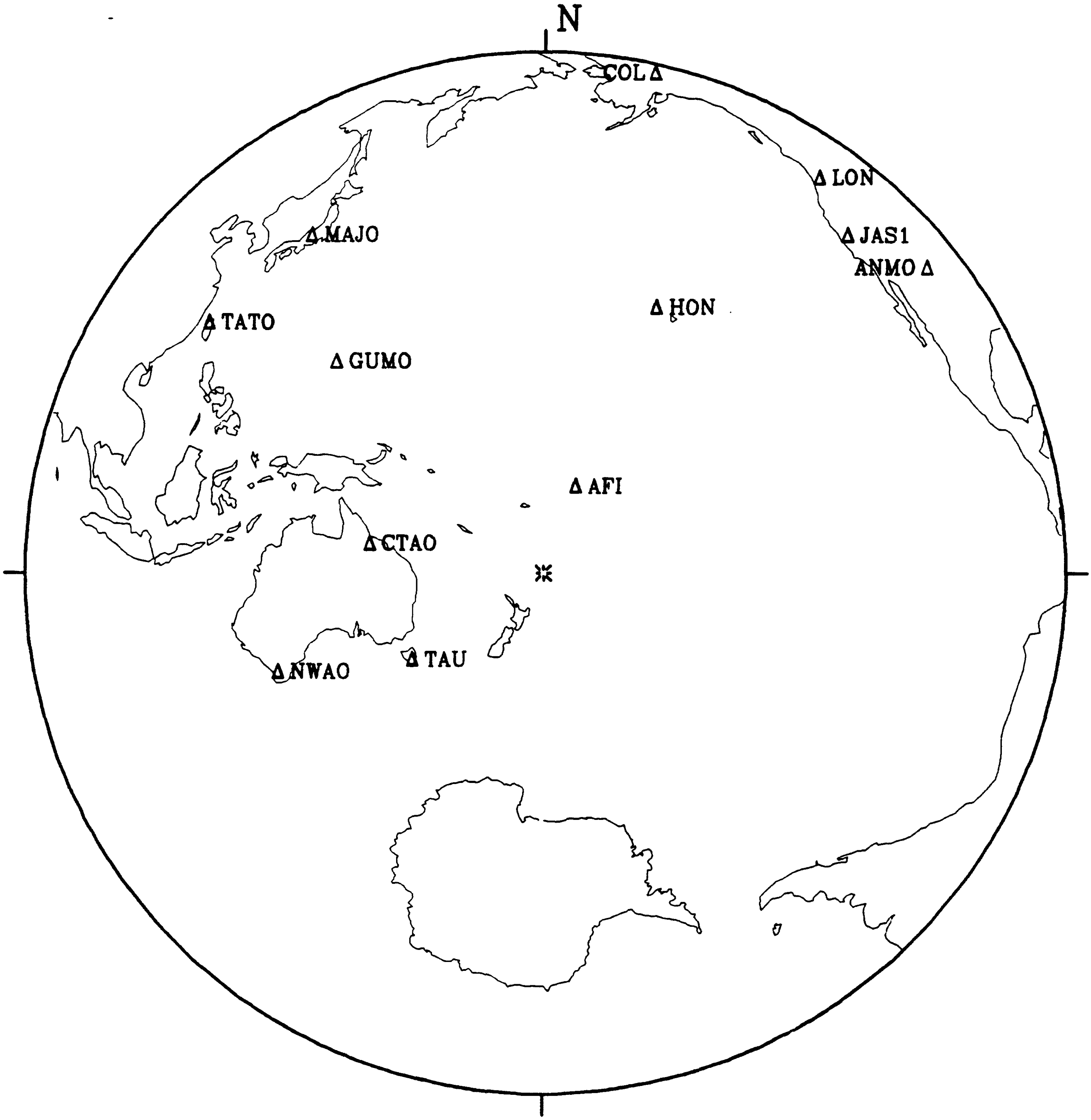
IPZ 09 October 1985 09:33:32.80 IPZ

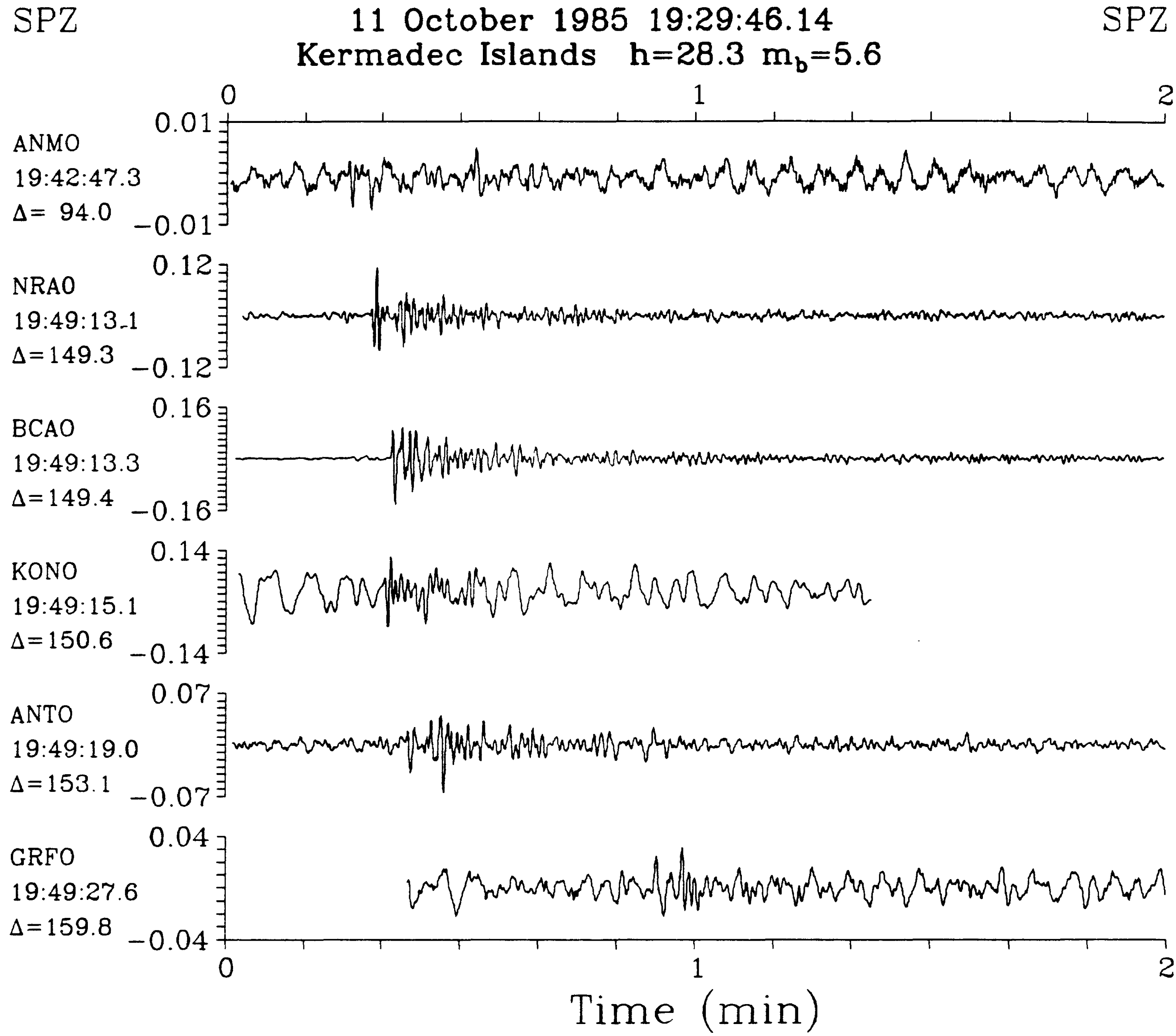
South of Alaska h=31.2 m_b=6.3 M_{SZ}=6.5



11 October 1985 19:29:46.14

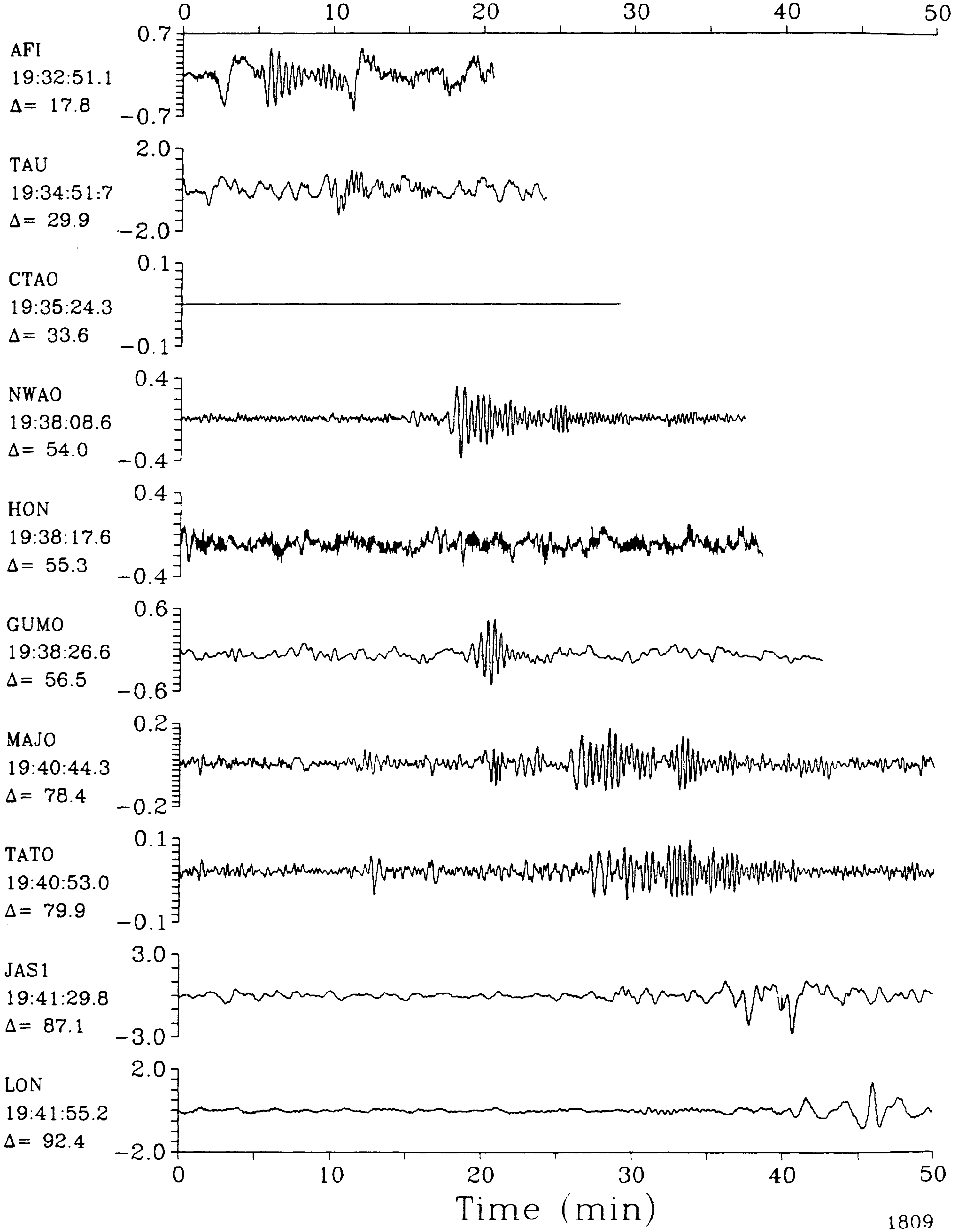
Kermadec Islands



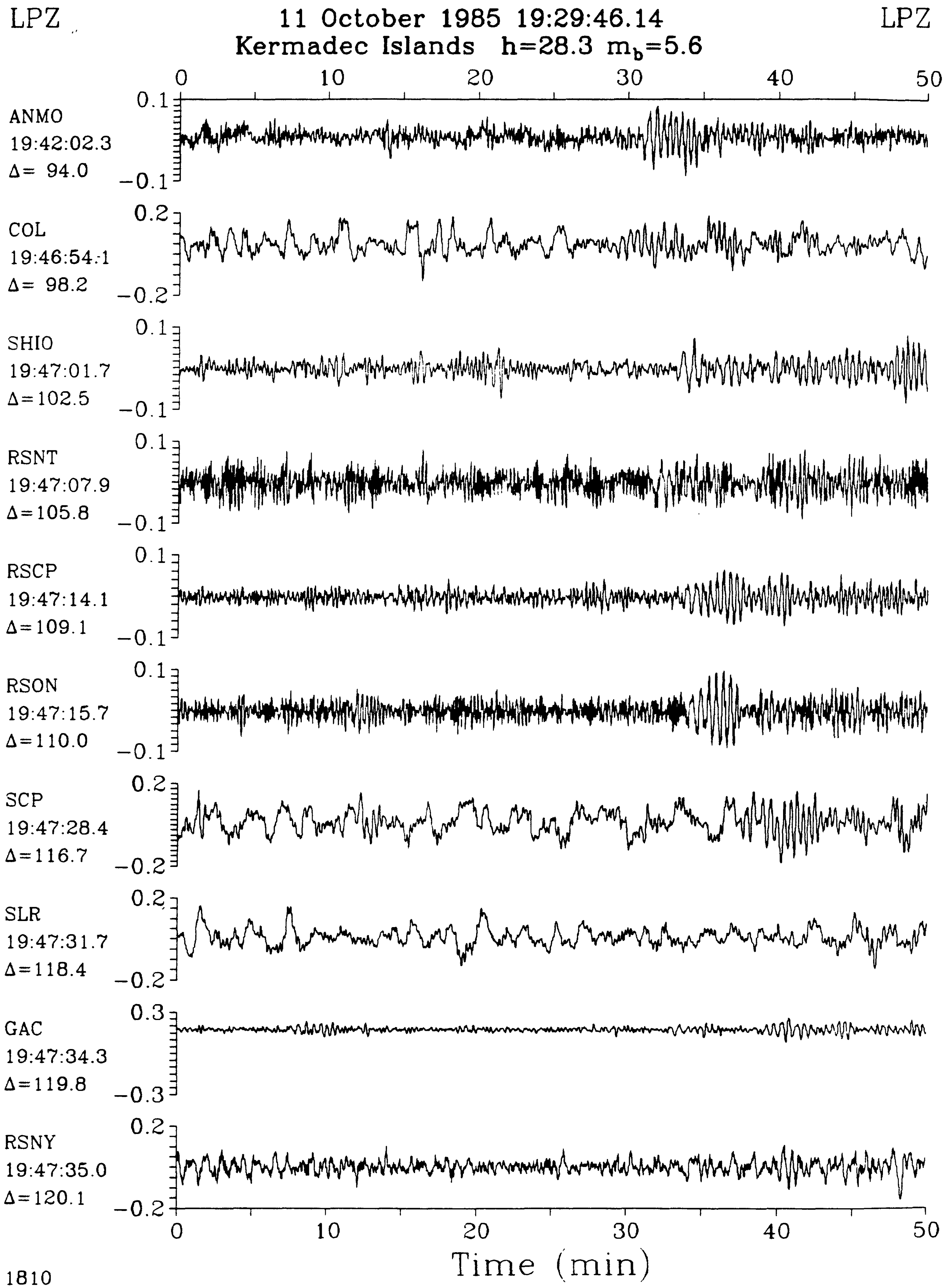

SPZ
11 October 1985 19:29:46.14
Kermadec Islands h=28.3 m_b=5.6
SPZ
ANMO
19:42:47.3
Δ= 94.0
NRAO
19:49:13.1
Δ=149.3
BCAO
19:49:13.3
Δ=149.4
KONO
19:49:15.1
Δ=150.6
ANTO
19:49:19.0
Δ=153.1
GRFO
19:49:27.6
Δ=159.8
0.01
−0.01
0.12
−0.12
0.16
−0.16
0.14
−0.14
0.07
−0.07
0.04
−0.04
0
1
2
Time (min)

LPZ 11 October 1985 19:29:46.14 LPZ

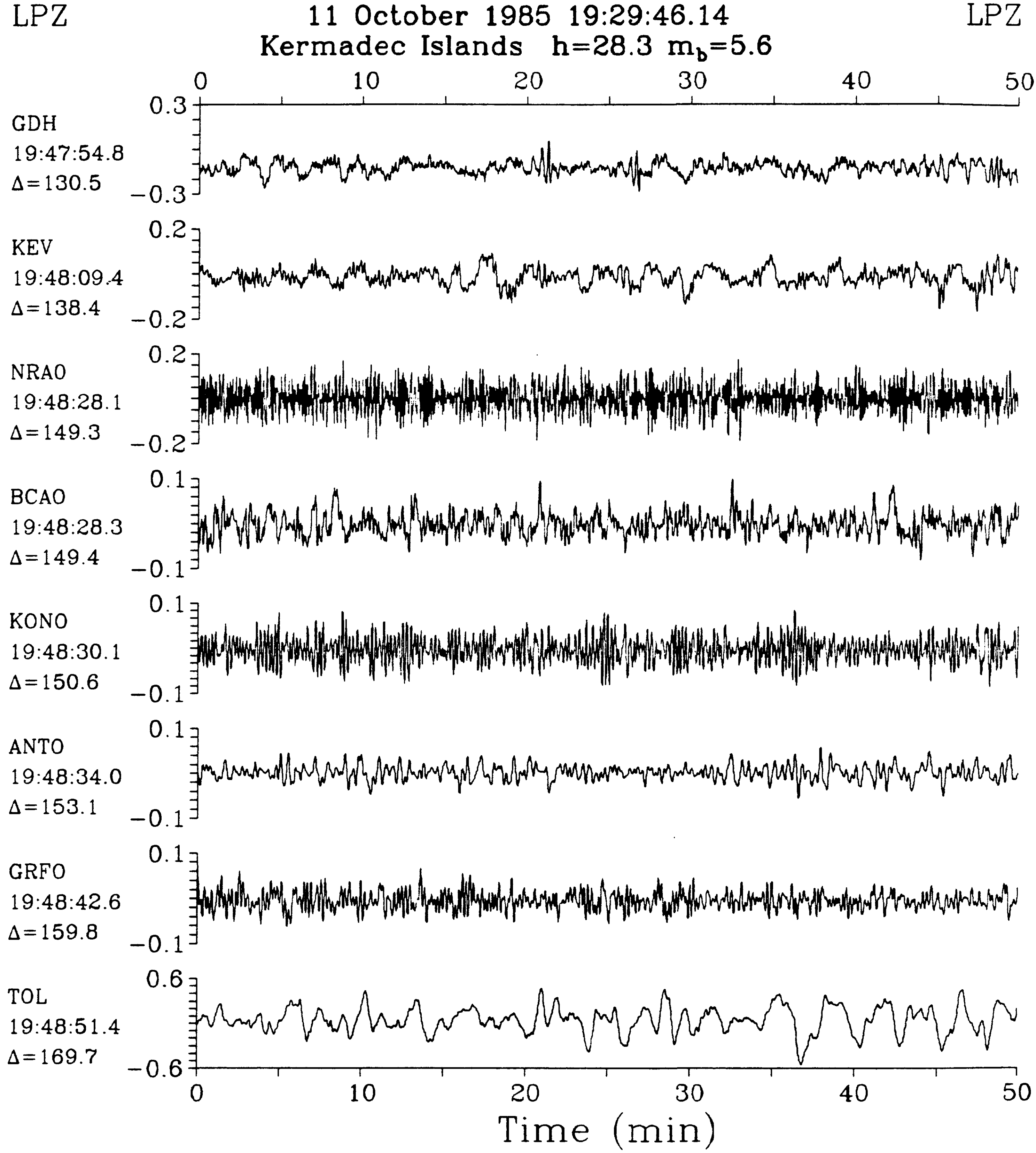
Kermadec Islands h=28.3 m_b=5.6



1809

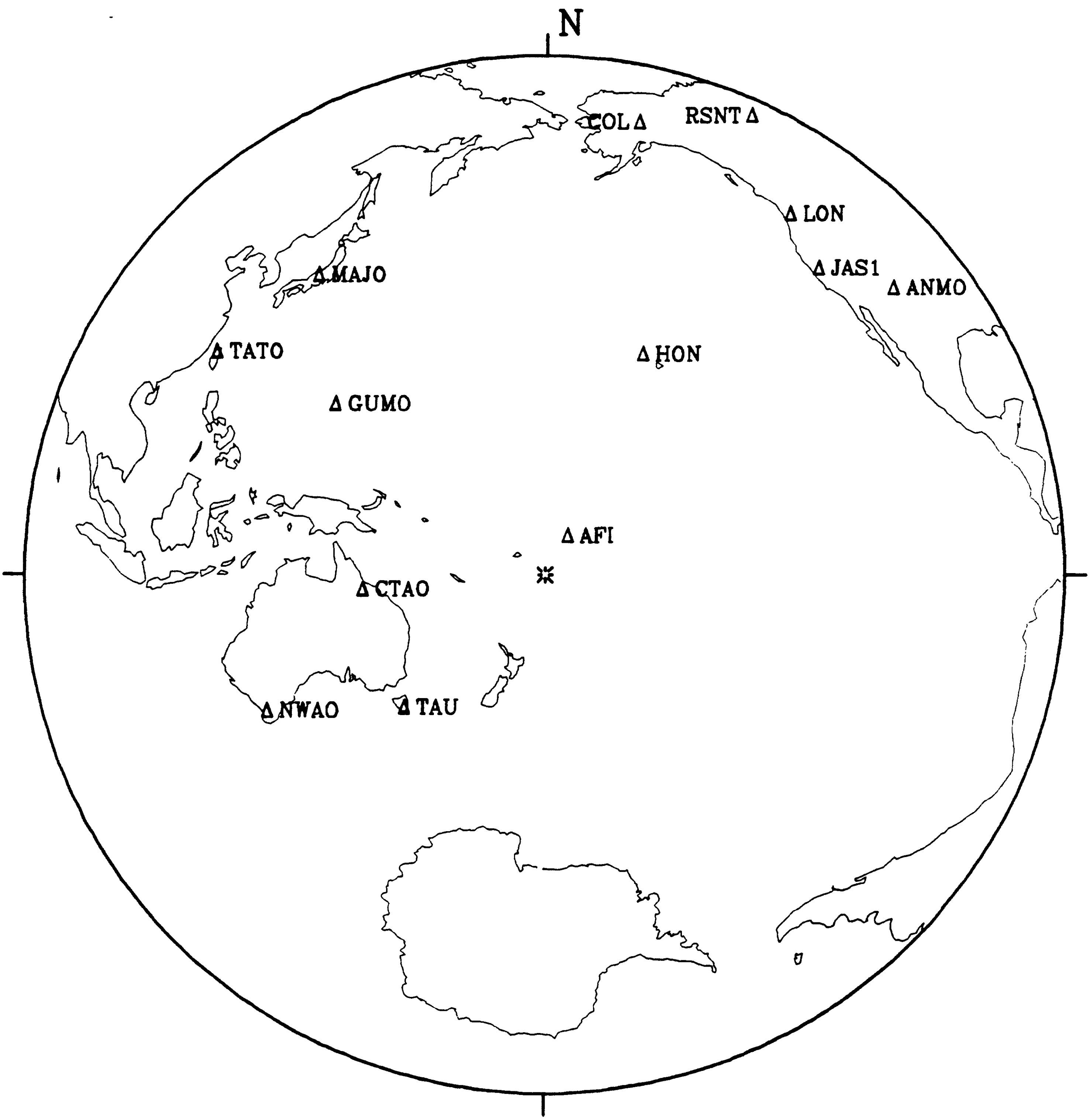


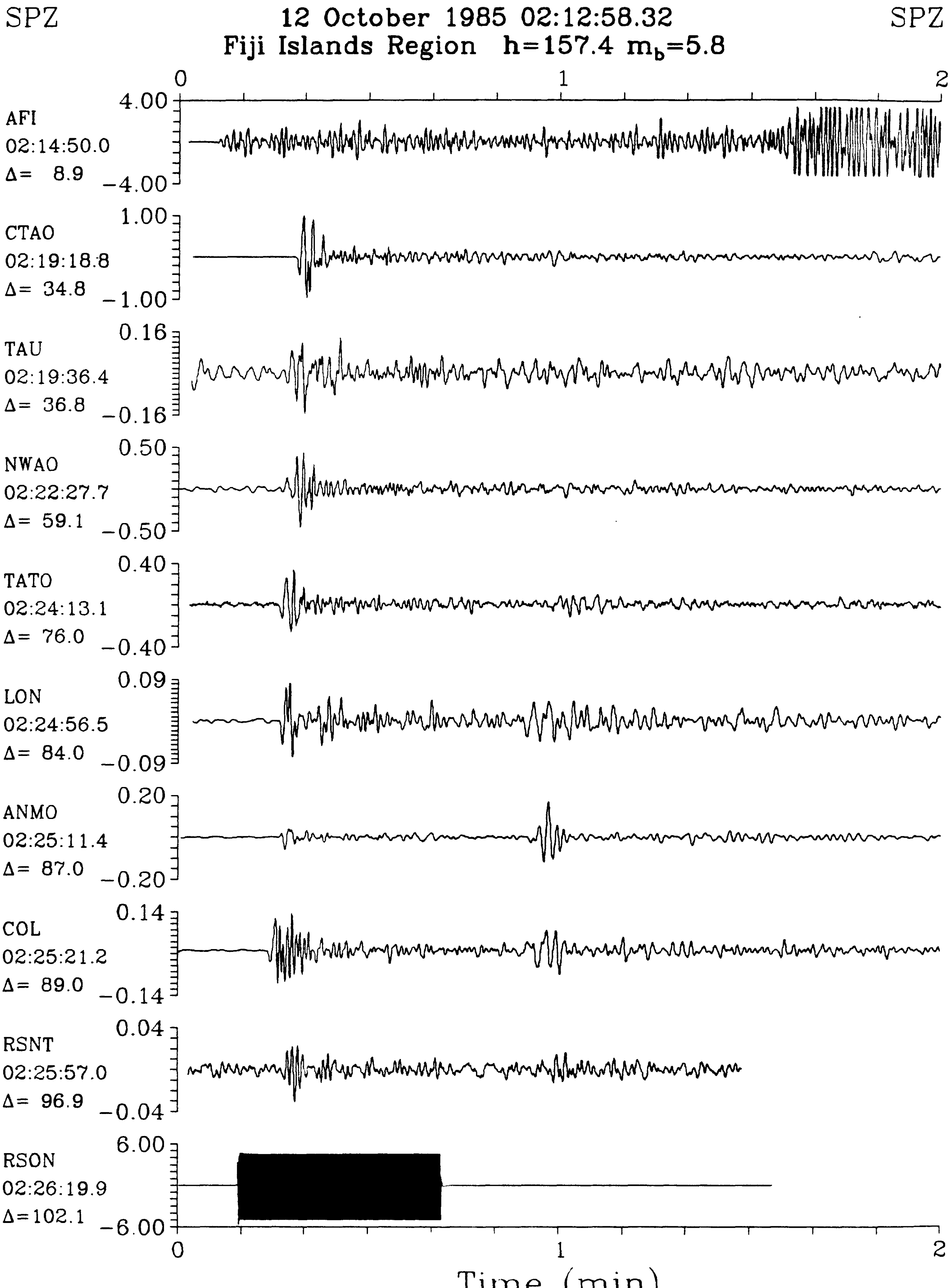
LPZ
11 October 1985 19:29:46.14
Kermadec Islands h=28.3 m_b=5.6
LPZ
ANMO
19:42:02.3
Δ= 94.0
COL
19:46:54.1
Δ= 98.2
SHIO
19:47:01.7
Δ=102.5
RSNT
19:47:07.9
Δ=105.8
RSCP
19:47:14.1
Δ=109.1
RSON
19:47:15.7
Δ=110.0
SCP
19:47:28.4
Δ=116.7
SLR
19:47:31.7
Δ=118.4
GAC
19:47:34.3
Δ=119.8
RSNY
19:47:35.0
Δ=120.1
0.1
−0.1
0.2
−0.2
0.3
−0.3
0
10
20
30
40
50
Time (min)


LPZ
11 October 1985 19:29:46.14
Kermadec Islands h=28.3 m_b=5.6
LPZ
GDH
19:47:54.8
Δ=130.5
KEV
19:48:09.4
Δ=138.4
NRAO
19:48:28.1
Δ=149.3
BCAO
19:48:28.3
Δ=149.4
KONO
19:48:30.1
Δ=150.6
ANTO
19:48:34.0
Δ=153.1
GRFO
19:48:42.6
Δ=159.8
TOL
19:48:51.4
Δ=169.7
0.3
−0.3
0.2
−0.2
0.1
−0.1
0.6
−0.6
0
10
20
30
40
50
Time (min)

12 October 1985 02:12:58.32

Fiji Islands Region

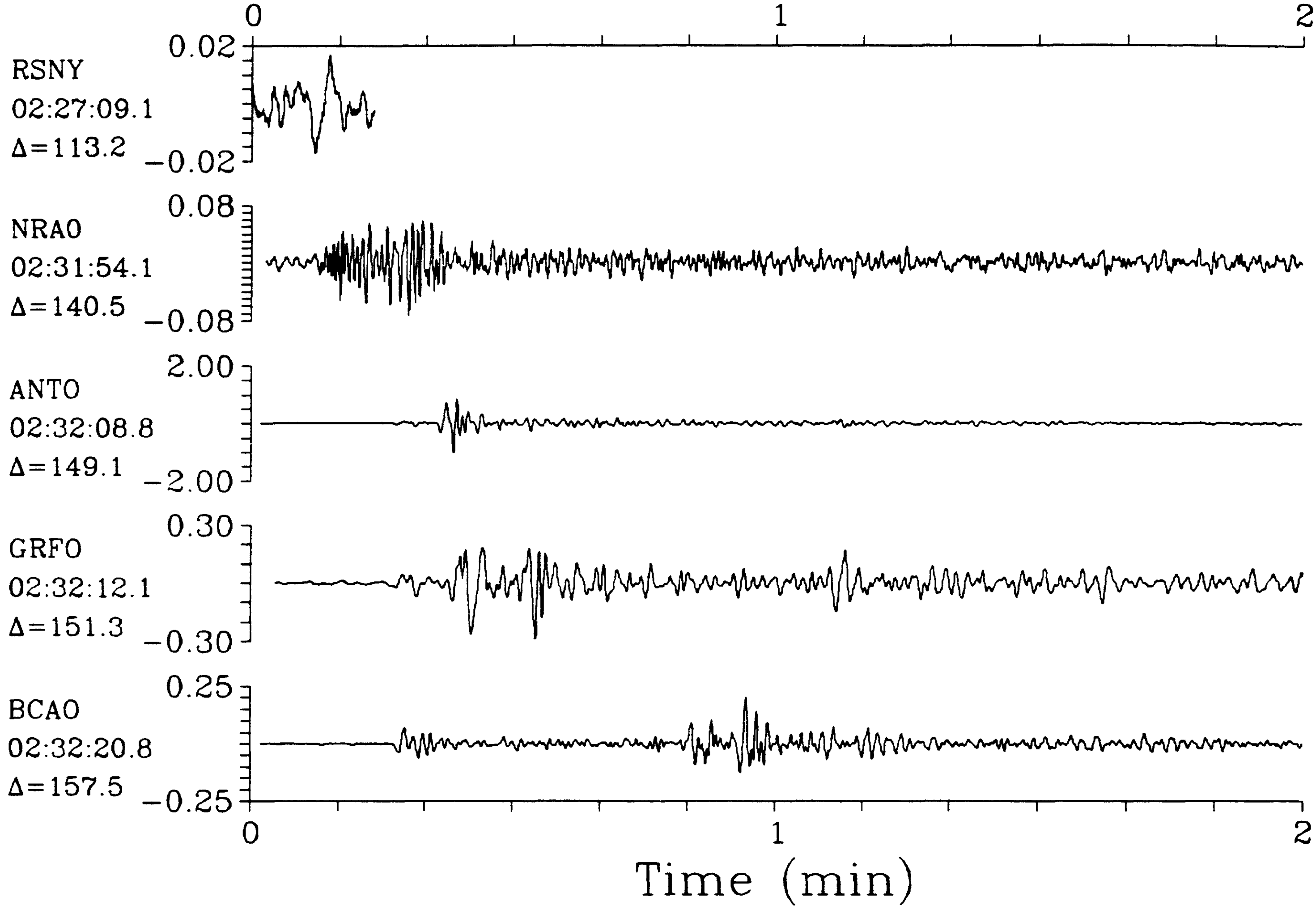


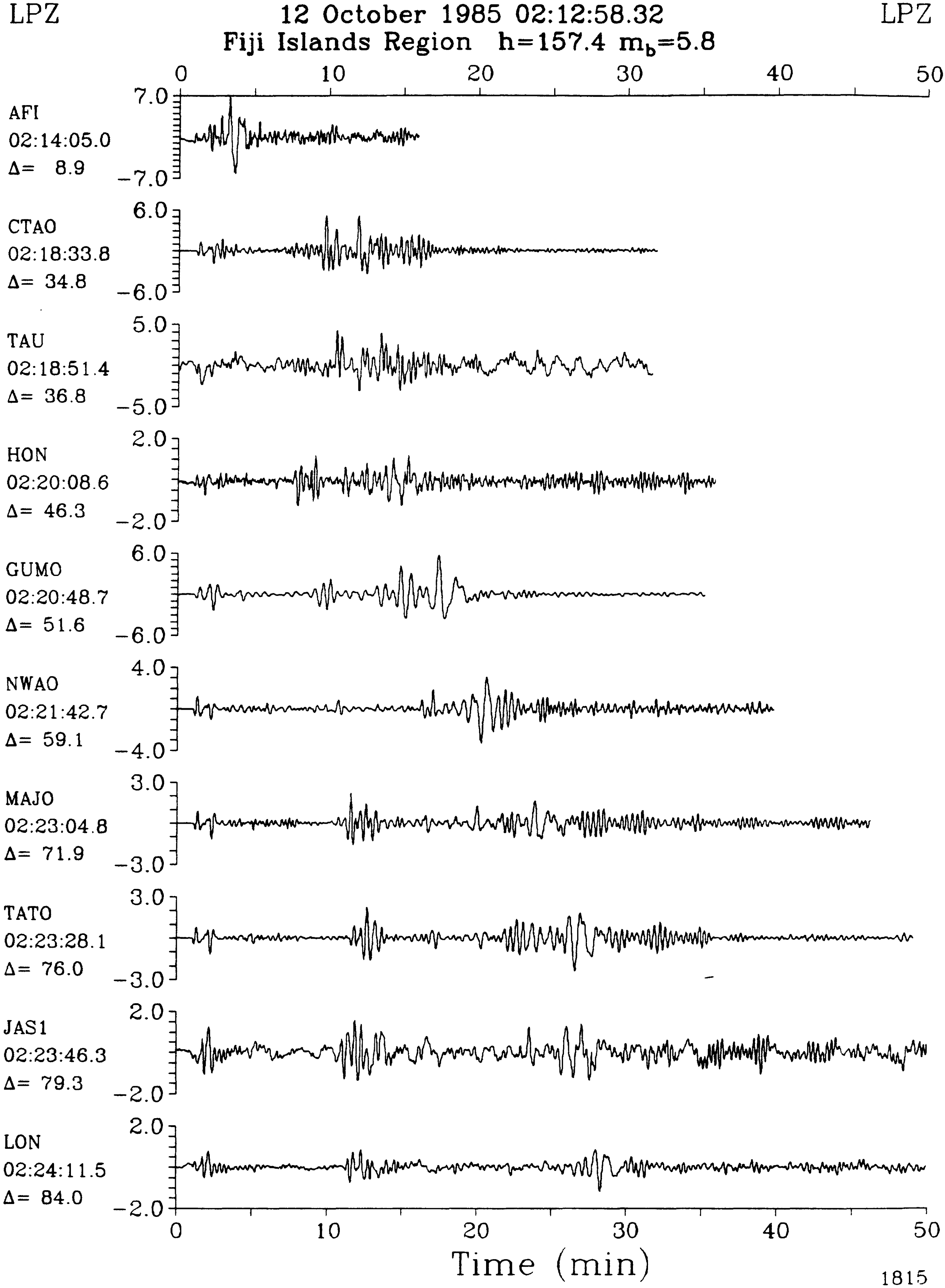

SPZ
12 October 1985 02:12:58.32
SPZ
Fiji Islands Region h=157.4 m_b=5.8
AFI
02:14:50.0
Δ= 8.9
CTAO
02:19:18.8
Δ= 34.8
TAU
02:19:36.4
Δ= 36.8
NWAO
02:22:27.7
Δ= 59.1
TATO
02:24:13.1
Δ= 76.0
LON
02:24:56.5
Δ= 84.0
ANMO
02:25:11.4
Δ= 87.0
COL
02:25:21.2
Δ= 89.0
RSNT
02:25:57.0
Δ= 96.9
RSON
02:26:19.9
Δ=102.1
4.00
−4.00
1.00
−1.00
0.16
−0.16
0.50
−0.50
0.40
−0.40
0.09
−0.09
0.20
−0.20
0.14
−0.14
0.04
−0.04
6.00
−6.00
0
1
2
Time (min)

1813

SPZ 12 October 1985 02:12:58.32 SPZ

Fiji Islands Region h=157.4 m_b=5.8

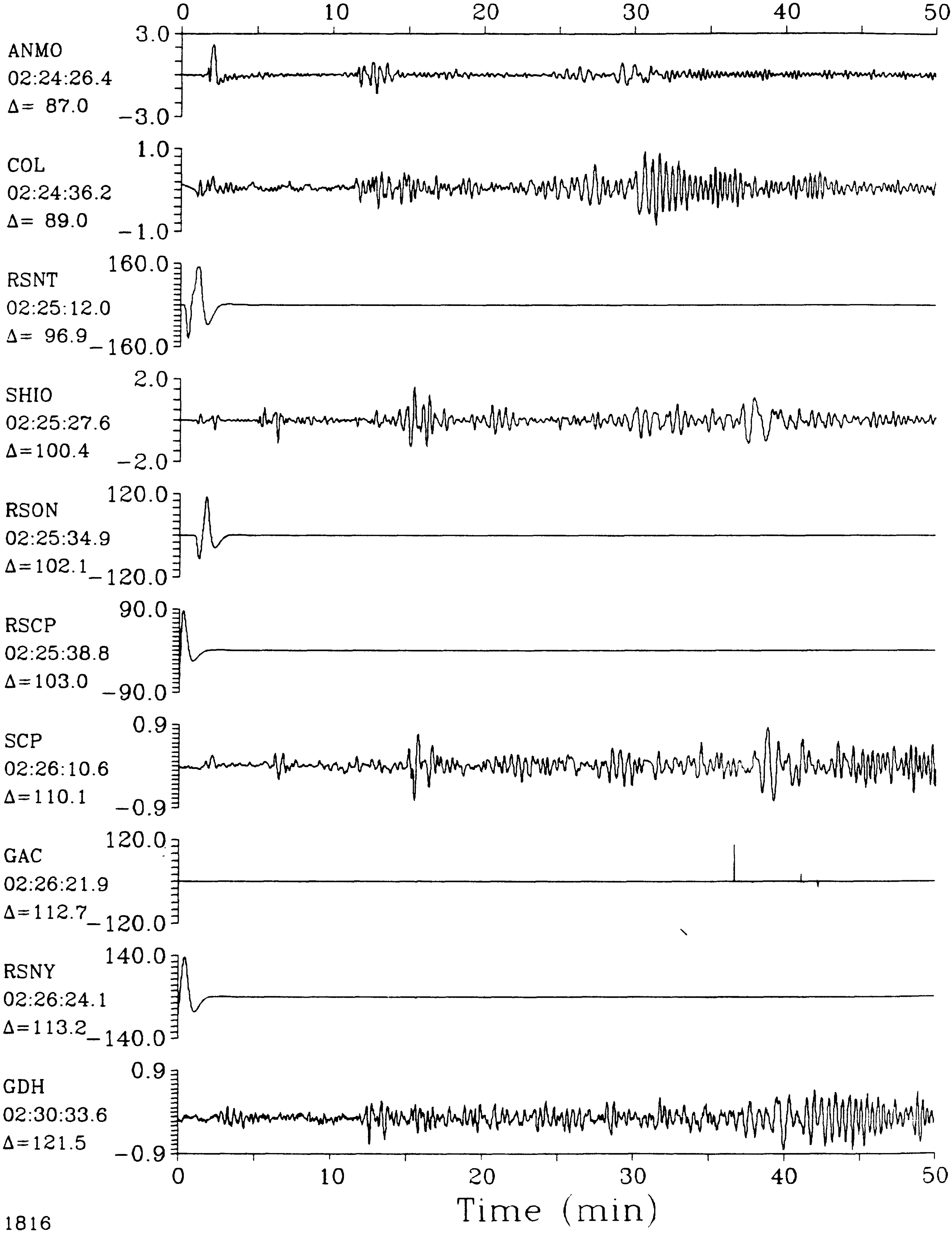




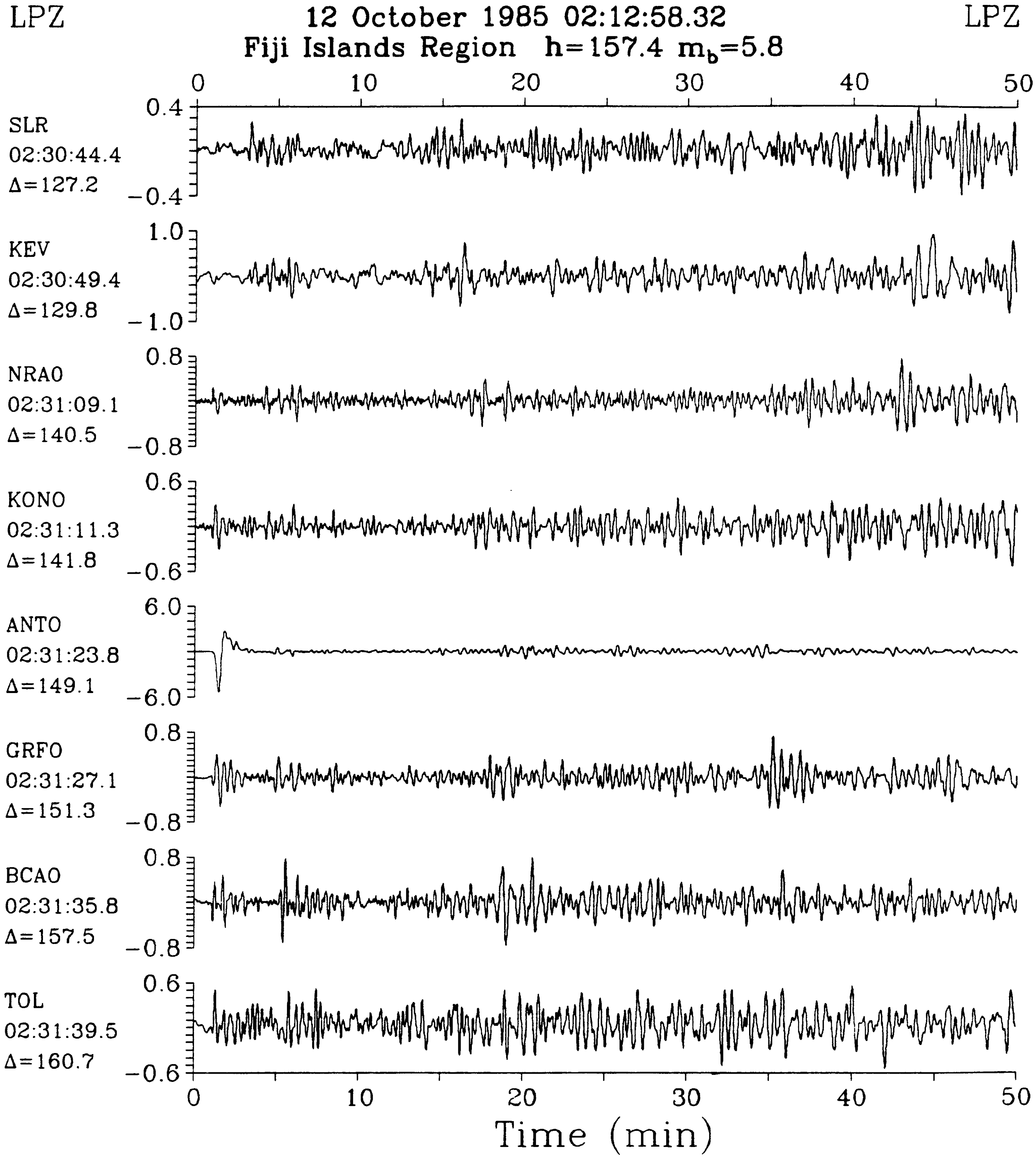
LPZ
12 October 1985 02:12:58.32
Fiji Islands Region h=157.4 m_b=5.8
LPZ
AFI
02:14:05.0
Δ= 8.9
CTAO
02:18:33.8
Δ= 34.8
TAU
02:18:51.4
Δ= 36.8
HON
02:20:08.6
Δ= 46.3
GUMO
02:20:48.7
Δ= 51.6
NWAO
02:21:42.7
Δ= 59.1
MAJO
02:23:04.8
Δ= 71.9
TATO
02:23:28.1
Δ= 76.0
JAS1
02:23:46.3
Δ= 79.3
LON
02:24:11.5
Δ= 84.0
Time (min)

LPZ 12 October 1985 02:12:58.32 LPZ

Fiji Islands Region h=157.4 m_b=5.8



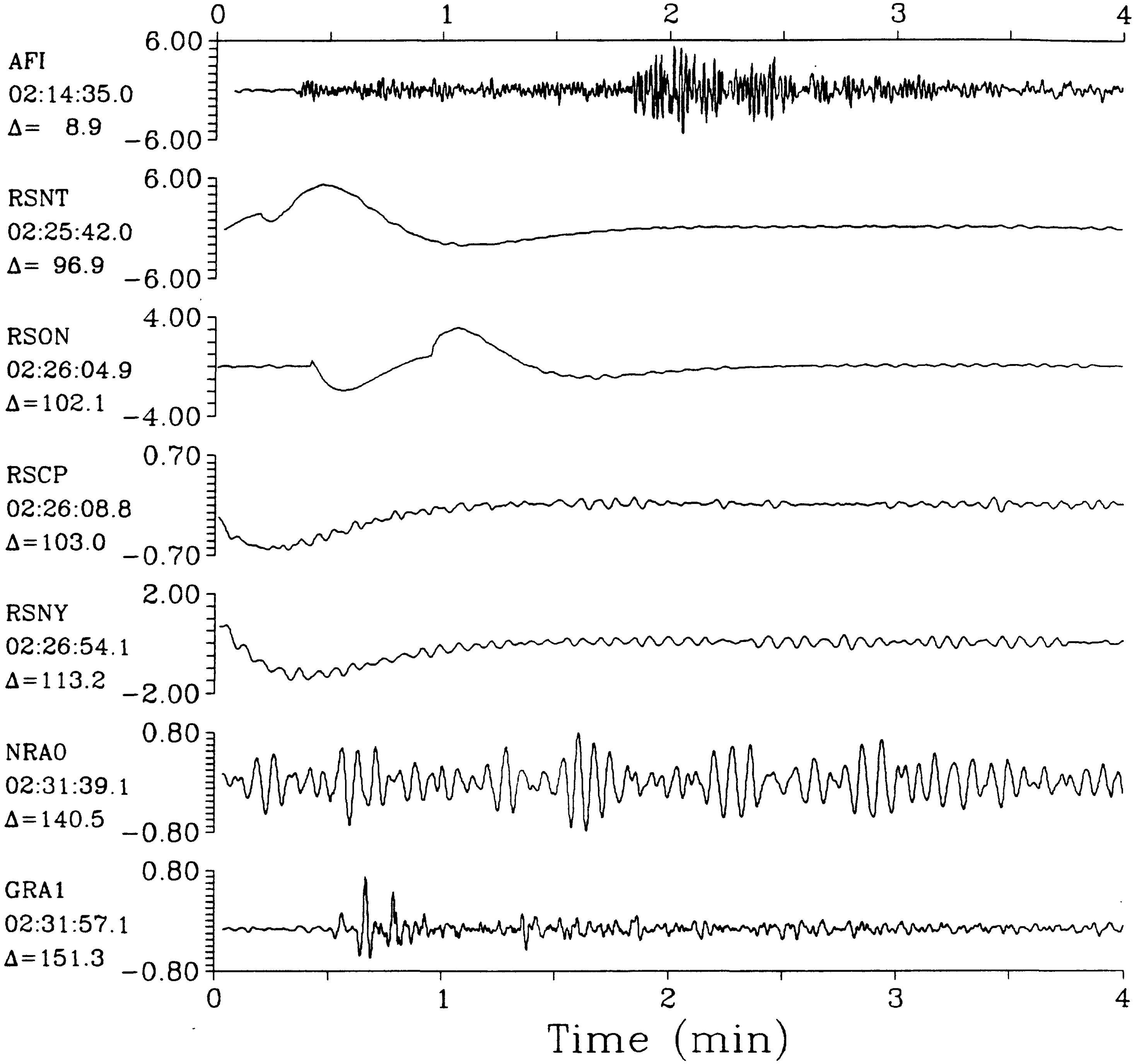
1816



LPZ
12 October 1985 02:12:58.32
LPZ
Fiji Islands Region h=157.4 m_b=5.8
SLR
02:30:44.4
Δ=127.2
KEV
02:30:49.4
Δ=129.8
NRAO
02:31:09.1
Δ=140.5
KONO
02:31:11.3
Δ=141.8
ANTO
02:31:23.8
Δ=149.1
GRFO
02:31:27.1
Δ=151.3
BCAO
02:31:35.8
Δ=157.5
TOL
02:31:39.5
Δ=160.7
Time (min)

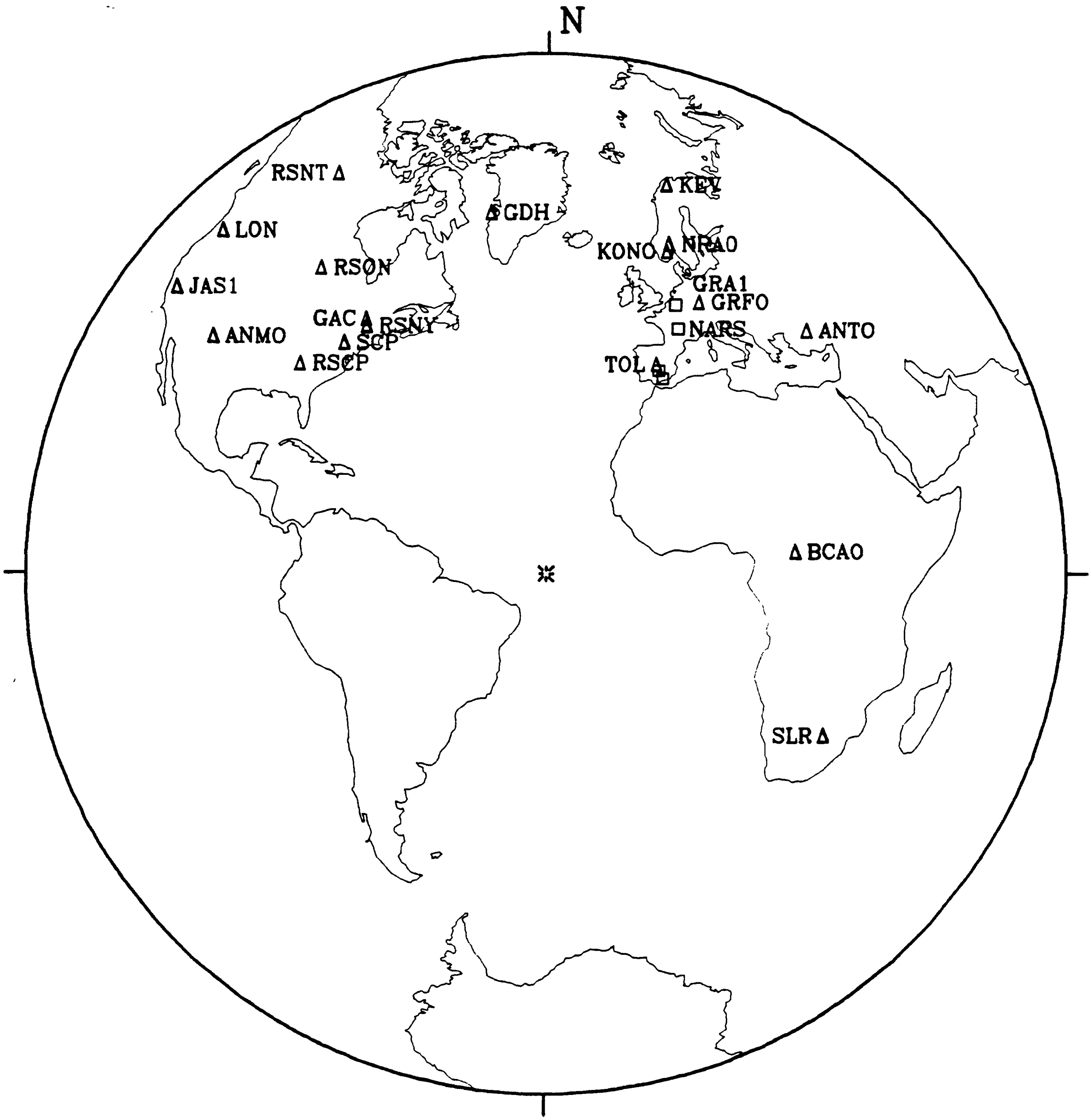
IPZ 12 October 1985 02:12:58.32 IPZ

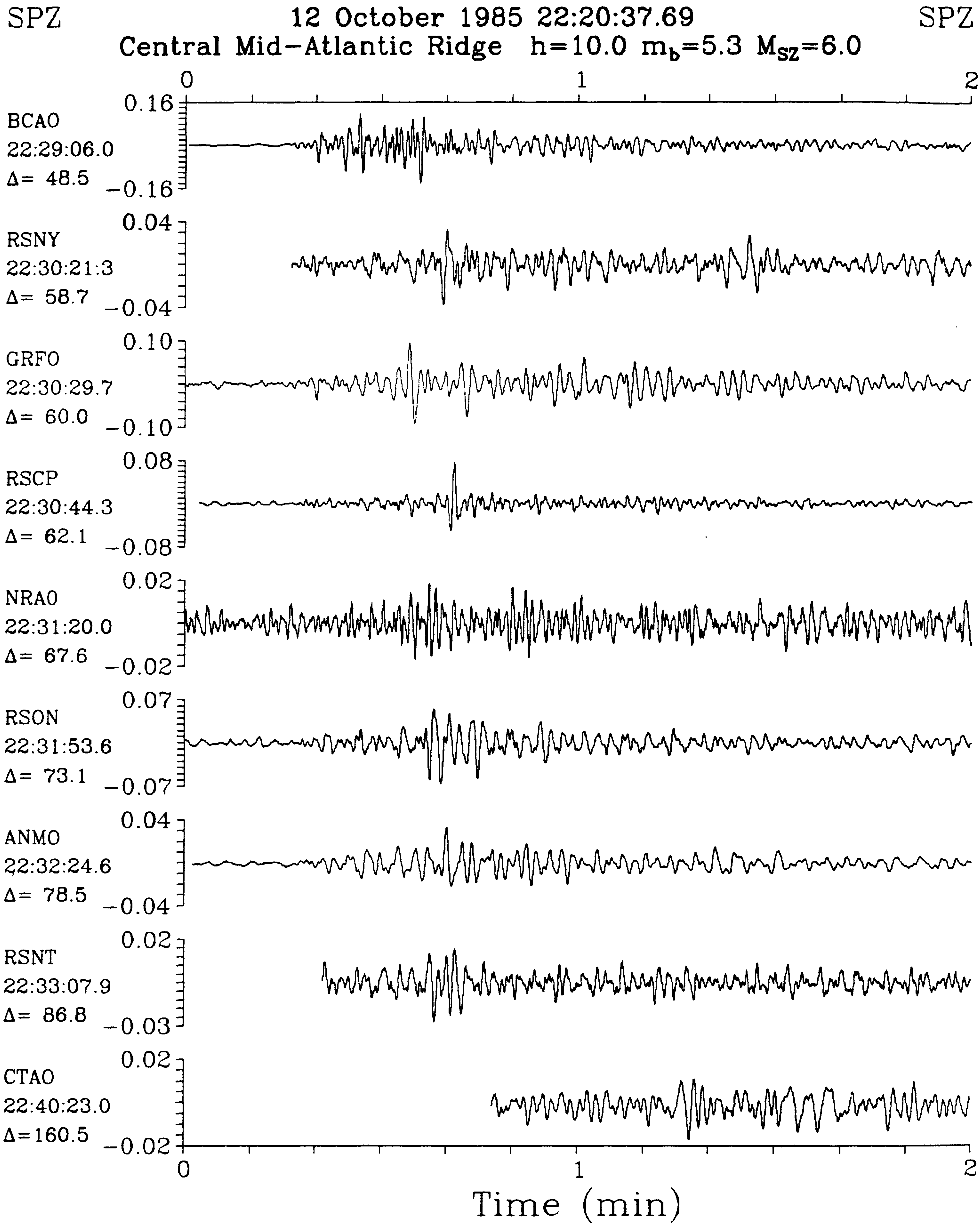
Fiji Islands Region h=157.4 m_b=5.8

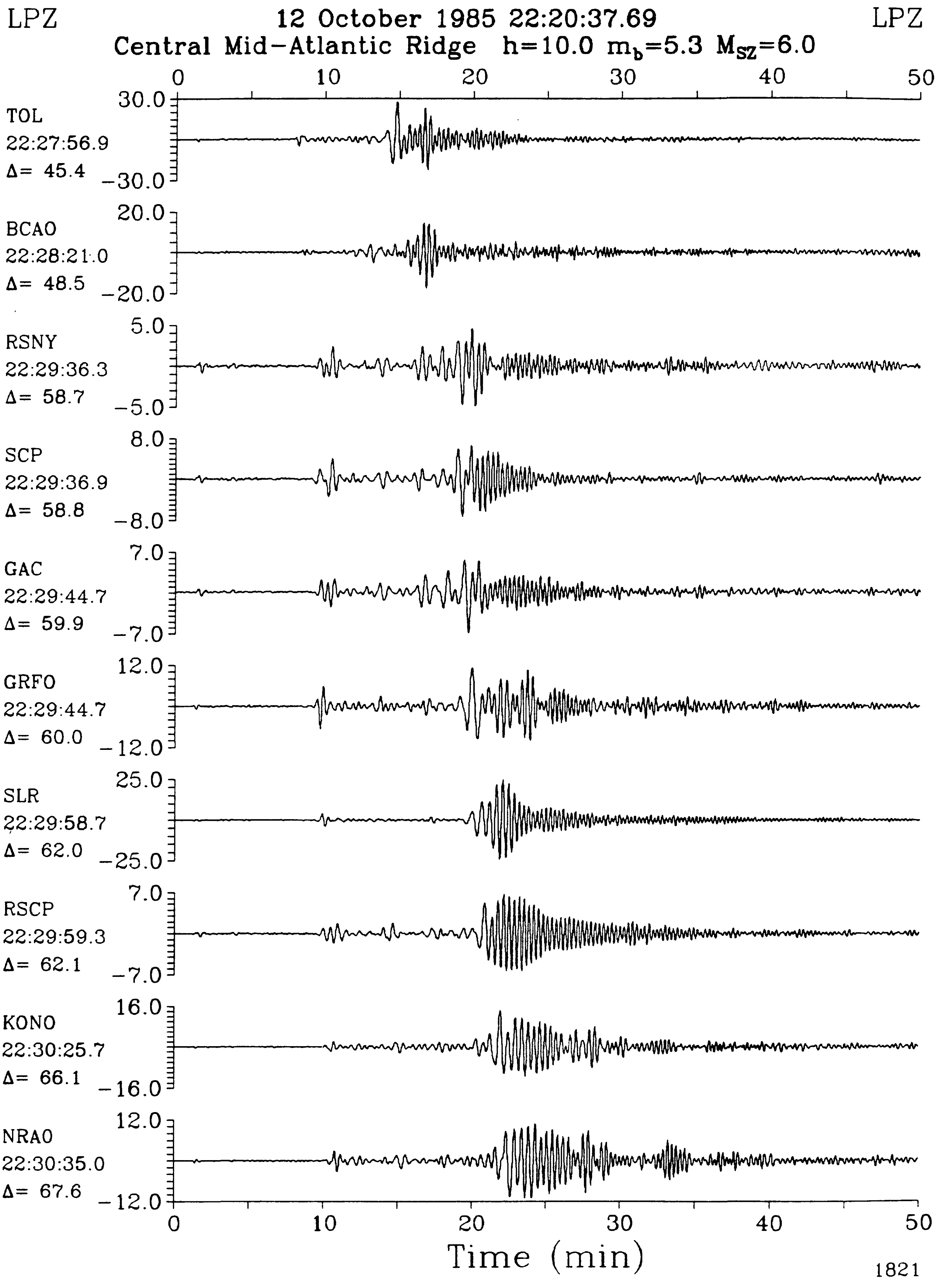


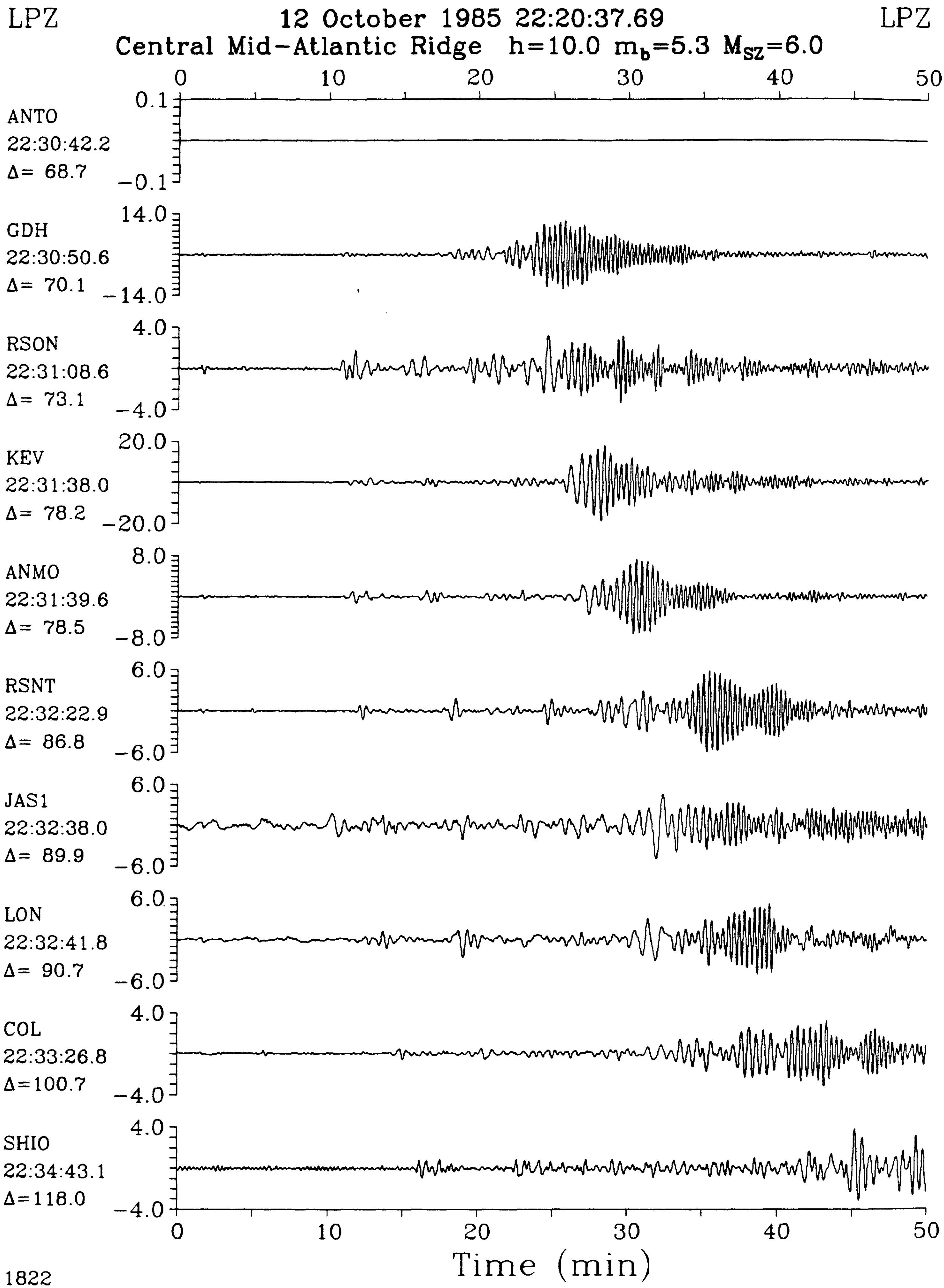
12 October 1985 22:20:37.69

Central Mid-Atlantic Ridge




SPZ
12 October 1985 22:20:37.69
SPZ
Central Mid-Atlantic Ridge h=10.0 m_b=5.3 M_SZ=6.0
0
1
2
BCAO
22:29:06.0
Δ= 48.5
0.16
−0.16
RSNY
22:30:21:3
Δ= 58.7
0.04
−0.04
GRFO
22:30:29.7
Δ= 60.0
0.10
−0.10
RSCP
22:30:44.3
Δ= 62.1
0.08
−0.08
NRAO
22:31:20.0
Δ= 67.6
0.02
−0.02
RSON
22:31:53.6
Δ= 73.1
0.07
−0.07
ANMO
22:32:24.6
Δ= 78.5
0.04
−0.04
RSNT
22:33:07.9
Δ= 86.8
0.02
−0.03
CTAO
22:40:23.0
Δ=160.5
0.02
−0.02
0
1
2
Time (min)

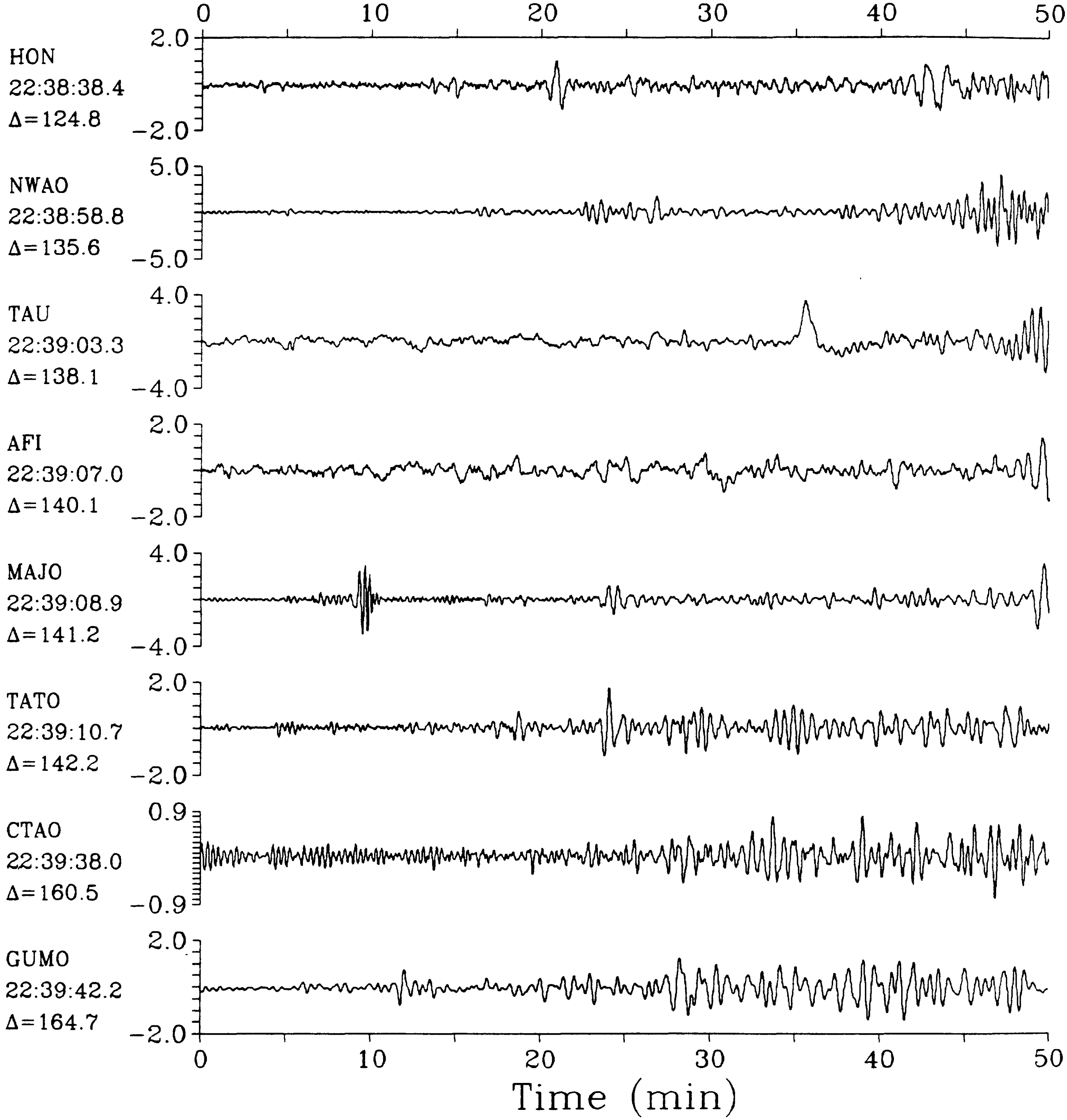

LPZ
12 October 1985 22:20:37.69
LPZ
Central Mid-Atlantic Ridge h=10.0 m_b=5.3 M_{SZ}=6.0
0 10 20 30 40 50
TOL
22:27:56.9
Δ= 45.4
30.0
−30.0
BCAO
22:28:21.0
Δ= 48.5
20.0
−20.0
RSNY
22:29:36.3
Δ= 58.7
5.0
−5.0
SCP
22:29:36.9
Δ= 58.8
8.0
−8.0
GAC
22:29:44.7
Δ= 59.9
7.0
−7.0
GRFO
22:29:44.7
Δ= 60.0
12.0
−12.0
SLR
22:29:58.7
Δ= 62.0
25.0
−25.0
RSCP
22:29:59.3
Δ= 62.1
7.0
−7.0
KONO
22:30:25.7
Δ= 66.1
16.0
−16.0
NRAO
22:30:35.0
Δ= 67.6
12.0
−12.0
0 10 20 30 40 50
Time (min)
1821


LPZ
12 October 1985 22:20:37.69
Central Mid-Atlantic Ridge h=10.0 m_b=5.3 M_{SZ}=6.0
LPZ
ANTO
22:30:42.2
Δ= 68.7
GDH
22:30:50.6
Δ= 70.1
RSON
22:31:08.6
Δ= 73.1
KEV
22:31:38.0
Δ= 78.2
ANMO
22:31:39.6
Δ= 78.5
RSNT
22:32:22.9
Δ= 86.8
JAS1
22:32:38.0
Δ= 89.9
LON
22:32:41.8
Δ= 90.7
COL
22:33:26.8
Δ=100.7
SHIO
22:34:43.1
Δ=118.0
0.1
−0.1
14.0
−14.0
4.0
−4.0
20.0
−20.0
8.0
−8.0
6.0
−6.0
0 10 20 30 40 50
Time (min)

1822

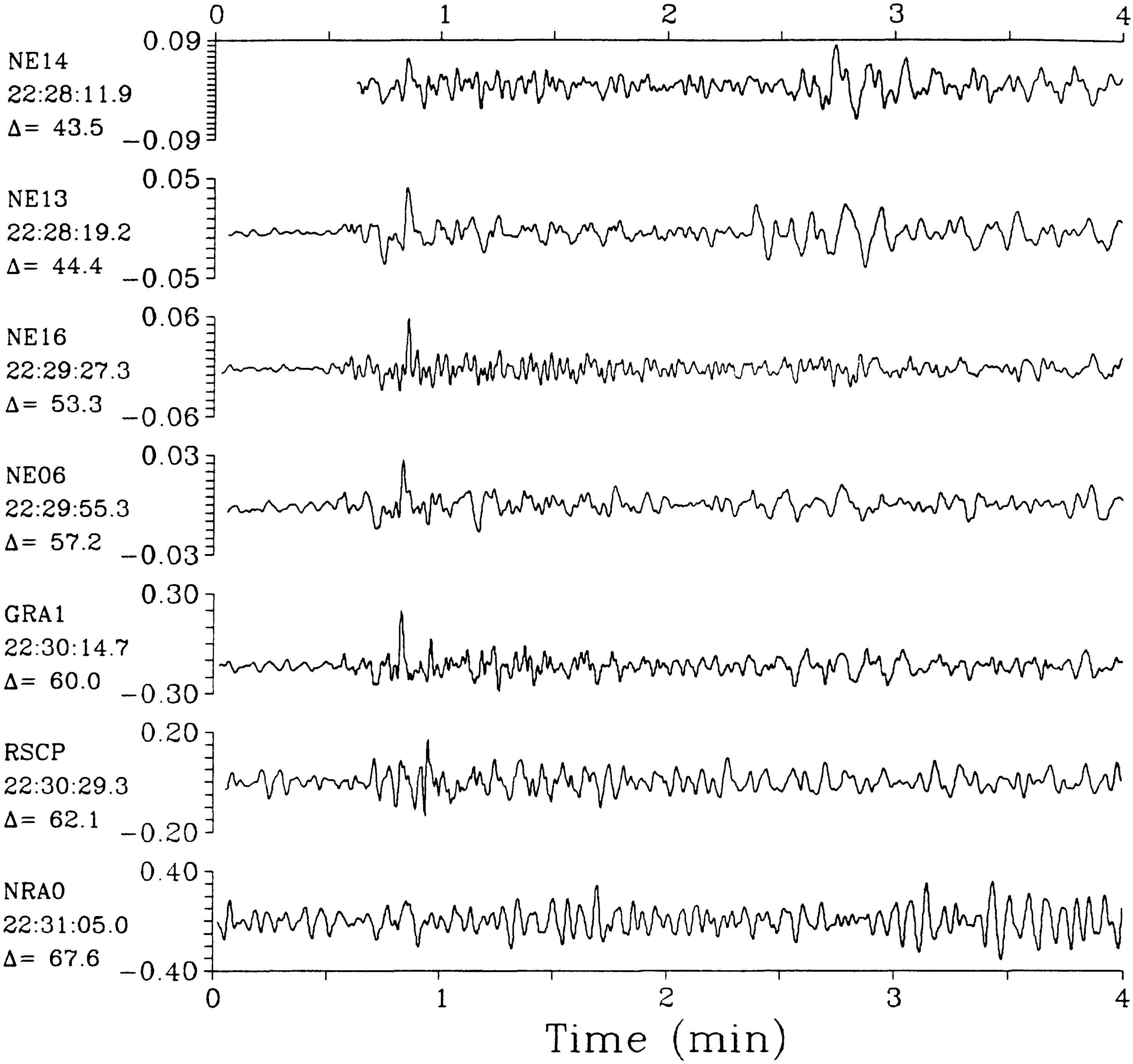
LPZ 12 October 1985 22:20:37.69 LPZ

Central Mid-Atlantic Ridge $h=10.0$ $m_b=5.3$ $M_{SZ}=6.0$



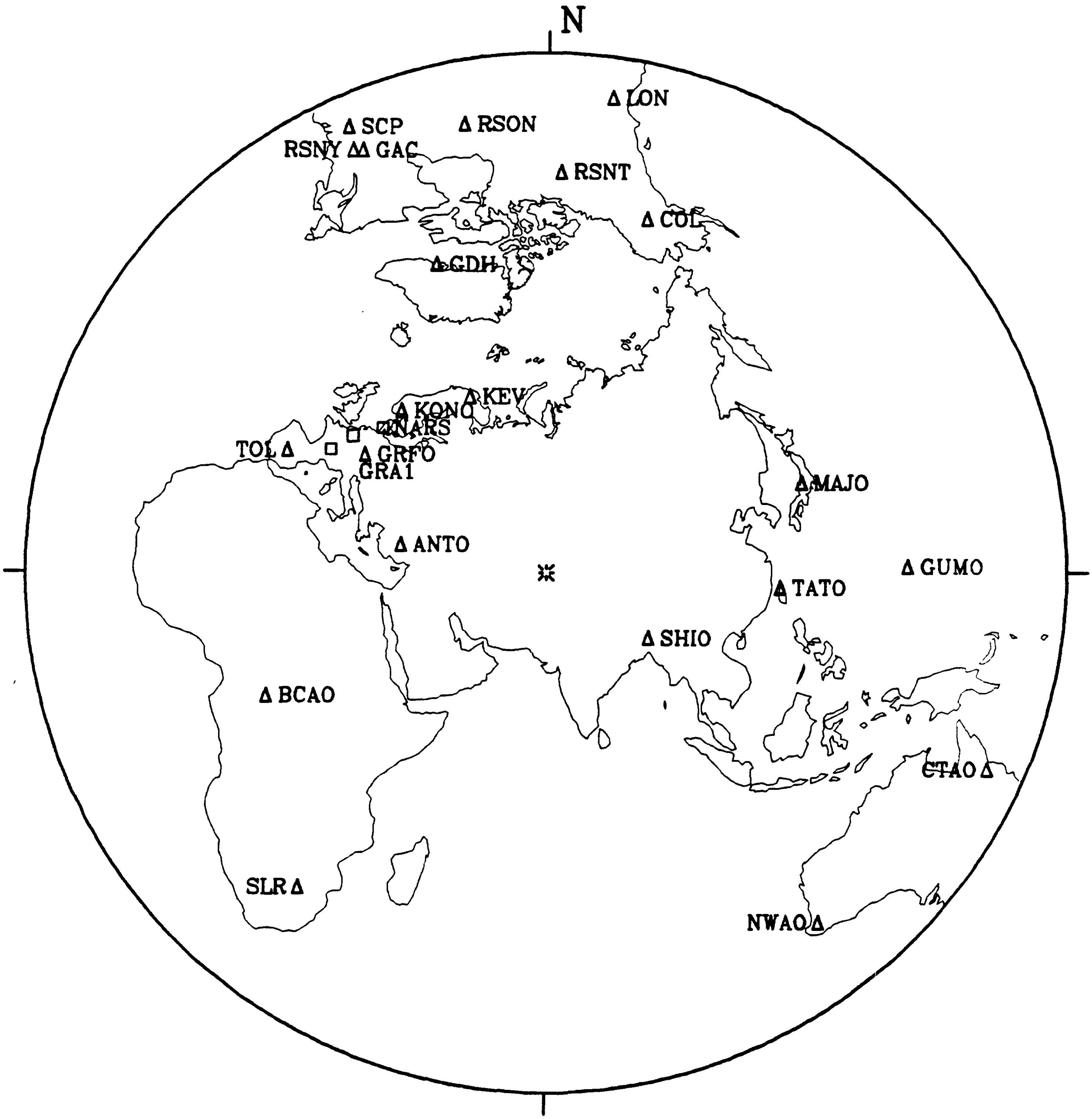
IPZ 12 October 1985 22:20:37.69 IPZ

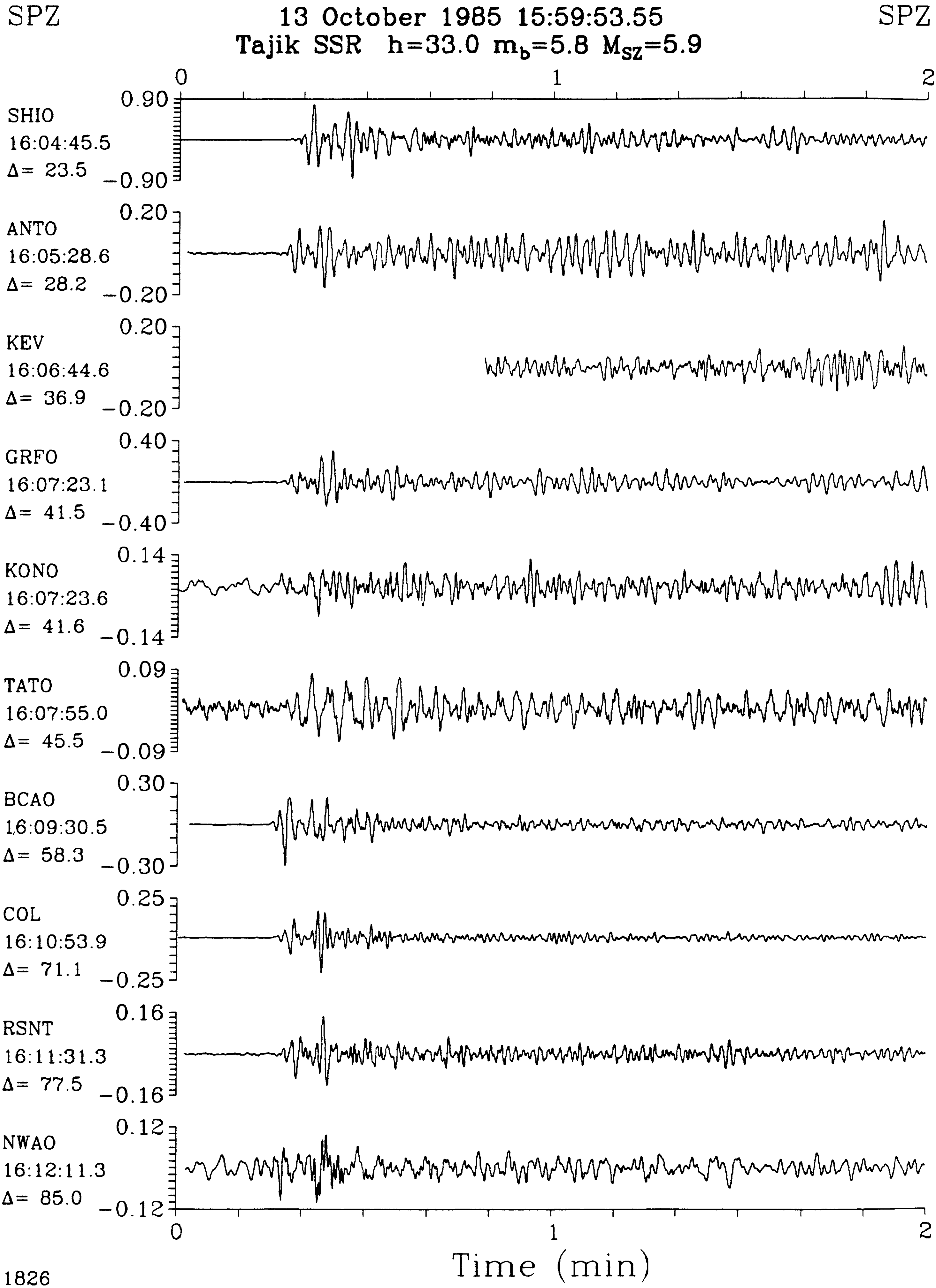
Central Mid-Atlantic Ridge h=10.0 m_b=5.3 M_{SZ}=6.0



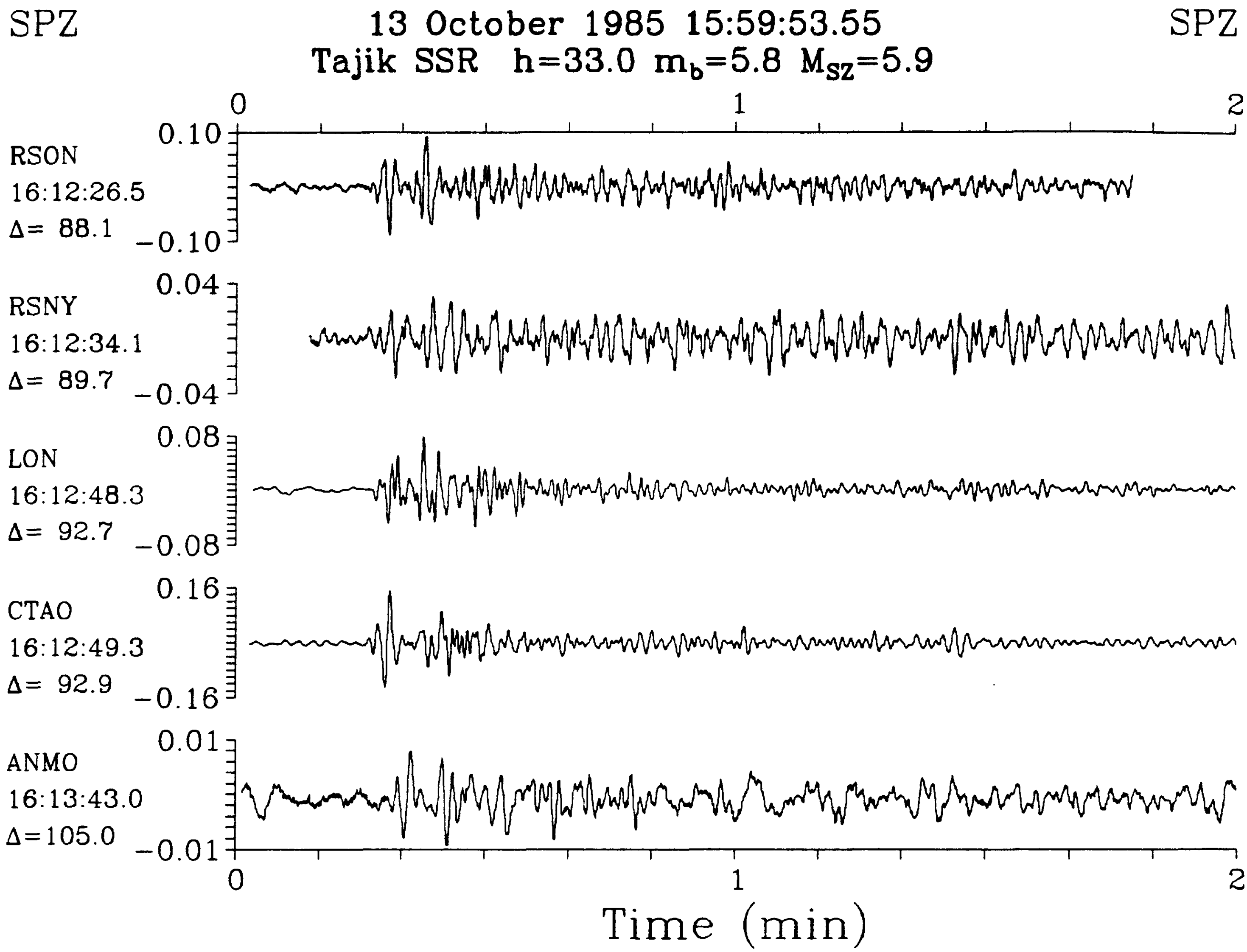
13 October 1985 15:59:53.55

Tajik SSR



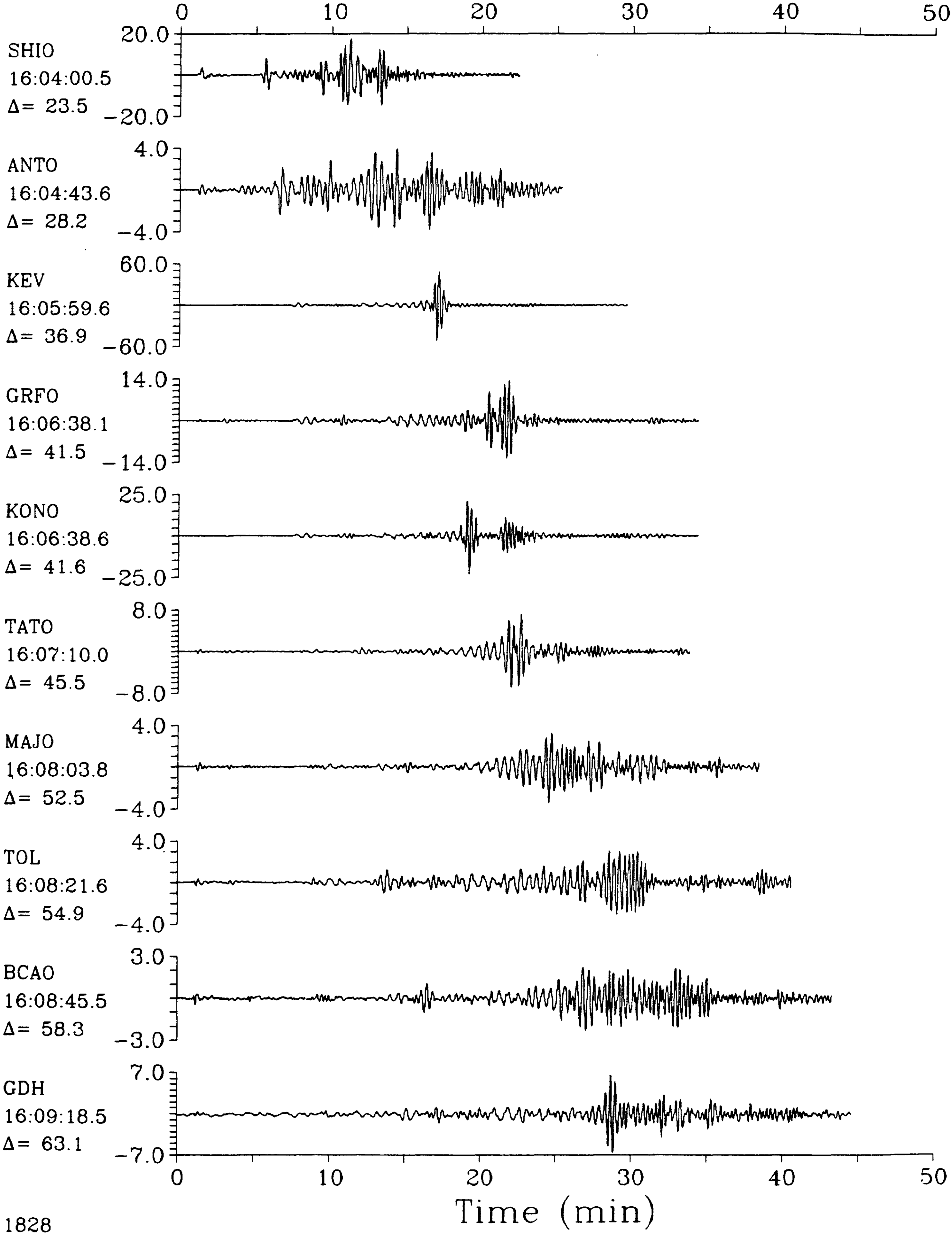

SPZ
13 October 1985 15:59:53.55
Tajik SSR h=33.0 m_b=5.8 M_{SZ}=5.9
SPZ
SHIO 16:04:45.5 Δ= 23.5
ANTO 16:05:28.6 Δ= 28.2
KEV 16:06:44.6 Δ= 36.9
GRFO 16:07:23.1 Δ= 41.5
KONO 16:07:23.6 Δ= 41.6
TATO 16:07:55.0 Δ= 45.5
BCAO 16:09:30.5 Δ= 58.3
COL 16:10:53.9 Δ= 71.1
RSNT 16:11:31.3 Δ= 77.5
NWAO 16:12:11.3 Δ= 85.0
Time (min)

1826


SPZ
13 October 1985 15:59:53.55
Tajik SSR h=33.0 m_b=5.8 M_{SZ}=5.9
SPZ
RSON
16:12:26.5
Δ= 88.1
0.10
−0.10
RSNY
16:12:34.1
Δ= 89.7
0.04
−0.04
LON
16:12:48.3
Δ= 92.7
0.08
−0.08
CTAO
16:12:49.3
Δ= 92.9
0.16
−0.16
ANMO
16:13:43.0
Δ=105.0
0.01
−0.01
0
1
2
Time (min)

LPZ 13 October 1985 15:59:53.55 LPZ

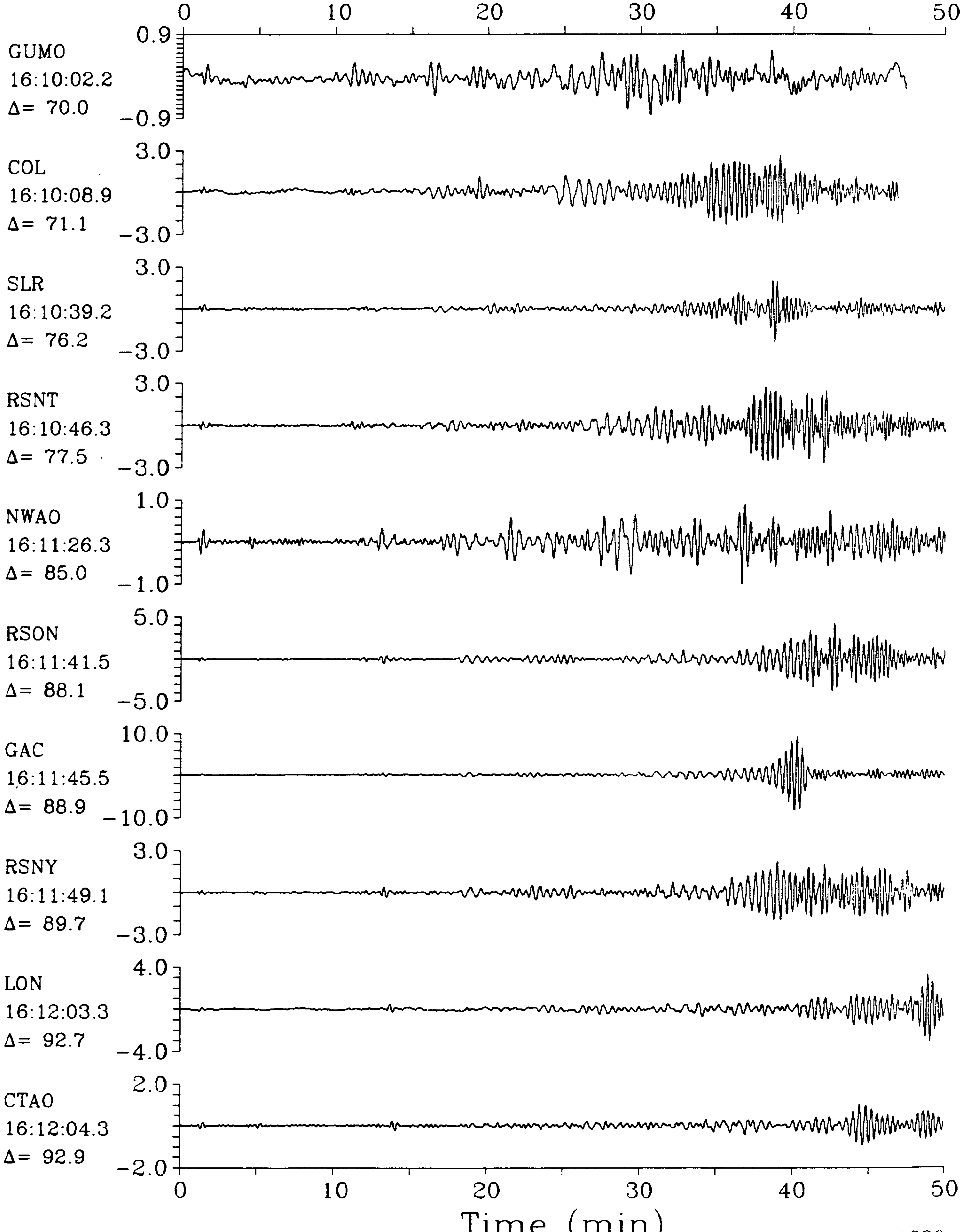
Tajik SSR h=33.0 m_b=5.8 M_{SZ}=5.9



1828

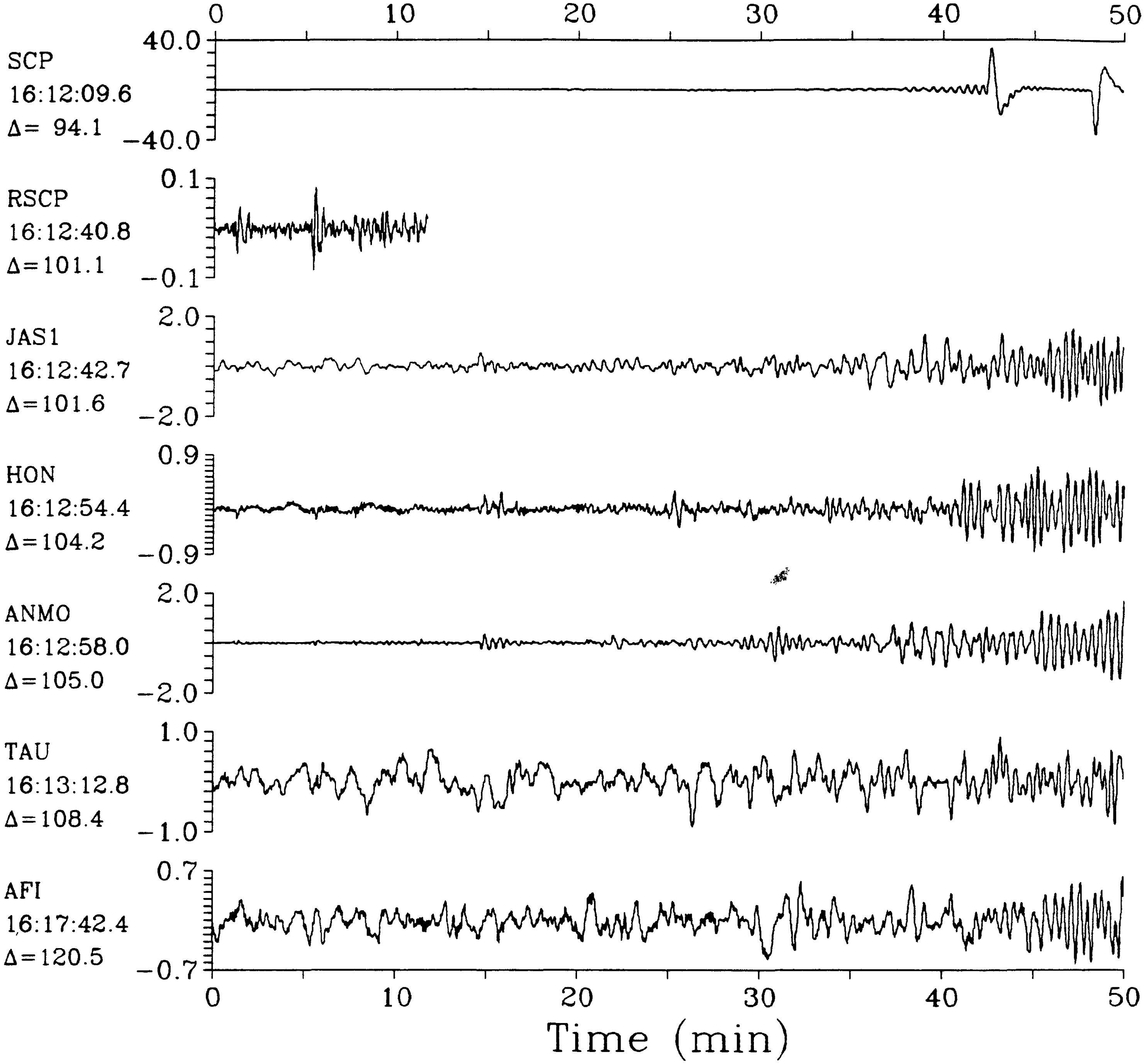
LPZ 13 October 1985 15:59:53.55 LPZ

Tajik SSR h=33.0 m_b=5.8 M_{SZ}=5.9



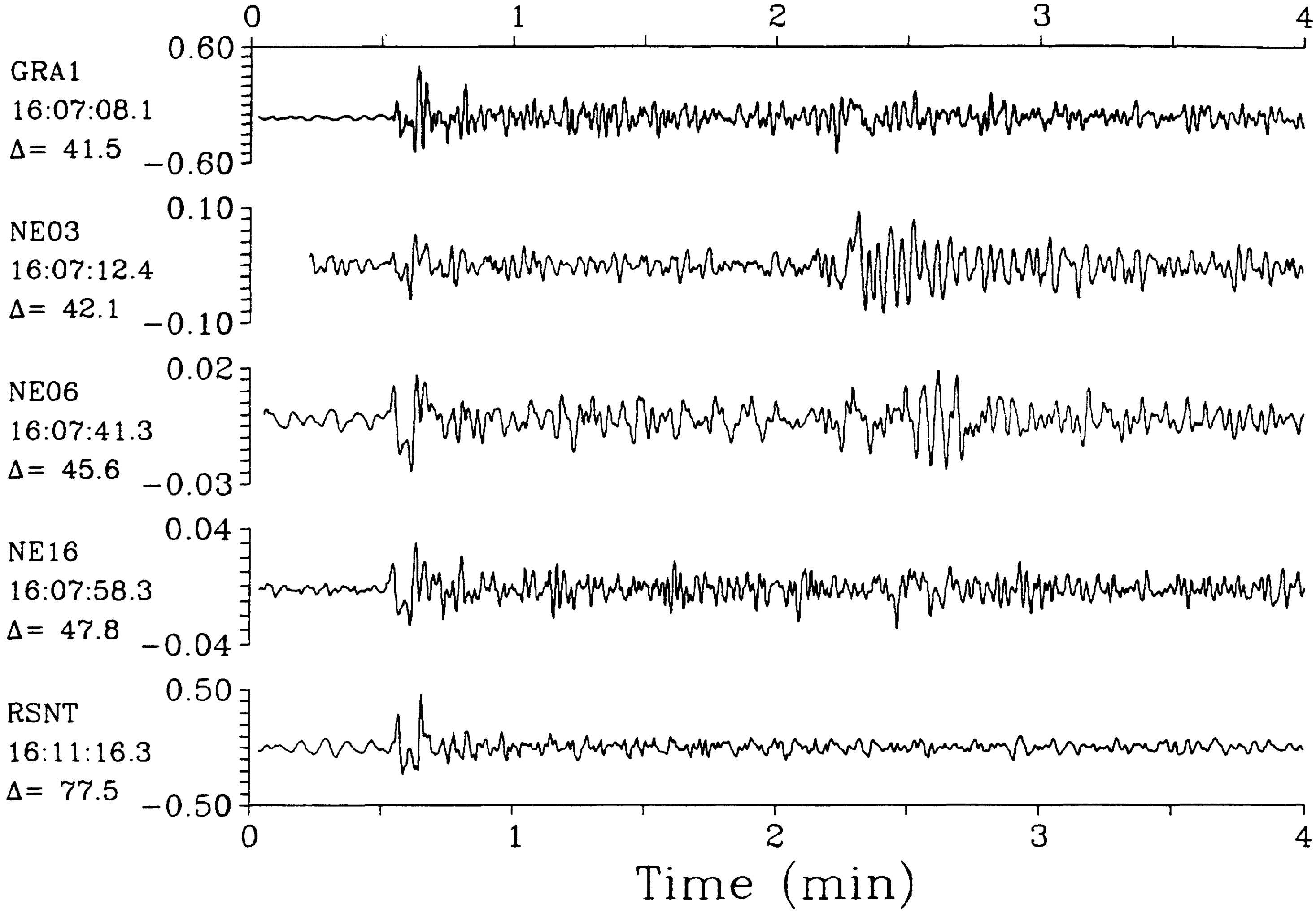
LPZ 13 October 1985 15:59:53.55 LPZ

Tajik SSR h=33.0 m_b=5.8 M_{SZ}=5.9



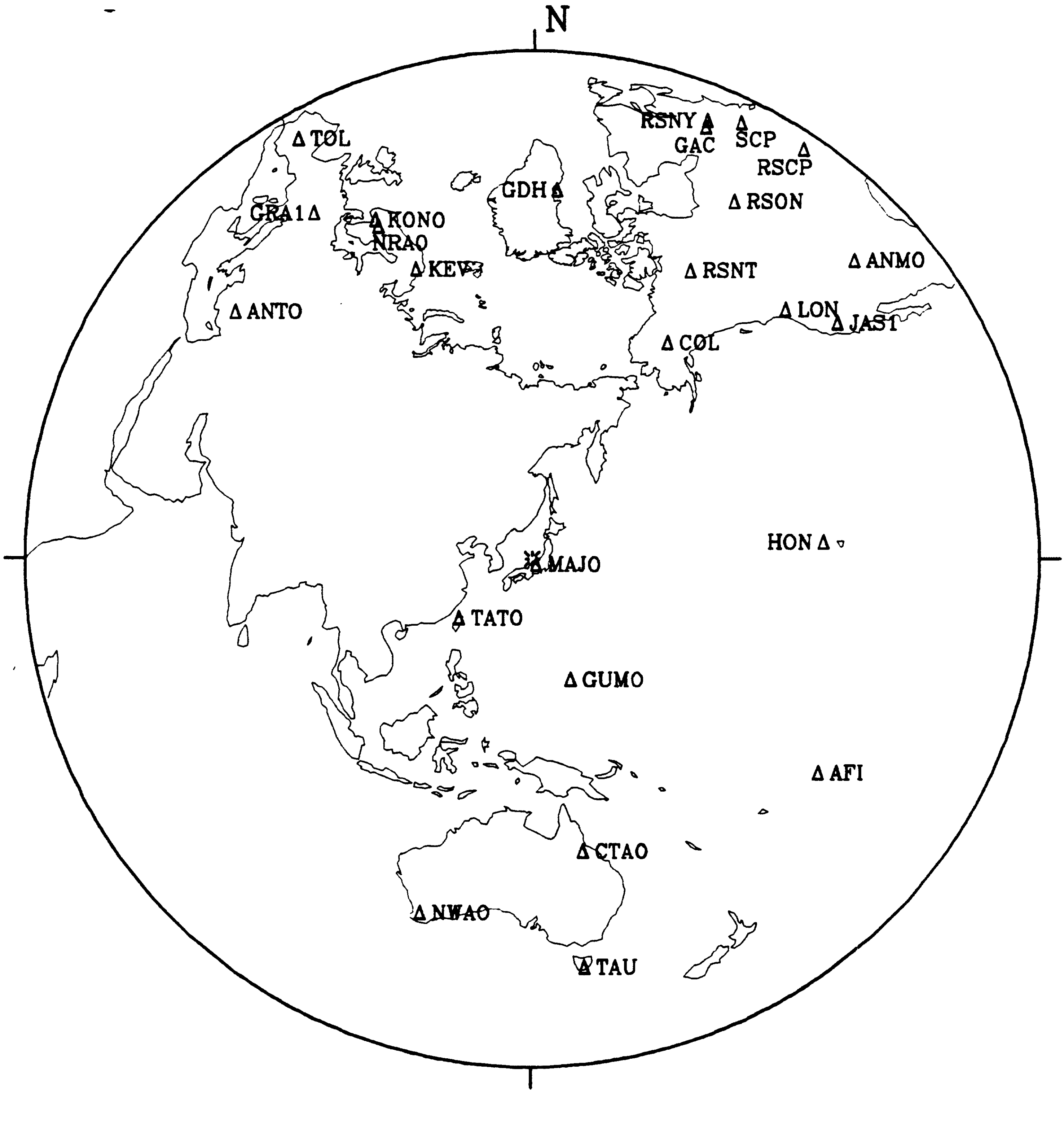
IPZ **13 October 1985 15:59:53.55** IPZ

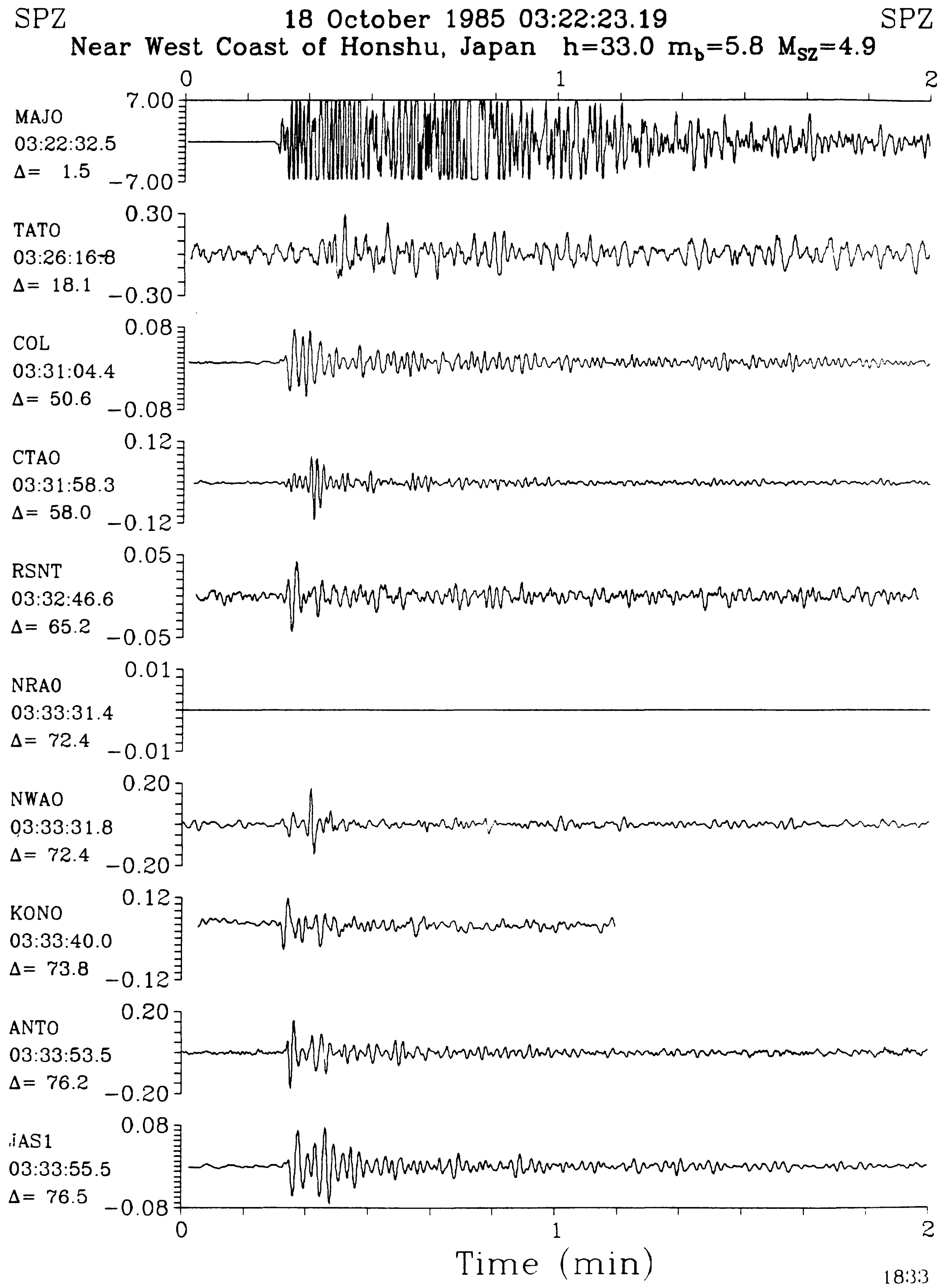
Tajik SSR h=33.0 m_b=5.8 M_{SZ}=5.9



18 October 1985 03:22:23.19

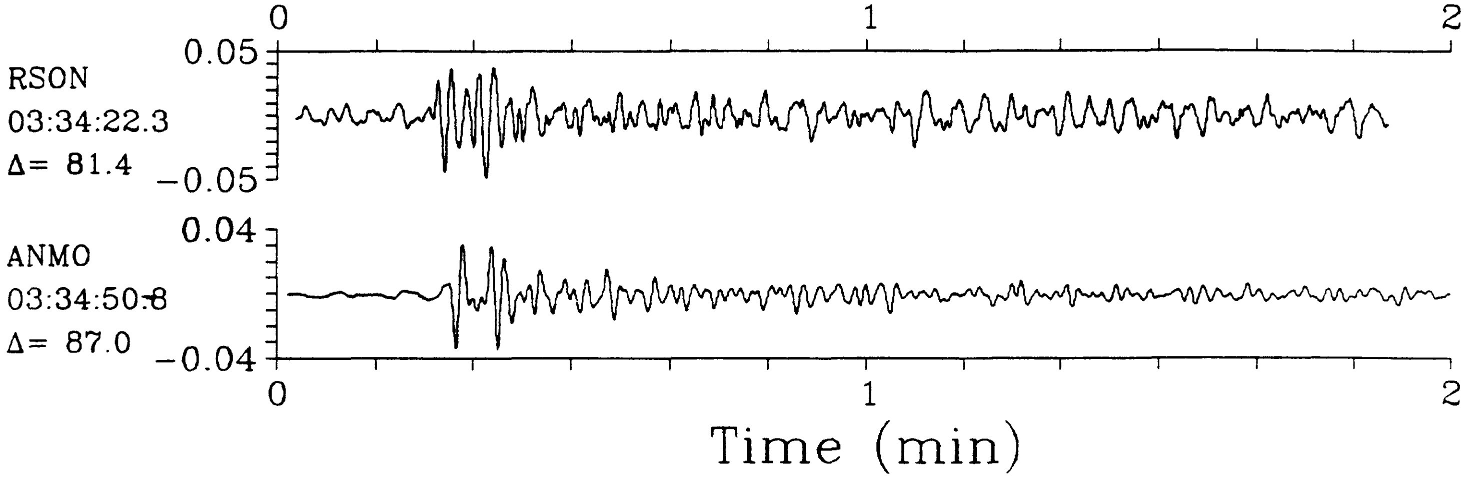
Near West Coast of Honshu, Japan

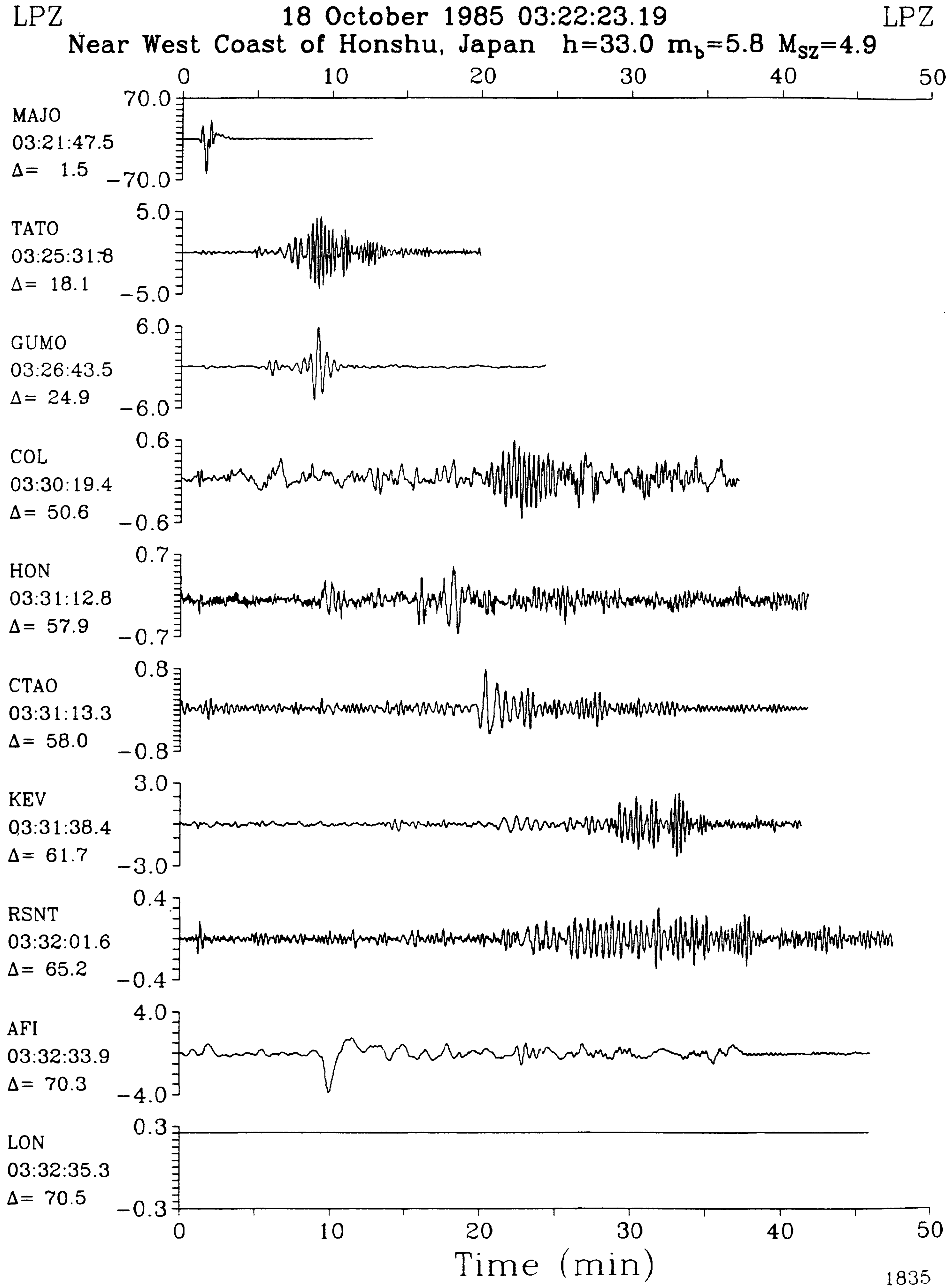



SPZ
18 October 1985 03:22:23.19
SPZ
Near West Coast of Honshu, Japan h=33.0 m_b=5.8 M_{SZ}=4.9
MAJO
03:22:32.5
Δ= 1.5
7.00
−7.00
TATO
03:26:16.8
Δ= 18.1
0.30
−0.30
COL
03:31:04.4
Δ= 50.6
0.08
−0.08
CTAO
03:31:58.3
Δ= 58.0
0.12
−0.12
RSNT
03:32:46.6
Δ= 65.2
0.05
−0.05
NRAO
03:33:31.4
Δ= 72.4
0.01
−0.01
NWAO
03:33:31.8
Δ= 72.4
0.20
−0.20
KONO
03:33:40.0
Δ= 73.8
0.12
−0.12
ANTO
03:33:53.5
Δ= 76.2
0.20
−0.20
JAS1
03:33:55.5
Δ= 76.5
0.08
−0.08
0
1
2
Time (min)
18:33

SPZ 18 October 1985 03:22:23.19 SPZ

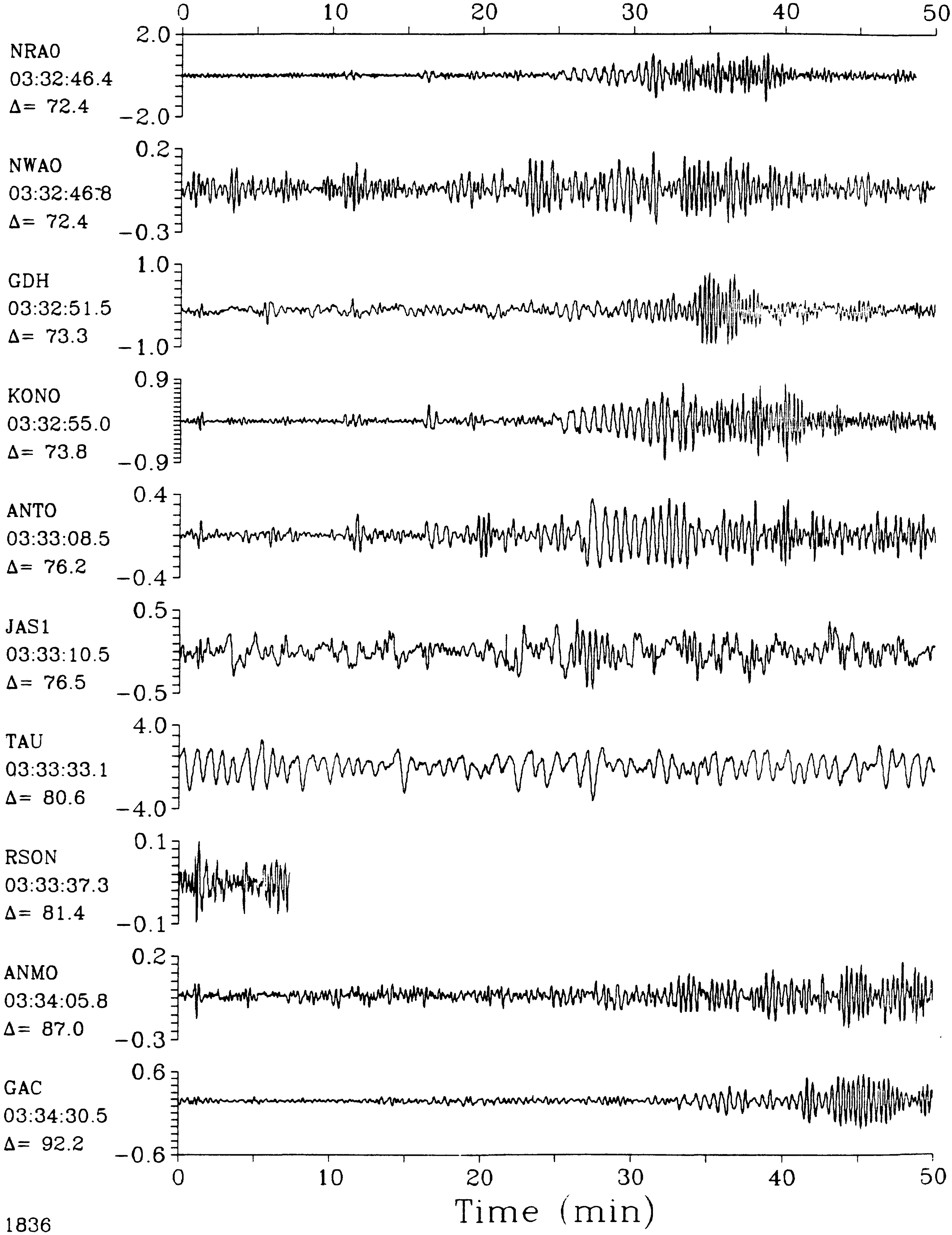
Near West Coast of Honshu, Japan h=33.0 m_b=5.8 M_{SZ}=4.9

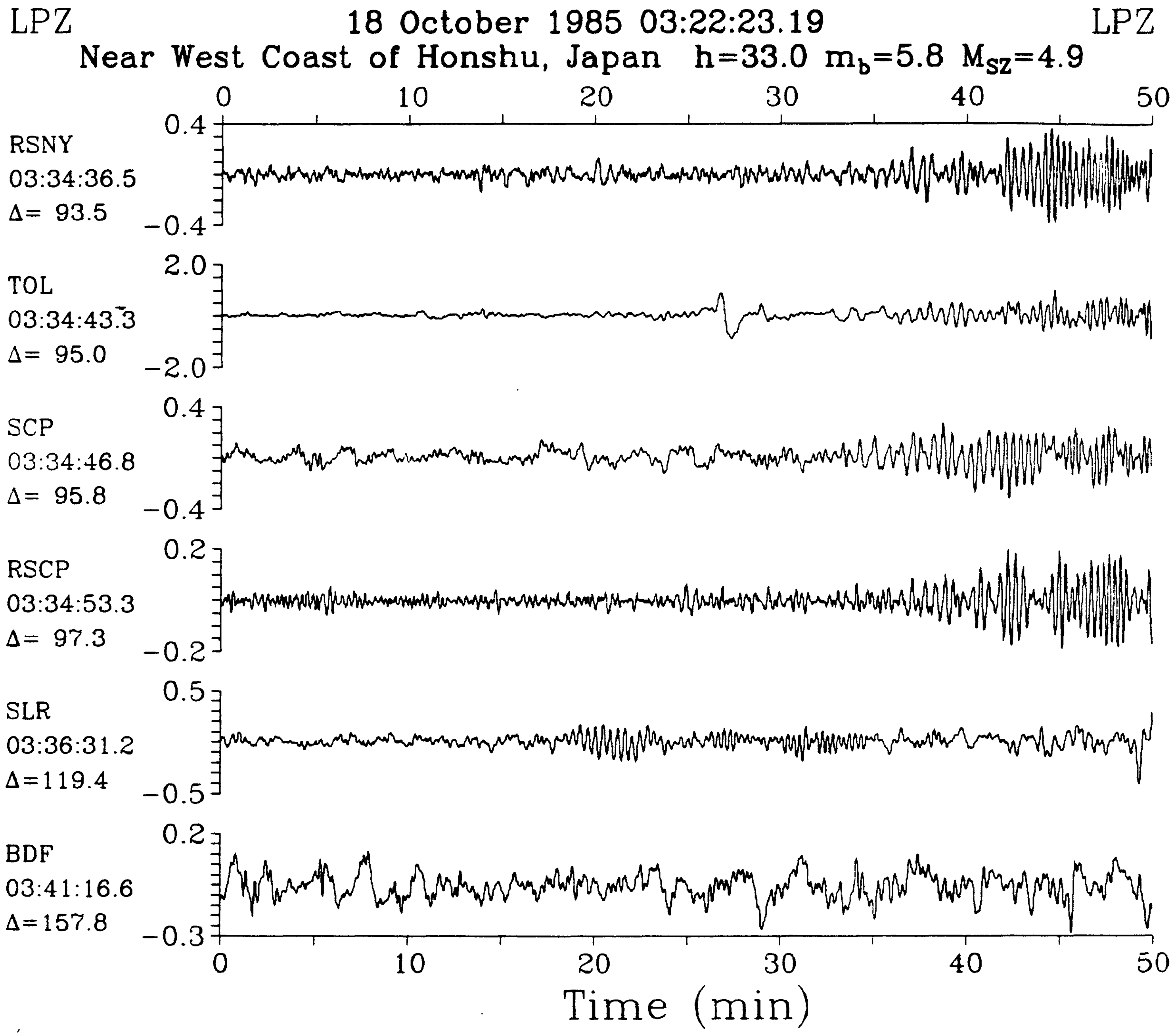



LPZ
18 October 1985 03:22:23.19
LPZ
Near West Coast of Honshu, Japan h=33.0 m_b=5.8 M_SZ=4.9
MAJO
03:21:47.5
Δ= 1.5
70.0
−70.0
TATO
03:25:31.8
Δ= 18.1
5.0
−5.0
GUMO
03:26:43.5
Δ= 24.9
6.0
−6.0
COL
03:30:19.4
Δ= 50.6
0.6
−0.6
HON
03:31:12.8
Δ= 57.9
0.7
−0.7
CTAO
03:31:13.3
Δ= 58.0
0.8
−0.8
KEV
03:31:38.4
Δ= 61.7
3.0
−3.0
RSNT
03:32:01.6
Δ= 65.2
0.4
−0.4
AFI
03:32:33.9
Δ= 70.3
4.0
−4.0
LON
03:32:35.3
Δ= 70.5
0.3
−0.3
0
10
20
30
40
50
Time (min)

LPZ 18 October 1985 03:22:23.19 LPZ

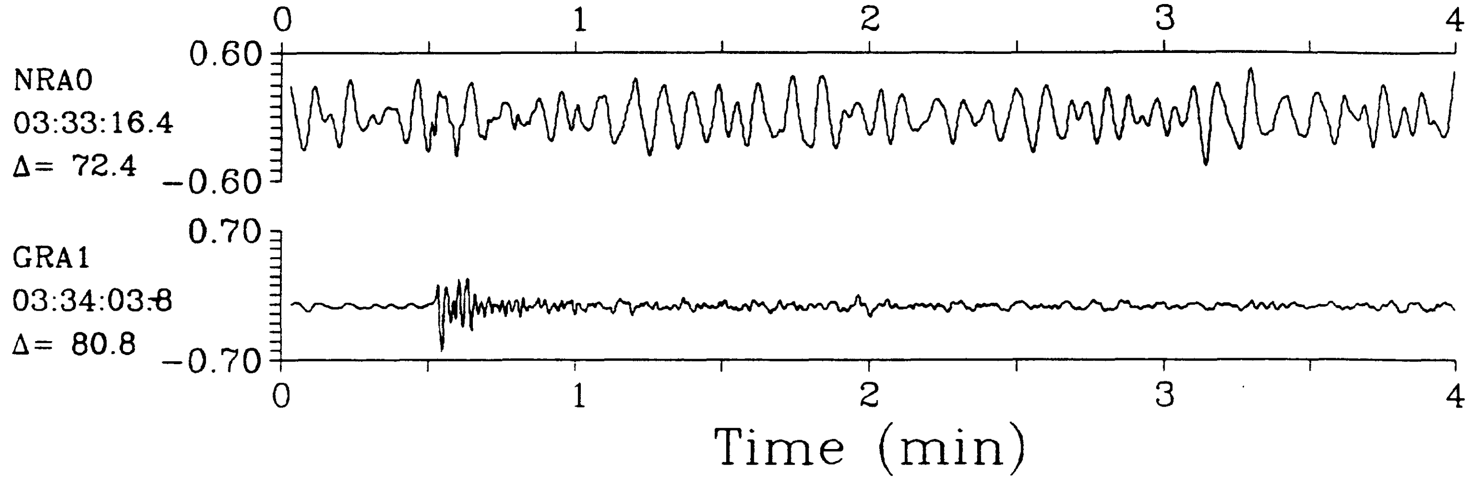
Near West Coast of Honshu, Japan $h=33.0$ $m_b=5.8$ $M_{SZ}=4.9$




LPZ
18 October 1985 03:22:23.19
LPZ
Near West Coast of Honshu, Japan h=33.0 m_b=5.8 M_SZ=4.9
RSNY
03:34:36.5
Δ= 93.5
TOL
03:34:43.3
Δ= 95.0
SCP
03:34:46.8
Δ= 95.8
RSCP
03:34:53.3
Δ= 97.3
SLR
03:36:31.2
Δ=119.4
BDF
03:41:16.6
Δ=157.8
0
10
20
30
40
50
Time (min)

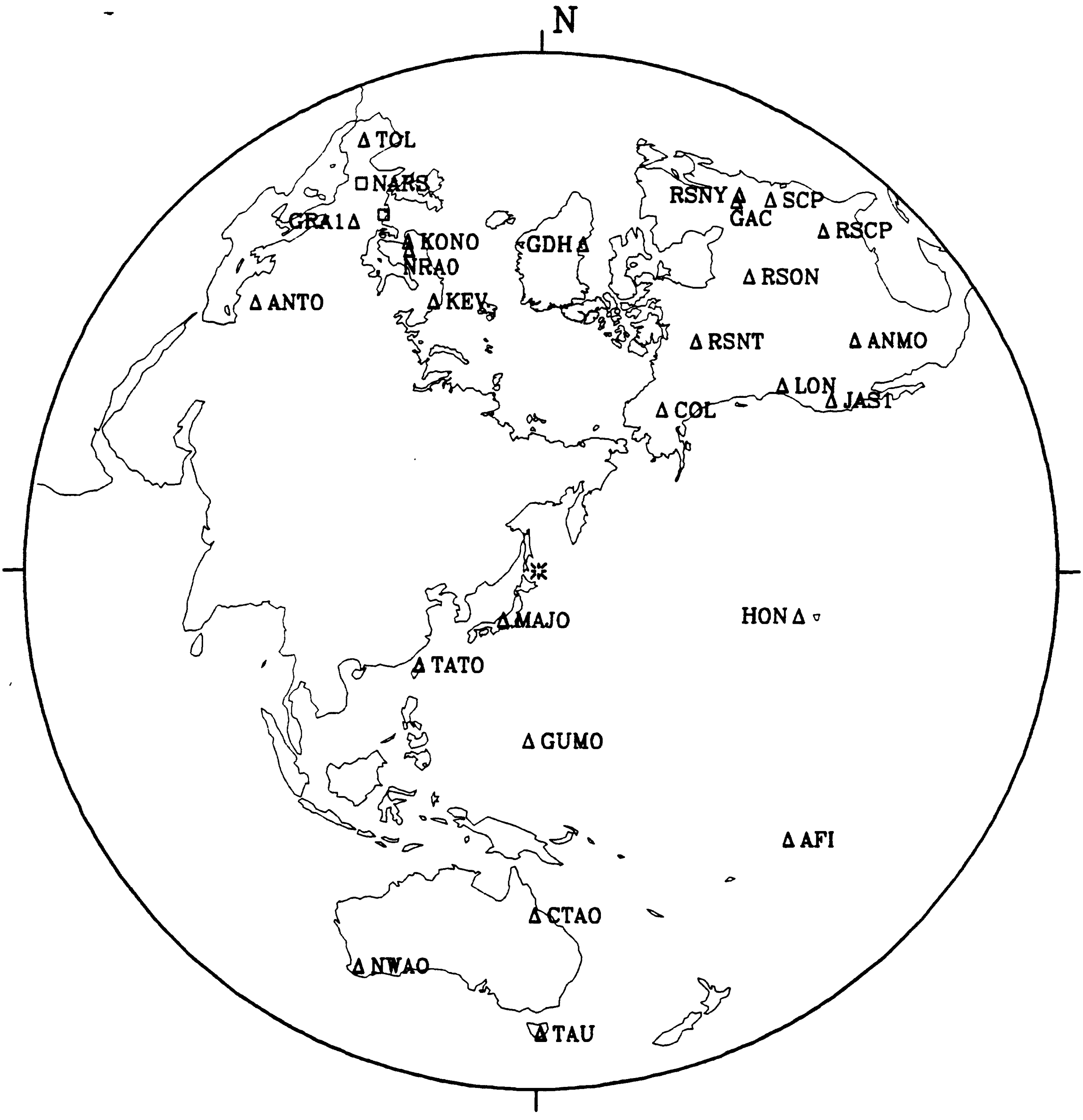
IPZ 18 October 1985 03:22:23.19 IPZ

Near West Coast of Honshu, Japan h=33.0 m_b=5.8 M_{SZ}=4.9



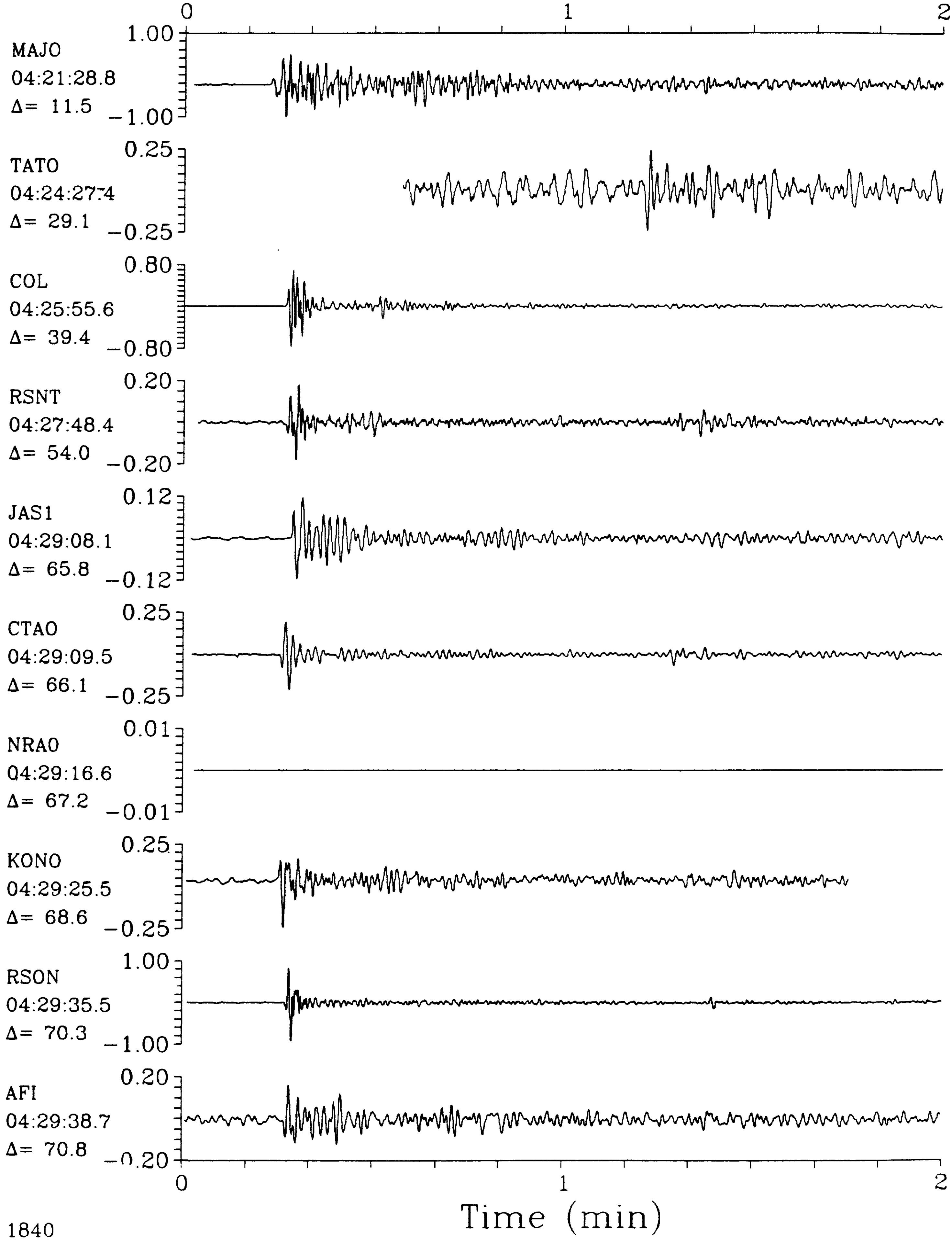
18 October 1985 04:19:08.36

Northwest of Kuril Islands



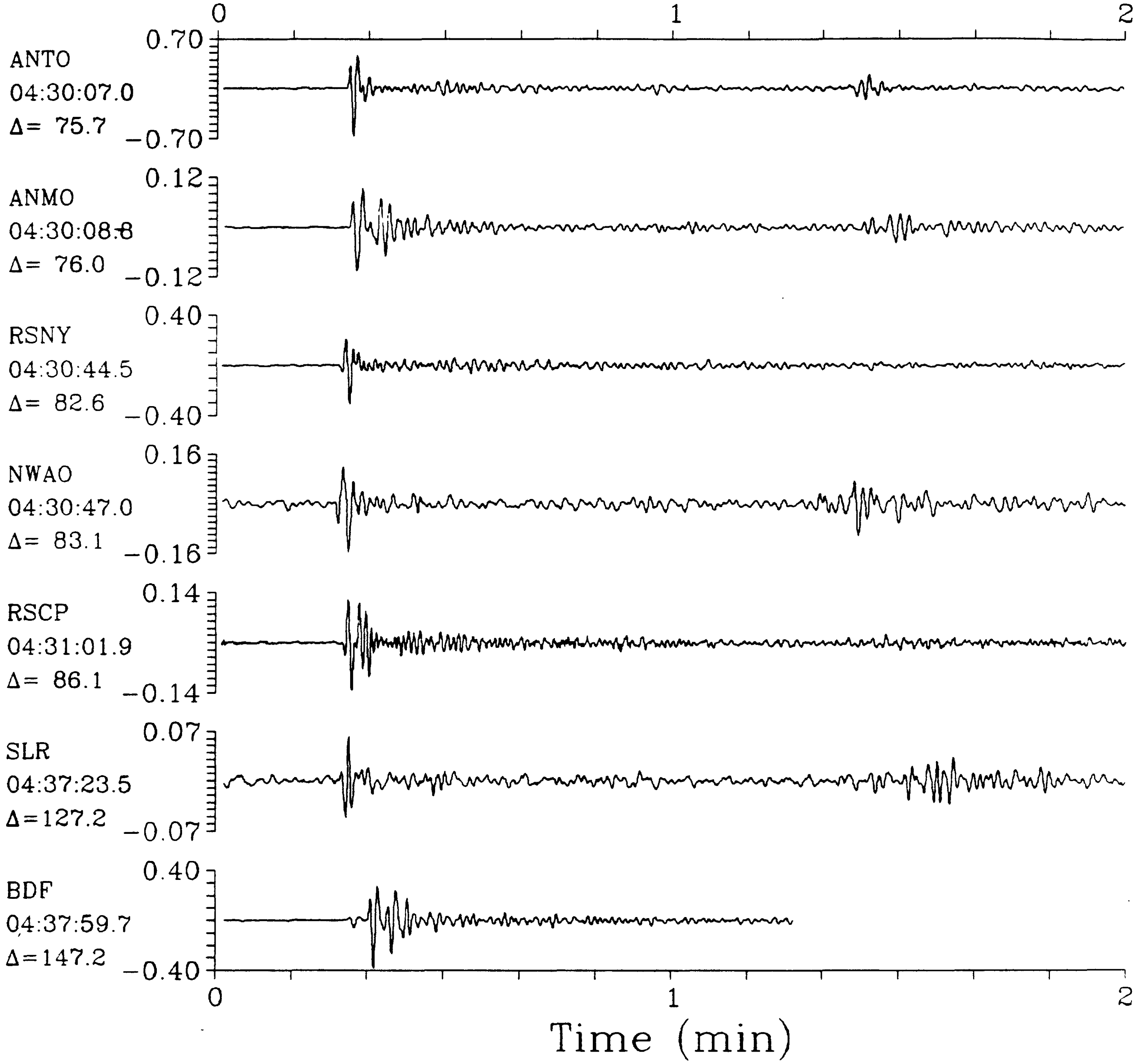
SPZ 18 October 1985 04:19:08.36 SPZ

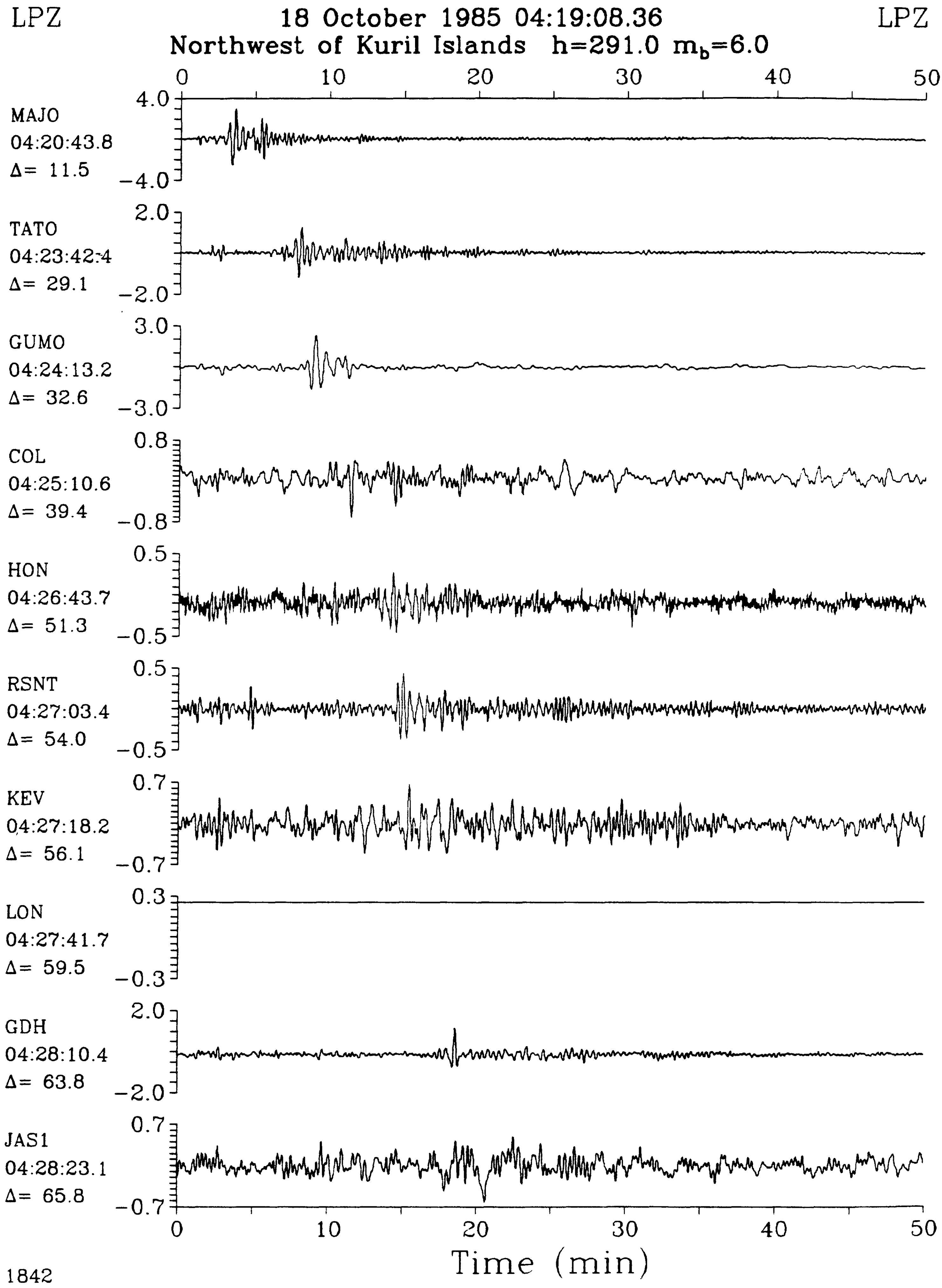
Northwest of Kuril Islands $h=291.0$ $m_b=6.0$



SPZ 18 October 1985 04:19:08.36 SPZ

Northwest of Kuril Islands h=291.0 m_b=6.0

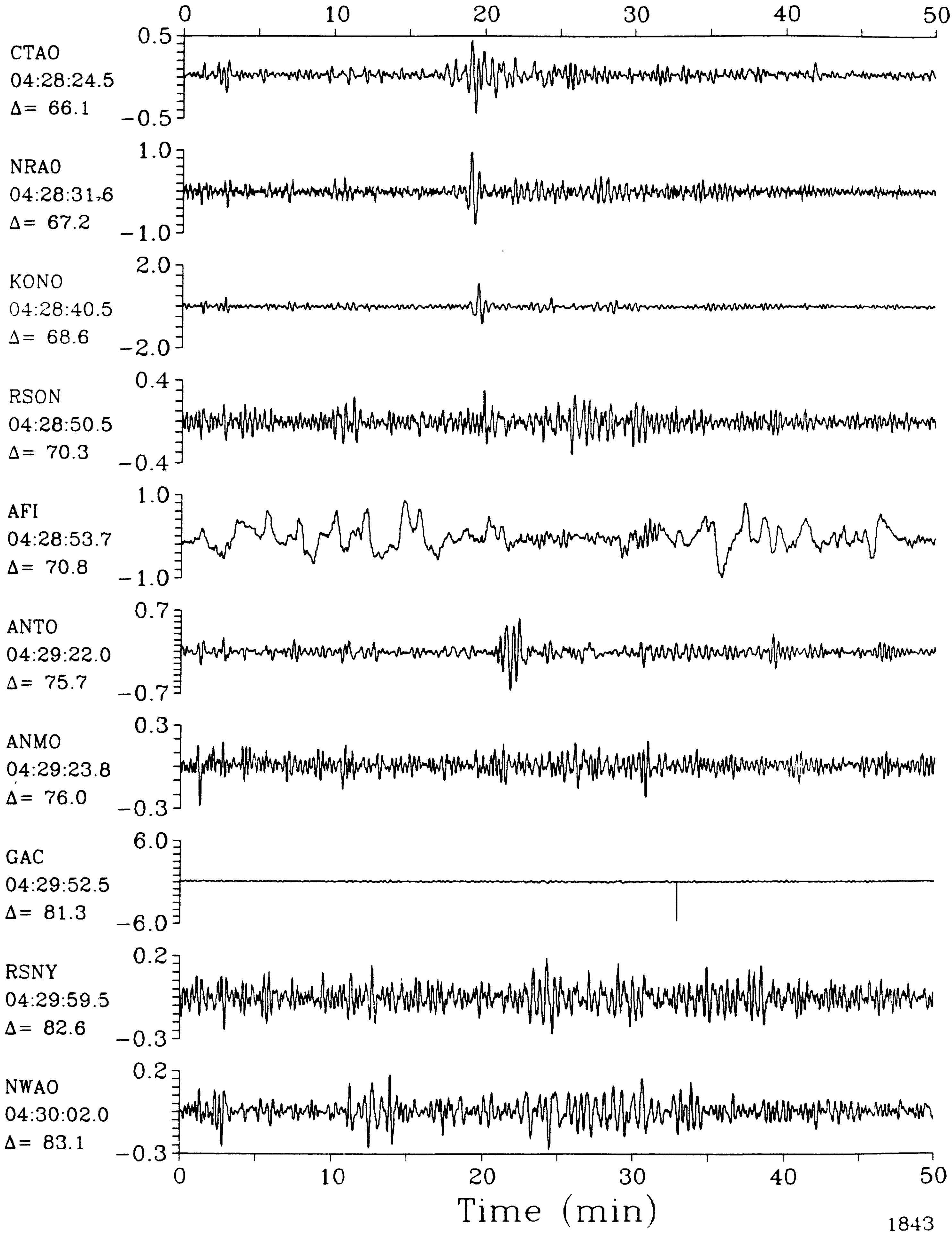


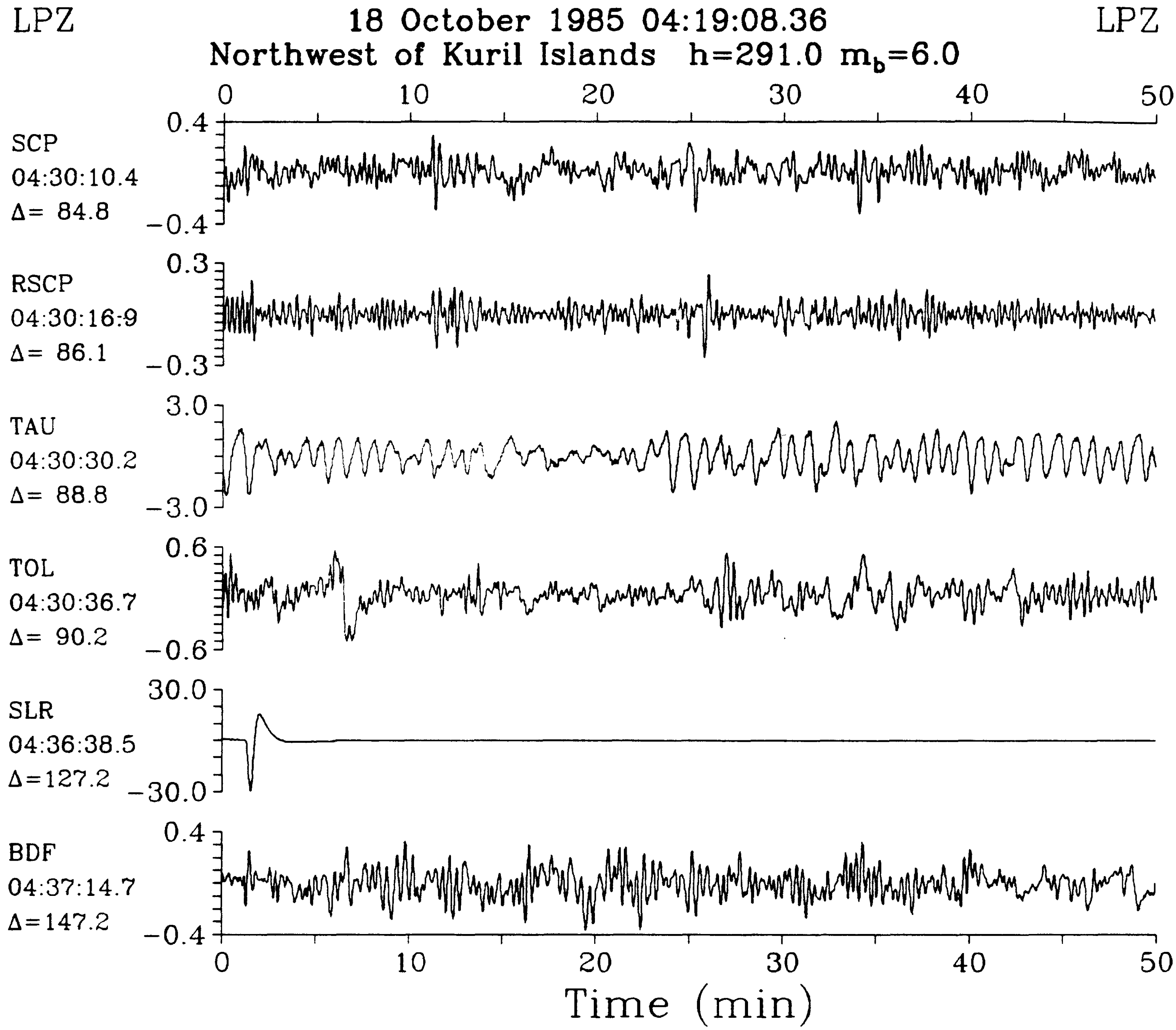


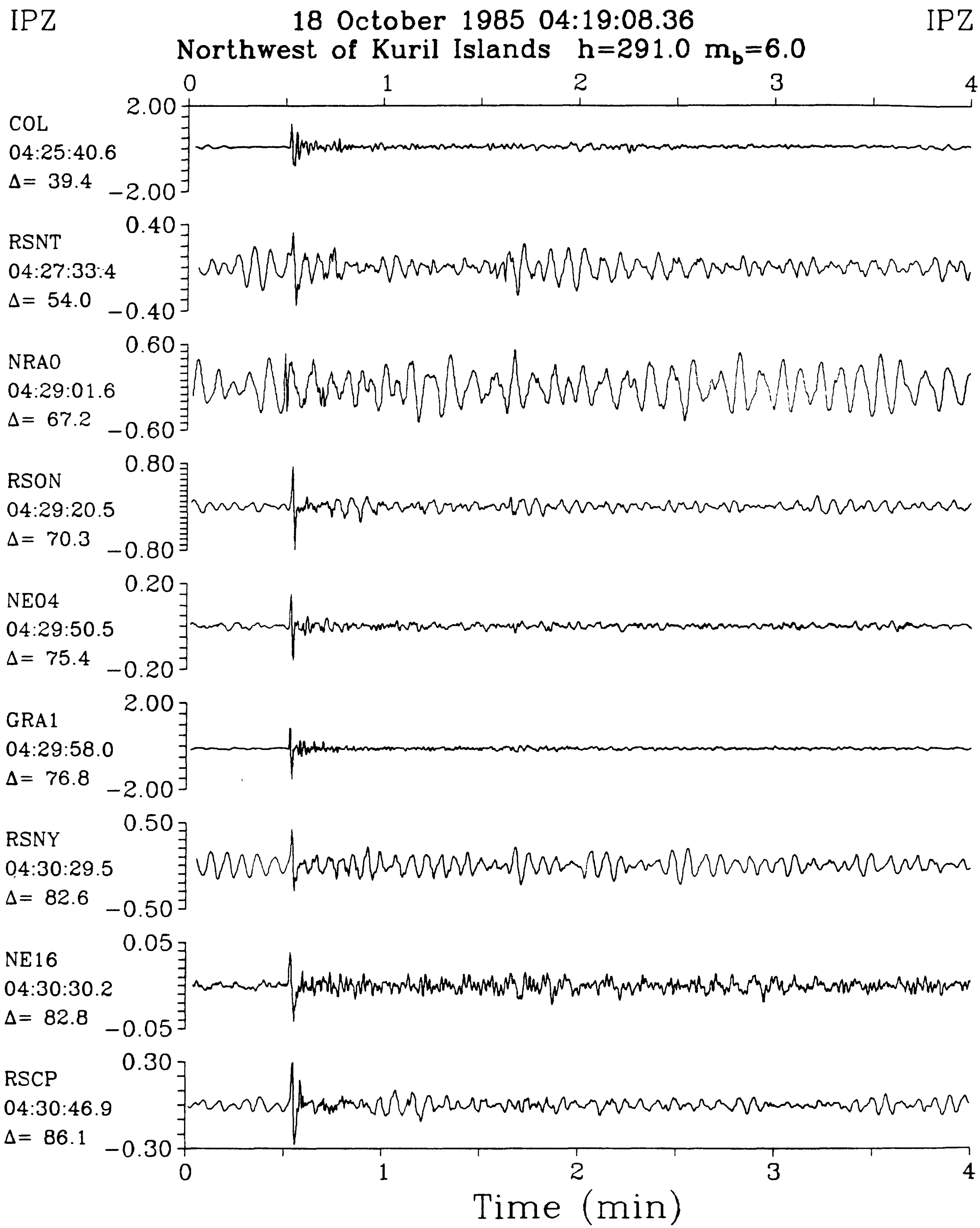
LPZ
18 October 1985 04:19:08.36
Northwest of Kuril Islands h=291.0 m_b=6.0
LPZ
MAJO
04:20:43.8
Δ= 11.5
TATO
04:23:42.4
Δ= 29.1
GUMO
04:24:13.2
Δ= 32.6
COL
04:25:10.6
Δ= 39.4
HON
04:26:43.7
Δ= 51.3
RSNT
04:27:03.4
Δ= 54.0
KEV
04:27:18.2
Δ= 56.1
LON
04:27:41.7
Δ= 59.5
GDH
04:28:10.4
Δ= 63.8
JAS1
04:28:23.1
Δ= 65.8
Time (min)

LPZ 18 October 1985 04:19:08.36 LPZ

Northwest of Kuril Islands h=291.0 m_b=6.0

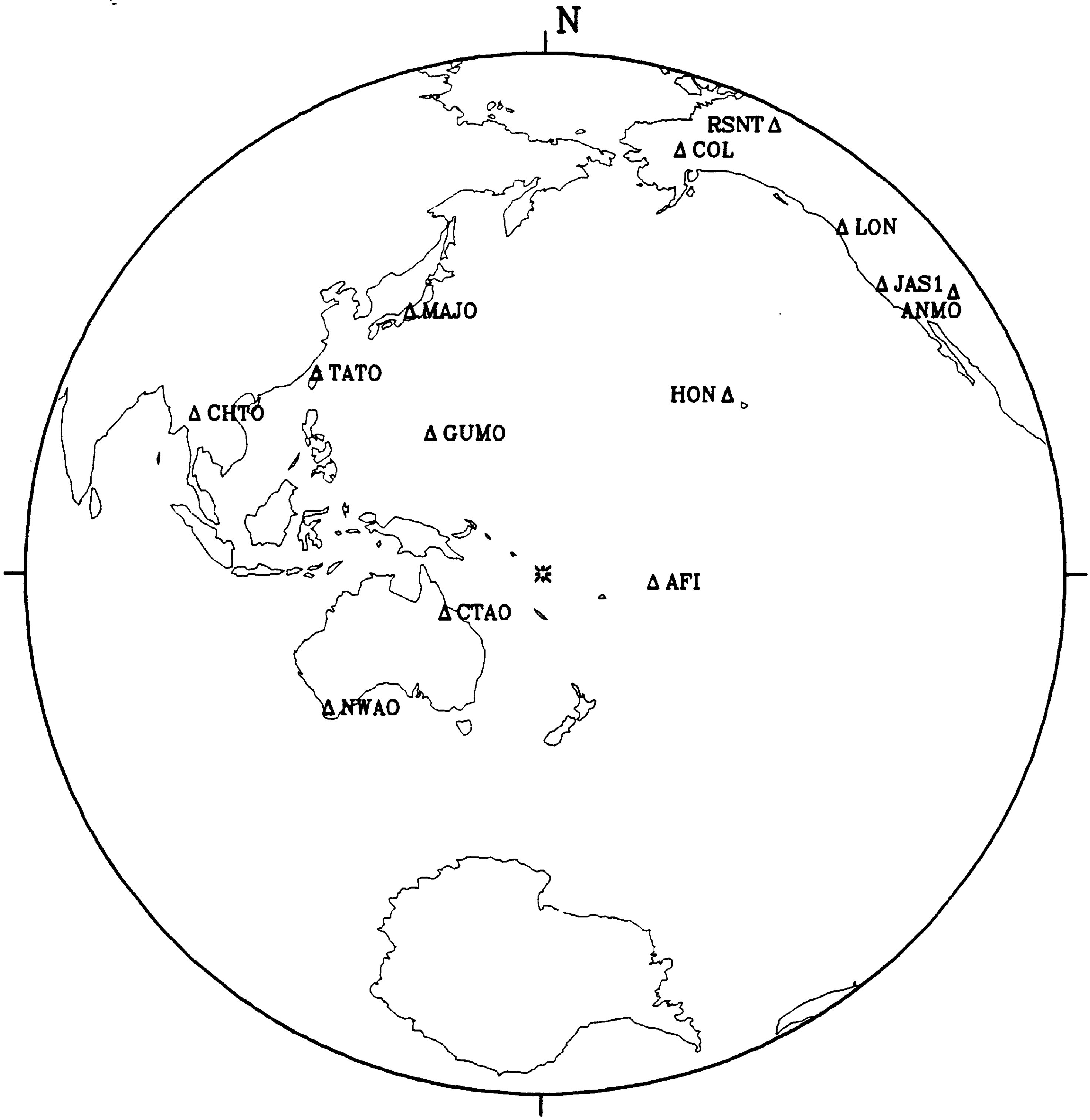


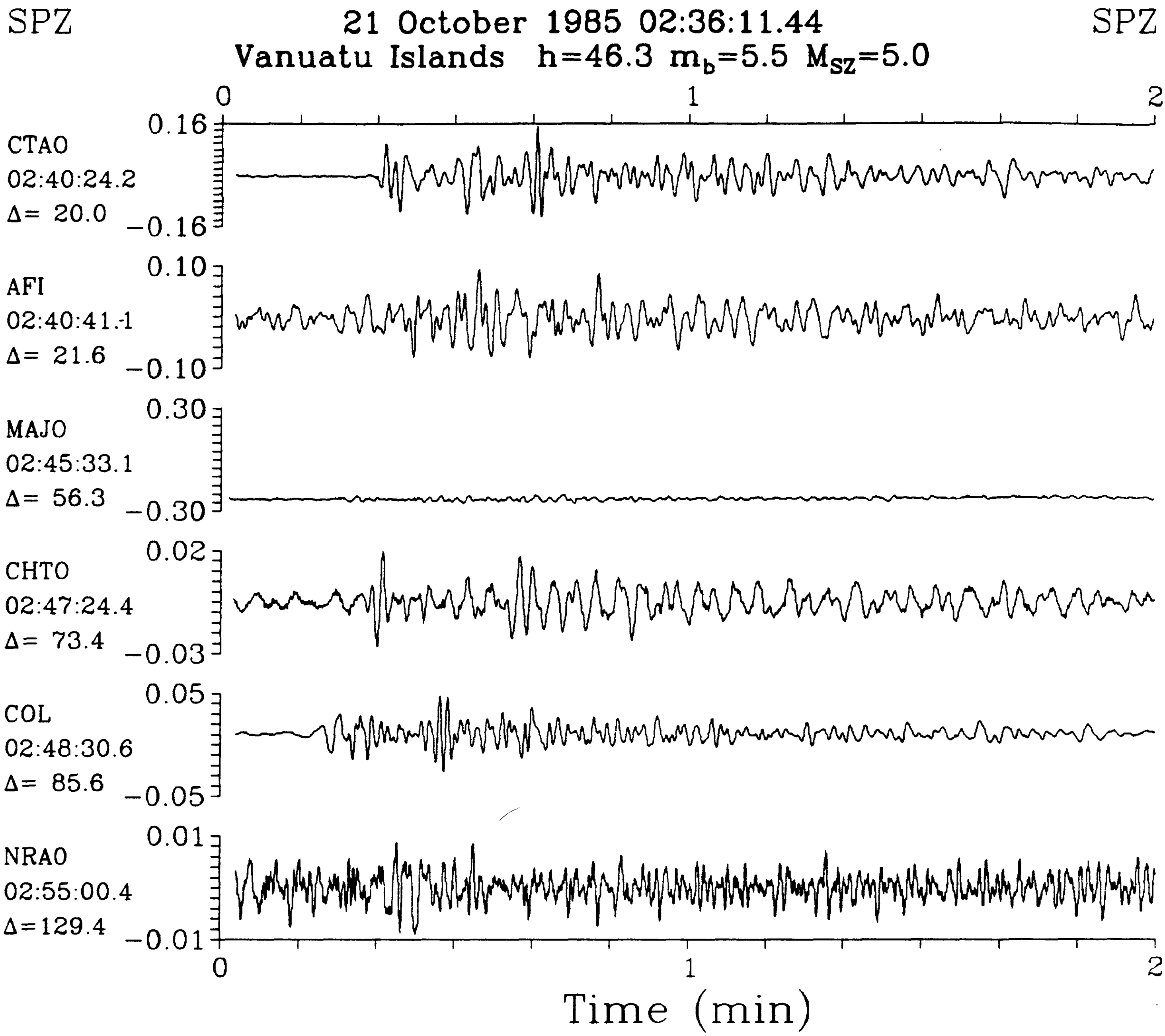

LPZ
18 October 1985 04:19:08.36
Northwest of Kuril Islands h=291.0 m_b=6.0
LPZ
SCP
04:30:10.4
Δ= 84.8
RSCP
04:30:16:9
Δ= 86.1
TAU
04:30:30.2
Δ= 88.8
TOL
04:30:36.7
Δ= 90.2
SLR
04:36:38.5
Δ=127.2
BDF
04:37:14.7
Δ=147.2
0.4
−0.4
0.3
−0.3
3.0
−3.0
0.6
−0.6
30.0
−30.0
0.4
−0.4
0
10
20
30
40
50
Time (min)


IPZ
18 October 1985 04:19:08.36
Northwest of Kuril Islands h=291.0 m_b=6.0
IPZ
COL
04:25:40.6
Δ= 39.4
2.00
-2.00
RSNT
04:27:33:4
Δ= 54.0
0.40
-0.40
NRA0
04:29:01.6
Δ= 67.2
0.60
-0.60
RSON
04:29:20.5
Δ= 70.3
0.80
-0.80
NE04
04:29:50.5
Δ= 75.4
0.20
-0.20
GRA1
04:29:58.0
Δ= 76.8
2.00
-2.00
RSNY
04:30:29.5
Δ= 82.6
0.50
-0.50
NE16
04:30:30.2
Δ= 82.8
0.05
-0.05
RSCP
04:30:46.9
Δ= 86.1
0.30
-0.30
0
1
2
3
4
Time (min)

21 October 1985 02:36:11.44

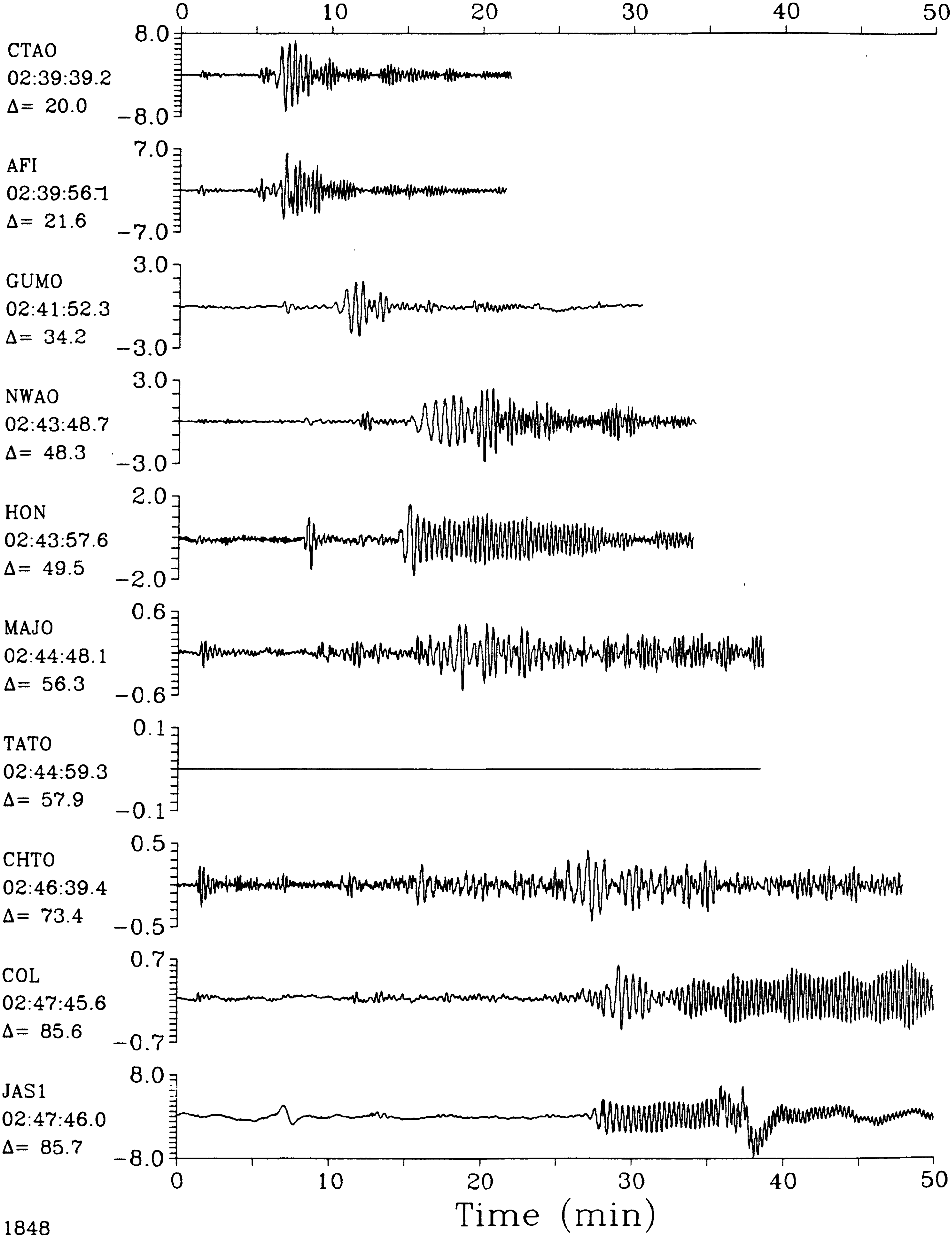
Vanuatu Islands




SPZ
21 October 1985 02:36:11.44
Vanuatu Islands h=46.3 m_b=5.5 M_SZ=5.0
SPZ
CTAO
02:40:24.2
Δ= 20.0
0.16
−0.16
AFI
02:40:41.1
Δ= 21.6
0.10
−0.10
MAJO
02:45:33.1
Δ= 56.3
0.30
−0.30
CHTO
02:47:24.4
Δ= 73.4
0.02
−0.03
COL
02:48:30.6
Δ= 85.6
0.05
−0.05
NRAO
02:55:00.4
Δ=129.4
0.01
−0.01
0
1
2
Time (min)

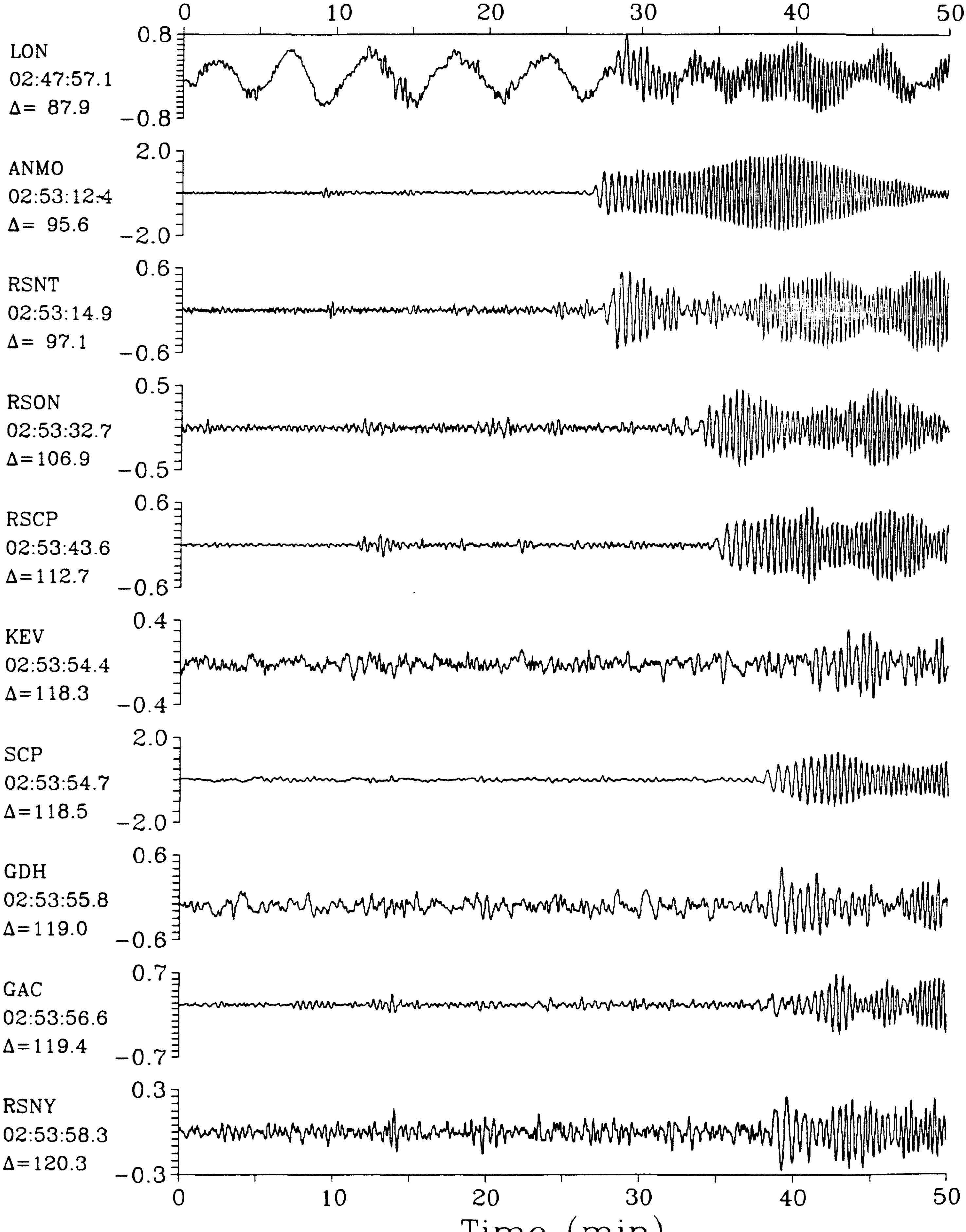
LPZ 21 October 1985 02:36:11.44 LPZ

Vanuatu Islands h=46.3 m_b=5.5 M_{SZ}=5.0

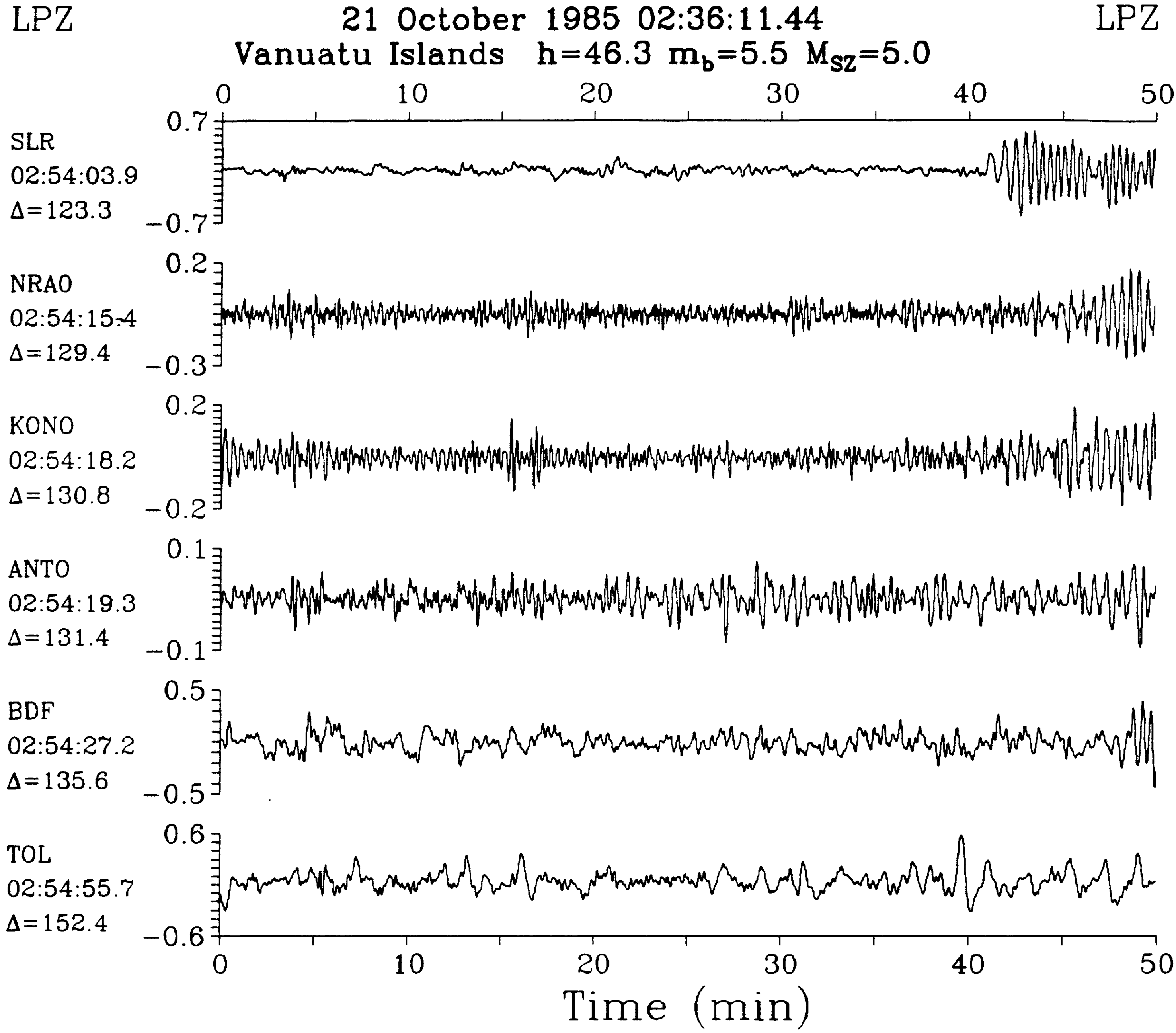


LPZ 21 October 1985 02:36:11.44 LPZ

Vanuatu Islands h=46.3 m_b=5.5 M_{SZ}=5.0

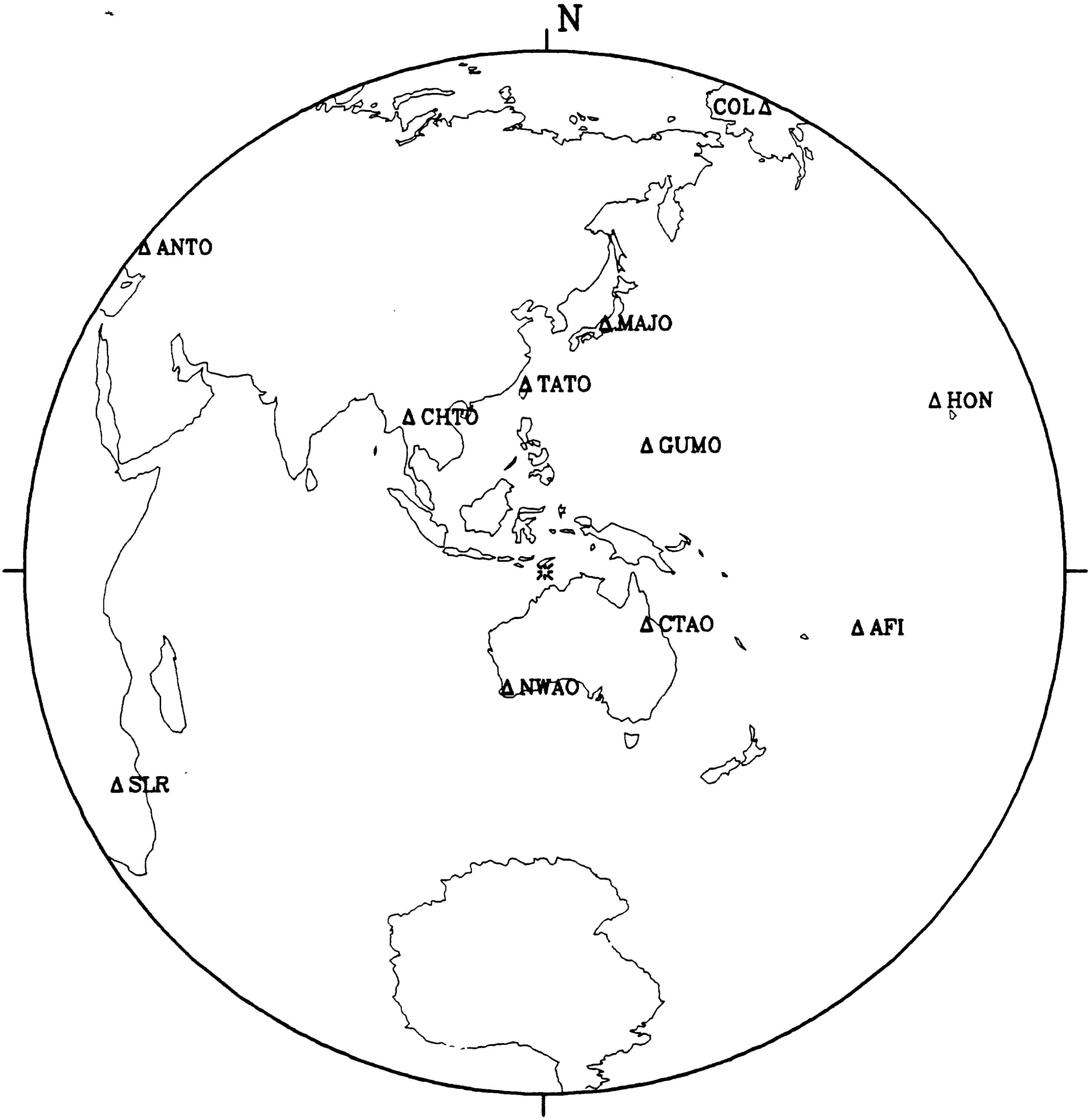


1849


LPZ
21 October 1985 02:36:11.44
Vanuatu Islands h=46.3 m_b=5.5 M_{SZ}=5.0
LPZ
SLR
02:54:03.9
Δ=123.3
0.7
−0.7
NRAO
02:54:15.4
Δ=129.4
0.2
−0.3
KONO
02:54:18.2
Δ=130.8
0.2
−0.2
ANTO
02:54:19.3
Δ=131.4
0.1
−0.1
BDF
02:54:27.2
Δ=135.6
0.5
−0.5
TOL
02:54:55.7
Δ=152.4
0.6
−0.6
0
10
20
30
40
50
Time (min)

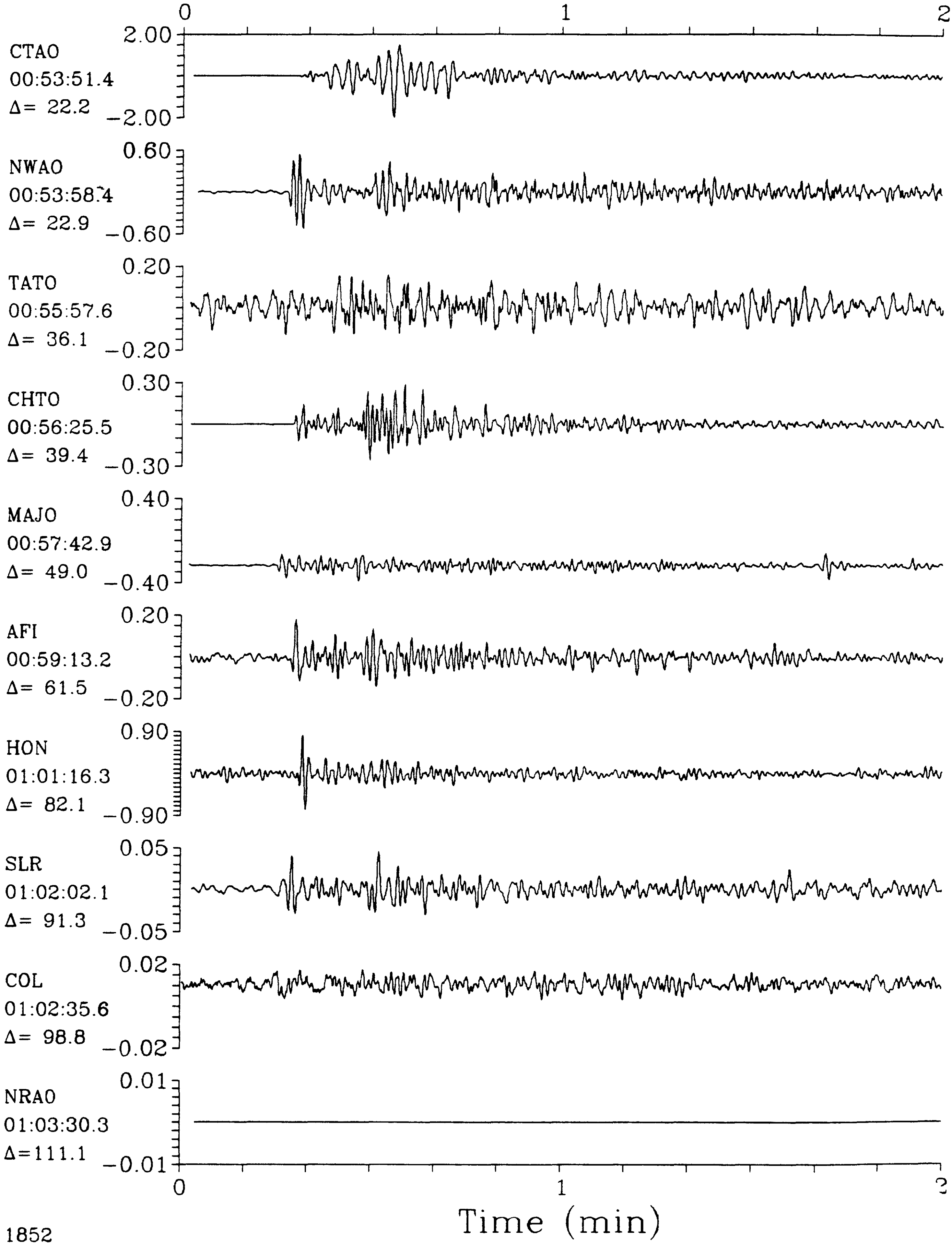
23 October 1985 00:49:13.92

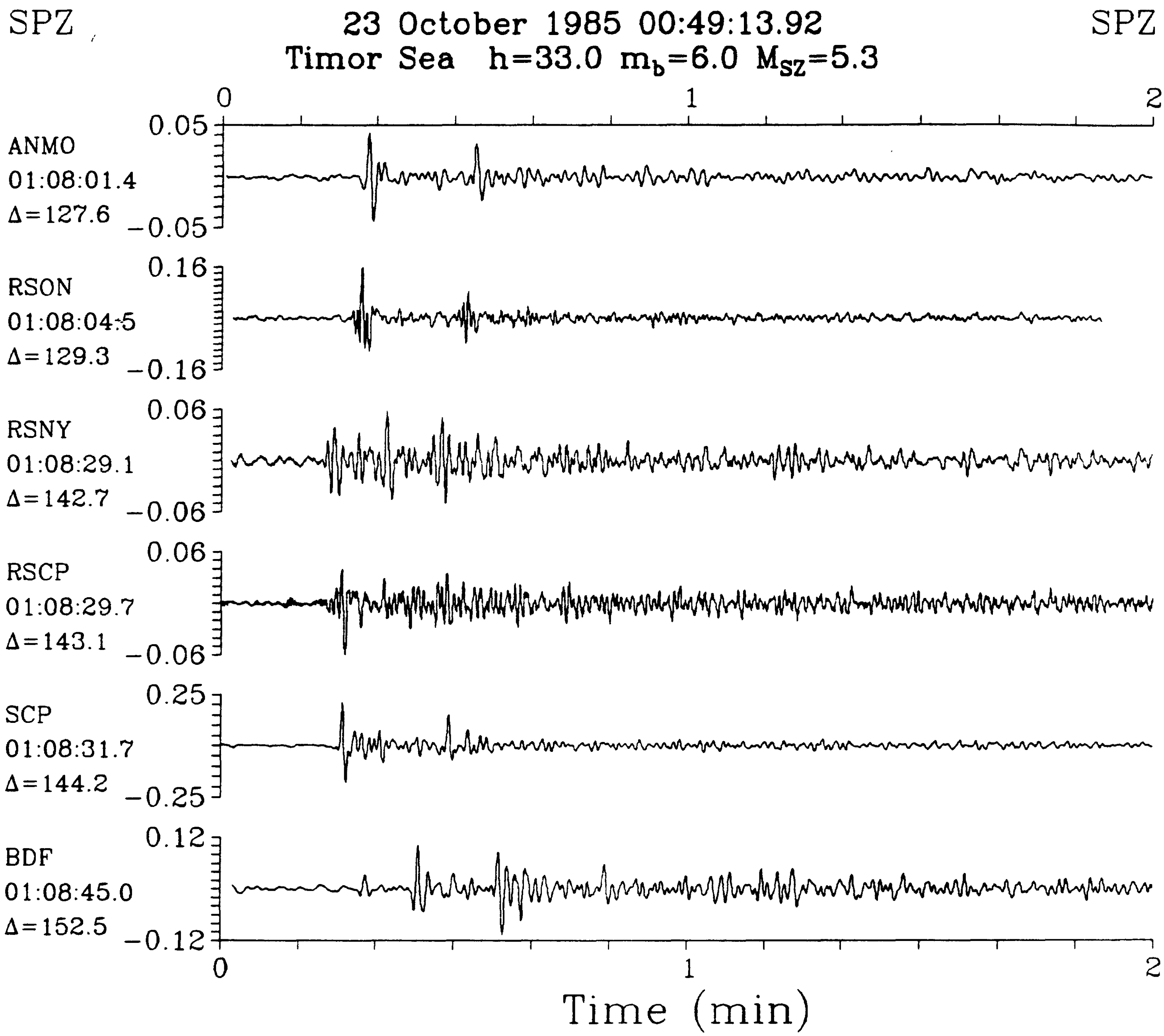
Timor Sea

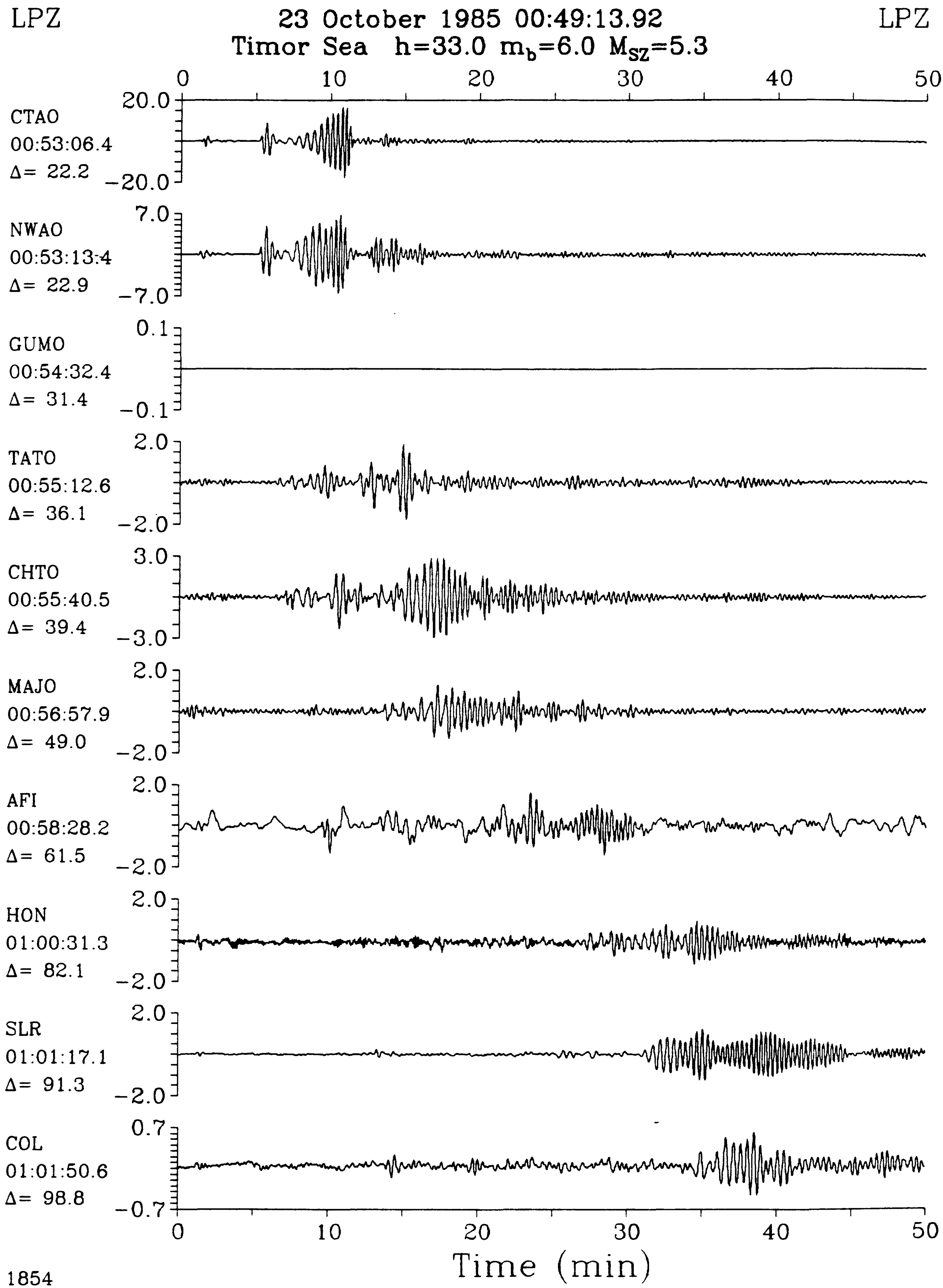


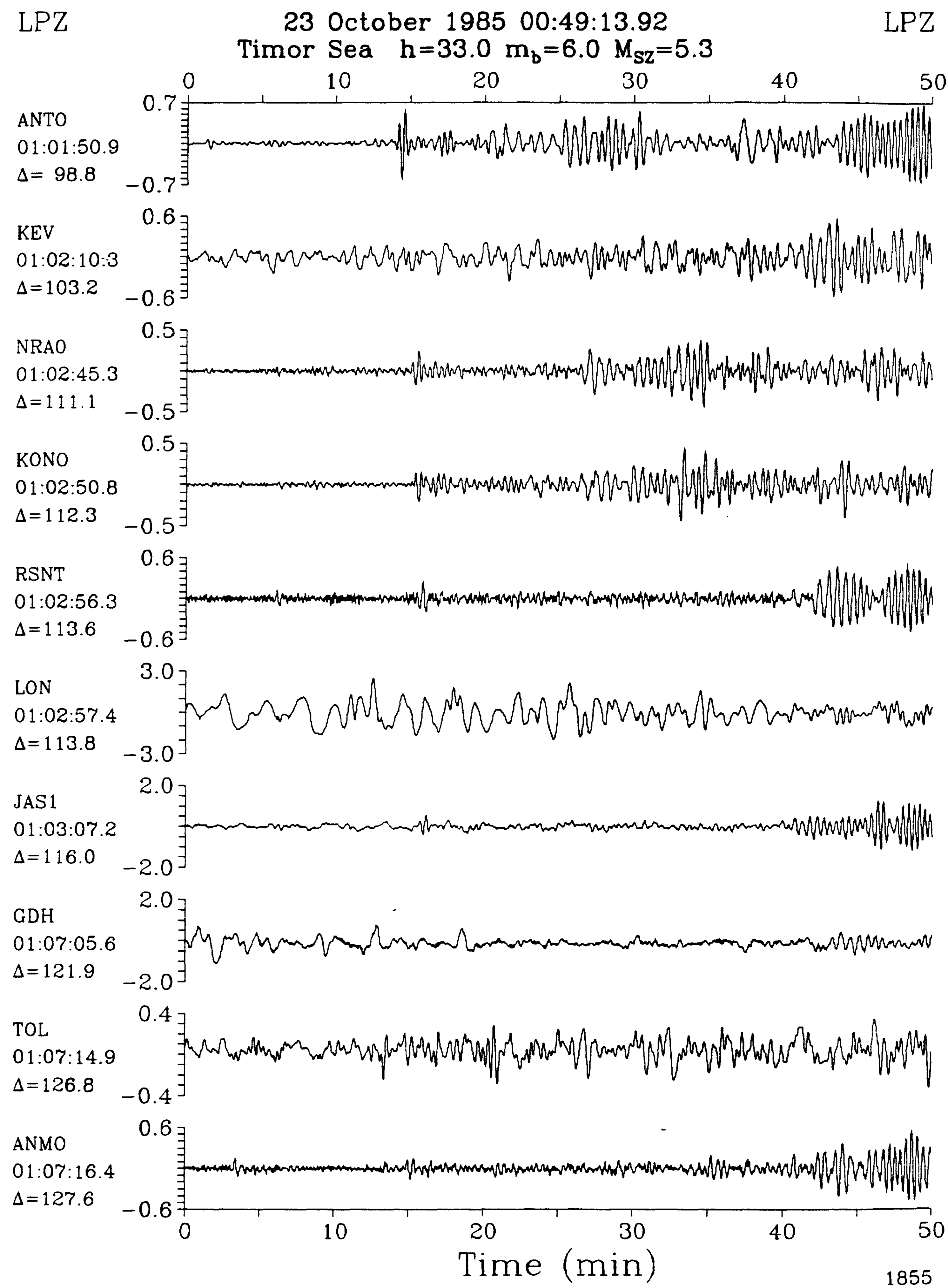
SPZ 23 October 1985 00:49:13.92 SPZ

Timor Sea h=33.0 m_b=6.0 M_{SZ}=5.3



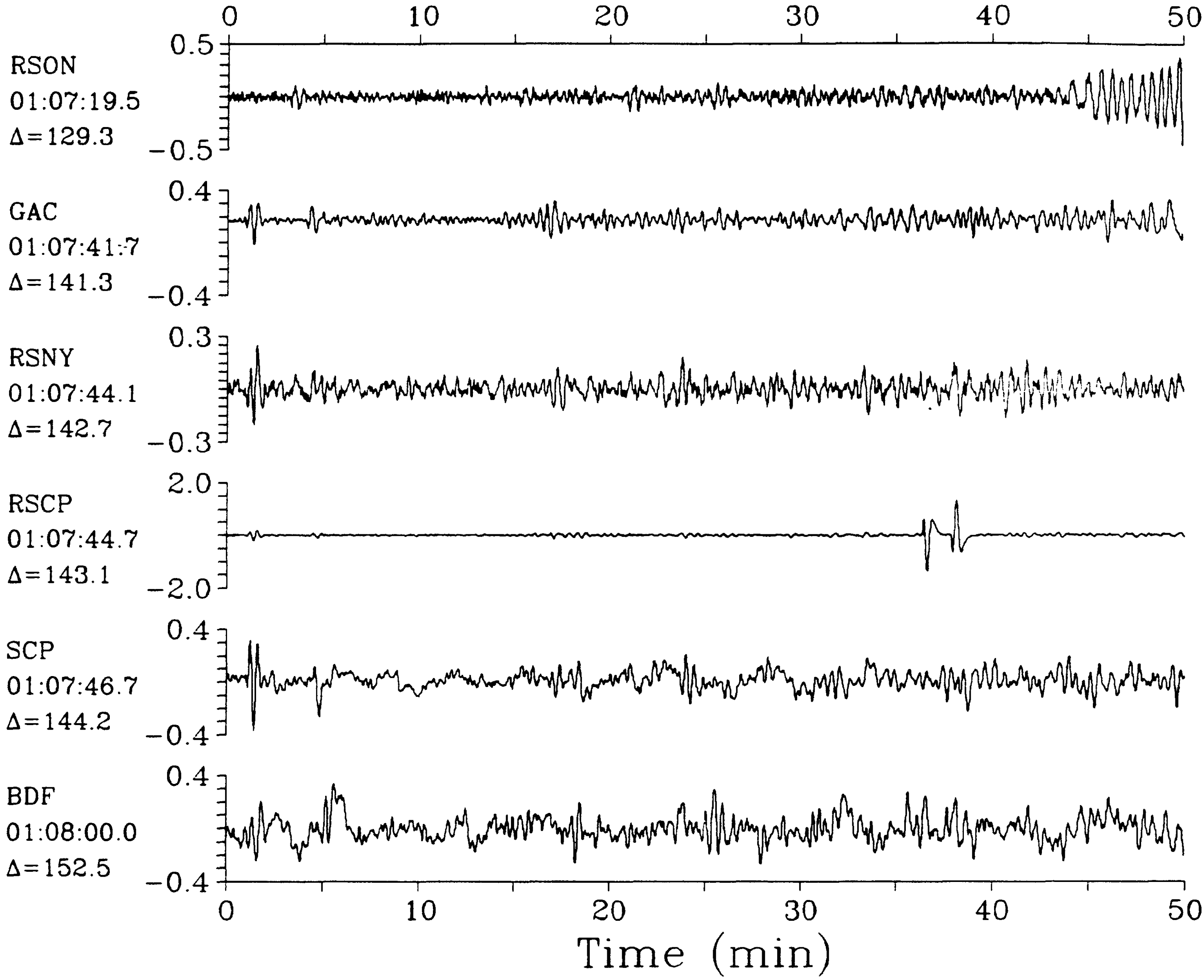

SPZ
23 October 1985 00:49:13.92
Timor Sea h=33.0 m_b=6.0 M_{SZ}=5.3
SPZ
ANMO
01:08:01.4
Δ=127.6
RSON
01:08:04.5
Δ=129.3
RSNY
01:08:29.1
Δ=142.7
RSCP
01:08:29.7
Δ=143.1
SCP
01:08:31.7
Δ=144.2
BDF
01:08:45.0
Δ=152.5
0.05
−0.05
0.16
−0.16
0.06
−0.06
0.06
−0.06
0.25
−0.25
0.12
−0.12
0
1
2
Time (min)

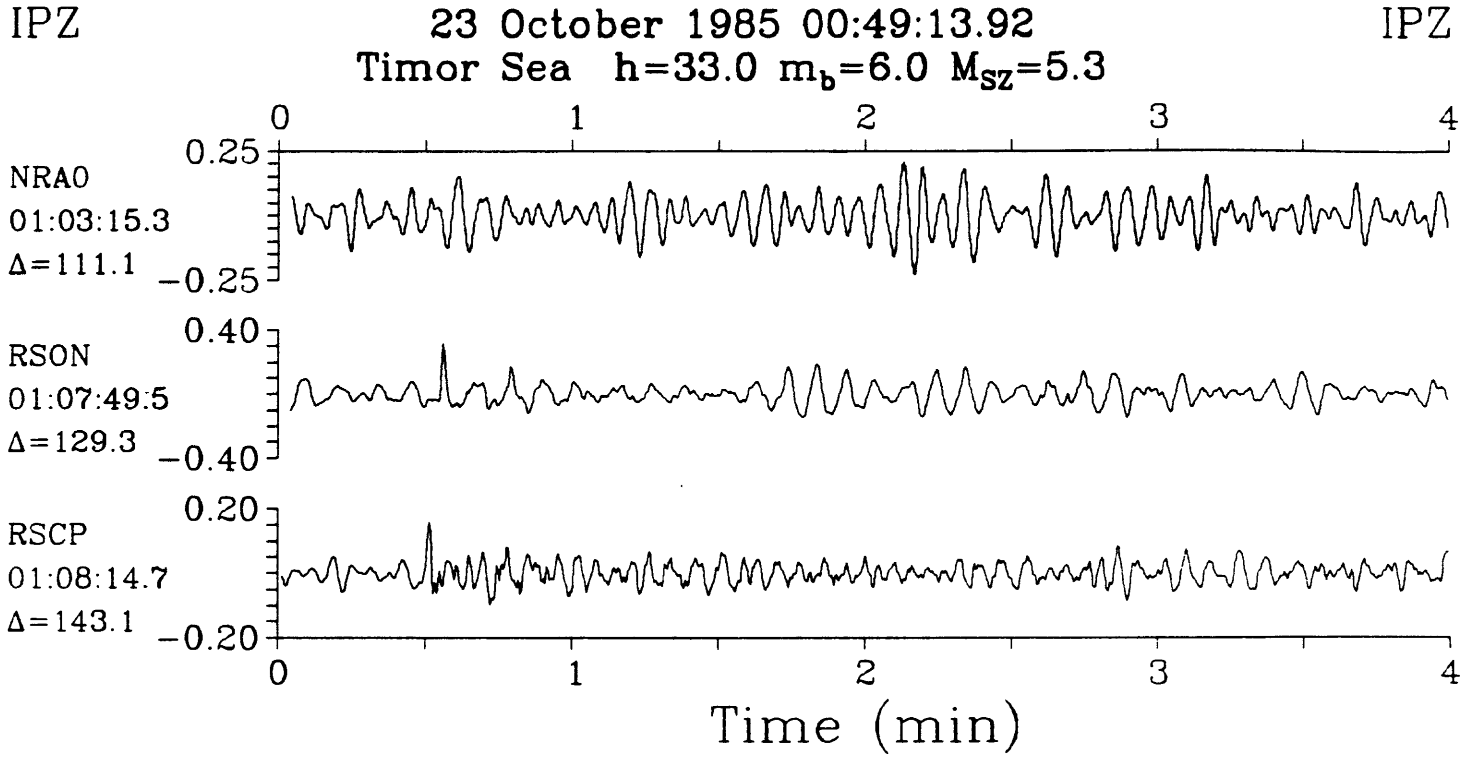

LPZ
23 October 1985 00:49:13.92
Timor Sea h=33.0 m_b=6.0 M_{SZ}=5.3
LPZ
CTAO
00:53:06.4
Δ= 22.2
NWAO
00:53:13.4
Δ= 22.9
GUMO
00:54:32.4
Δ= 31.4
TATO
00:55:12.6
Δ= 36.1
CHTO
00:55:40.5
Δ= 39.4
MAJO
00:56:57.9
Δ= 49.0
AFI
00:58:28.2
Δ= 61.5
HON
01:00:31.3
Δ= 82.1
SLR
01:01:17.1
Δ= 91.3
COL
01:01:50.6
Δ= 98.8
20.0
-20.0
7.0
-7.0
0.1
-0.1
2.0
-2.0
3.0
-3.0
0.7
-0.7
0
10
20
30
40
50
Time (min)


LPZ
23 October 1985 00:49:13.92
Timor Sea h=33.0 m_b=6.0 M_SZ=5.3
LPZ
ANTO
01:01:50.9
Δ= 98.8
KEV
01:02:10:3
Δ=103.2
NRAO
01:02:45.3
Δ=111.1
KONO
01:02:50.8
Δ=112.3
RSNT
01:02:56.3
Δ=113.6
LON
01:02:57.4
Δ=113.8
JAS1
01:03:07.2
Δ=116.0
GDH
01:07:05.6
Δ=121.9
TOL
01:07:14.9
Δ=126.8
ANMO
01:07:16.4
Δ=127.6
0.7
−0.7
0.6
−0.6
0.5
−0.5
3.0
−3.0
2.0
−2.0
0.4
−0.4
0
10
20
30
40
50
Time (min)

LPZ 23 October 1985 00:49:13.92 LPZ

Timor Sea h=33.0 m_b=6.0 M_{SZ}=5.3

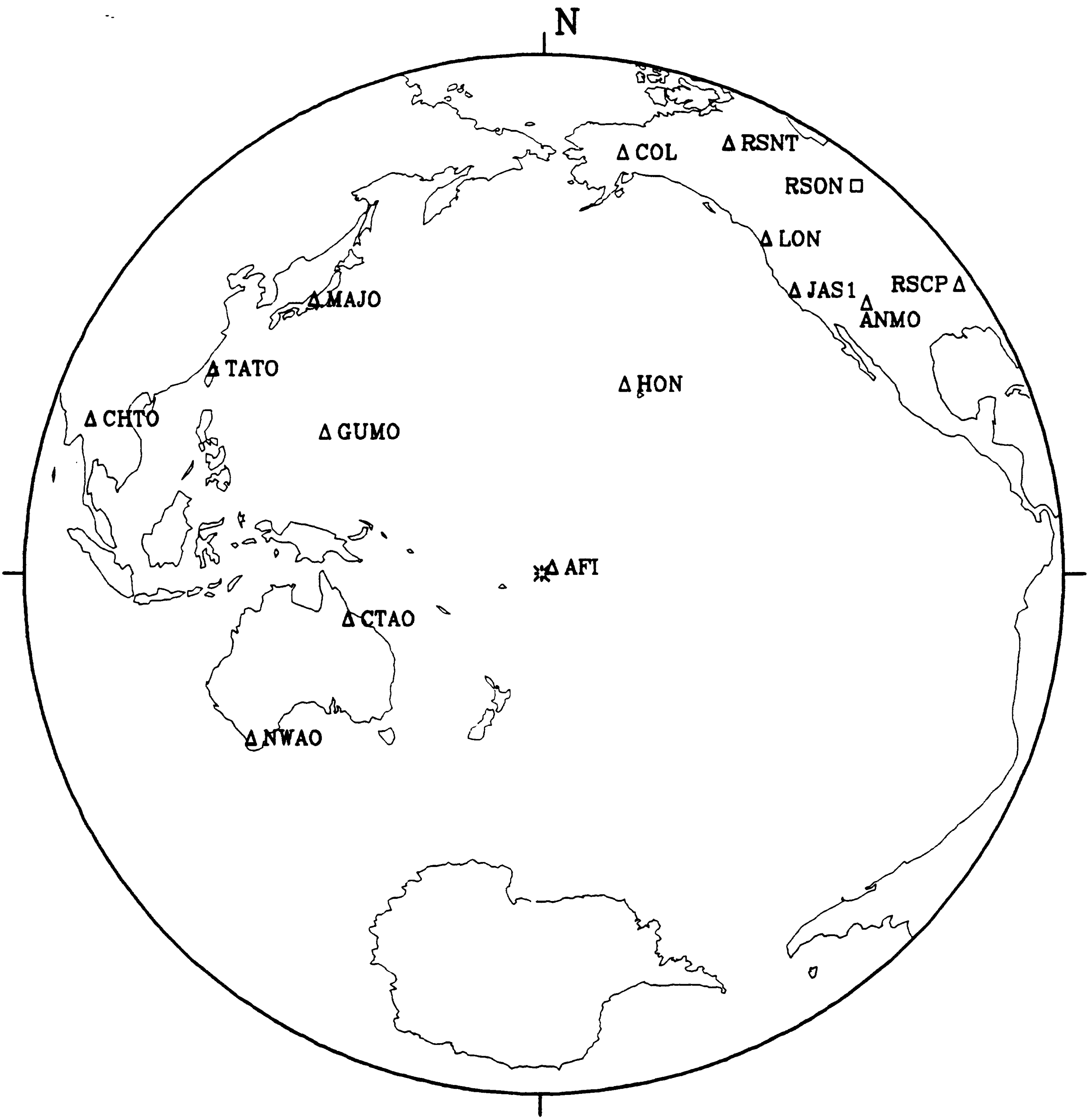




IPZ
23 October 1985 00:49:13.92
Timor Sea h=33.0 m_b=6.0 M_SZ=5.3
IPZ
NRAO
01:03:15.3
Δ=111.1
0.25
−0.25
RSON
01:07:49:5
Δ=129.3
0.40
−0.40
RSCP
01:08:14.7
Δ=143.1
0.20
−0.20
0
1
2
3
4
Time (min)

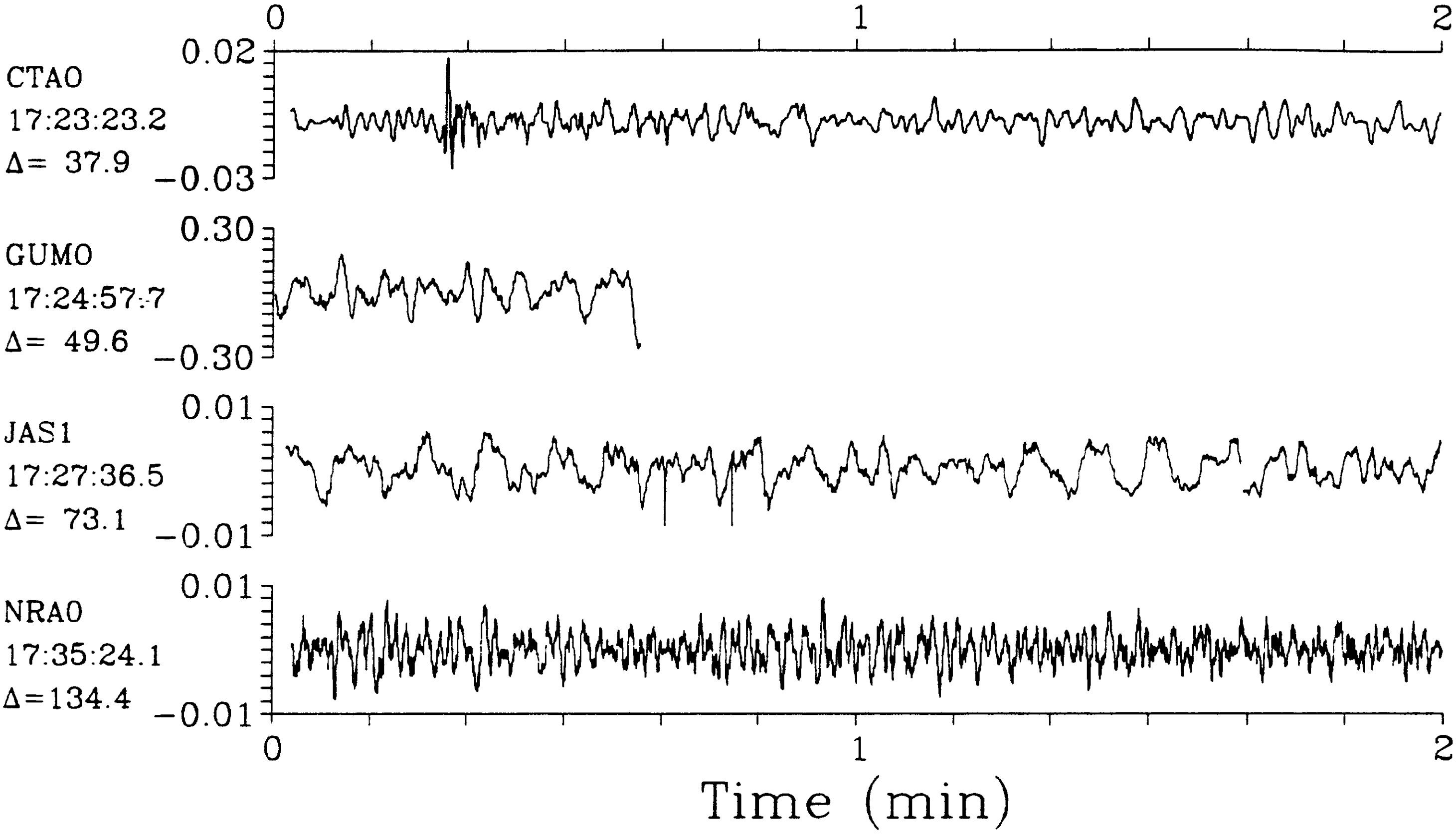
23 October 1985 17:16:23.88

Tonga Islands



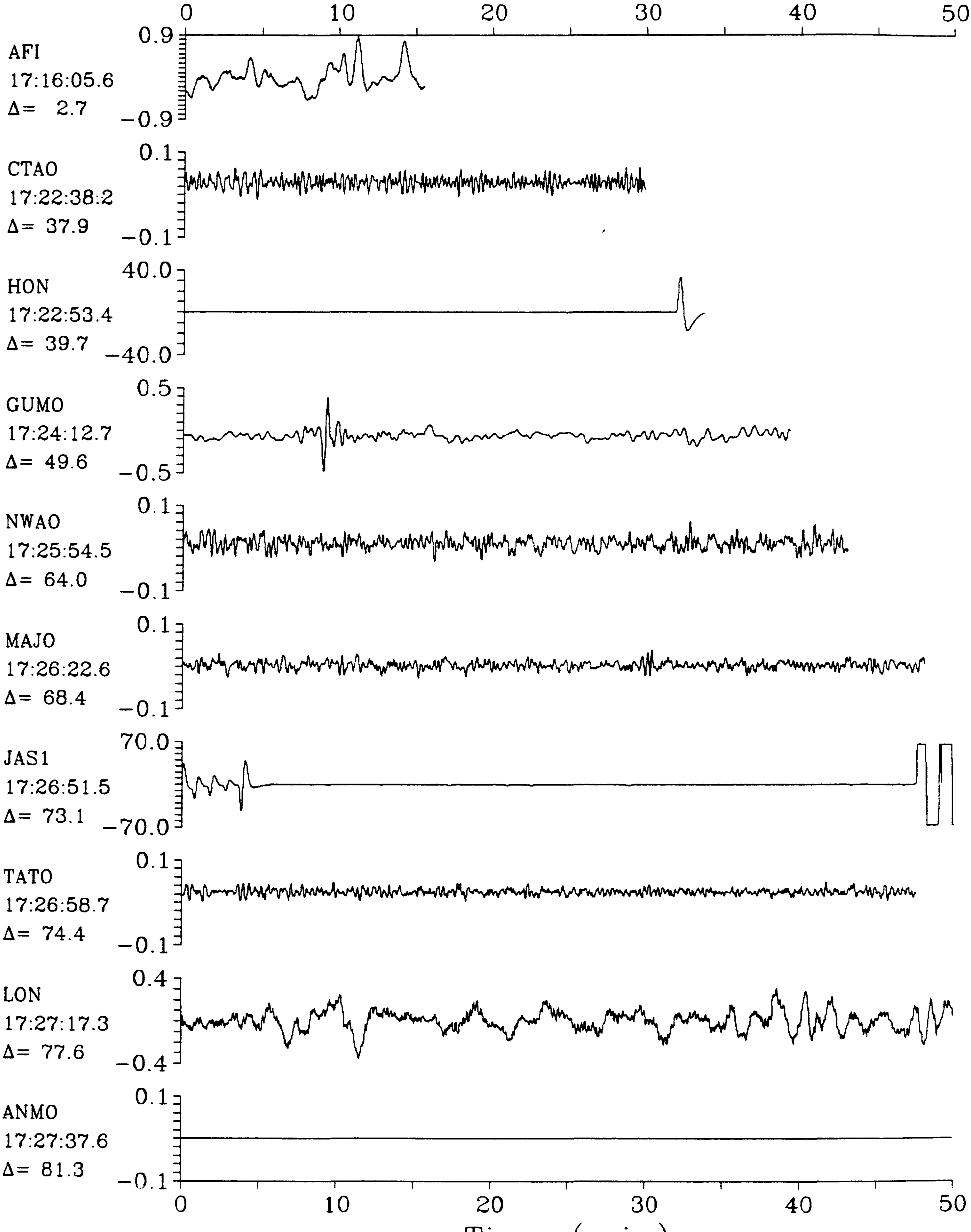
SPZ **23 October 1985 17:16:23.88** SPZ

Tonga Islands h=33.0 m_b=5.9

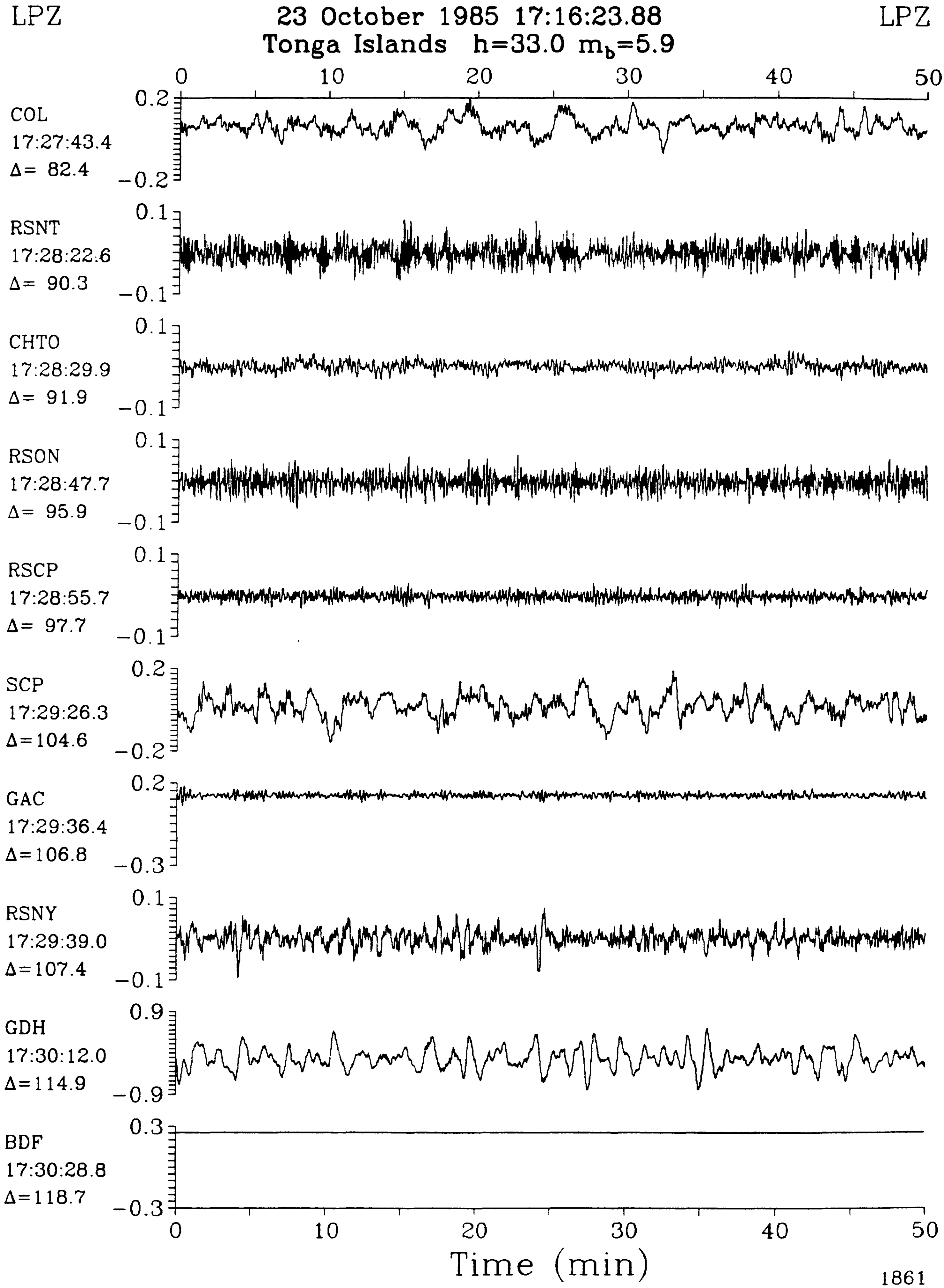


LPZ 23 October 1985 17:16:23.88 LPZ

Tonga Islands h=33.0 m_b=5.9

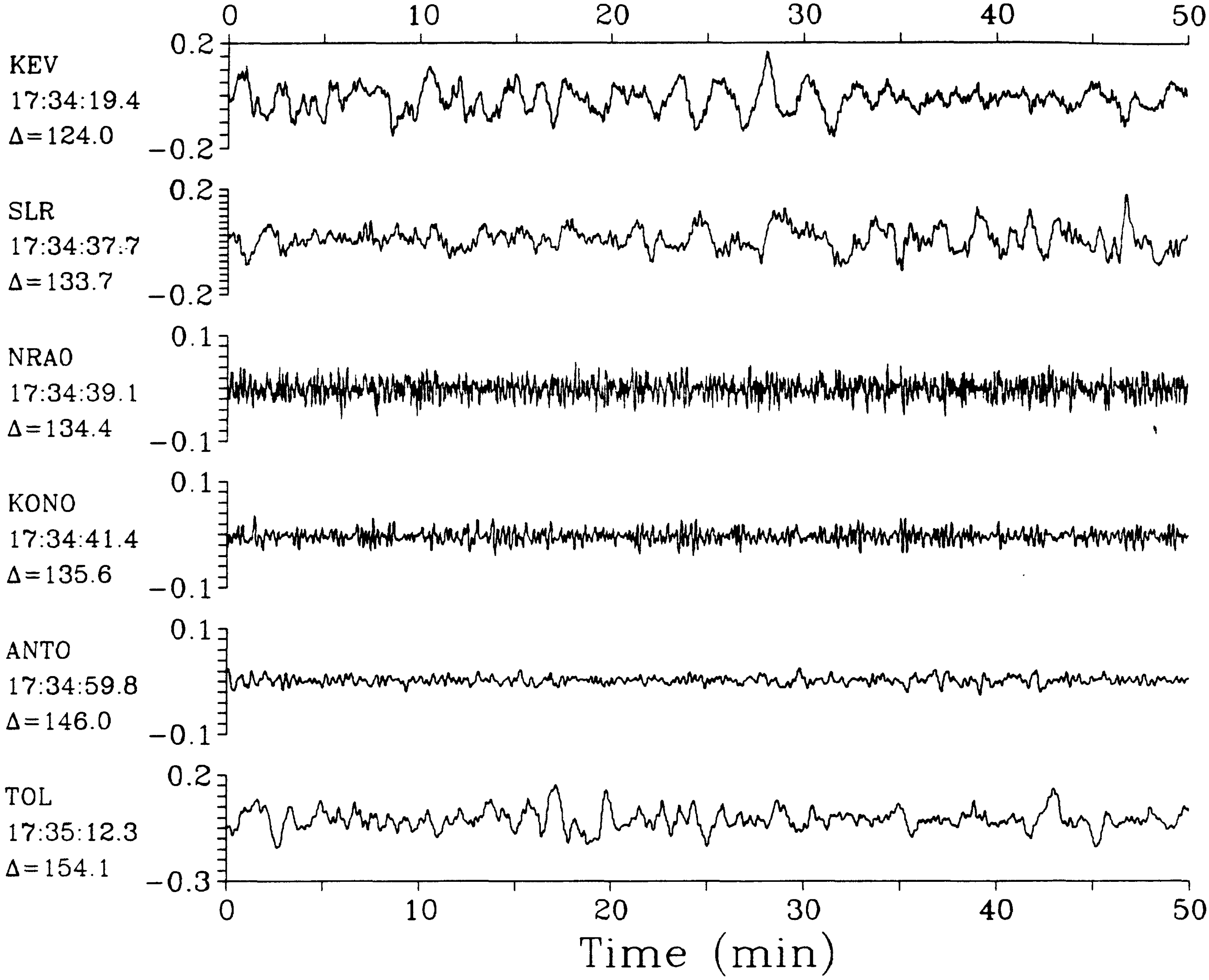


1860


LPZ
23 October 1985 17:16:23.88
Tonga Islands h=33.0 m_b=5.9
LPZ
COL
17:27:43.4
Δ= 82.4
RSNT
17:28:22.6
Δ= 90.3
CHTO
17:28:29.9
Δ= 91.9
RSON
17:28:47.7
Δ= 95.9
RSCP
17:28:55.7
Δ= 97.7
SCP
17:29:26.3
Δ=104.6
GAC
17:29:36.4
Δ=106.8
RSNY
17:29:39.0
Δ=107.4
GDH
17:30:12.0
Δ=114.9
BDF
17:30:28.8
Δ=118.7
Time (min)

LPZ 23 October 1985 17:16:23.88 LPZ

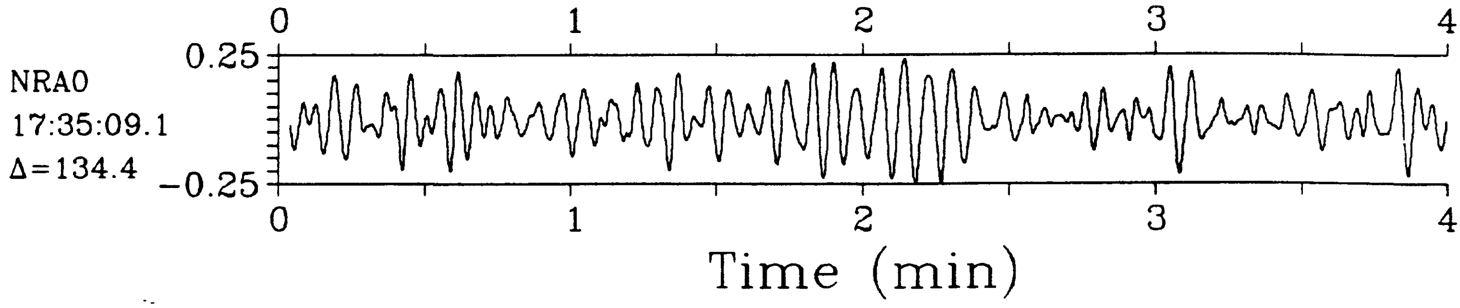
Tonga Islands h=33.0 m_b=5.9



23 October 1985 17:16:23.88

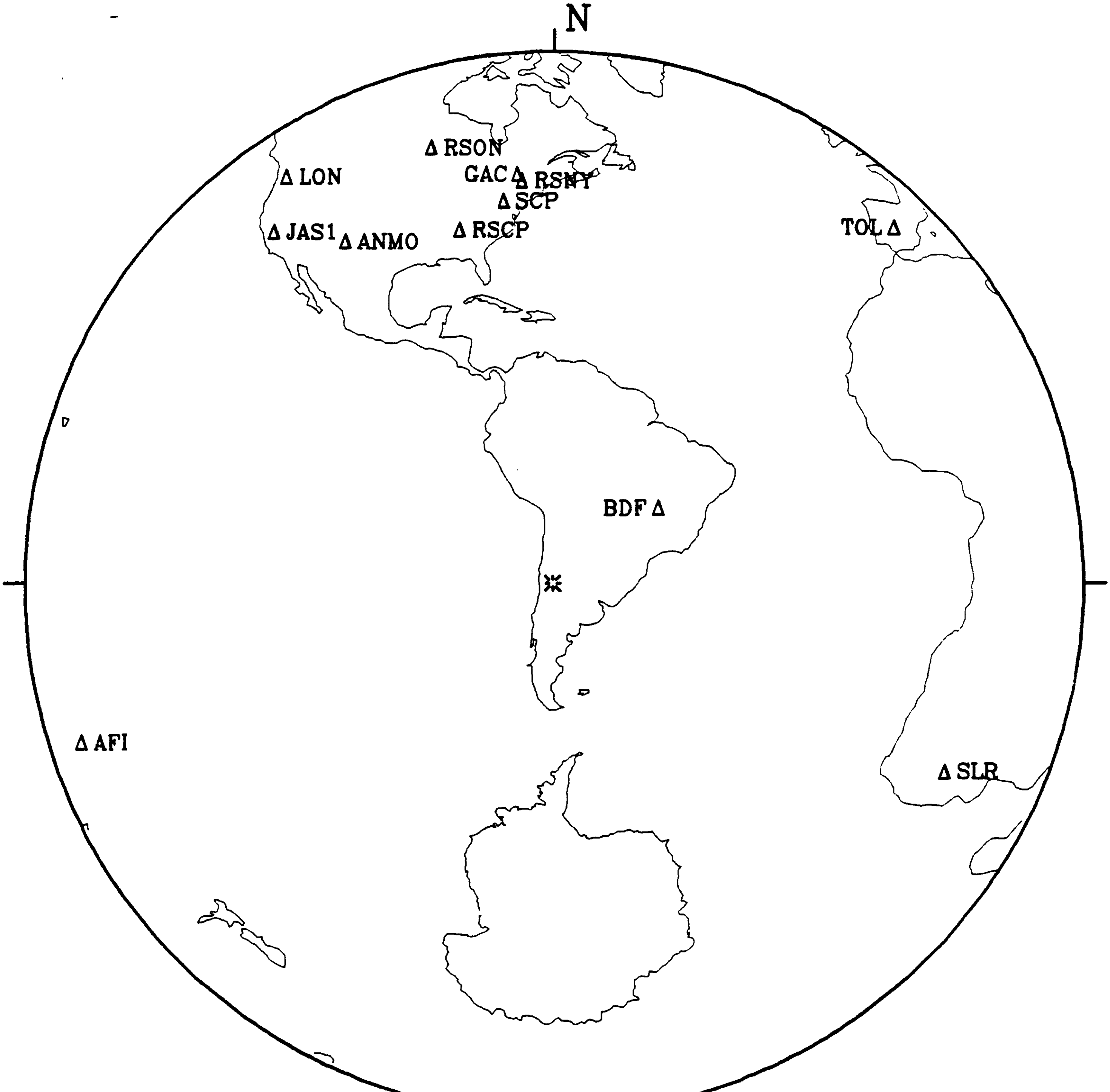
Tonga Islands h=33.0 m_b=5.9

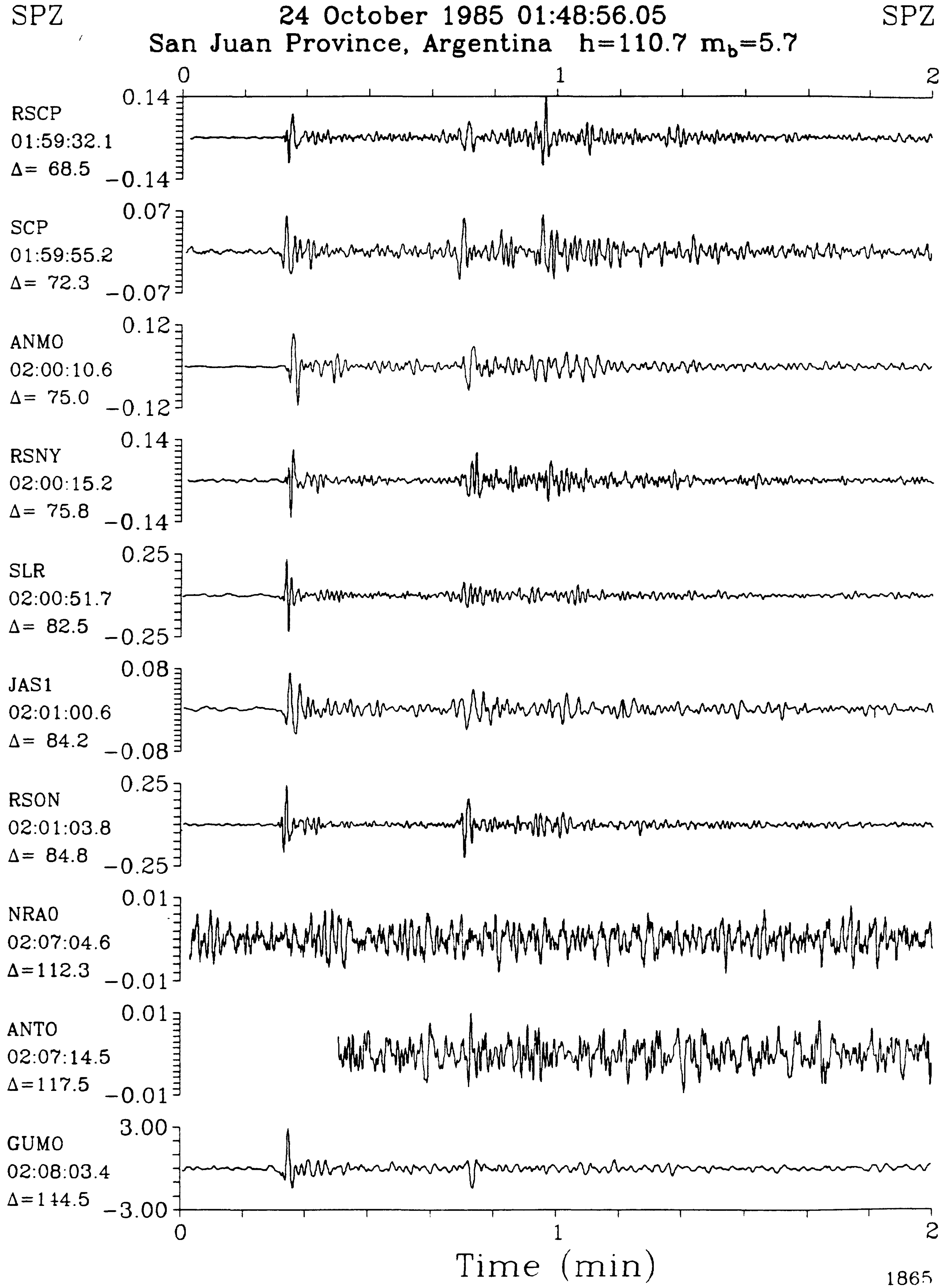
IPZ



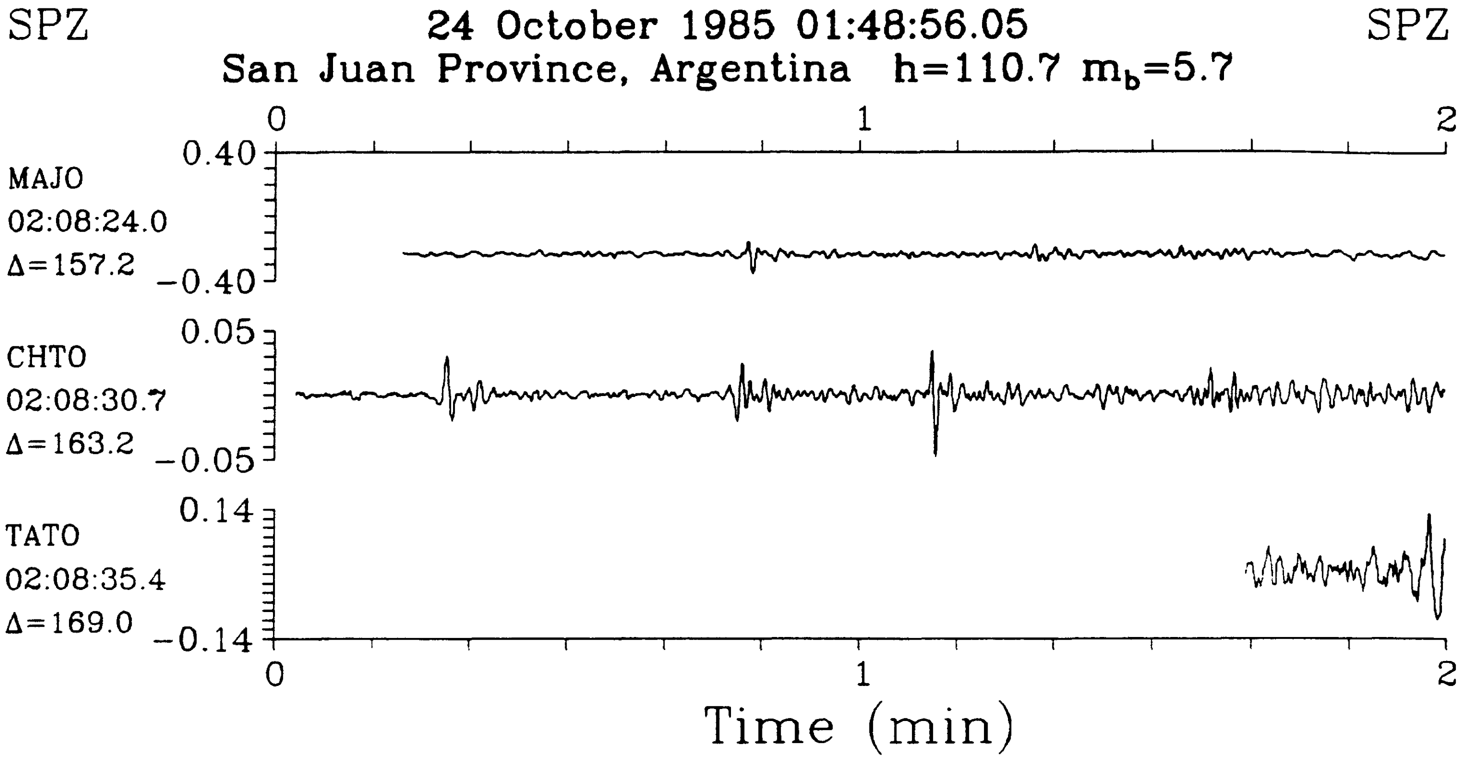
24 October 1985 01:48:56.05

San Juan Province, Argentina

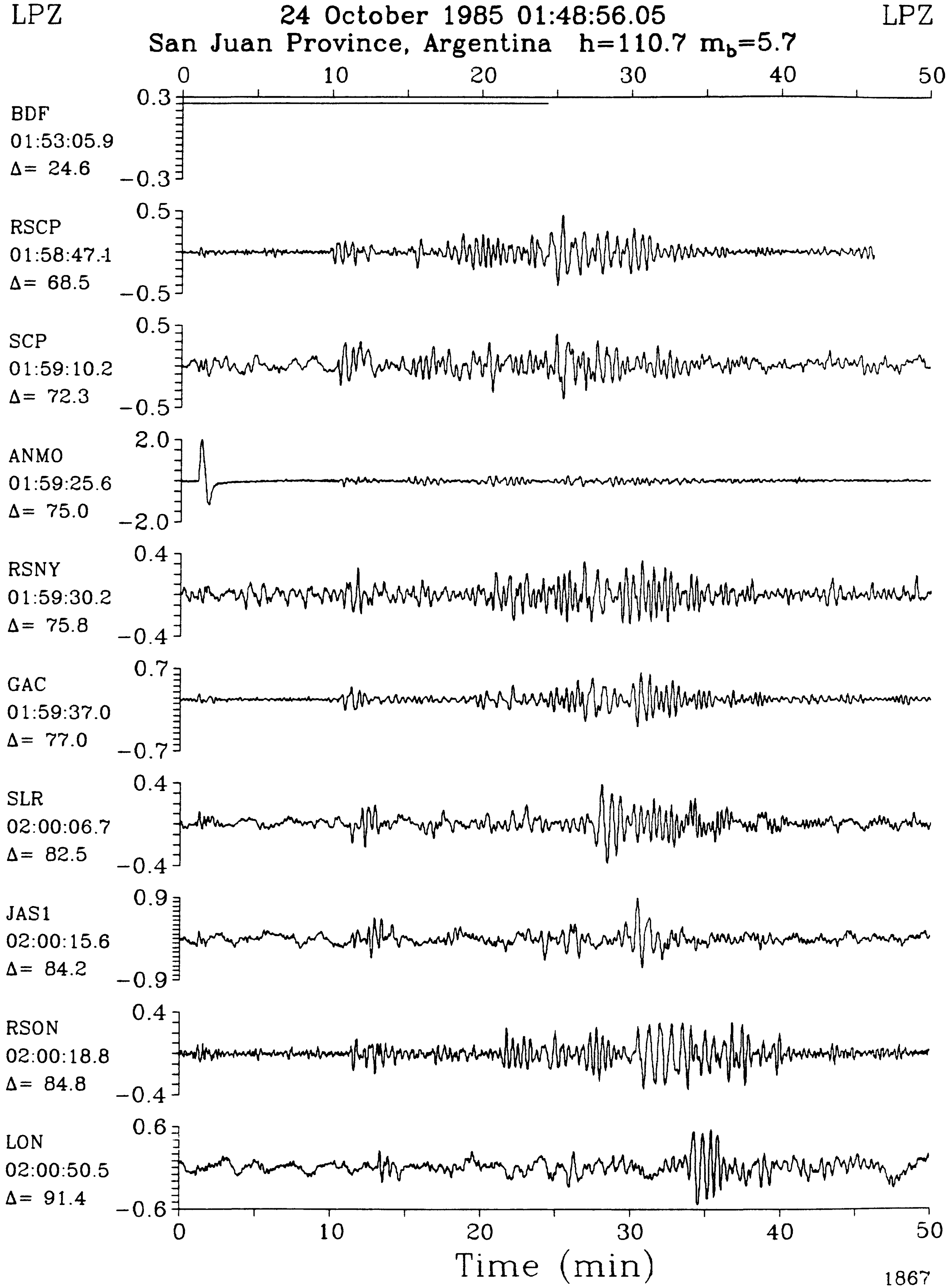



SPZ
24 October 1985 01:48:56.05
San Juan Province, Argentina h=110.7 m_b=5.7
SPZ
RSCP 01:59:32.1 Δ= 68.5
0.14 −0.14
SCP 01:59:55.2 Δ= 72.3
0.07 −0.07
ANMO 02:00:10.6 Δ= 75.0
0.12 −0.12
RSNY 02:00:15.2 Δ= 75.8
0.14 −0.14
SLR 02:00:51.7 Δ= 82.5
0.25 −0.25
JAS1 02:01:00.6 Δ= 84.2
0.08 −0.08
RSON 02:01:03.8 Δ= 84.8
0.25 −0.25
NRAO 02:07:04.6 Δ=112.3
0.01 −0.01
ANTO 02:07:14.5 Δ=117.5
0.01 −0.01
GUMO 02:08:03.4 Δ=144.5
3.00 −3.00
0 1 2
Time (min)

1865



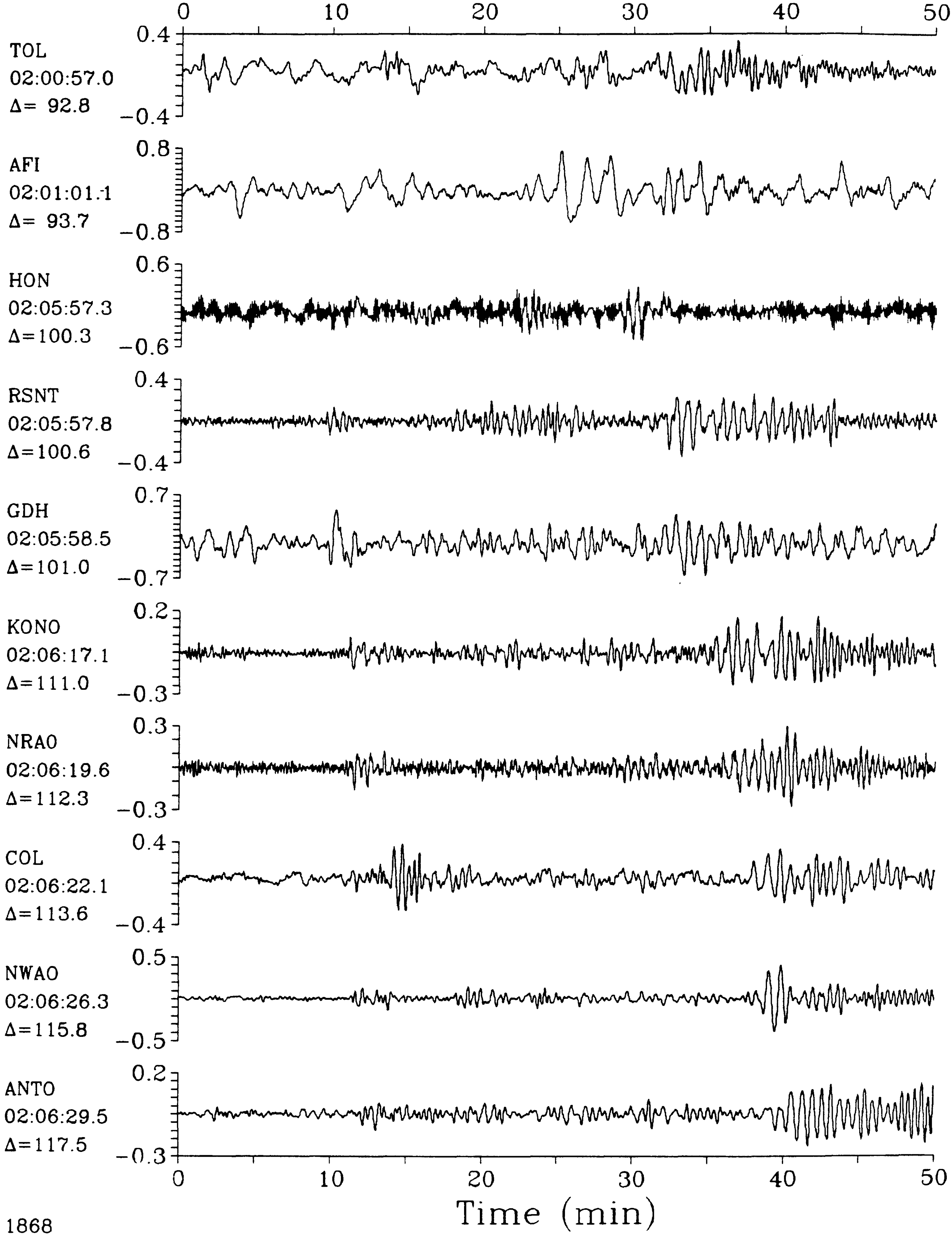
SPZ
24 October 1985 01:48:56.05
San Juan Province, Argentina h=110.7 m_b=5.7
SPZ
MAJO
02:08:24.0
Δ=157.2
0.40
−0.40
CHTO
02:08:30.7
Δ=163.2
0.05
−0.05
TATO
02:08:35.4
Δ=169.0
0.14
−0.14
0
1
2
Time (min)


LPZ
24 October 1985 01:48:56.05
LPZ
San Juan Province, Argentina h=110.7 m_b=5.7
BDF
01:53:05.9
Δ= 24.6
RSCP
01:58:47.1
Δ= 68.5
SCP
01:59:10.2
Δ= 72.3
ANMO
01:59:25.6
Δ= 75.0
RSNY
01:59:30.2
Δ= 75.8
GAC
01:59:37.0
Δ= 77.0
SLR
02:00:06.7
Δ= 82.5
JAS1
02:00:15.6
Δ= 84.2
RSON
02:00:18.8
Δ= 84.8
LON
02:00:50.5
Δ= 91.4
0.3
−0.3
0.5
−0.5
0.5
−0.5
2.0
−2.0
0.4
−0.4
0.7
−0.7
0.4
−0.4
0.9
−0.9
0.4
−0.4
0.6
−0.6
0
10
20
30
40
50
Time (min)

1867

LPZ 24 October 1985 01:48:56.05 LPZ

San Juan Province, Argentina $h=110.7$ $m_b=5.7$

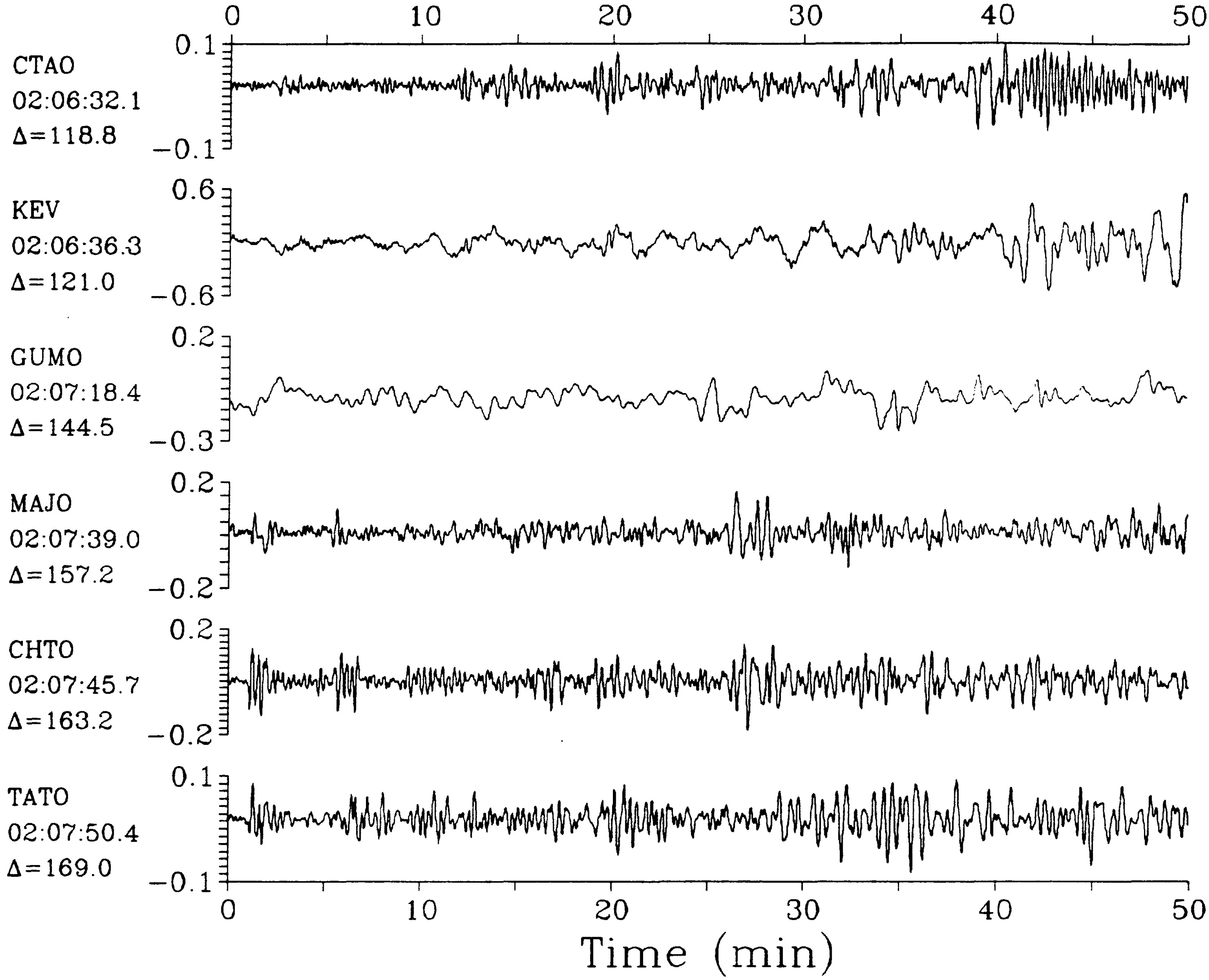


LPZ

24 October 1985 01:48:56.05

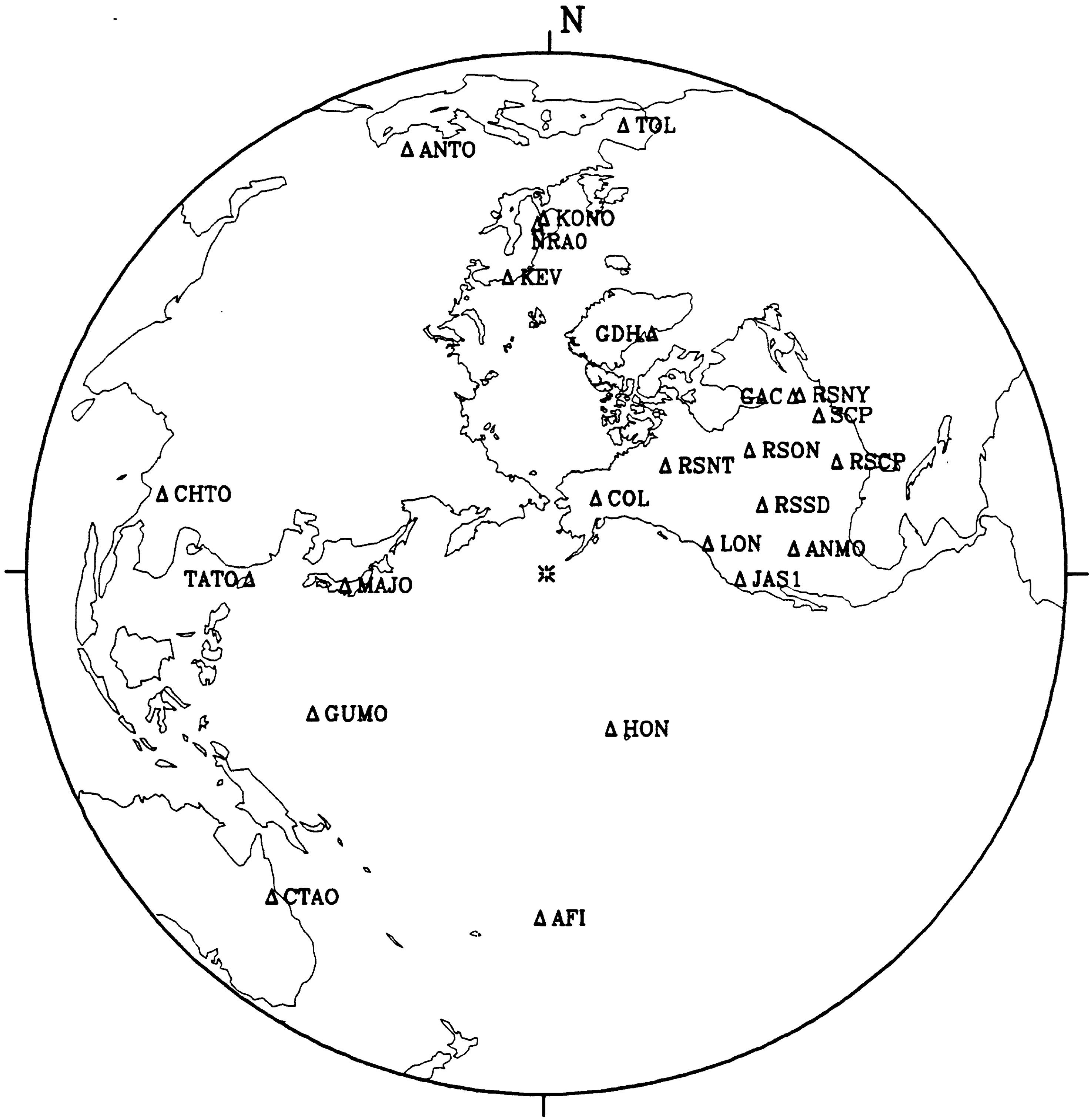
San Juan Province, Argentina h=110.7 m_b=5.7

LPZ



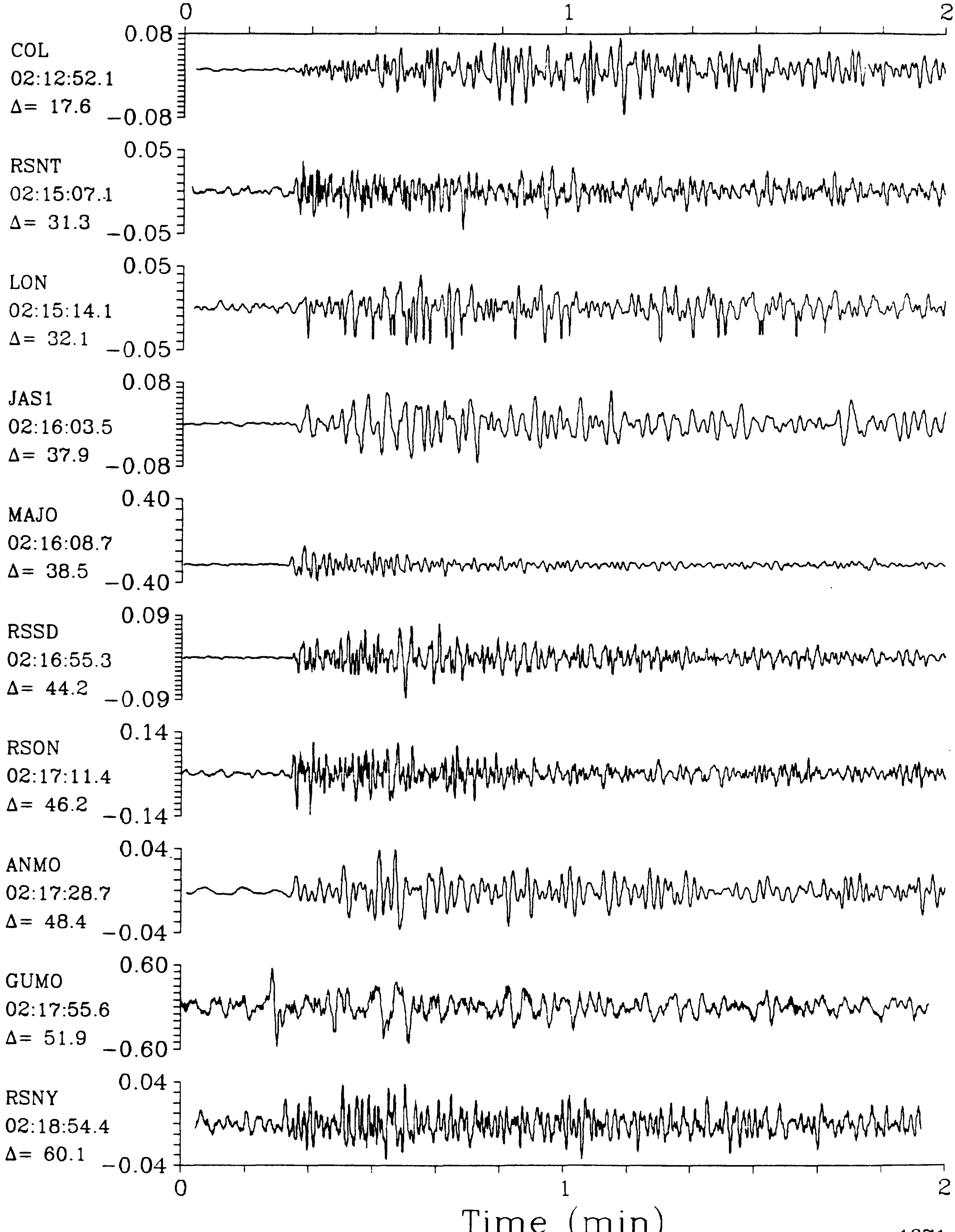
25 October 1985 02:09:04.47

Fox Islands, Aleutian Islands



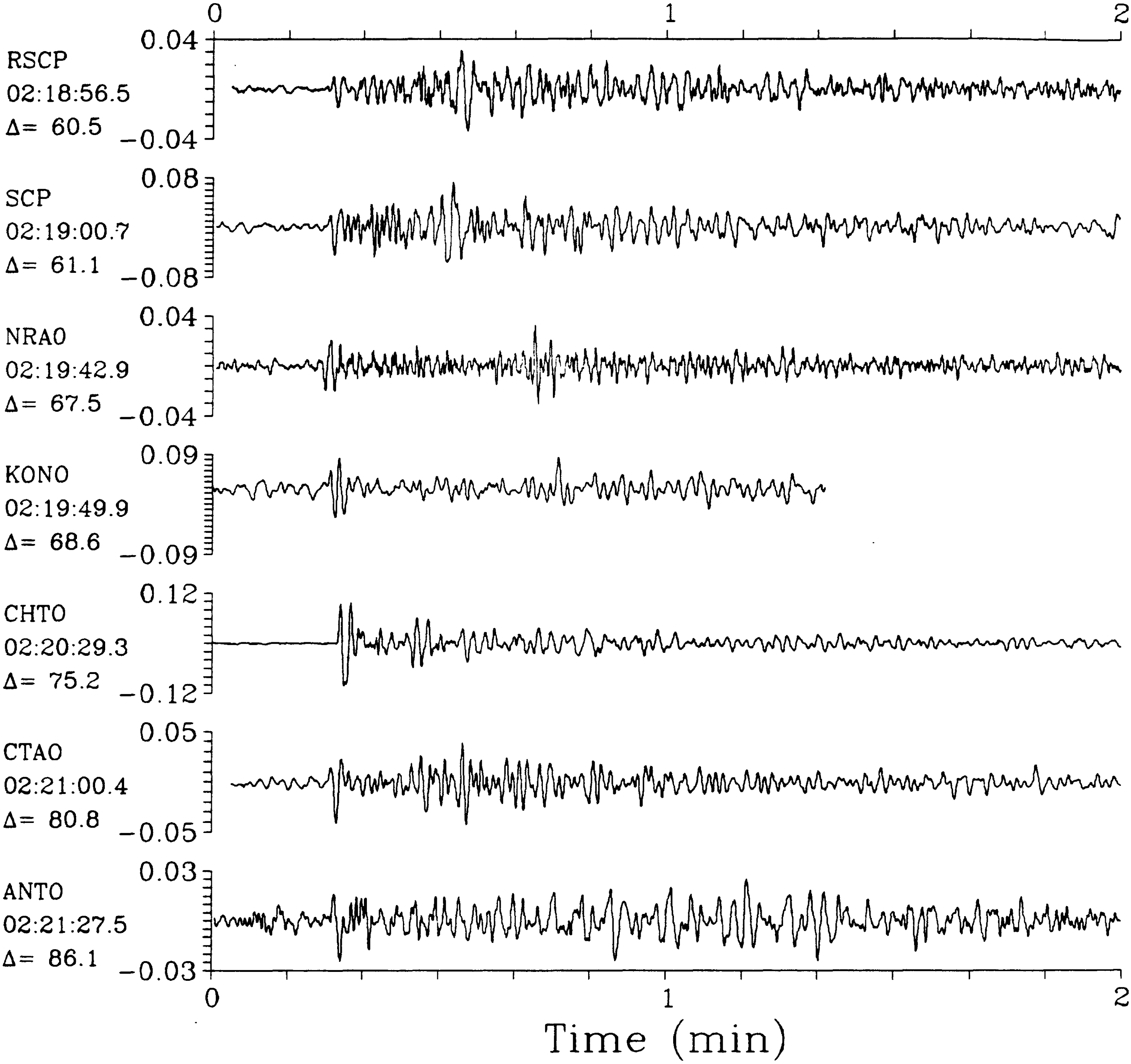
SPZ 25 October 1985 02:09:04.47 SPZ

Fox Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.6



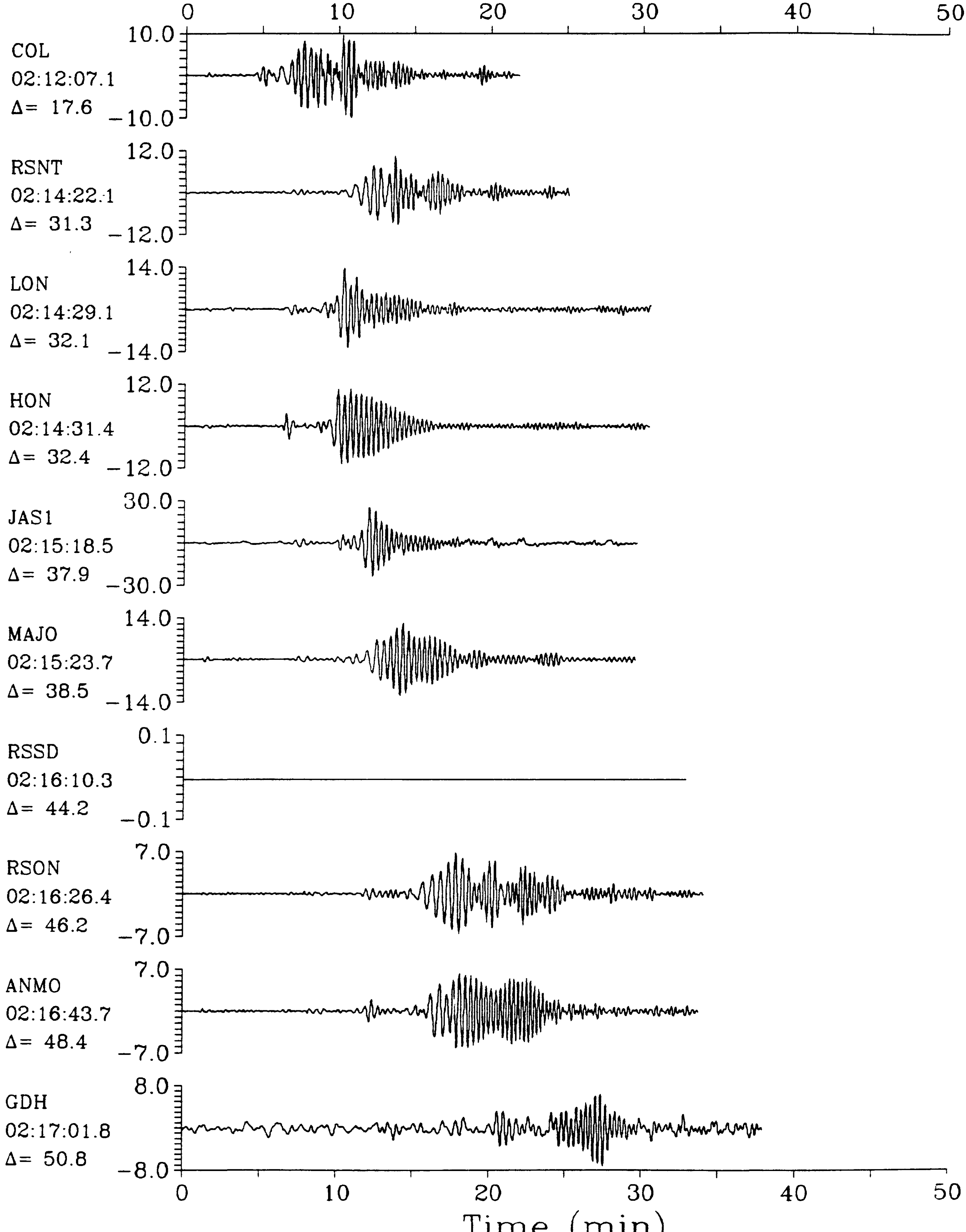
SPZ 25 October 1985 02:09:04.47 SPZ

Fox Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.6

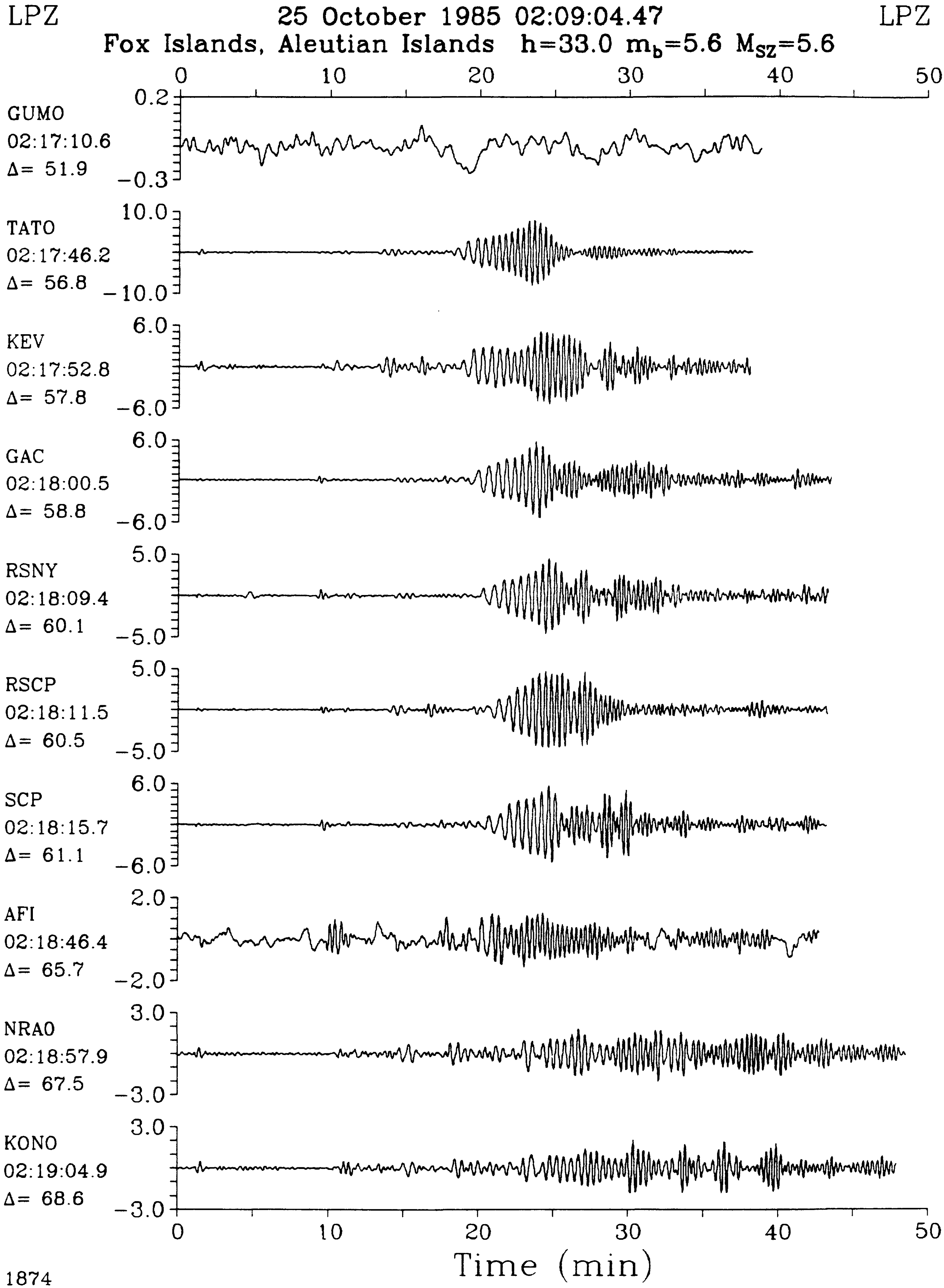


LPZ 25 October 1985 02:09:04.47 LPZ

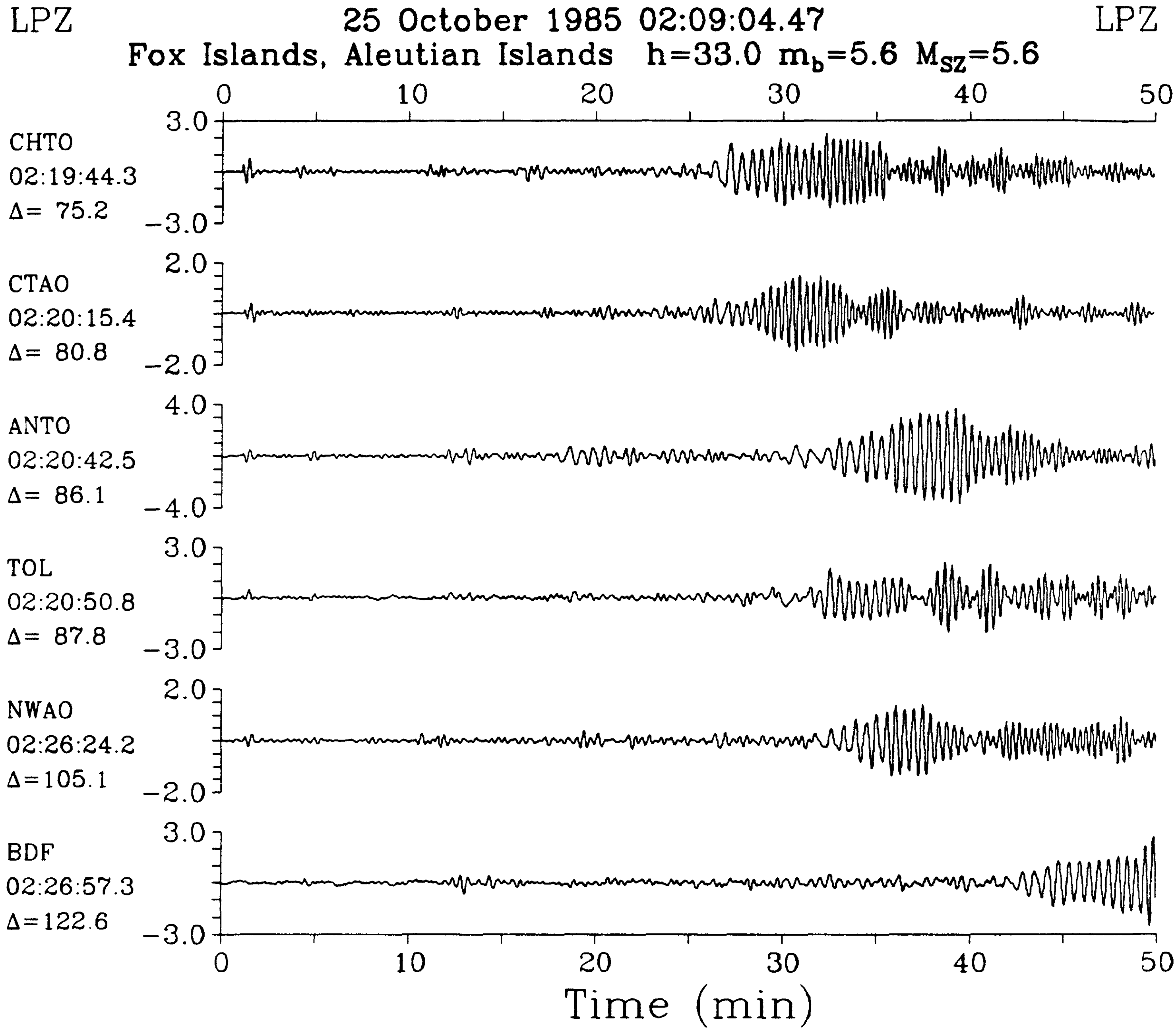
Fox Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.6



1873


LPZ
25 October 1985 02:09:04.47
LPZ
Fox Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.6
GUMO
02:17:10.6
Δ= 51.9
0.2
−0.3
TATO
02:17:46.2
Δ= 56.8
10.0
−10.0
KEV
02:17:52.8
Δ= 57.8
6.0
−6.0
GAC
02:18:00.5
Δ= 58.8
6.0
−6.0
RSNY
02:18:09.4
Δ= 60.1
5.0
−5.0
RSCP
02:18:11.5
Δ= 60.5
5.0
−5.0
SCP
02:18:15.7
Δ= 61.1
6.0
−6.0
AFI
02:18:46.4
Δ= 65.7
2.0
−2.0
NRAO
02:18:57.9
Δ= 67.5
3.0
−3.0
KONO
02:19:04.9
Δ= 68.6
3.0
−3.0
0
10
20
30
40
50
Time (min)

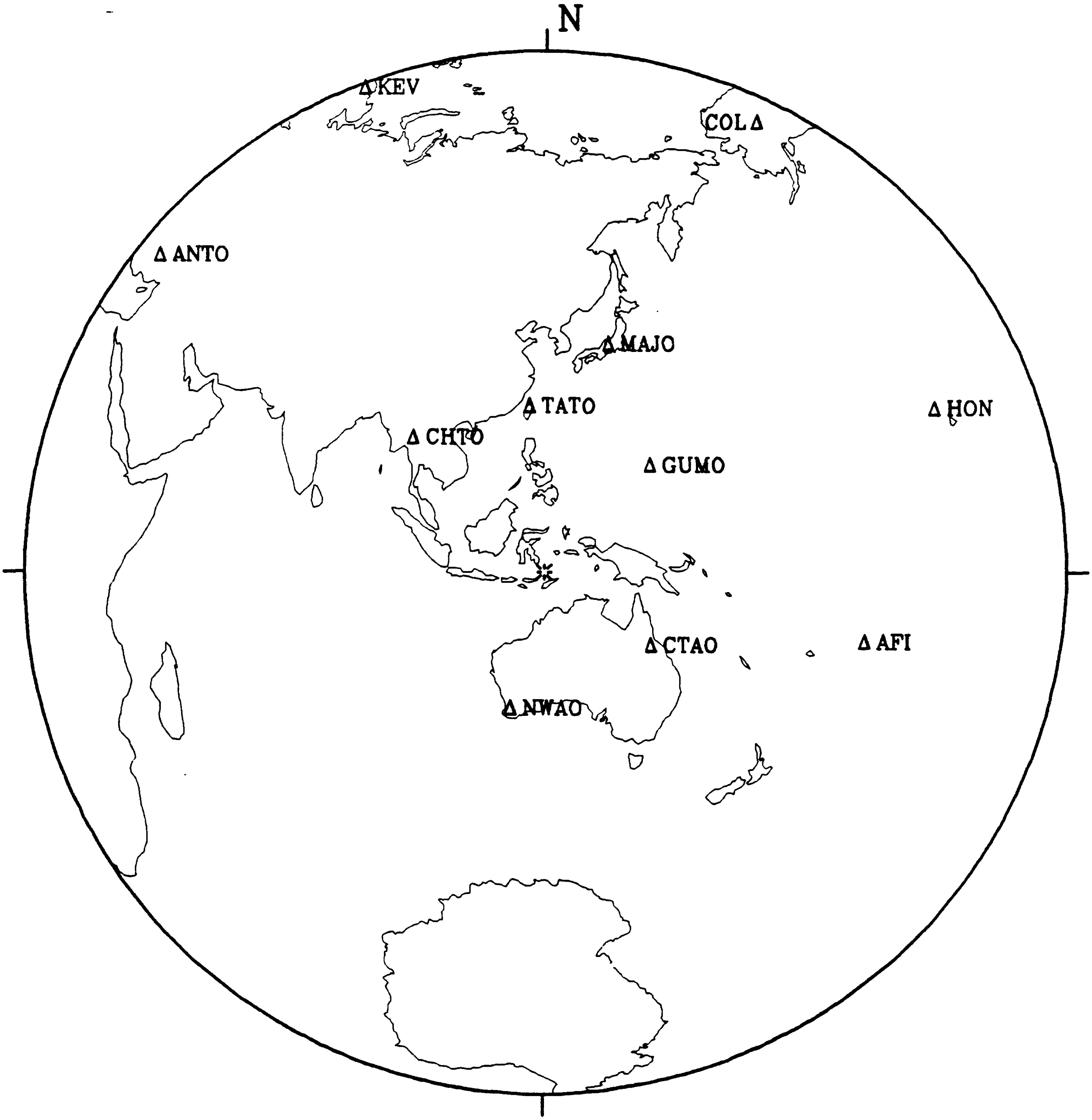
1874

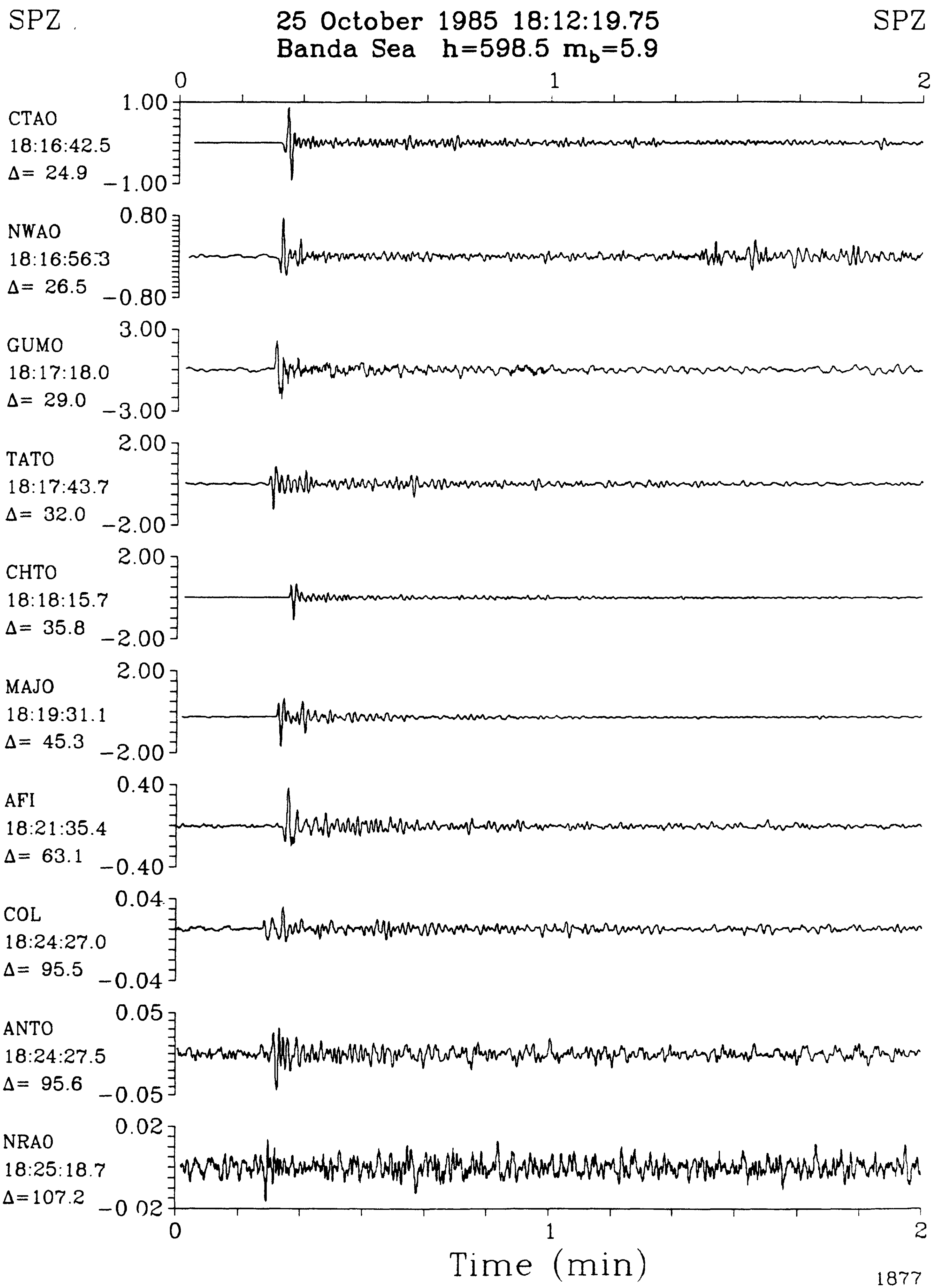


LPZ
25 October 1985 02:09:04.47
LPZ
Fox Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.6
0
10
20
30
40
50
3.0
CHTO
02:19:44.3
Δ= 75.2
-3.0
2.0
CTAO
02:20:15.4
Δ= 80.8
-2.0
4.0
ANTO
02:20:42.5
Δ= 86.1
-4.0
3.0
TOL
02:20:50.8
Δ= 87.8
-3.0
2.0
NWAO
02:26:24.2
Δ=105.1
-2.0
3.0
BDF
02:26:57.3
Δ=122.6
-3.0
0
10
20
30
40
50
Time (min)

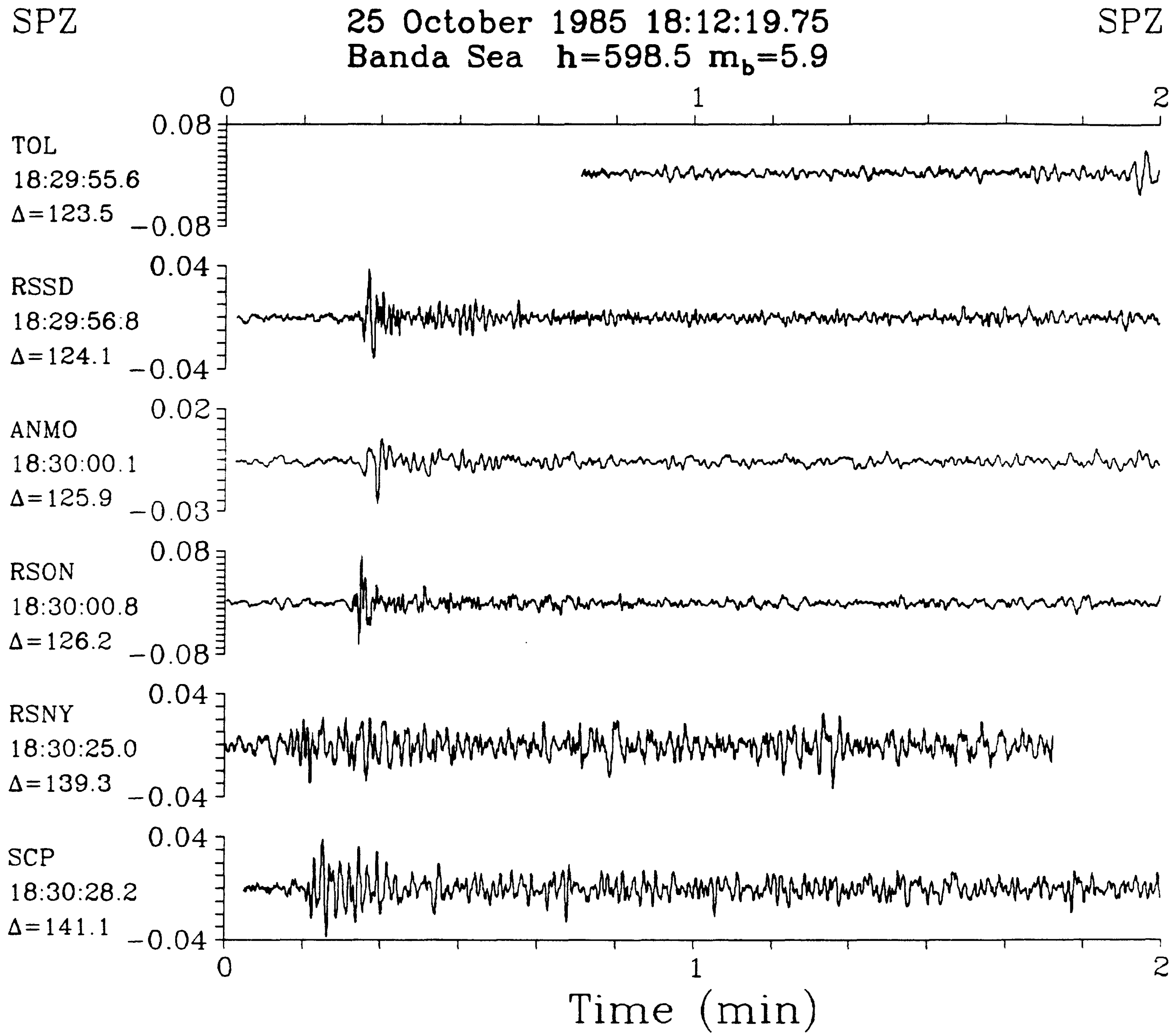
25 October 1985 18:12:19.75

Banda Sea

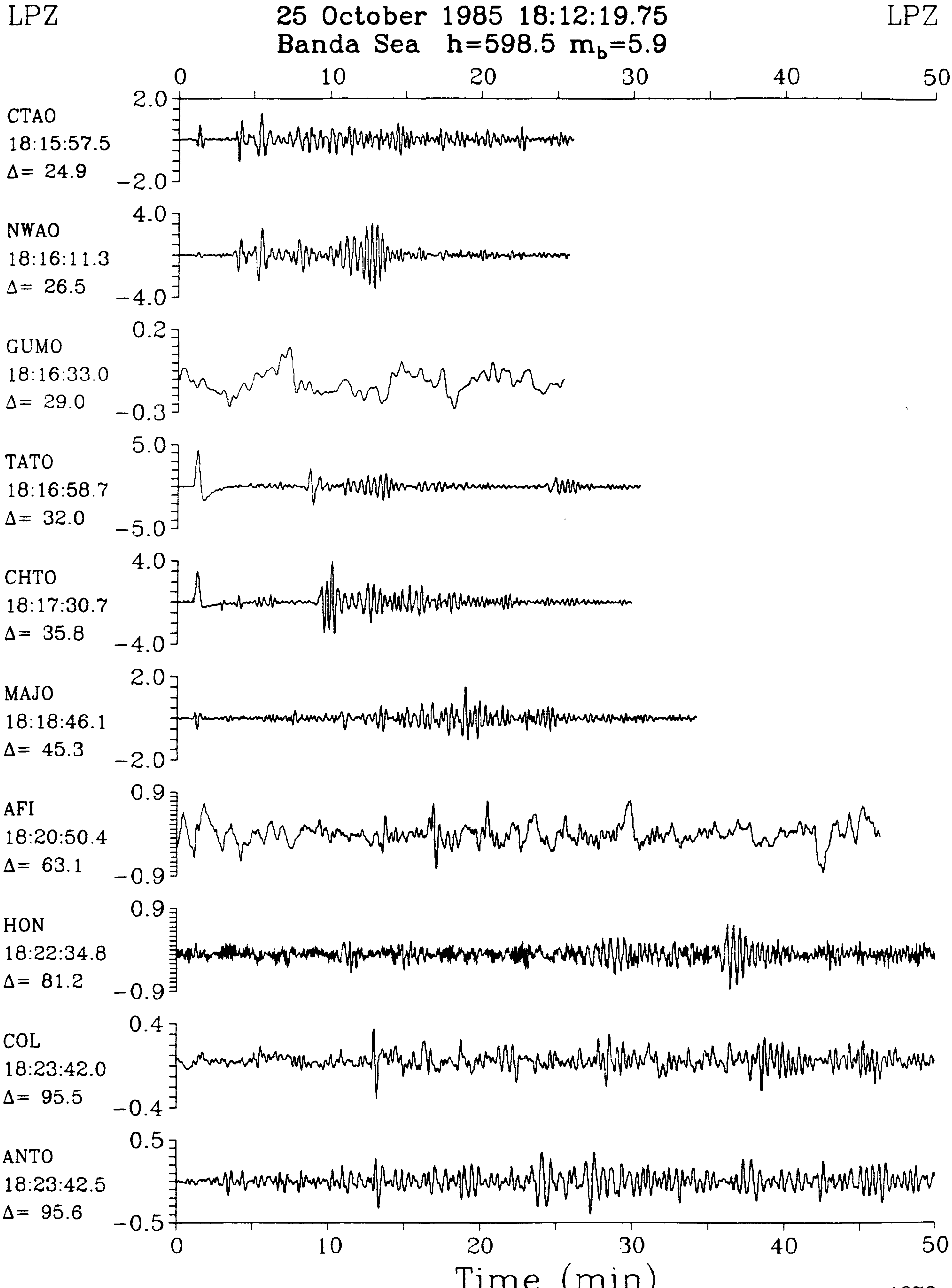



SPZ
25 October 1985 18:12:19.75
Banda Sea h=598.5 m_b=5.9
SPZ
0
1
2
CTAO
18:16:42.5
Δ= 24.9
1.00
−1.00
NWAO
18:16:56.3
Δ= 26.5
0.80
−0.80
GUMO
18:17:18.0
Δ= 29.0
3.00
−3.00
TATO
18:17:43.7
Δ= 32.0
2.00
−2.00
CHTO
18:18:15.7
Δ= 35.8
2.00
−2.00
MAJO
18:19:31.1
Δ= 45.3
2.00
−2.00
AFI
18:21:35.4
Δ= 63.1
0.40
−0.40
COL
18:24:27.0
Δ= 95.5
0.04
−0.04
ANTO
18:24:27.5
Δ= 95.6
0.05
−0.05
NRAO
18:25:18.7
Δ=107.2
0.02
−0.02
0
1
2
Time (min)

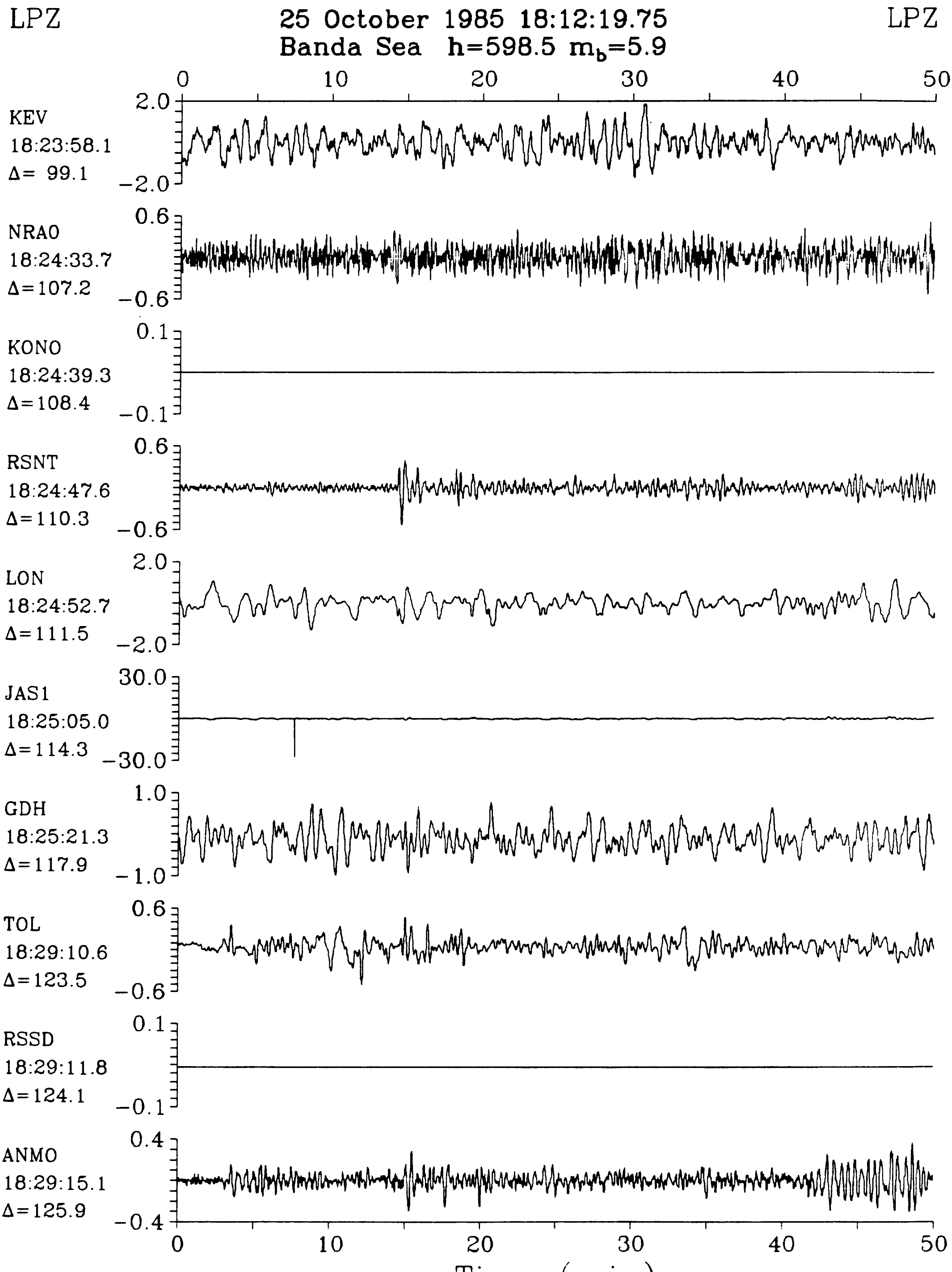
1877



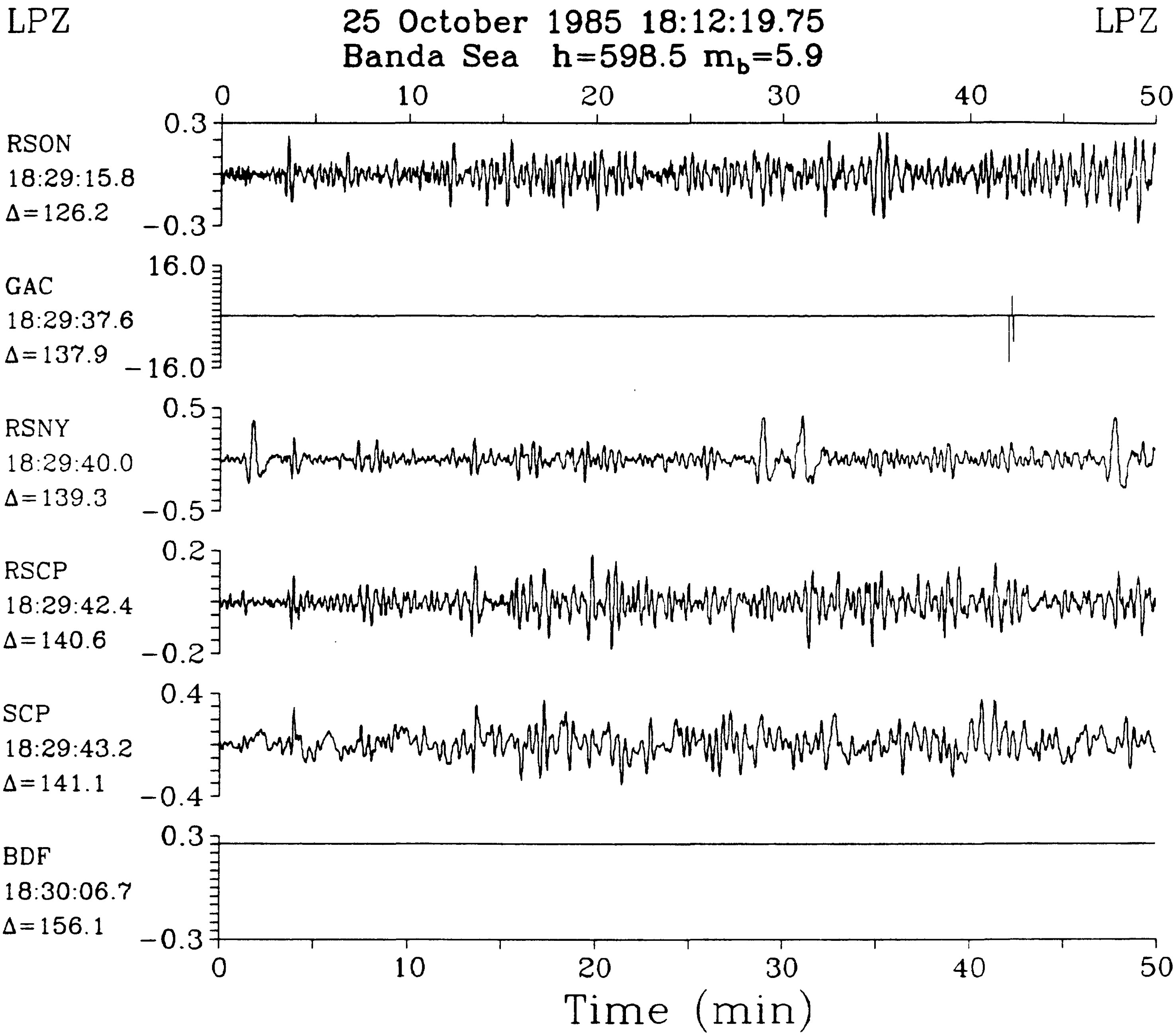
SPZ
25 October 1985 18:12:19.75
Banda Sea h=598.5 m_b=5.9
SPZ
TOL
18:29:55.6
Δ=123.5
RSSD
18:29:56.8
Δ=124.1
ANMO
18:30:00.1
Δ=125.9
RSON
18:30:00.8
Δ=126.2
RSNY
18:30:25.0
Δ=139.3
SCP
18:30:28.2
Δ=141.1
0.08
−0.08
0.04
−0.04
0.02
−0.03
0.08
−0.08
0.04
−0.04
0.04
−0.04
0
1
2
Time (min)


LPZ
25 October 1985 18:12:19.75
Banda Sea h=598.5 m_b=5.9
LPZ
CTAO
18:15:57.5
Δ= 24.9
NWAO
18:16:11.3
Δ= 26.5
GUMO
18:16:33.0
Δ= 29.0
TATO
18:16:58.7
Δ= 32.0
CHTO
18:17:30.7
Δ= 35.8
MAJO
18:18:46.1
Δ= 45.3
AFI
18:20:50.4
Δ= 63.1
HON
18:22:34.8
Δ= 81.2
COL
18:23:42.0
Δ= 95.5
ANTO
18:23:42.5
Δ= 95.6
2.0
−2.0
4.0
−4.0
0.2
−0.3
5.0
−5.0
4.0
−4.0
2.0
−2.0
0.9
−0.9
0.9
−0.9
0.4
−0.4
0.5
−0.5
0
10
20
30
40
50
Time (min)

1879


LPZ
25 October 1985 18:12:19.75
Banda Sea h=598.5 m_b=5.9
LPZ
KEV
18:23:58.1
Δ= 99.1
NRAO
18:24:33.7
Δ=107.2
KONO
18:24:39.3
Δ=108.4
RSNT
18:24:47.6
Δ=110.3
LON
18:24:52.7
Δ=111.5
JAS1
18:25:05.0
Δ=114.3
GDH
18:25:21.3
Δ=117.9
TOL
18:29:10.6
Δ=123.5
RSSD
18:29:11.8
Δ=124.1
ANMO
18:29:15.1
Δ=125.9
Time (min)

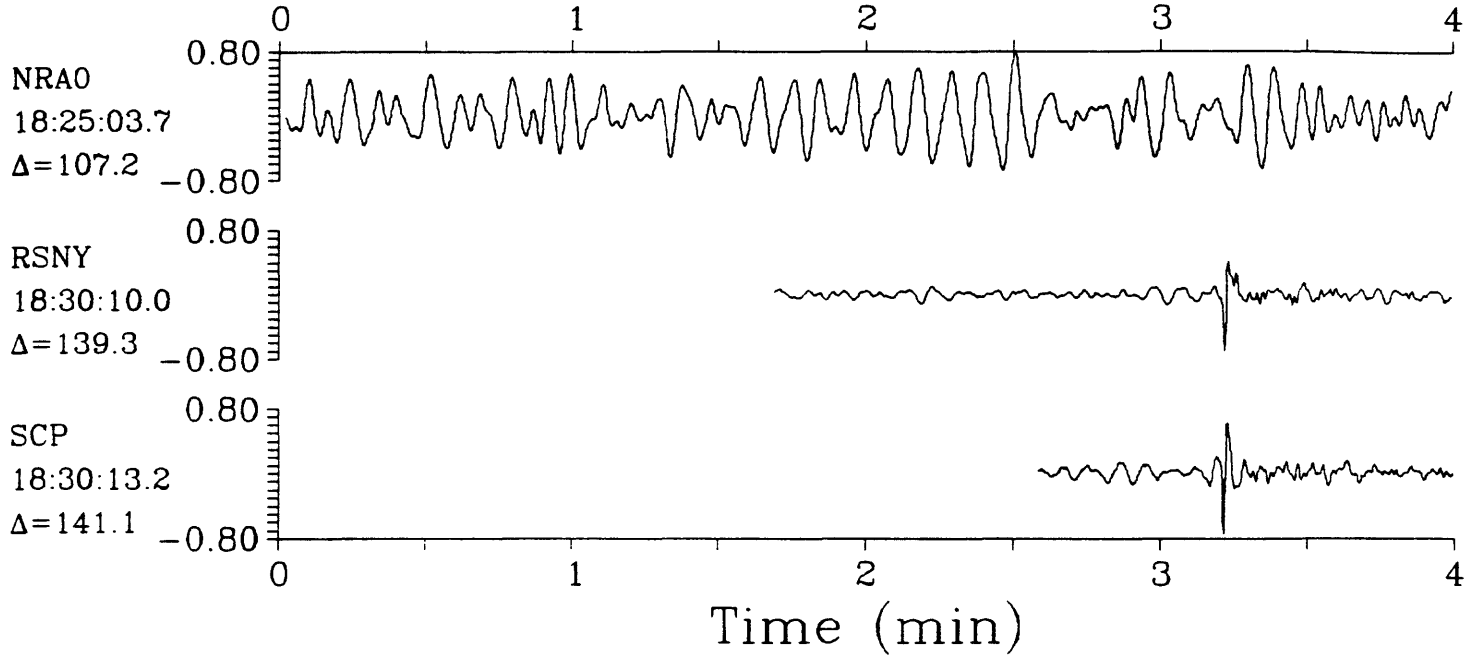
1880


LPZ
25 October 1985 18:12:19.75
Banda Sea h=598.5 m_b=5.9
LPZ
RSON
18:29:15.8
Δ=126.2
GAC
18:29:37.6
Δ=137.9
RSNY
18:29:40.0
Δ=139.3
RSCP
18:29:42.4
Δ=140.6
SCP
18:29:43.2
Δ=141.1
BDF
18:30:06.7
Δ=156.1
Time (min)

IPZ

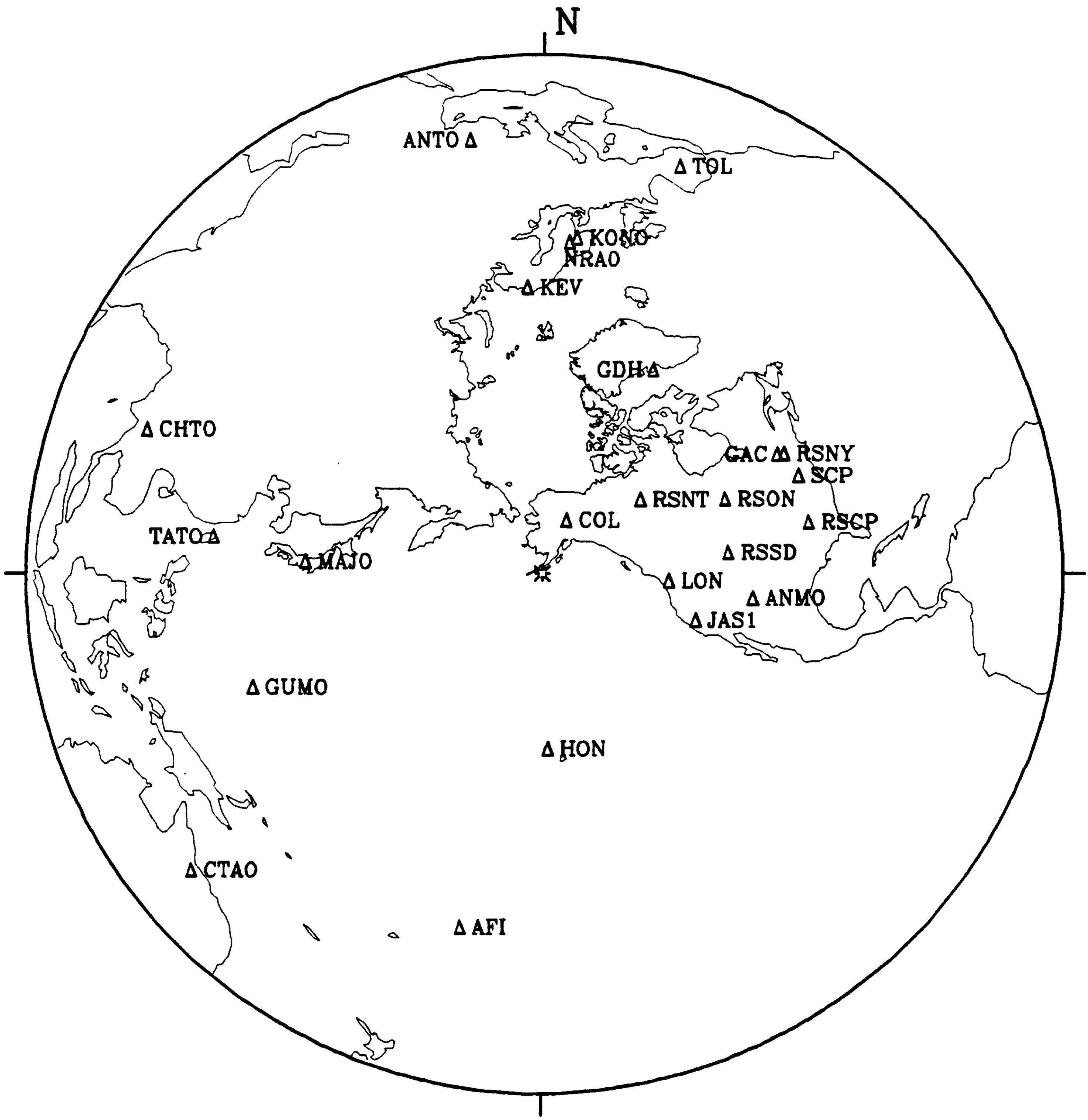
25 October 1985 18:12:19.75
Banda Sea h=598.5 m_b=5.9

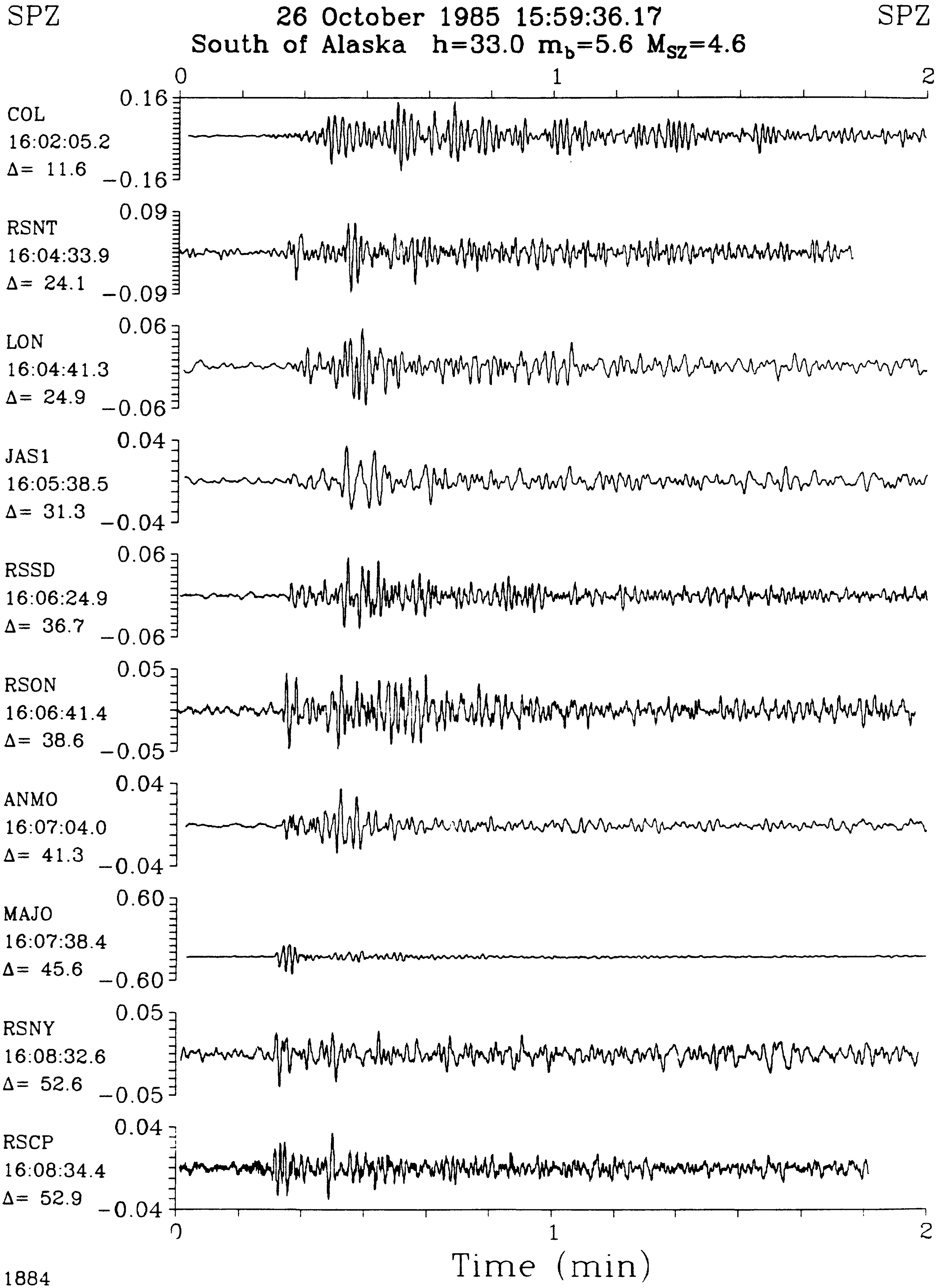
IPZ



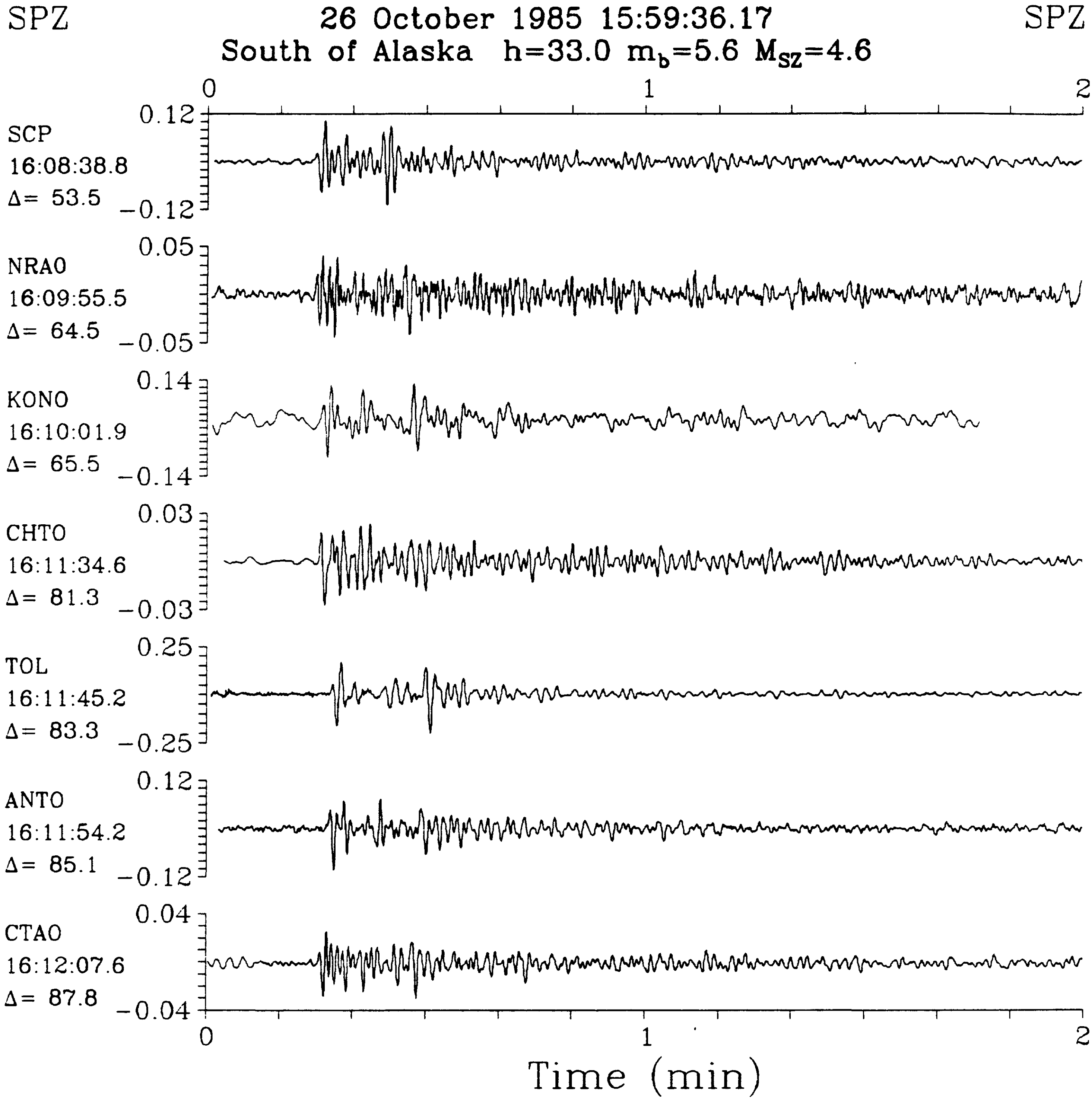
26 October 1985 15:59:36.17

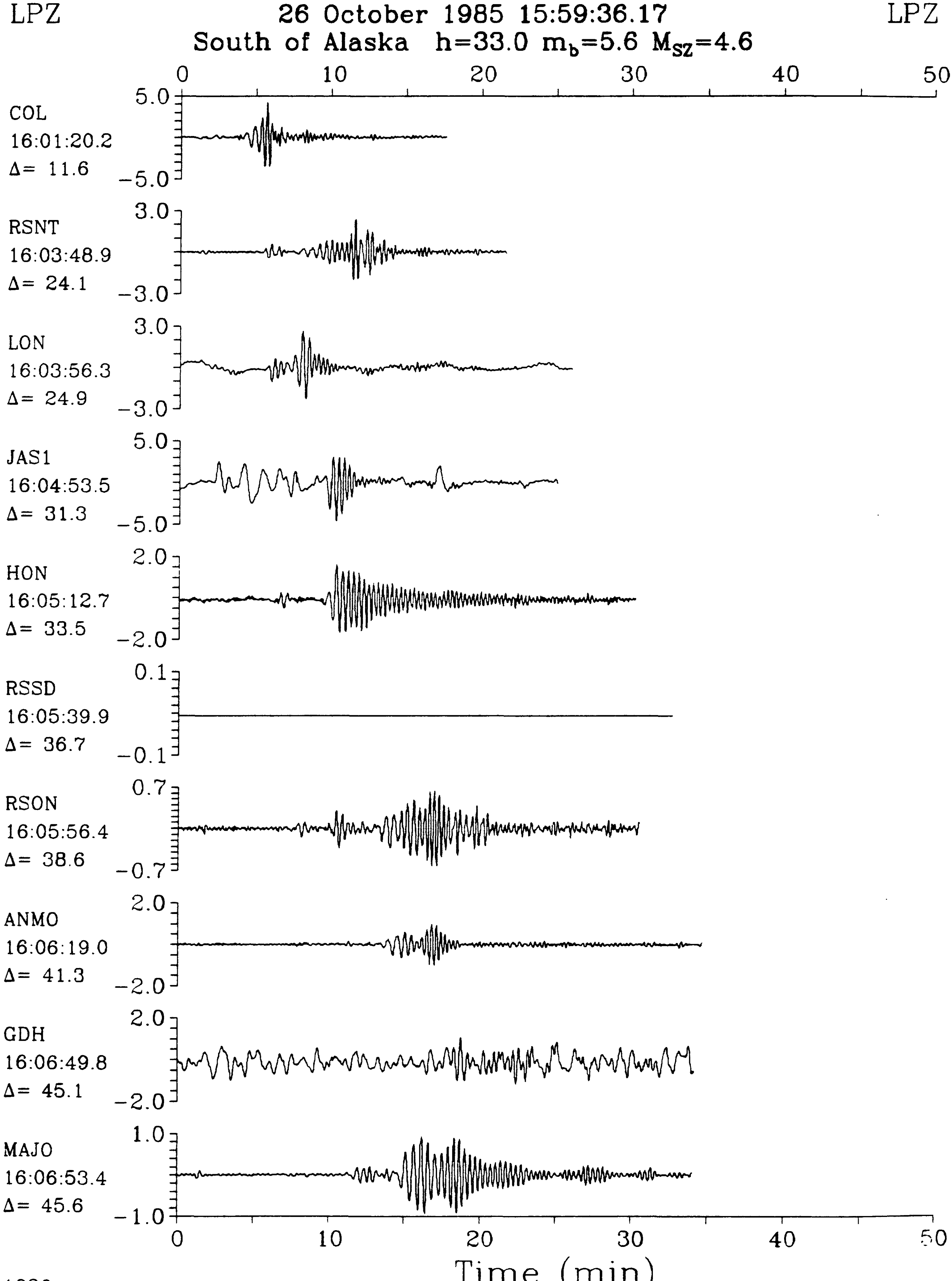
South of Alaska





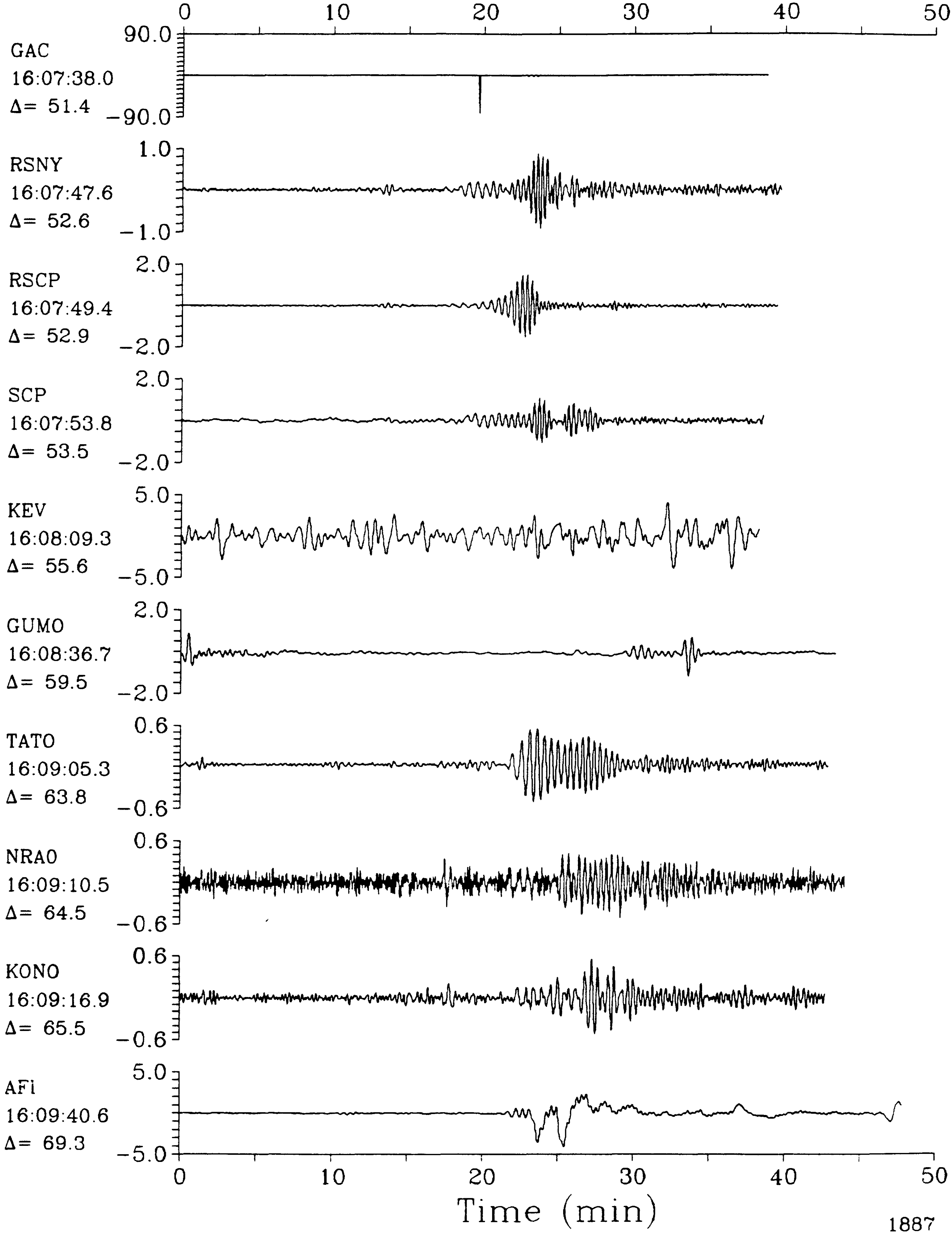
SPZ
26 October 1985 15:59:36.17
South of Alaska h=33.0 m_b=5.6 M_{SZ}=4.6
SPZ
COL
16:02:05.2
Δ= 11.6
0.16
−0.16
RSNT
16:04:33.9
Δ= 24.1
0.09
−0.09
LON
16:04:41.3
Δ= 24.9
0.06
−0.06
JAS1
16:05:38.5
Δ= 31.3
0.04
−0.04
RSSD
16:06:24.9
Δ= 36.7
0.06
−0.06
RSON
16:06:41.4
Δ= 38.6
0.05
−0.05
ANMO
16:07:04.0
Δ= 41.3
0.04
−0.04
MAJO
16:07:38.4
Δ= 45.6
0.60
−0.60
RSNY
16:08:32.6
Δ= 52.6
0.05
−0.05
RSCP
16:08:34.4
Δ= 52.9
0.04
−0.04
0
1
2
Time (min)


SPZ
26 October 1985 15:59:36.17
South of Alaska h=33.0 m_b=5.6 M_{SZ}=4.6
SPZ
SCP
16:08:38.8
Δ= 53.5
NRAO
16:09:55.5
Δ= 64.5
KONO
16:10:01.9
Δ= 65.5
CHTO
16:11:34.6
Δ= 81.3
TOL
16:11:45.2
Δ= 83.3
ANTO
16:11:54.2
Δ= 85.1
CTAO
16:12:07.6
Δ= 87.8
Time (min)

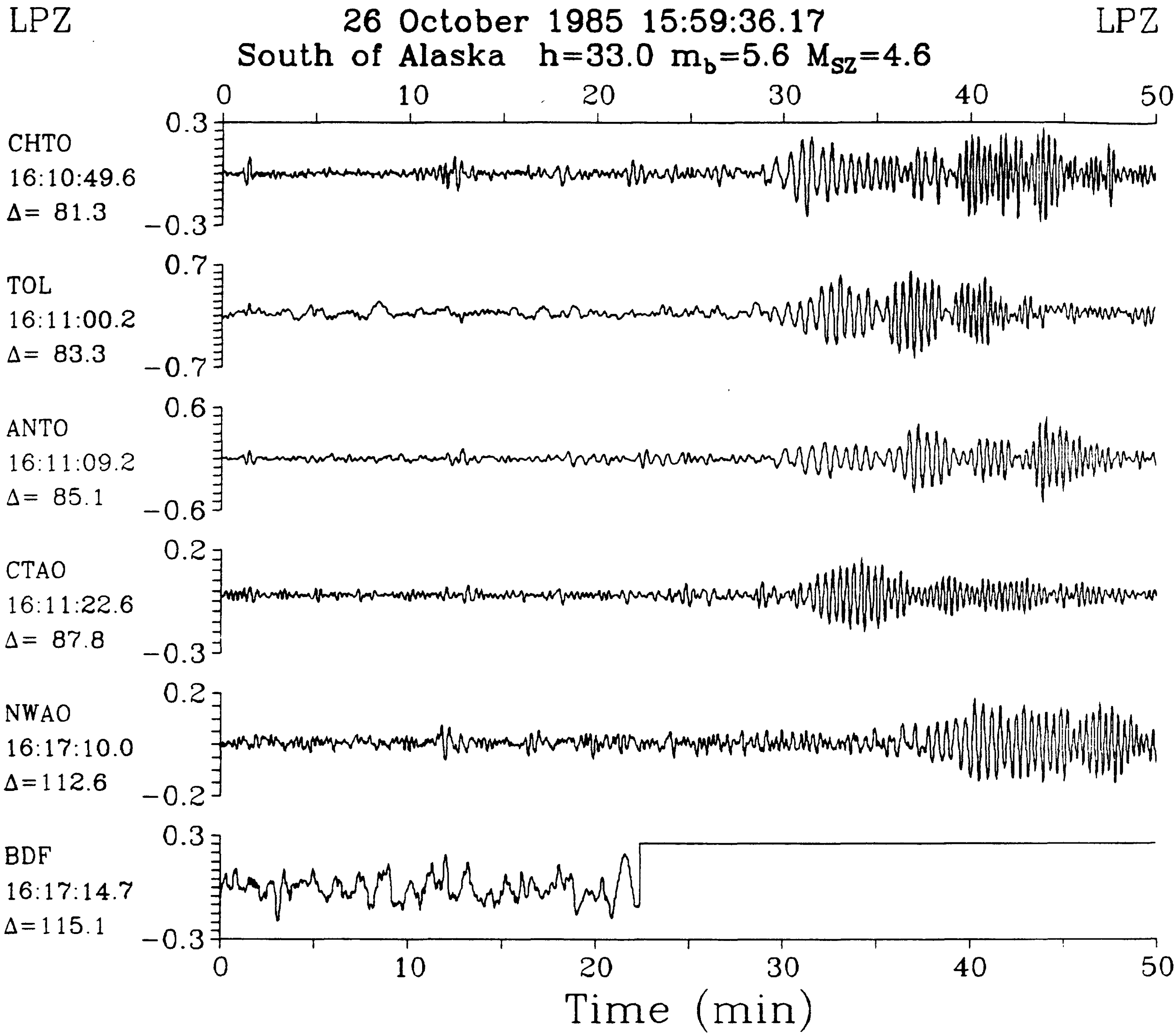

LPZ
26 October 1985 15:59:36.17
South of Alaska h=33.0 m_b=5.6 M_{SZ}=4.6
LPZ
COL
16:01:20.2
Δ= 11.6
RSNT
16:03:48.9
Δ= 24.1
LON
16:03:56.3
Δ= 24.9
JAS1
16:04:53.5
Δ= 31.3
HON
16:05:12.7
Δ= 33.5
RSSD
16:05:39.9
Δ= 36.7
RSON
16:05:56.4
Δ= 38.6
ANMO
16:06:19.0
Δ= 41.3
GDH
16:06:49.8
Δ= 45.1
MAJO
16:06:53.4
Δ= 45.6
Time (min)

LPZ 26 October 1985 15:59:36.17 LPZ

South of Alaska h=33.0 m_b=5.6 M_{SZ}=4.6

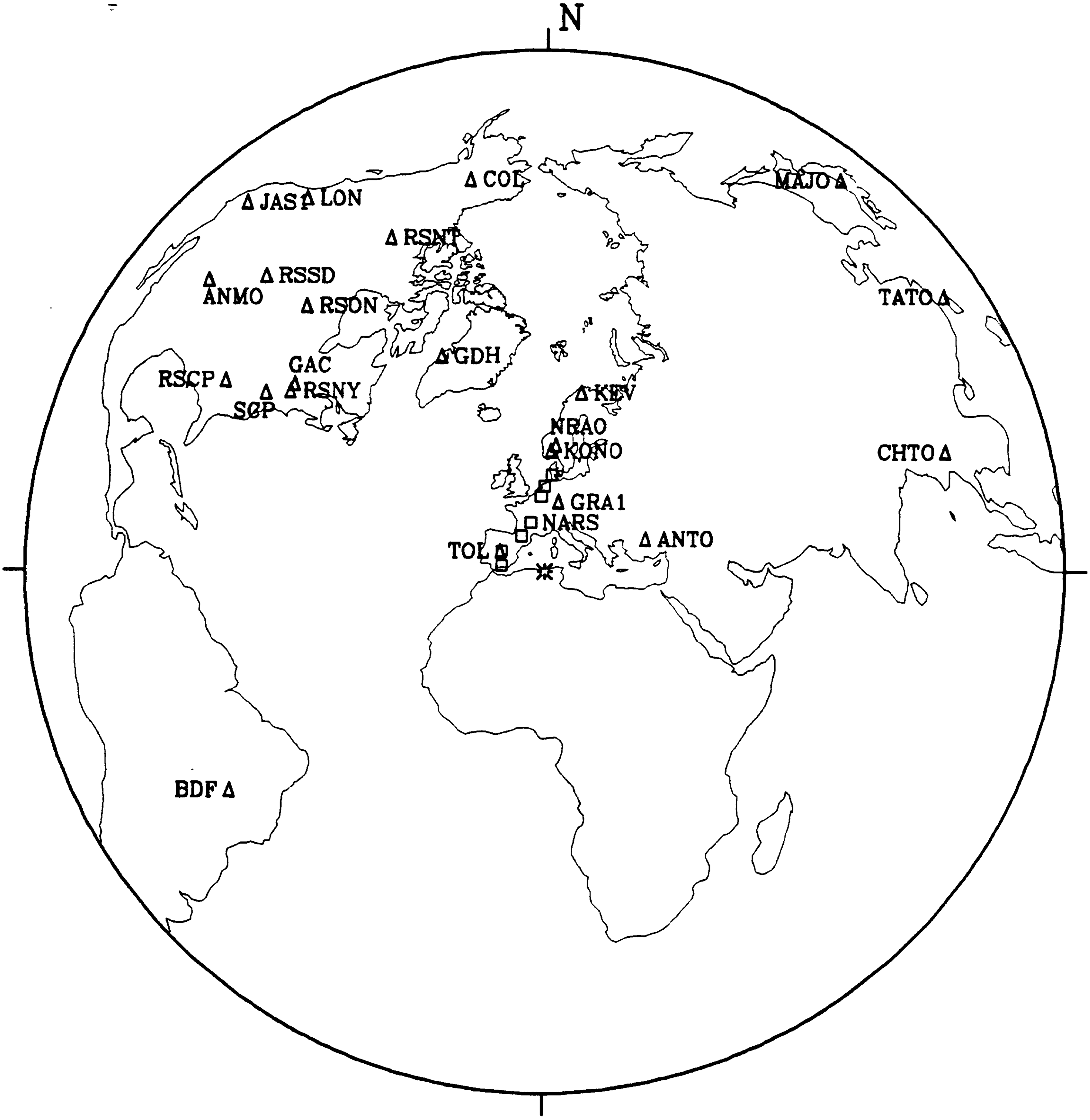


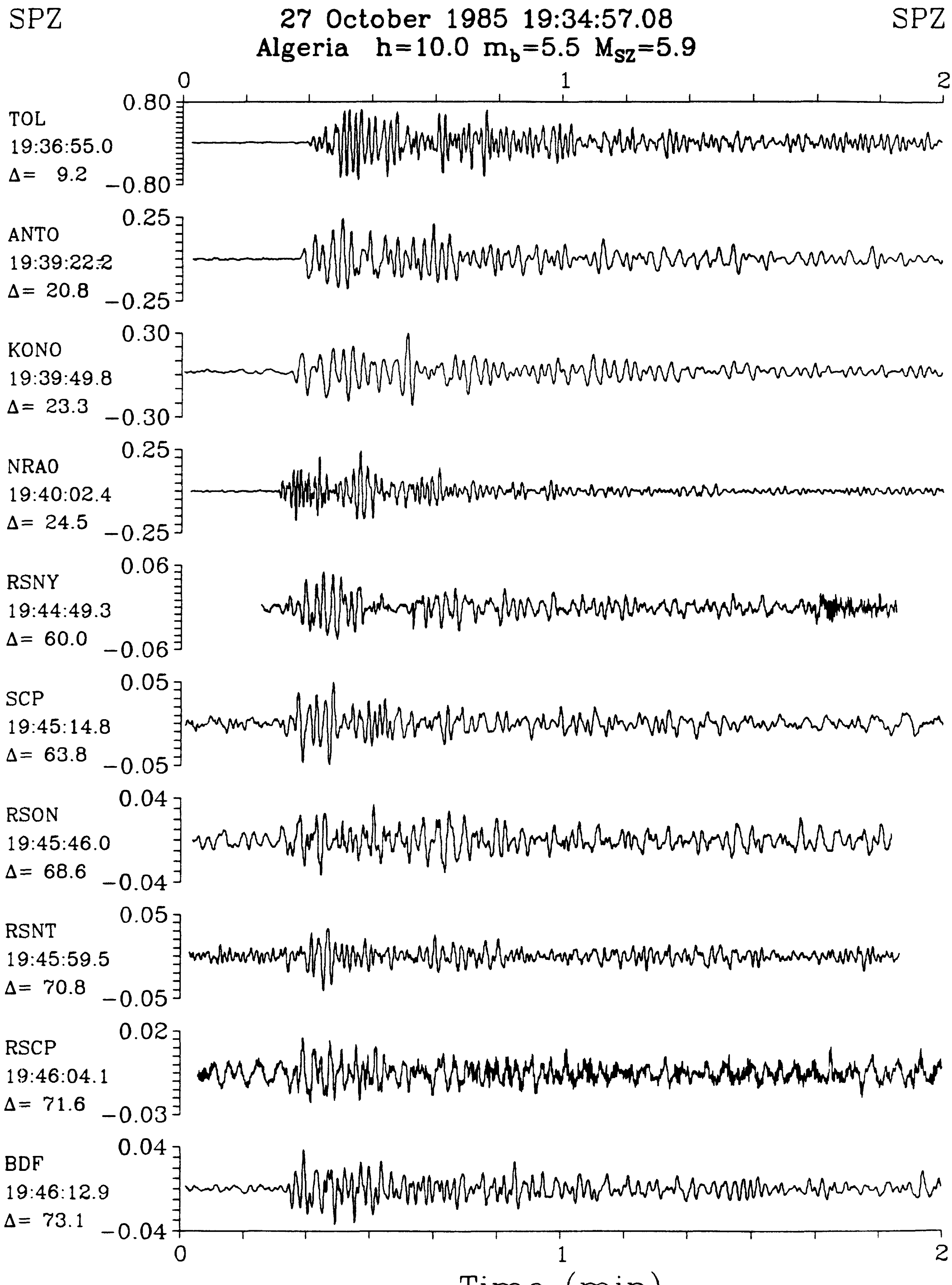
1887


LPZ
26 October 1985 15:59:36.17
South of Alaska h=33.0 m_b=5.6 M_{SZ}=4.6
LPZ
CHTO
16:10:49.6
Δ= 81.3
TOL
16:11:00.2
Δ= 83.3
ANTO
16:11:09.2
Δ= 85.1
CTAO
16:11:22.6
Δ= 87.8
NWAO
16:17:10.0
Δ=112.6
BDF
16:17:14.7
Δ=115.1
Time (min)

27 October 1985 19:34:57.08

Algeria

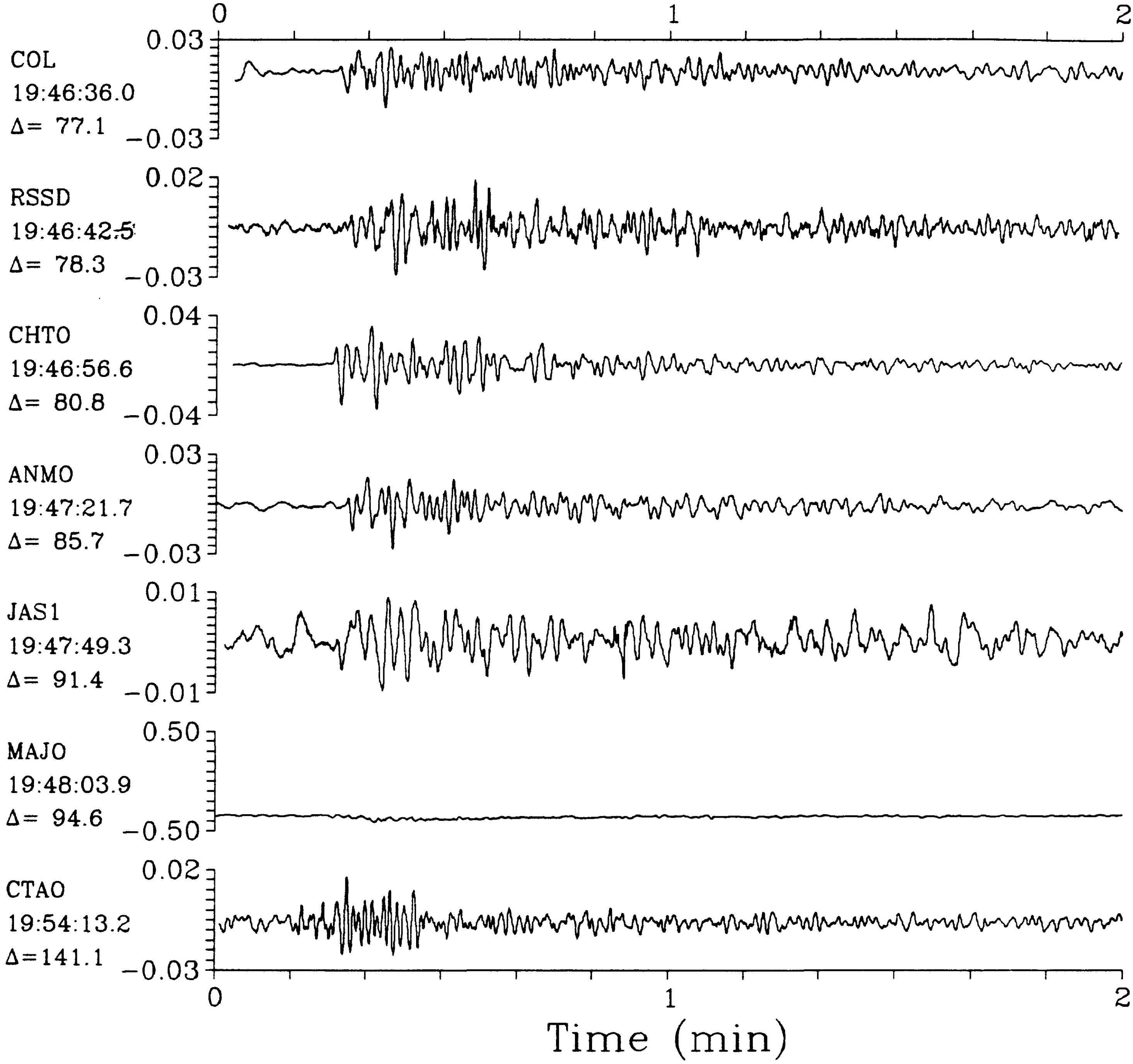


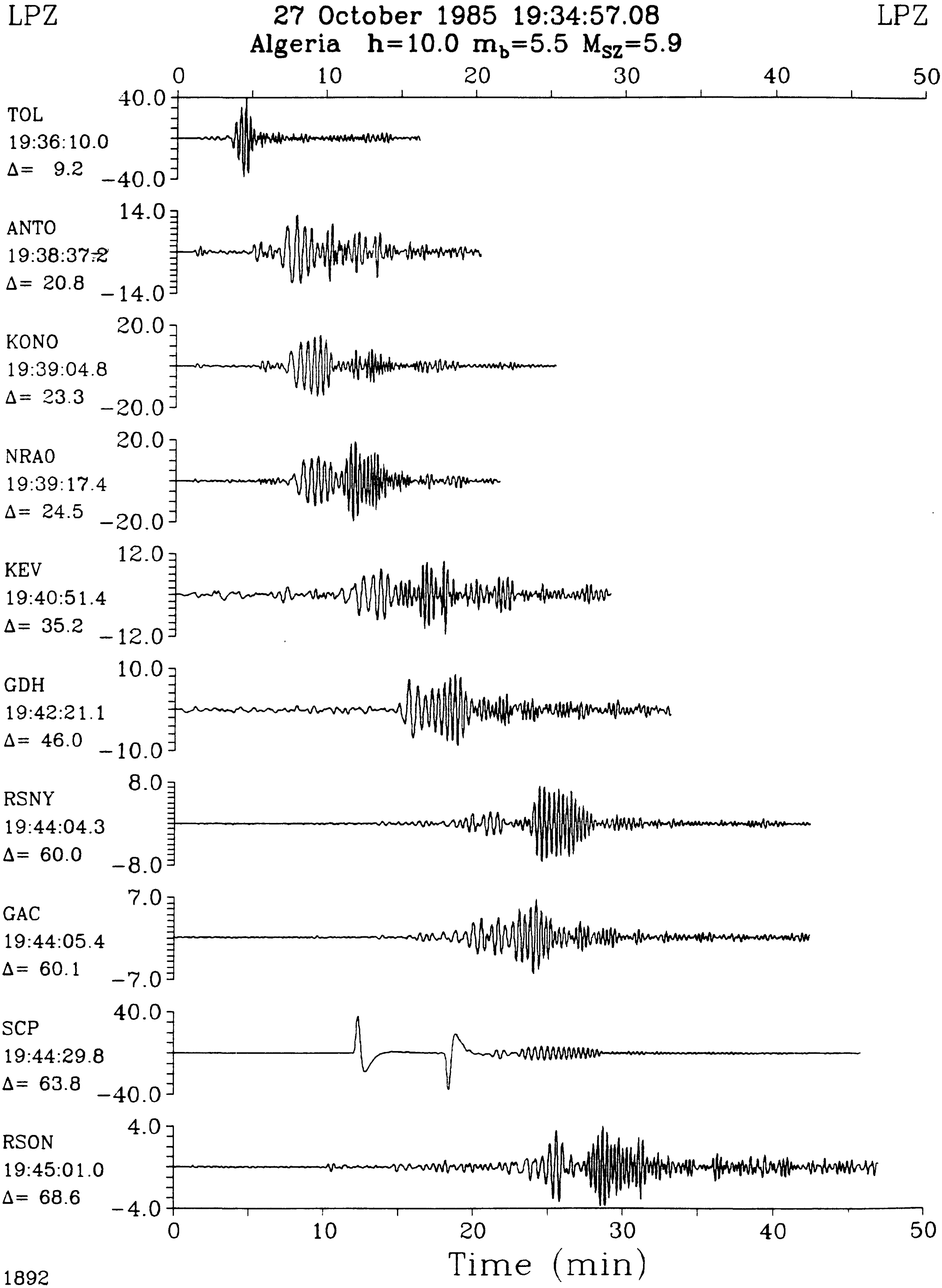


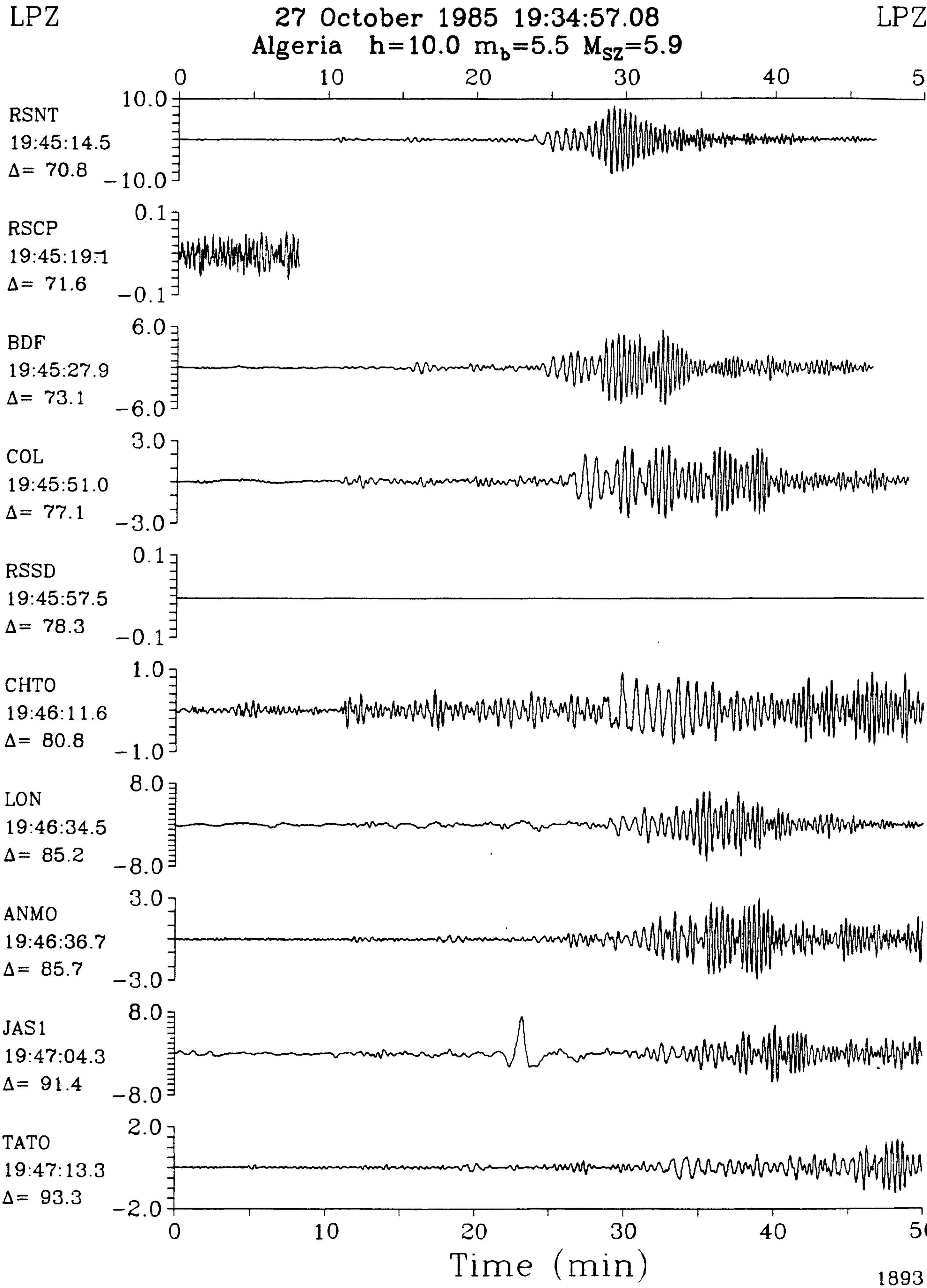
SPZ
27 October 1985 19:34:57.08
Algeria h=10.0 m_b=5.5 M_{SZ}=5.9
SPZ
TOL
19:36:55.0
Δ= 9.2
0.80
−0.80
ANTO
19:39:22.2
Δ= 20.8
0.25
−0.25
KONO
19:39:49.8
Δ= 23.3
0.30
−0.30
NRAO
19:40:02.4
Δ= 24.5
0.25
−0.25
RSNY
19:44:49.3
Δ= 60.0
0.06
−0.06
SCP
19:45:14.8
Δ= 63.8
0.05
−0.05
RSON
19:45:46.0
Δ= 68.6
0.04
−0.04
RSNT
19:45:59.5
Δ= 70.8
0.05
−0.05
RSCP
19:46:04.1
Δ= 71.6
0.02
−0.03
BDF
19:46:12.9
Δ= 73.1
0.04
−0.04
0
1
2
Time (min)

SPZ 27 October 1985 19:34:57.08 SPZ

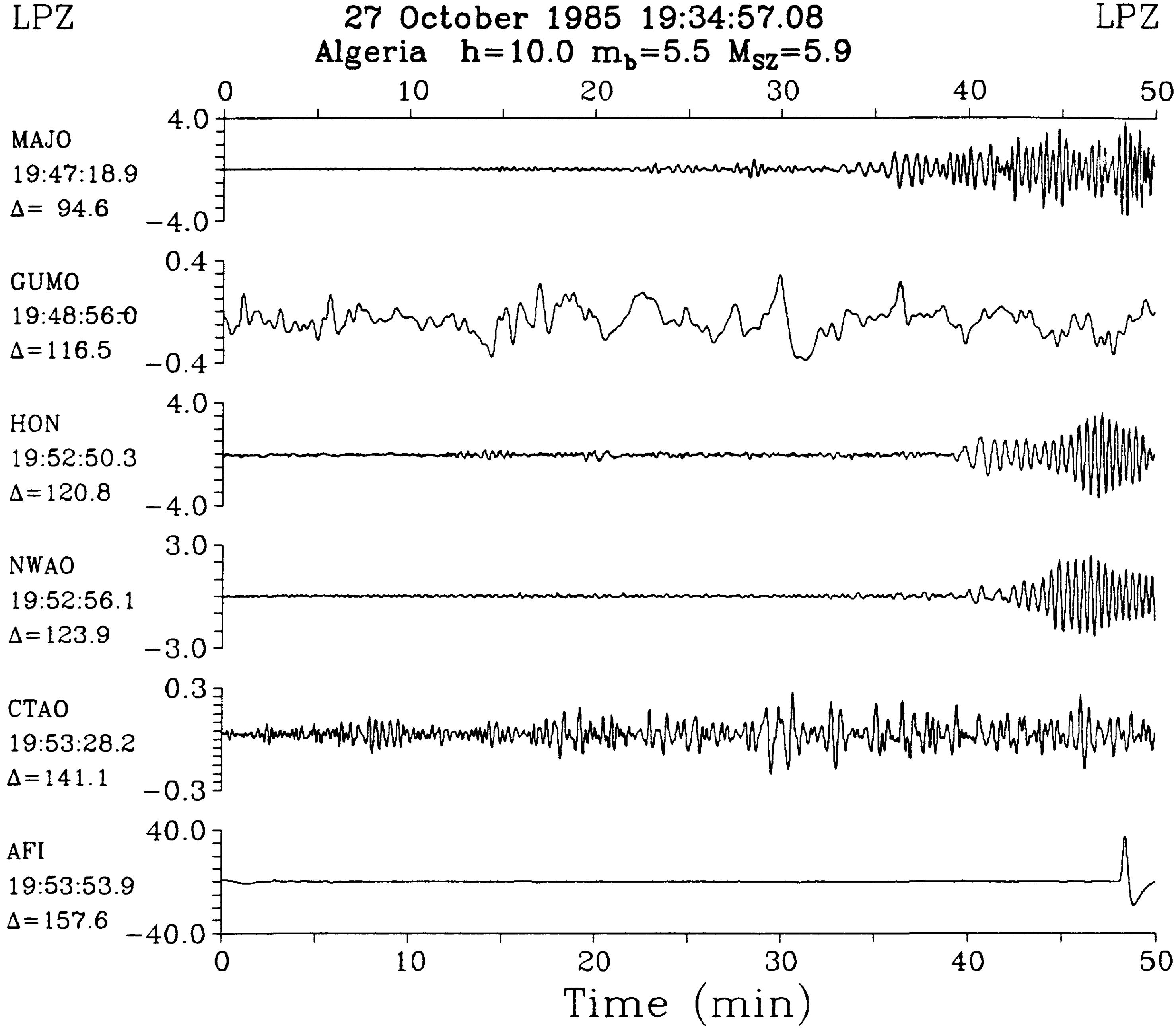
Algeria h=10.0 m_b=5.5 M_{SZ}=5.9

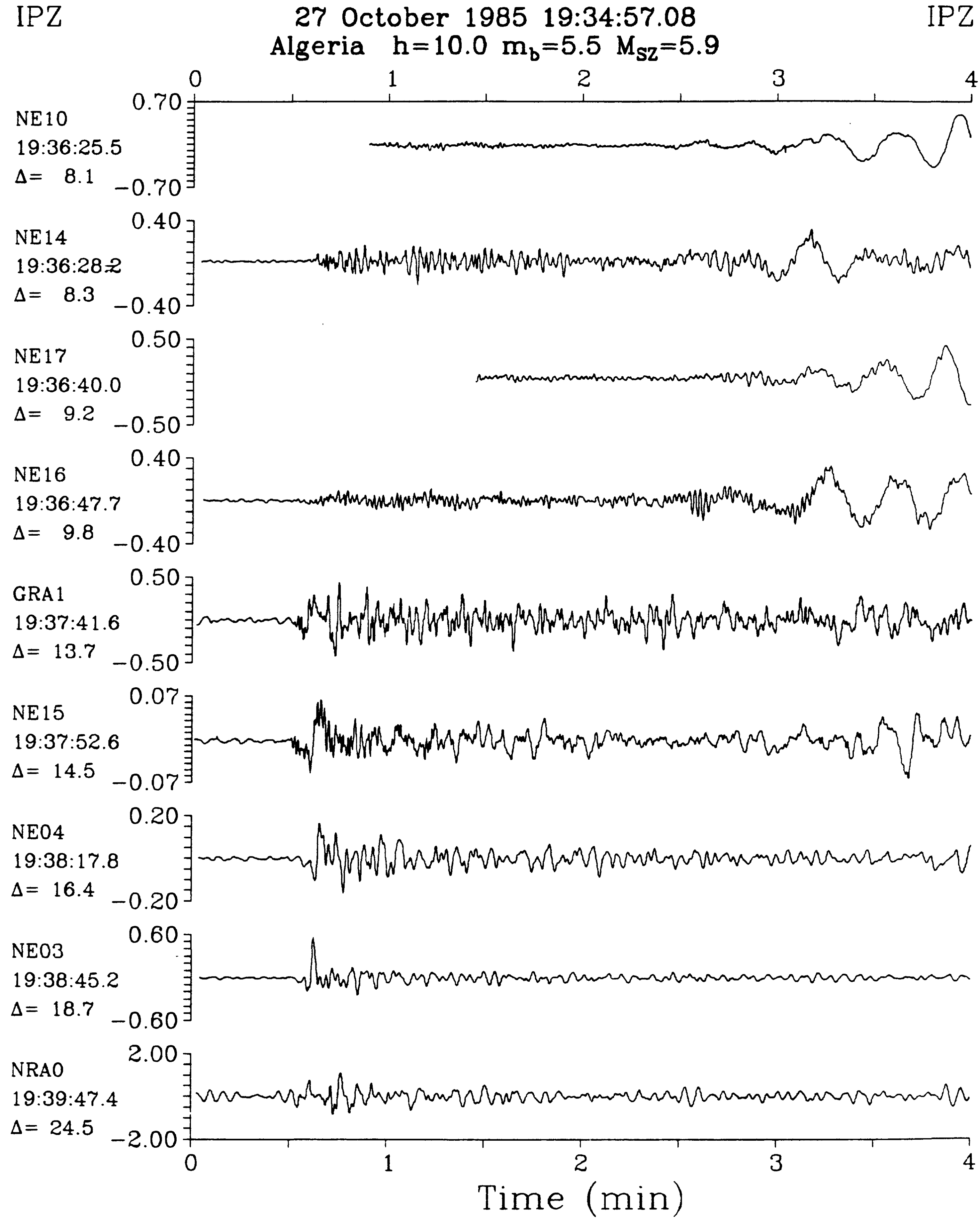



LPZ
27 October 1985 19:34:57.08
Algeria h=10.0 m_b=5.5 M_{SZ}=5.9
LPZ
TOL
19:36:10.0
Δ= 9.2
ANTO
19:38:37.2
Δ= 20.8
KONO
19:39:04.8
Δ= 23.3
NRAO
19:39:17.4
Δ= 24.5
KEV
19:40:51.4
Δ= 35.2
GDH
19:42:21.1
Δ= 46.0
RSNY
19:44:04.3
Δ= 60.0
GAC
19:44:05.4
Δ= 60.1
SCP
19:44:29.8
Δ= 63.8
RSON
19:45:01.0
Δ= 68.6
Time (min)


LPZ
27 October 1985 19:34:57.08
Algeria h=10.0 m_b=5.5 M_{SZ}=5.9
LPZ
RSNT
19:45:14.5
Δ= 70.8
10.0
−10.0
RSCP
19:45:19.1
Δ= 71.6
0.1
−0.1
BDF
19:45:27.9
Δ= 73.1
6.0
−6.0
COL
19:45:51.0
Δ= 77.1
3.0
−3.0
RSSD
19:45:57.5
Δ= 78.3
0.1
−0.1
CHTO
19:46:11.6
Δ= 80.8
1.0
−1.0
LON
19:46:34.5
Δ= 85.2
8.0
−8.0
ANMO
19:46:36.7
Δ= 85.7
3.0
−3.0
JAS1
19:47:04.3
Δ= 91.4
8.0
−8.0
TATO
19:47:13.3
Δ= 93.3
2.0
−2.0
0
10
20
30
40
50
Time (min)

1893

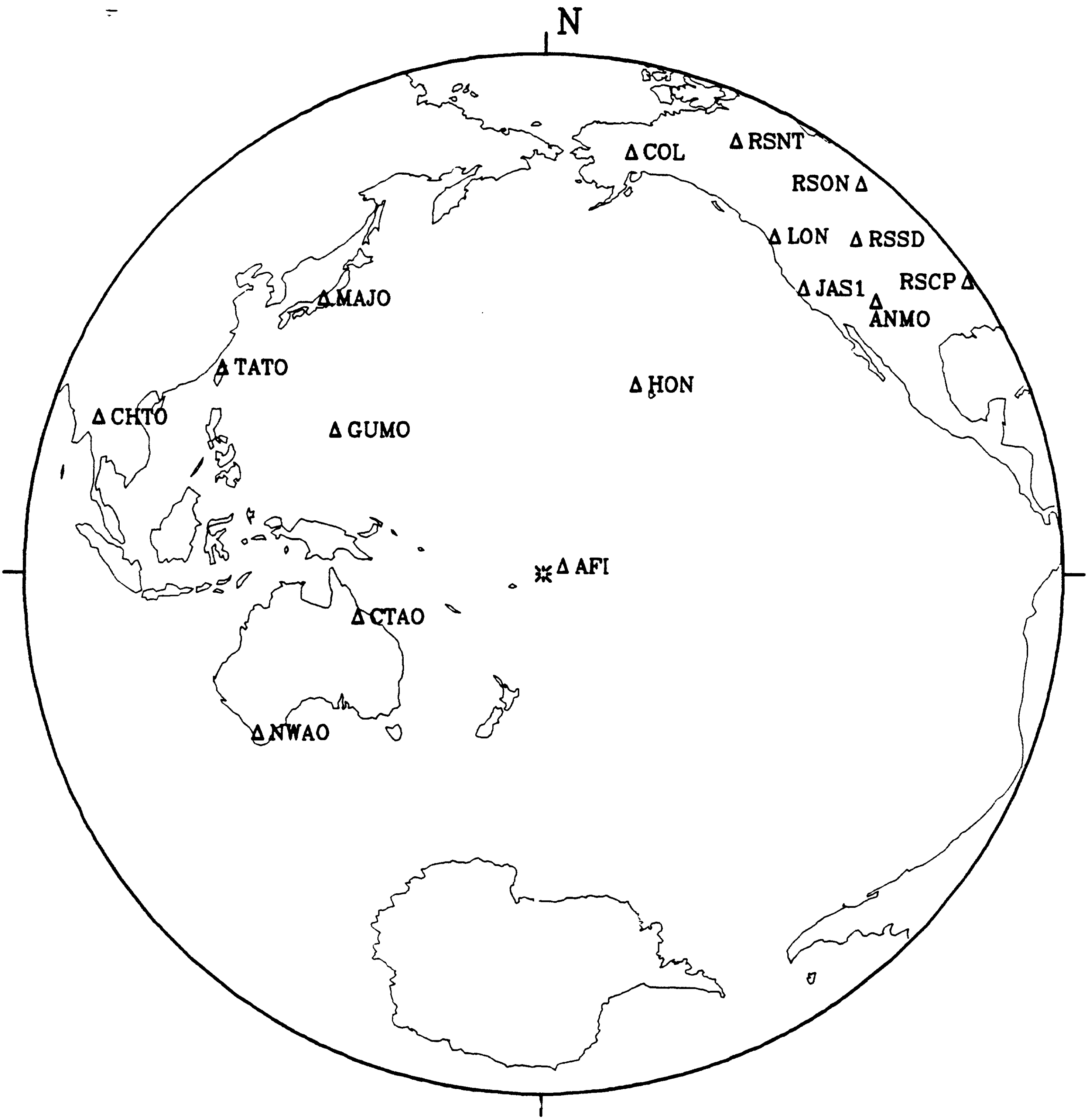

LPZ
27 October 1985 19:34:57.08
Algeria h=10.0 m_b=5.5 M_SZ=5.9
LPZ
MAJO
19:47:18.9
Δ= 94.6
GUMO
19:48:56.0
Δ=116.5
HON
19:52:50.3
Δ=120.8
NWAO
19:52:56.1
Δ=123.9
CTAO
19:53:28.2
Δ=141.1
AFI
19:53:53.9
Δ=157.6
Time (min)



IPZ
27 October 1985 19:34:57.08
Algeria h=10.0 m_b=5.5 M_SZ=5.9
IPZ
NE10
19:36:25.5
Δ= 8.1
NE14
19:36:28.2
Δ= 8.3
NE17
19:36:40.0
Δ= 9.2
NE16
19:36:47.7
Δ= 9.8
GRA1
19:37:41.6
Δ= 13.7
NE15
19:37:52.6
Δ= 14.5
NE04
19:38:17.8
Δ= 16.4
NE03
19:38:45.2
Δ= 18.7
NRA0
19:39:47.4
Δ= 24.5
Time (min)

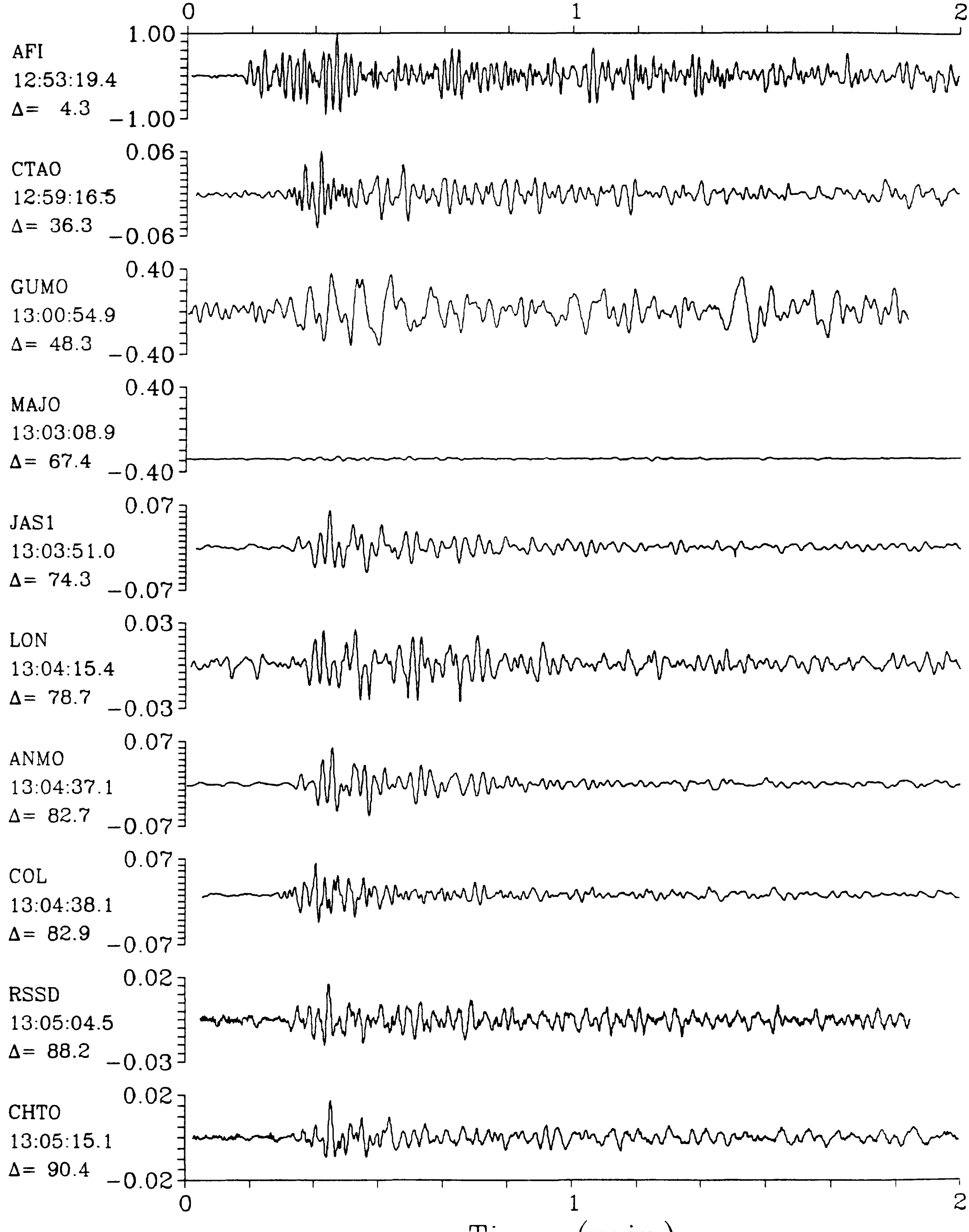
28 October 1985 12:52:31.24

Tonga Islands



SPZ 28 October 1985 12:52:31.24 SPZ

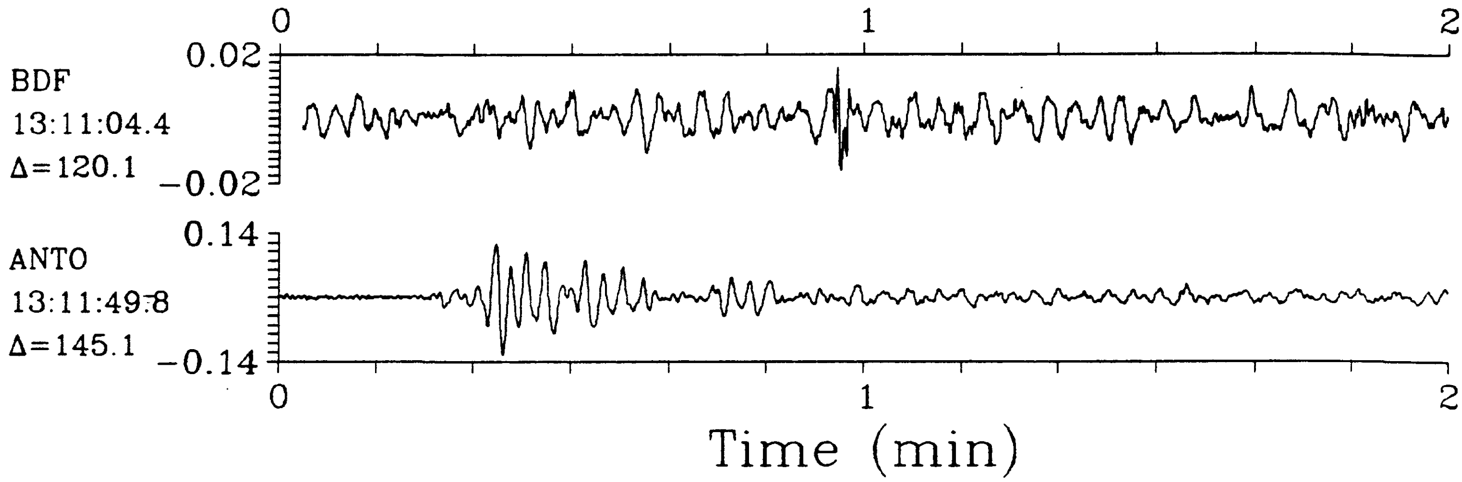
Tonga Islands h=33.0 m_b=5.5 M_{SZ}=5.7

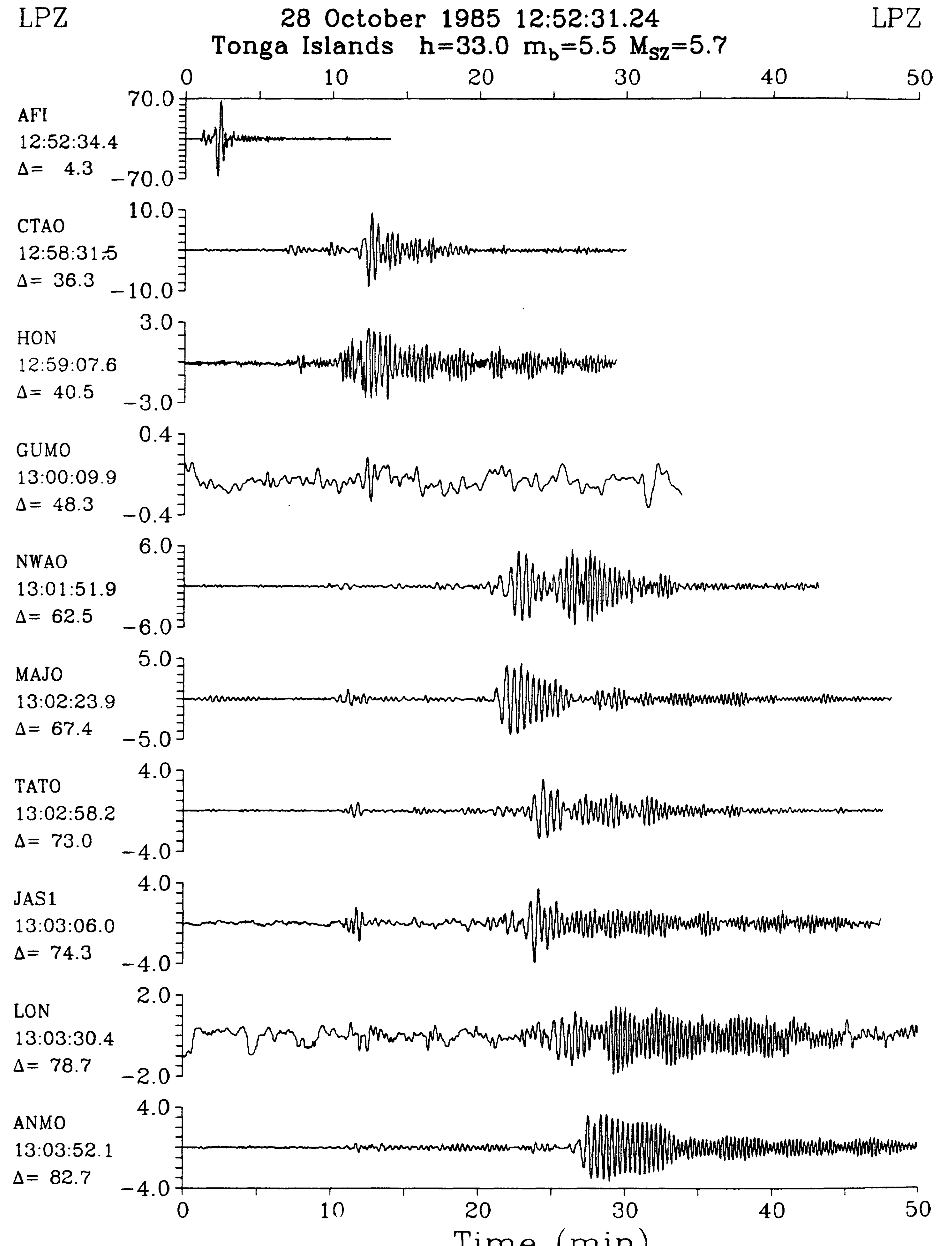


1897

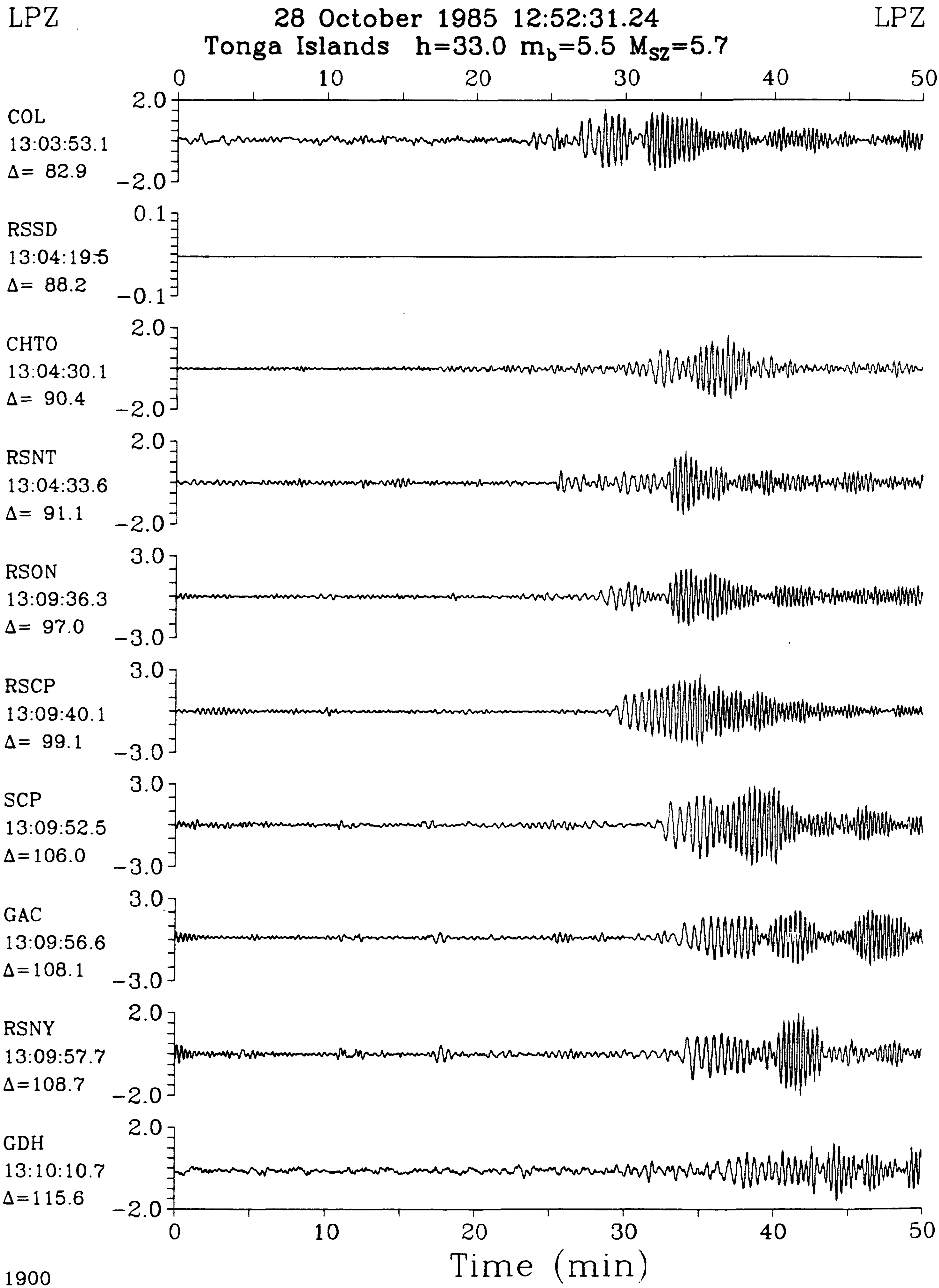
SPZ 28 October 1985 12:52:31.24 SPZ

Tonga Islands h=33.0 m_b=5.5 M_{SZ}=5.7

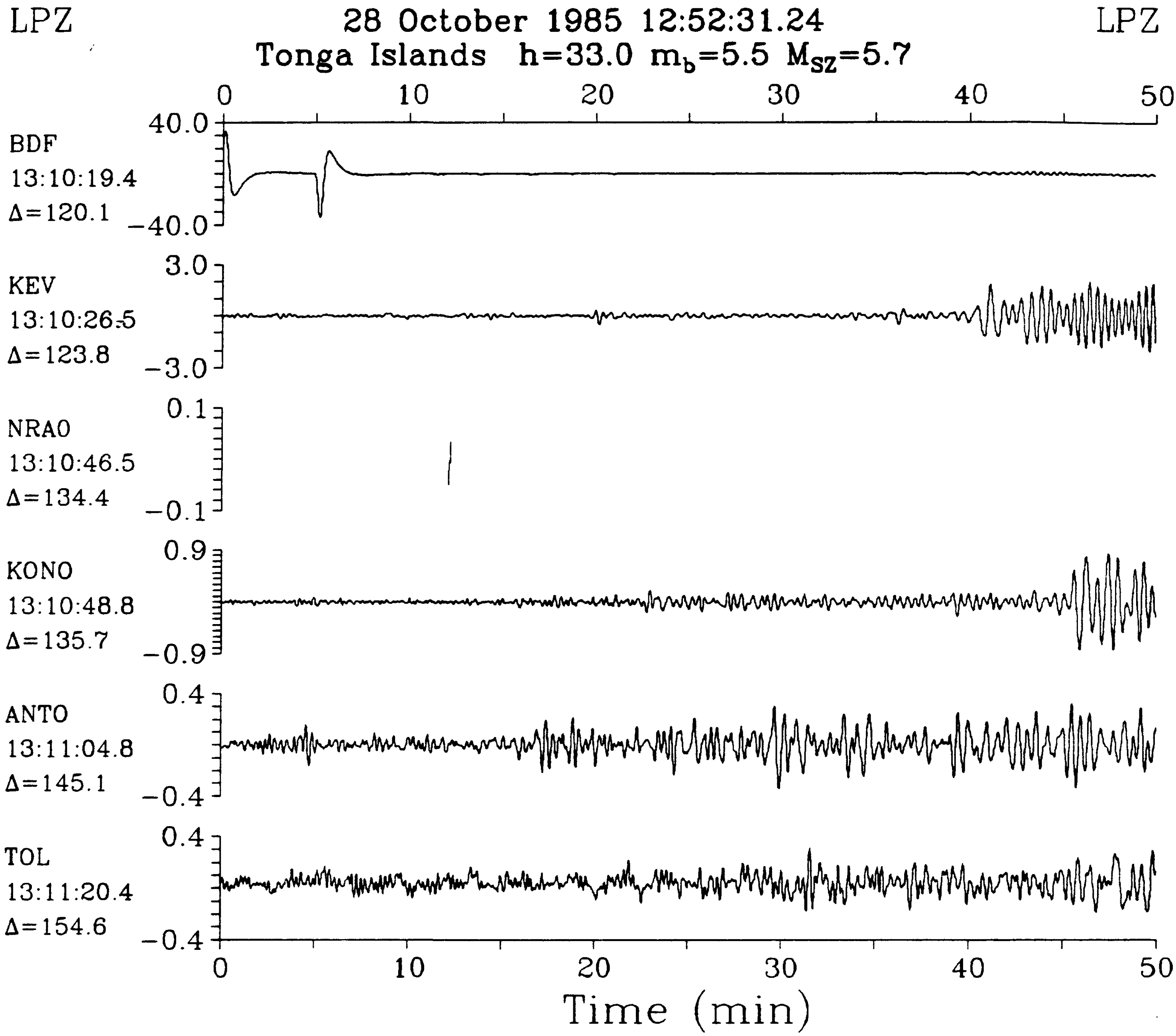



LPZ
28 October 1985 12:52:31.24
Tonga Islands h=33.0 m_b=5.5 M_{SZ}=5.7
LPZ
AFI
12:52:34.4
Δ= 4.3
70.0
−70.0
CTAO
12:58:31.5
Δ= 36.3
10.0
−10.0
HON
12:59:07.6
Δ= 40.5
3.0
−3.0
GUMO
13:00:09.9
Δ= 48.3
0.4
−0.4
NWAO
13:01:51.9
Δ= 62.5
6.0
−6.0
MAJO
13:02:23.9
Δ= 67.4
5.0
−5.0
TATO
13:02:58.2
Δ= 73.0
4.0
−4.0
JAS1
13:03:06.0
Δ= 74.3
4.0
−4.0
LON
13:03:30.4
Δ= 78.7
2.0
−2.0
ANMO
13:03:52.1
Δ= 82.7
4.0
−4.0
0
10
20
30
40
50
Time (min)

1899

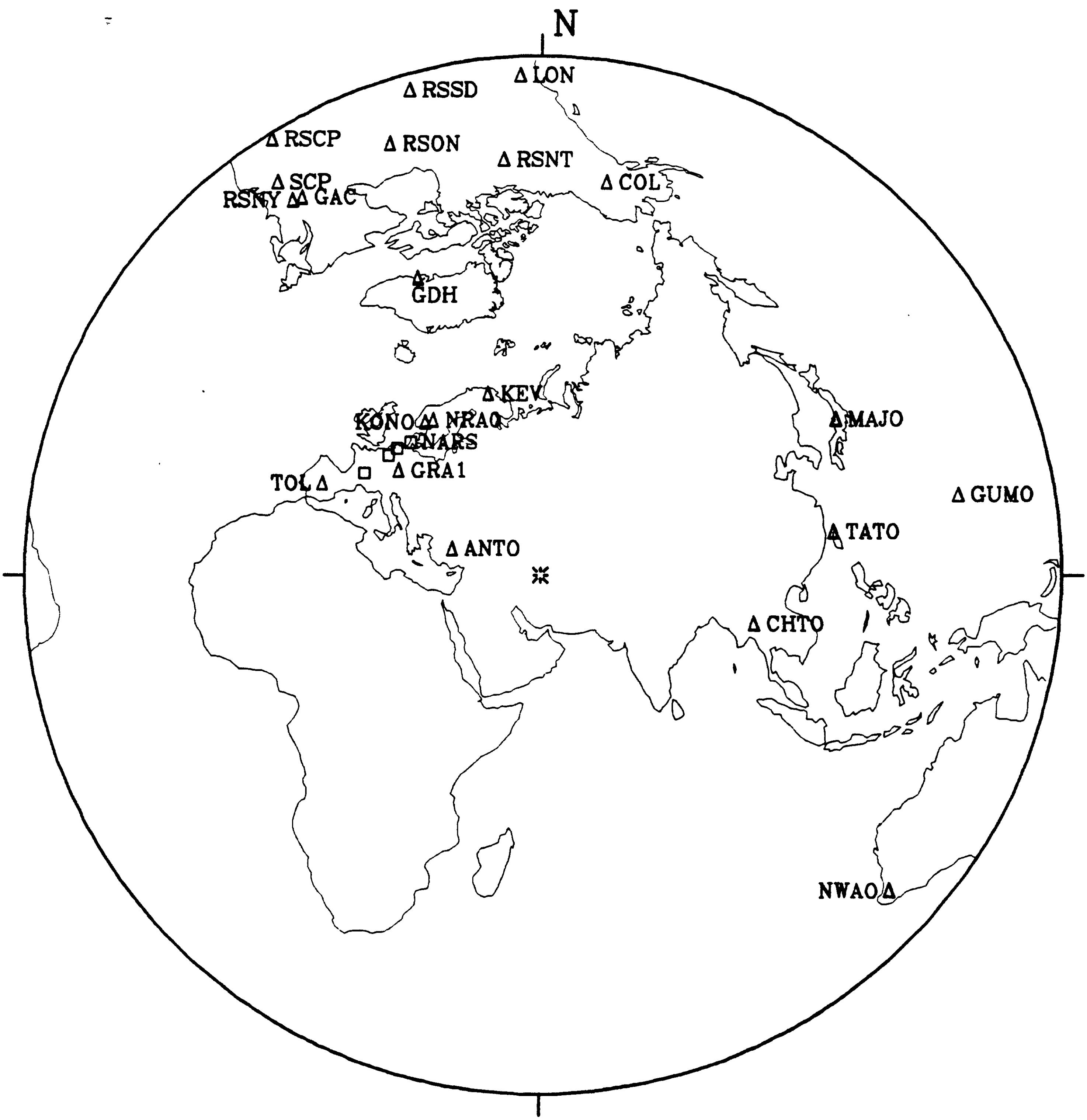

LPZ
28 October 1985 12:52:31.24
Tonga Islands h=33.0 m_b=5.5 M_{SZ}=5.7
LPZ
COL
13:03:53.1
Δ= 82.9
RSSD
13:04:19.5
Δ= 88.2
CHTO
13:04:30.1
Δ= 90.4
RSNT
13:04:33.6
Δ= 91.1
RSON
13:09:36.3
Δ= 97.0
RSCP
13:09:40.1
Δ= 99.1
SCP
13:09:52.5
Δ=106.0
GAC
13:09:56.6
Δ=108.1
RSNY
13:09:57.7
Δ=108.7
GDH
13:10:10.7
Δ=115.6
Time (min)

1900


LPZ
28 October 1985 12:52:31.24
Tonga Islands h=33.0 m_b=5.5 M_{SZ}=5.7
LPZ
BDF
13:10:19.4
Δ=120.1
40.0
-40.0
KEV
13:10:26.5
Δ=123.8
3.0
-3.0
NRAO
13:10:46.5
Δ=134.4
0.1
-0.1
KONO
13:10:48.8
Δ=135.7
0.9
-0.9
ANTO
13:11:04.8
Δ=145.1
0.4
-0.4
TOL
13:11:20.4
Δ=154.6
0.4
-0.4
0
10
20
30
40
50
Time (min)

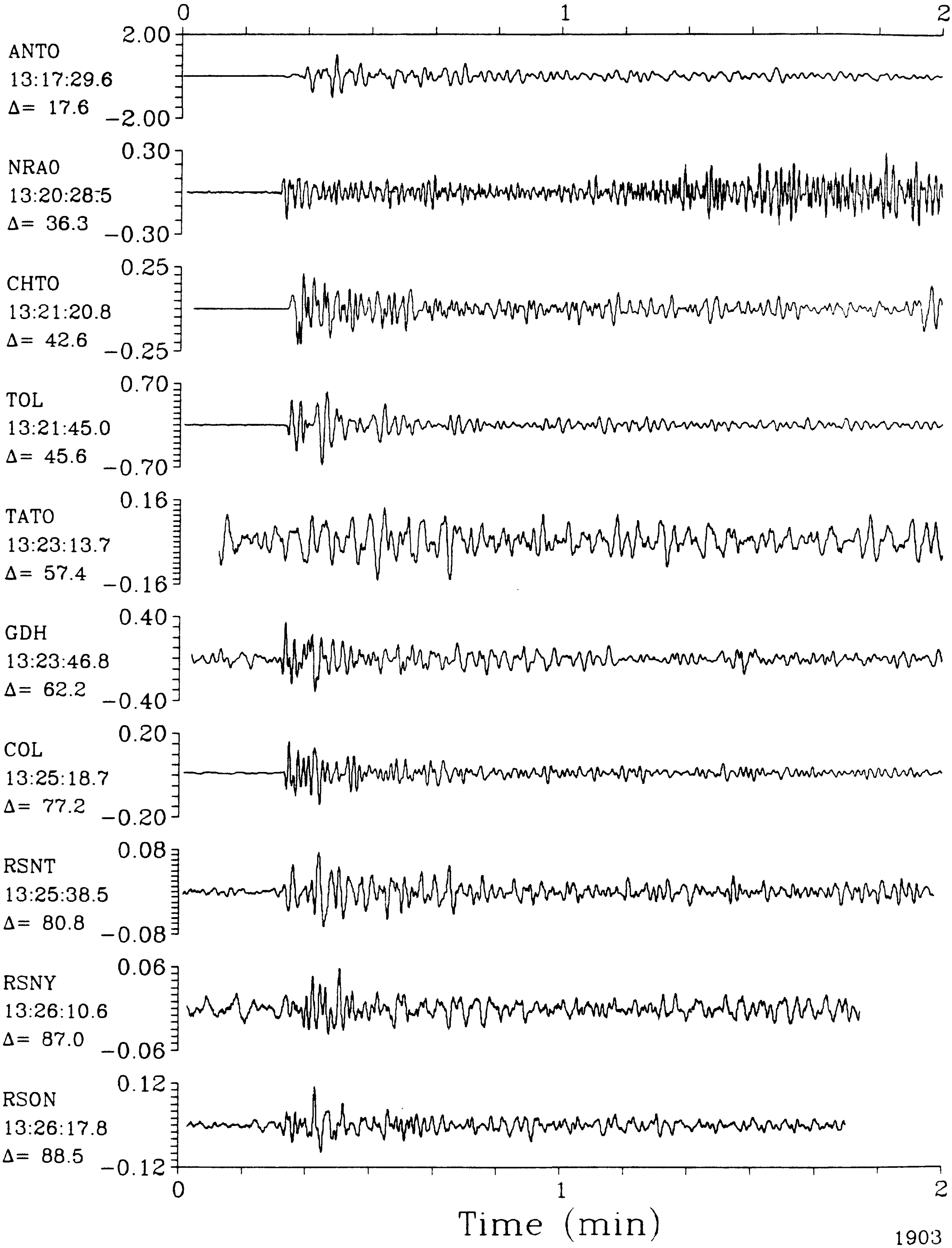
29 October 1985 13:13:42.79

Iran



SPZ 29 October 1985 13:13:42.79 SPZ

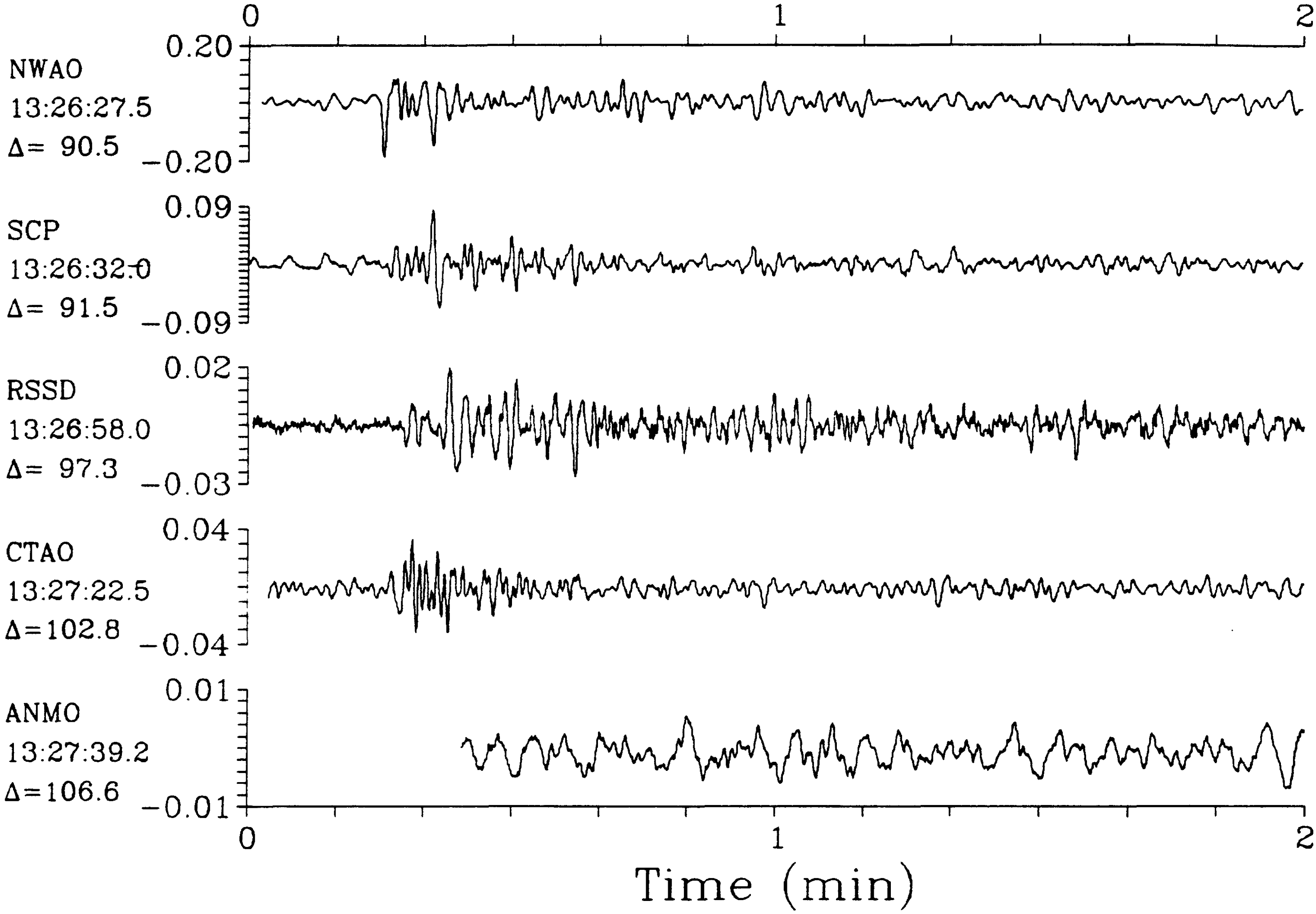
Iran h=33.0 m_b=6.0 M_{SZ}=5.9

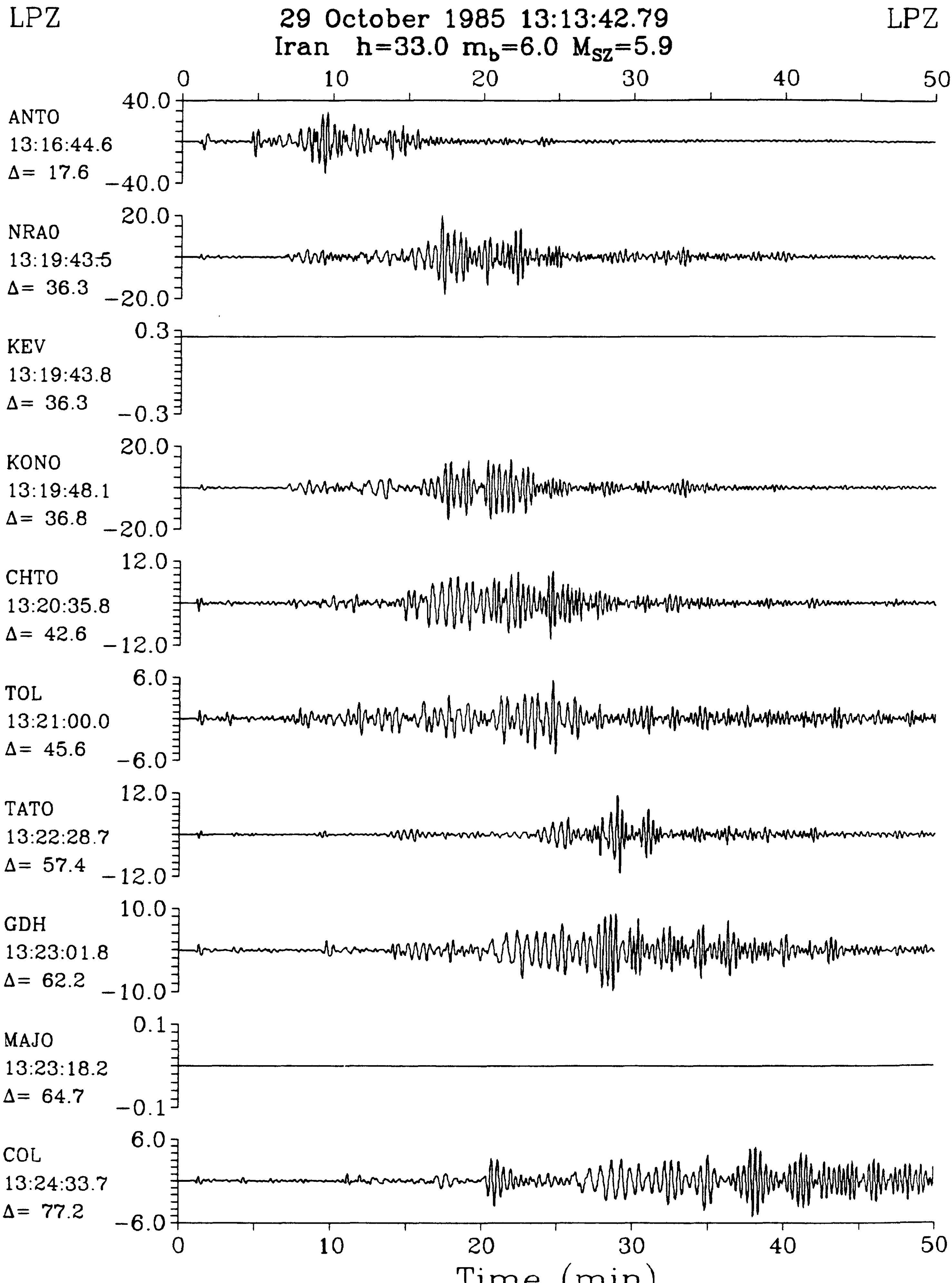


1903

SPZ 29 October 1985 13:13:42.79 SPZ

Iran h=33.0 m_b=6.0 M_{SZ}=5.9



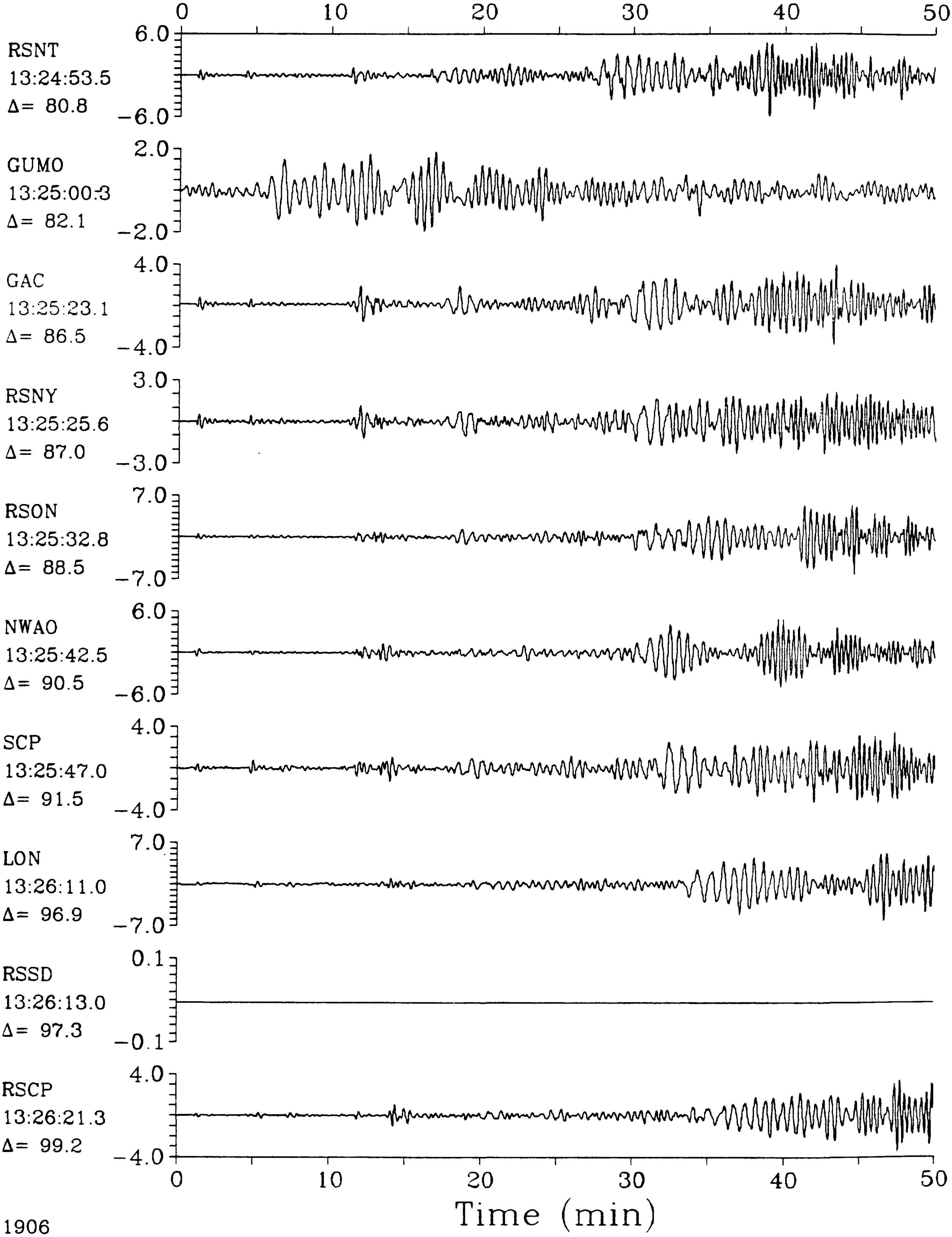


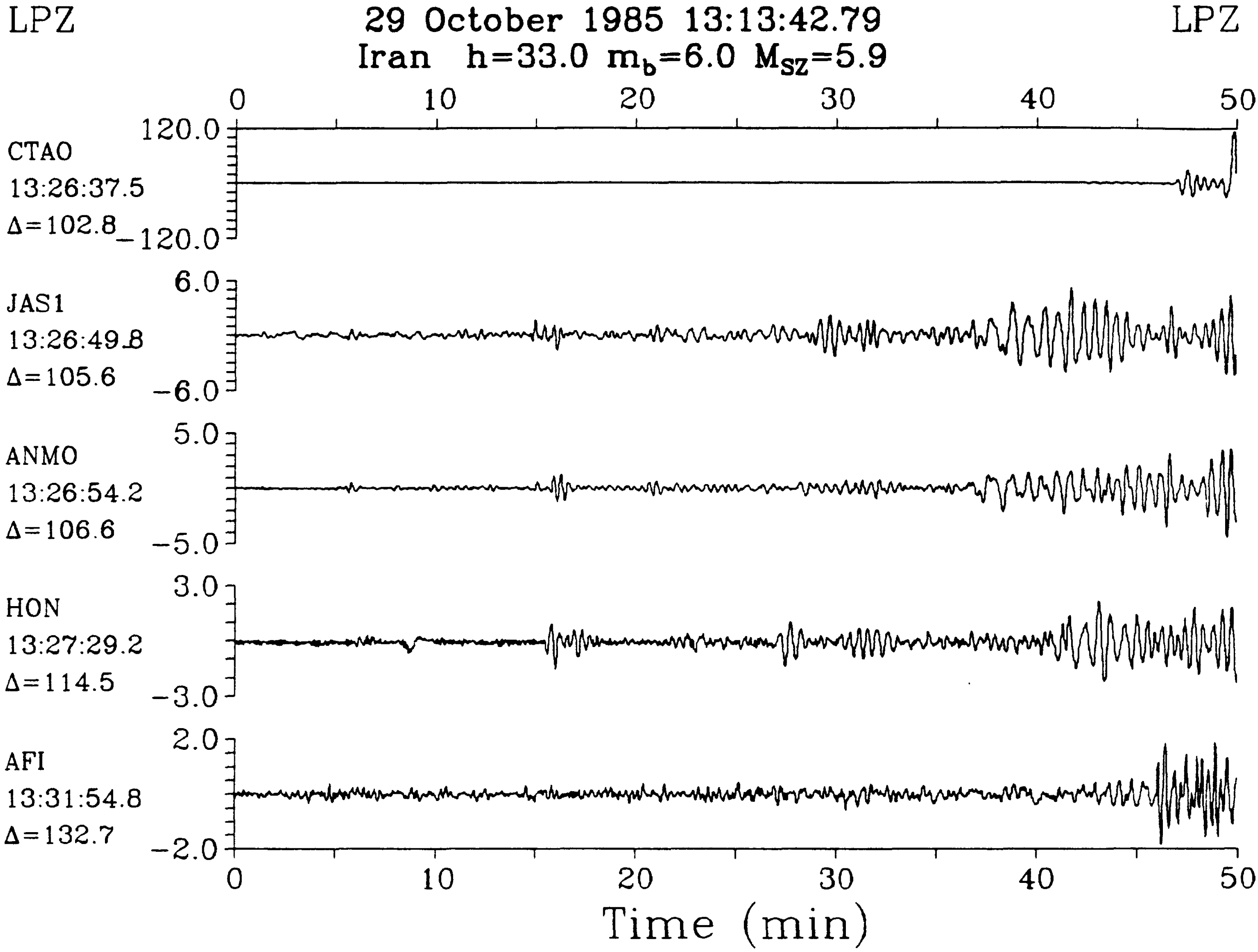
LPZ
29 October 1985 13:13:42.79
Iran h=33.0 m_b=6.0 M_SZ=5.9
LPZ
ANTO
13:16:44.6
Δ= 17.6
NRAO
13:19:43.5
Δ= 36.3
KEV
13:19:43.8
Δ= 36.3
KONO
13:19:48.1
Δ= 36.8
CHTO
13:20:35.8
Δ= 42.6
TOL
13:21:00.0
Δ= 45.6
TATO
13:22:28.7
Δ= 57.4
GDH
13:23:01.8
Δ= 62.2
MAJO
13:23:18.2
Δ= 64.7
COL
13:24:33.7
Δ= 77.2
Time (min)

1905

LPZ 29 October 1985 13:13:42.79 LPZ

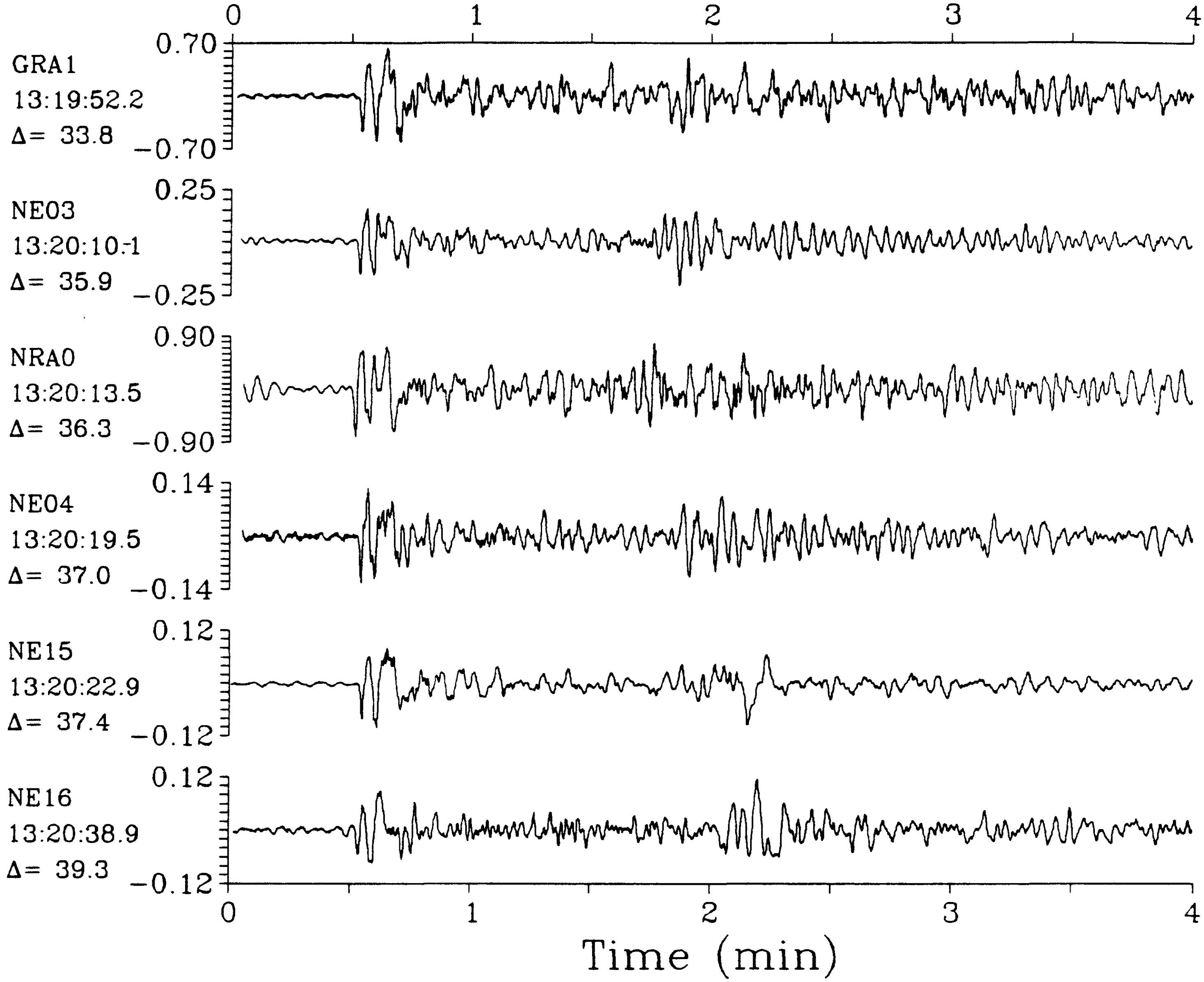
Iran h=33.0 m_b=6.0 M_{SZ}=5.9




LPZ
29 October 1985 13:13:42.79
Iran h=33.0 mb=6.0 MSZ=5.9
LPZ
CTAO
13:26:37.5
Δ=102.8
120.0
-120.0
JAS1
13:26:49.8
Δ=105.6
6.0
-6.0
ANMO
13:26:54.2
Δ=106.6
5.0
-5.0
HON
13:27:29.2
Δ=114.5
3.0
-3.0
AFI
13:31:54.8
Δ=132.7
2.0
-2.0
0
10
20
30
40
50
Time (min)

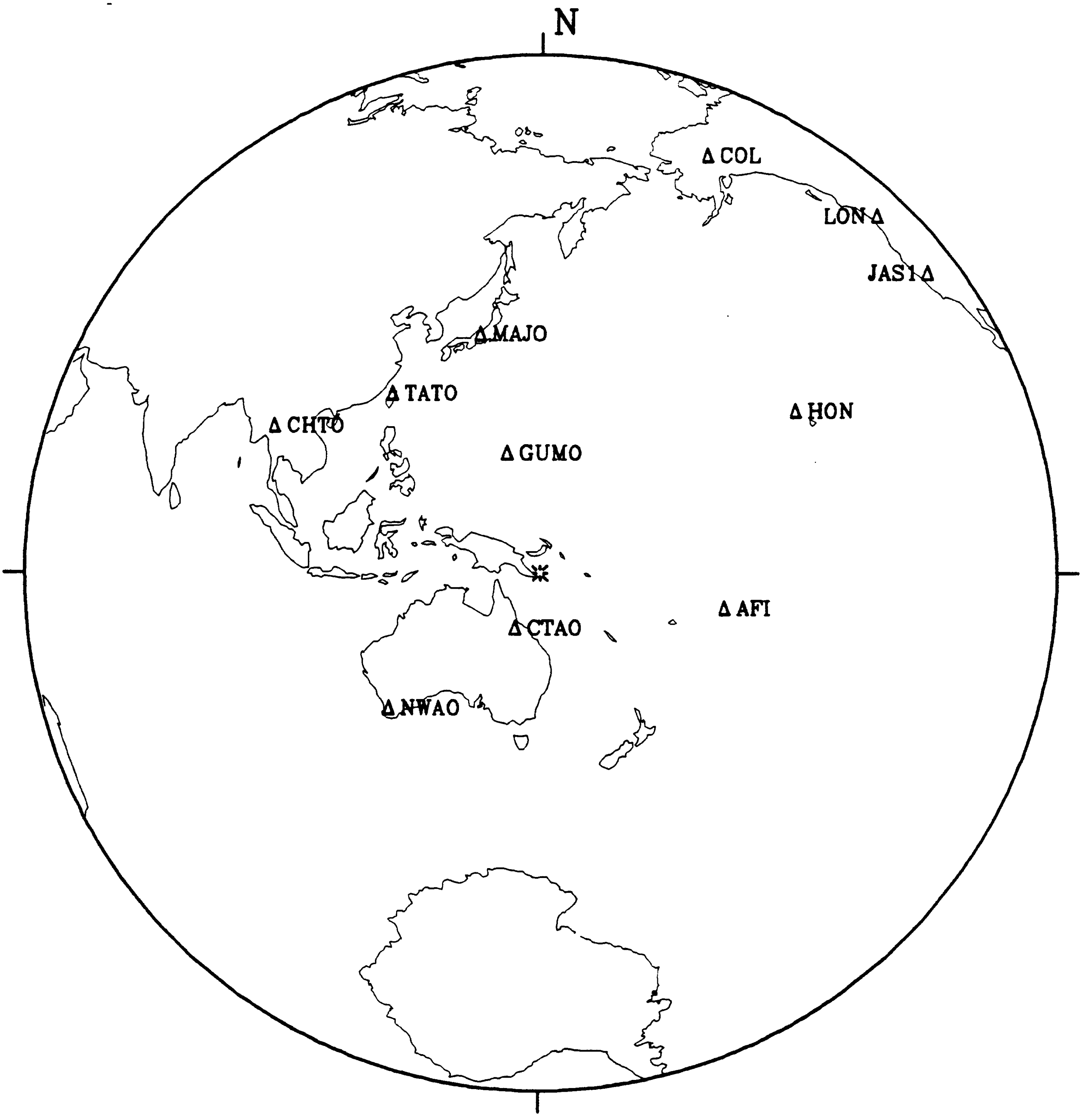
IPZ 29 October 1985 13:13:42.79 IPZ

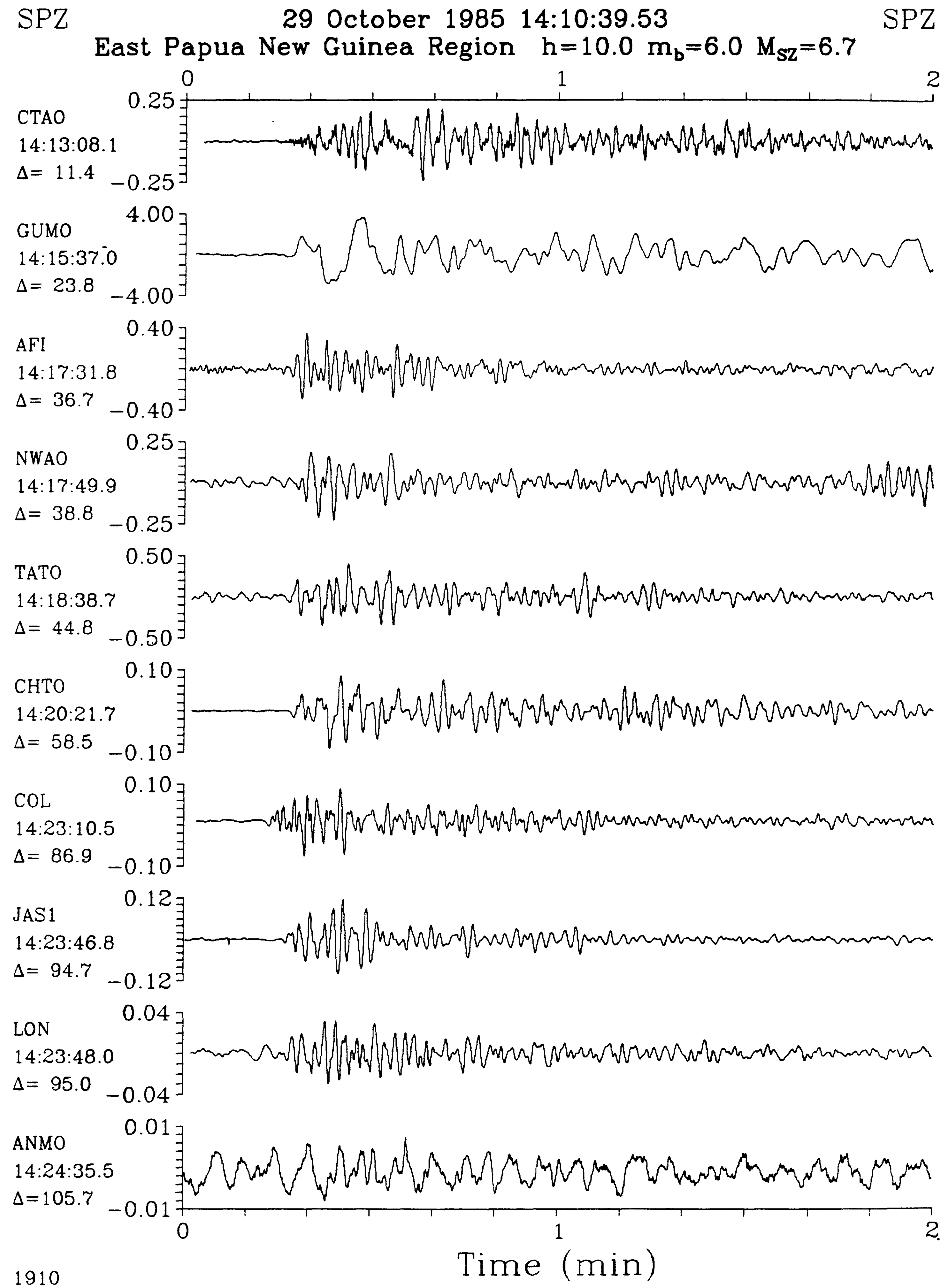
Iran h=33.0 m_b=6.0 M_{SZ}=5.9



29 October 1985 14:10:39.53

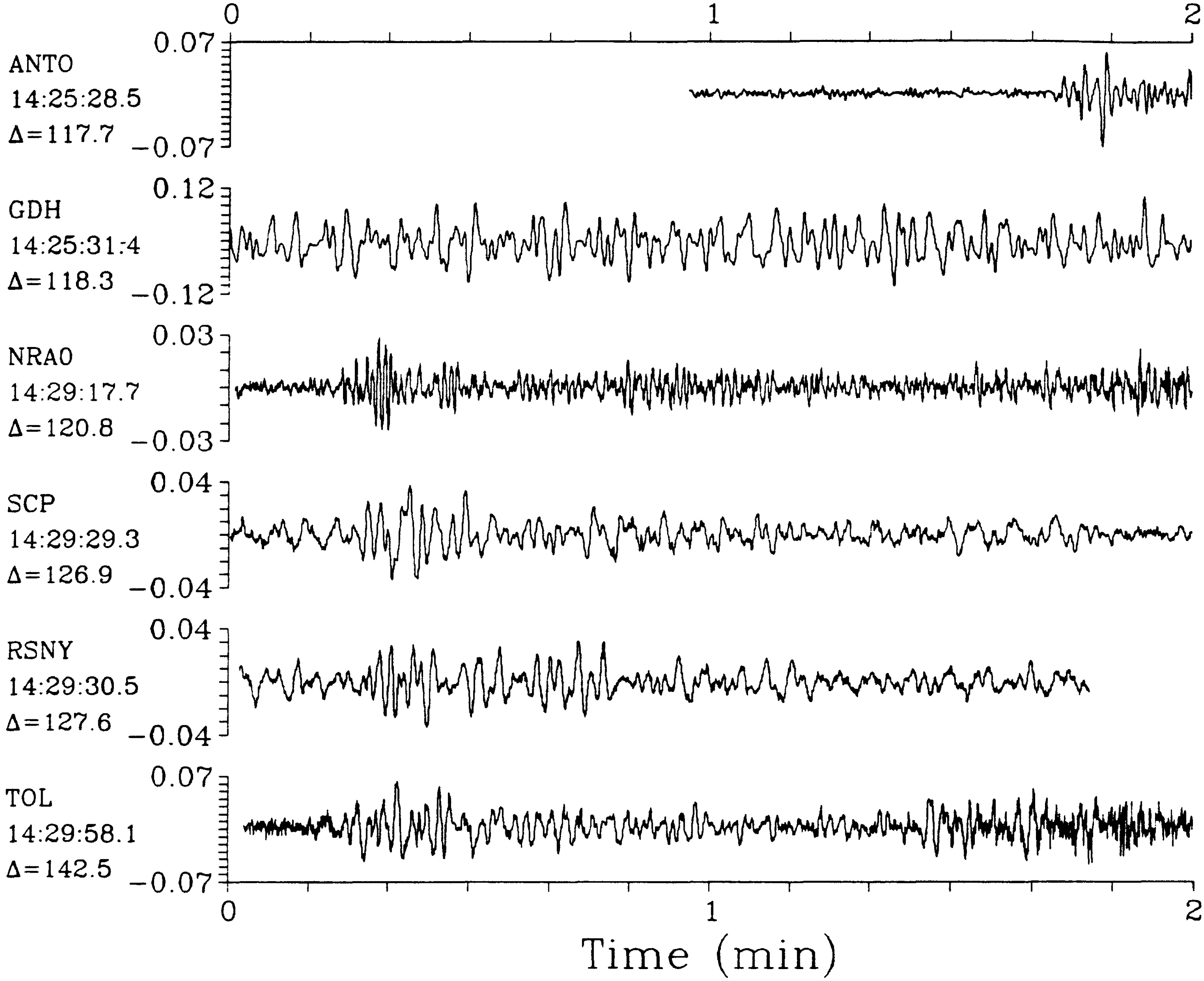
East Papua New Guinea Region




SPZ
29 October 1985 14:10:39.53
SPZ
East Papua New Guinea Region h=10.0 m_b=6.0 M_{SZ}=6.7
CTAO
14:13:08.1
Δ= 11.4
GUMO
14:15:37.0
Δ= 23.8
AFI
14:17:31.8
Δ= 36.7
NWAO
14:17:49.9
Δ= 38.8
TATO
14:18:38.7
Δ= 44.8
CHTO
14:20:21.7
Δ= 58.5
COL
14:23:10.5
Δ= 86.9
JAS1
14:23:46.8
Δ= 94.7
LON
14:23:48.0
Δ= 95.0
ANMO
14:24:35.5
Δ=105.7
0.25
−0.25
4.00
−4.00
0.40
−0.40
0.25
−0.25
0.50
−0.50
0.10
−0.10
0.10
−0.10
0.12
−0.12
0.04
−0.04
0.01
−0.01
0
1
2
Time (min)

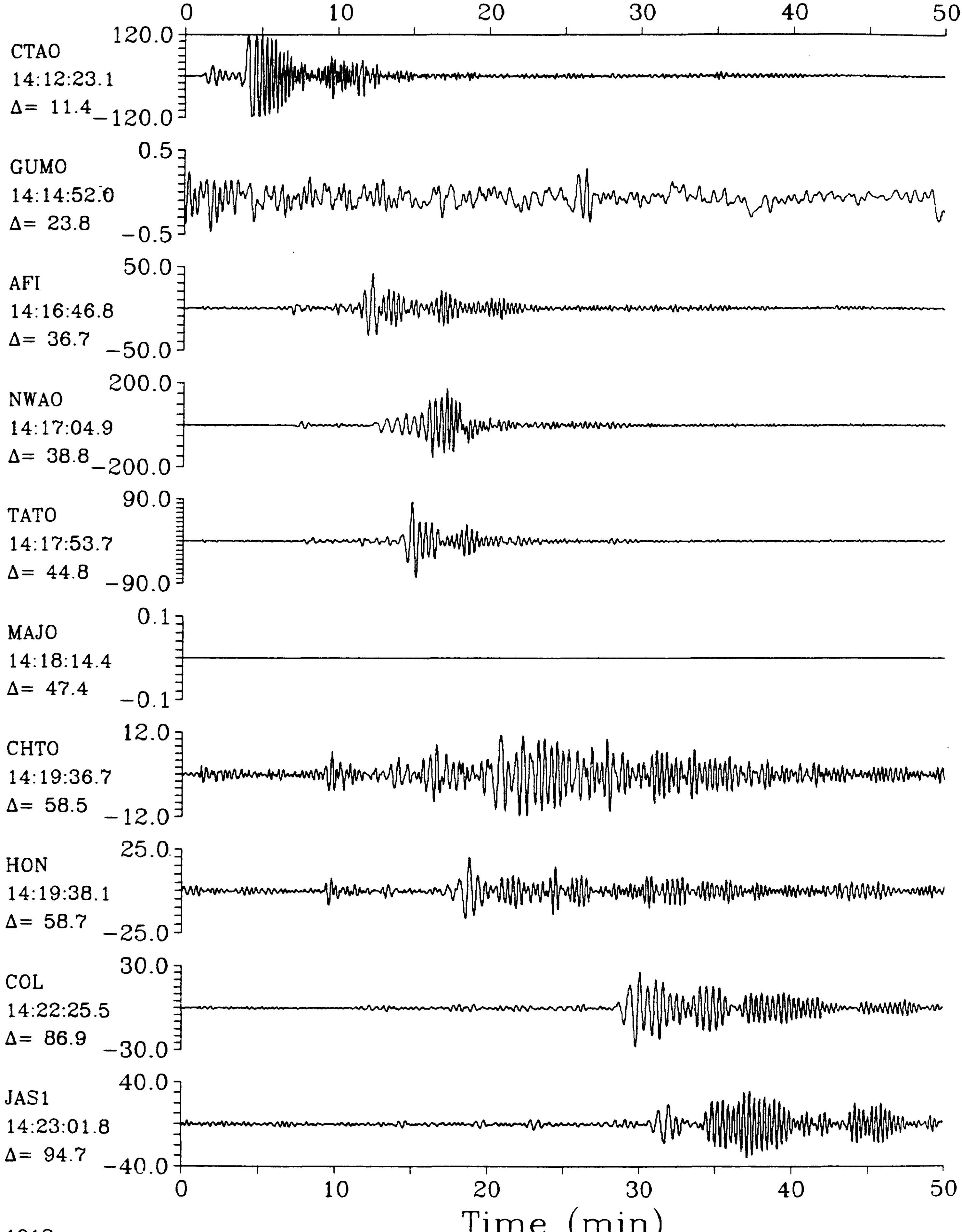
SPZ 29 October 1985 14:10:39.53 SPZ

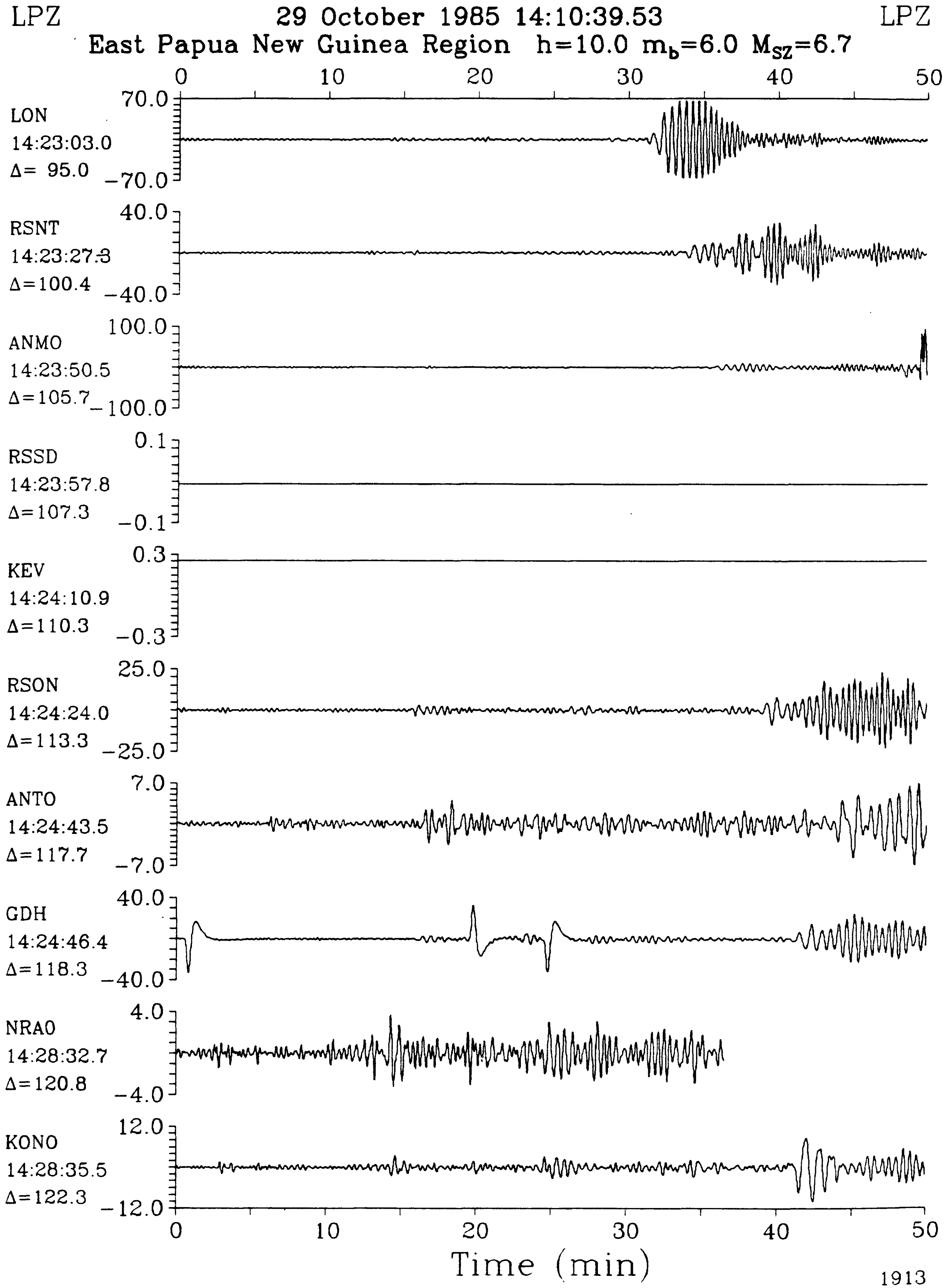
East Papua New Guinea Region h=10.0 m_b=6.0 M_{SZ}=6.7



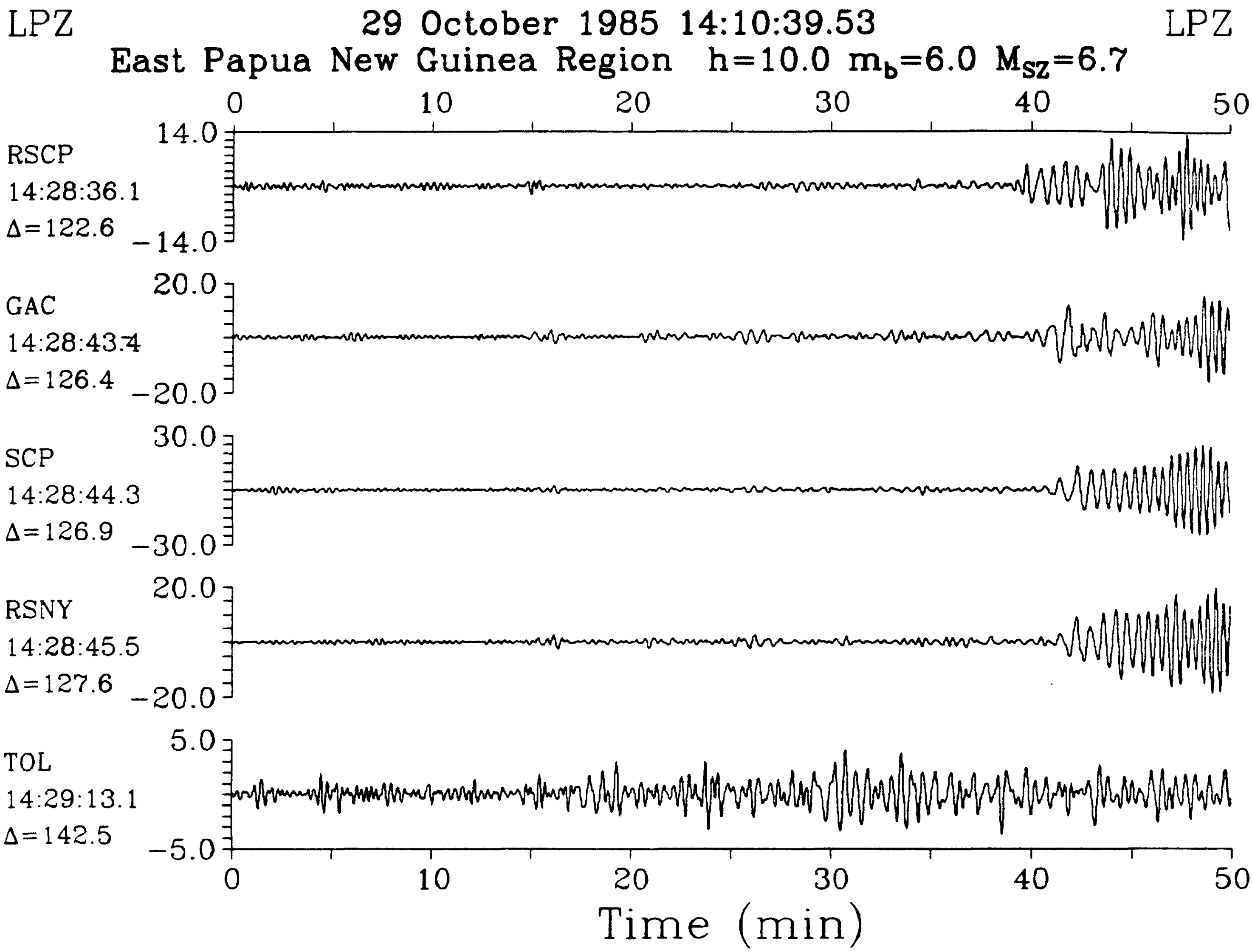
LPZ 29 October 1985 14:10:39.53 LPZ

East Papua New Guinea Region h=10.0 m_b=6.0 M_{SZ}=6.7

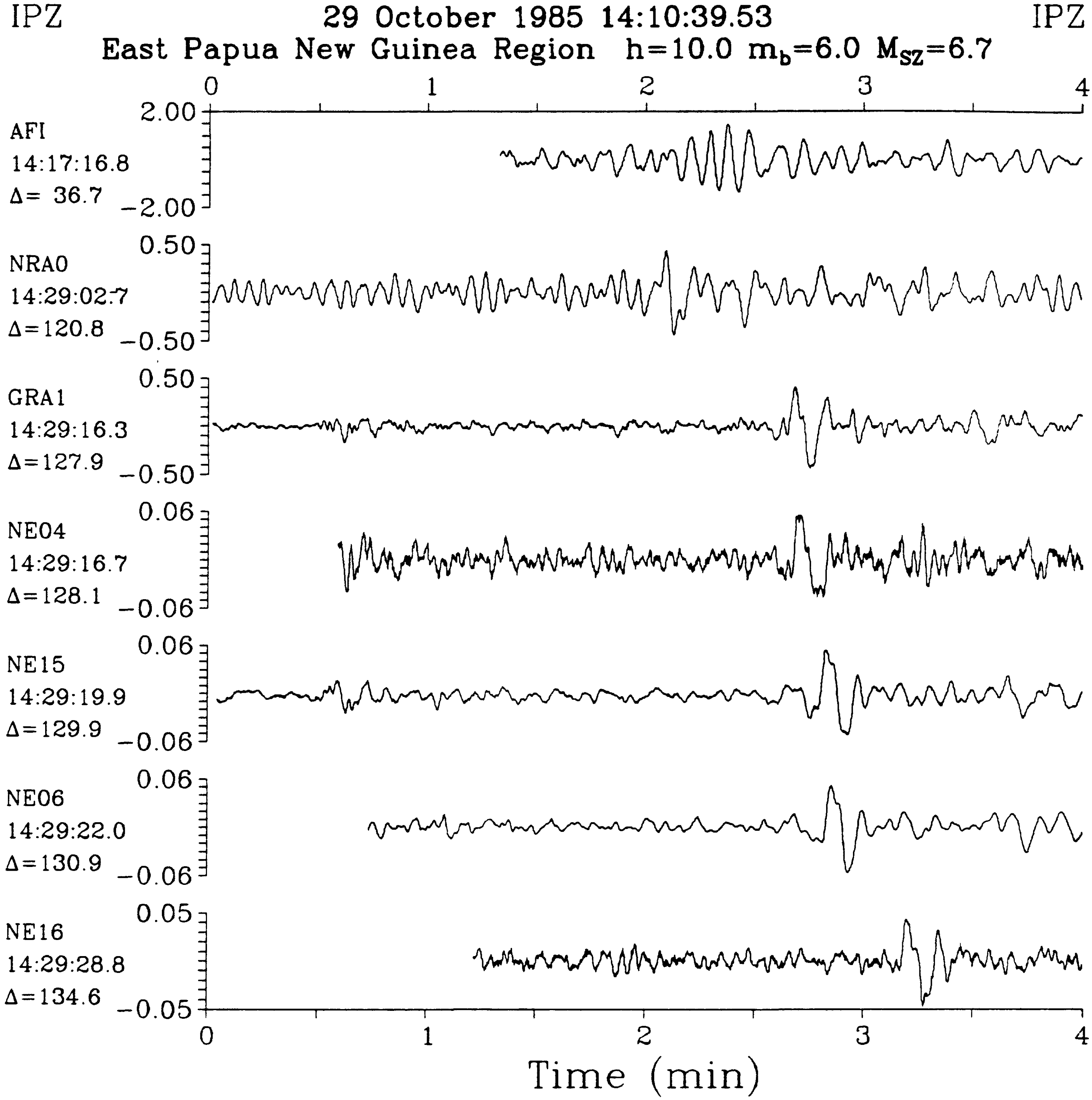



LPZ
29 October 1985 14:10:39.53
LPZ
East Papua New Guinea Region h=10.0 m_b=6.0 M_SZ=6.7
0 10 20 30 40 50
LON
14:23:03.0
Δ= 95.0
70.0
-70.0
RSNT
14:23:27.3
Δ=100.4
40.0
-40.0
ANMO
14:23:50.5
Δ=105.7
100.0
-100.0
RSSD
14:23:57.8
Δ=107.3
0.1
-0.1
KEV
14:24:10.9
Δ=110.3
0.3
-0.3
RSON
14:24:24.0
Δ=113.3
25.0
-25.0
ANTO
14:24:43.5
Δ=117.7
7.0
-7.0
GDH
14:24:46.4
Δ=118.3
40.0
-40.0
NRAO
14:28:32.7
Δ=120.8
4.0
-4.0
KONO
14:28:35.5
Δ=122.3
12.0
-12.0
0 10 20 30 40 50
Time (min)

1913

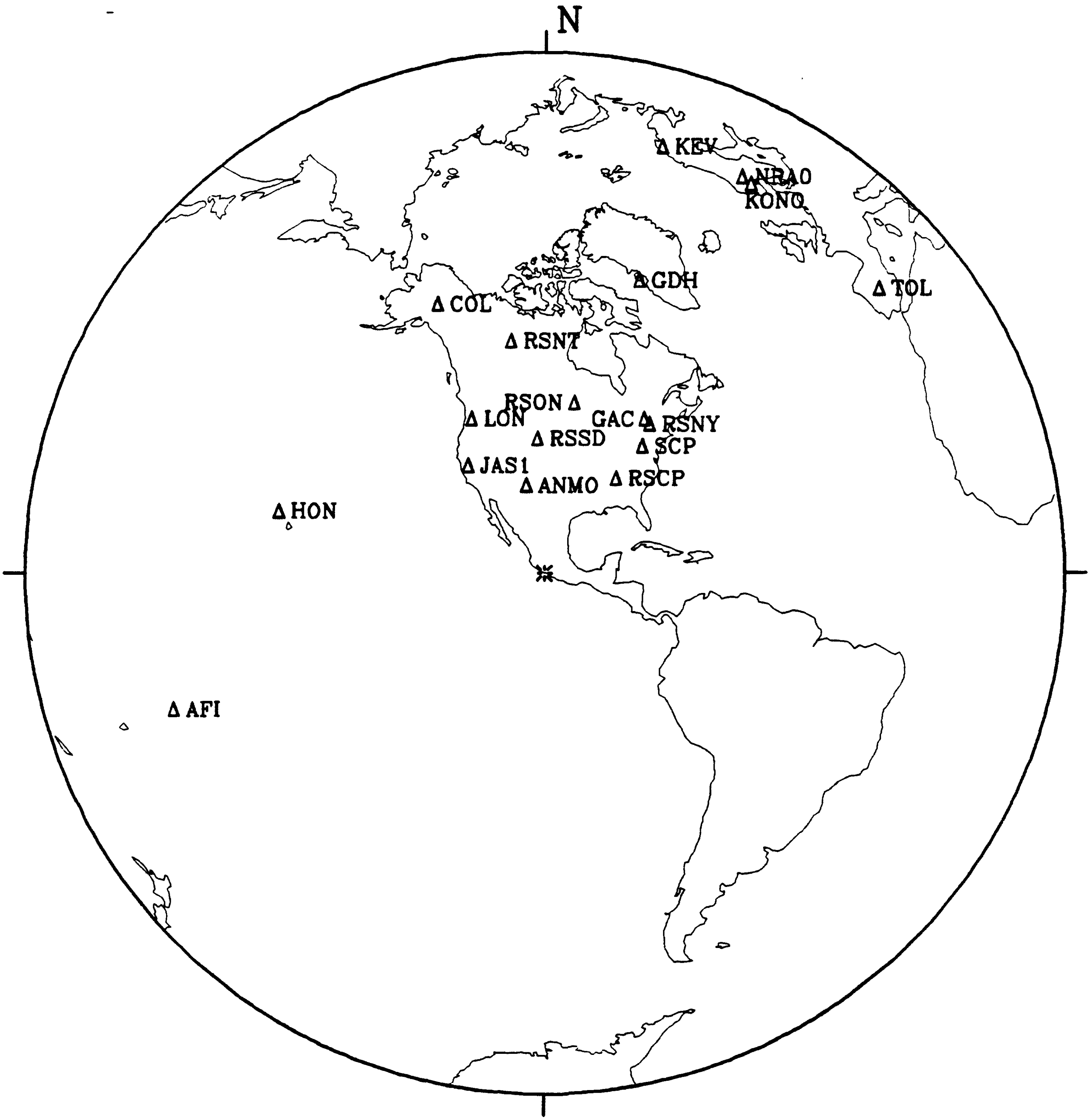


LPZ
29 October 1985 14:10:39.53
LPZ
East Papua New Guinea Region h=10.0 m_b=6.0 M_{SZ}=6.7
RSCP
14:28:36.1
Δ=122.6
14.0
−14.0
GAC
14:28:43.4
Δ=126.4
20.0
−20.0
SCP
14:28:44.3
Δ=126.9
30.0
−30.0
RSNY
14:28:45.5
Δ=127.6
20.0
−20.0
TOL
14:29:13.1
Δ=142.5
5.0
−5.0
0
10
20
30
40
50
Time (min)


IPZ
29 October 1985 14:10:39.53
IPZ
East Papua New Guinea Region h=10.0 m$_b$=6.0 M$_{SZ}$=6.7
AFI
14:17:16.8
Δ= 36.7
2.00
−2.00
NRA0
14:29:02.7
Δ=120.8
0.50
−0.50
GRA1
14:29:16.3
Δ=127.9
0.50
−0.50
NE04
14:29:16.7
Δ=128.1
0.06
−0.06
NE15
14:29:19.9
Δ=129.9
0.06
−0.06
NE06
14:29:22.0
Δ=130.9
0.06
−0.06
NE16
14:29:28.8
Δ=134.6
0.05
−0.05
0
1
2
3
4
Time (min)

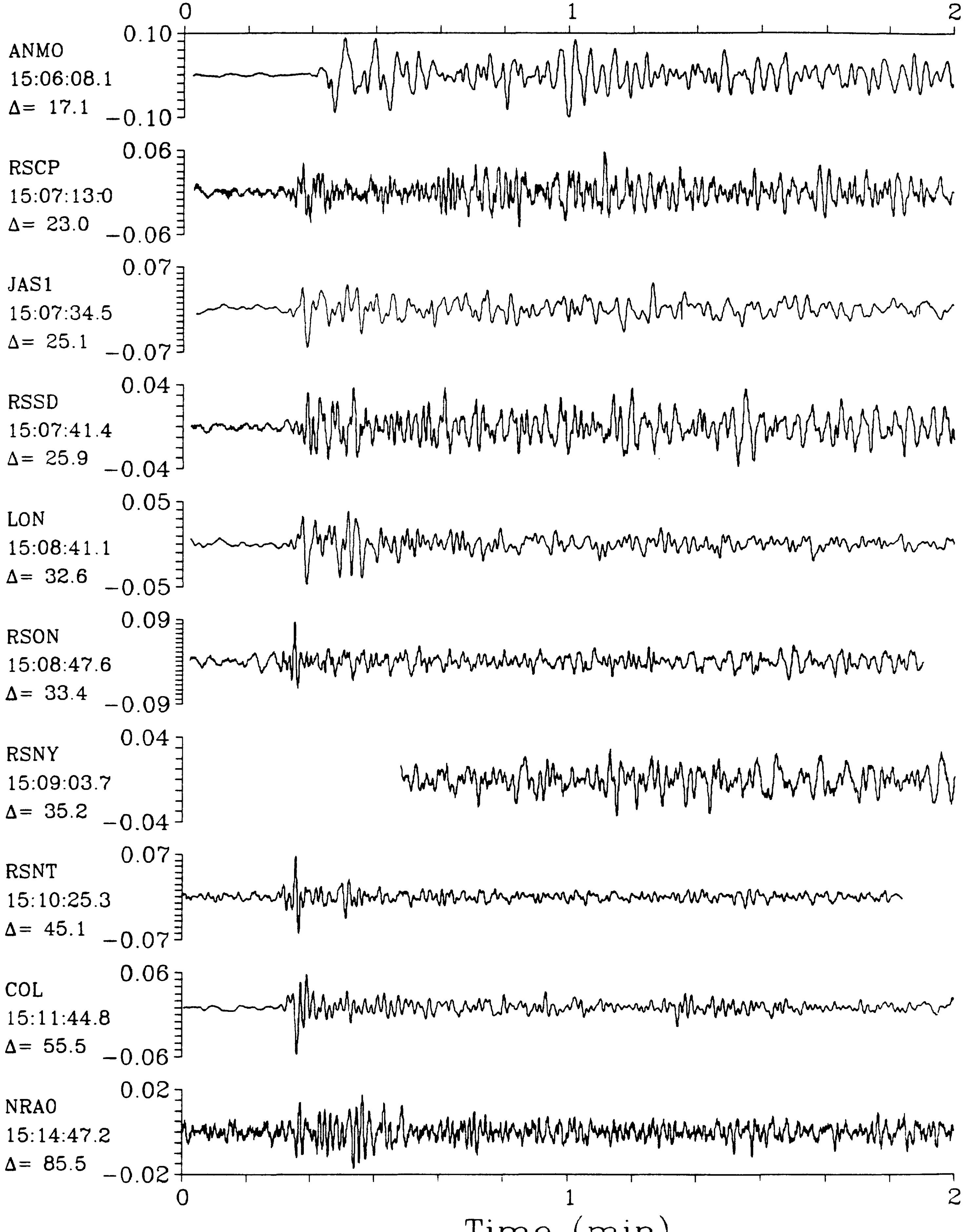
29 October 1985 15:02:27.15

Michoacan, Mexico



SPZ 29 October 1985 15:02:27.15 SPZ

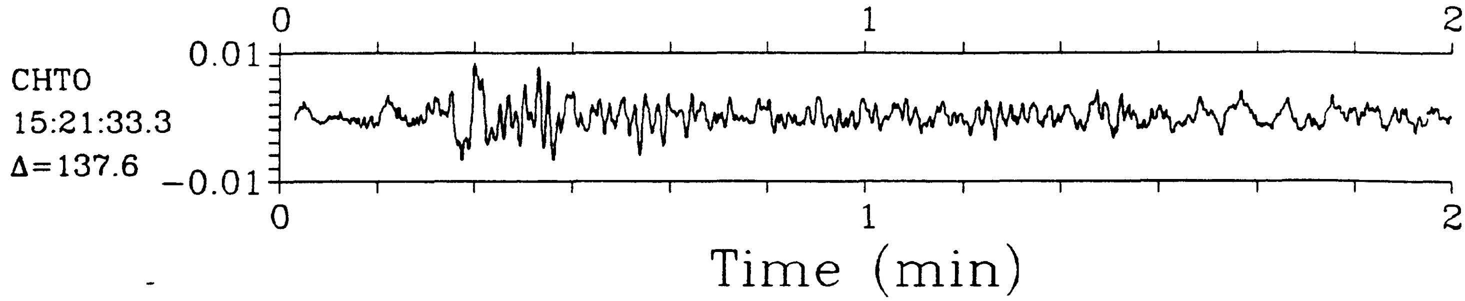
Michoacan, Mexico h=33.0 m_b=5.6 M_{SZ}=5.4

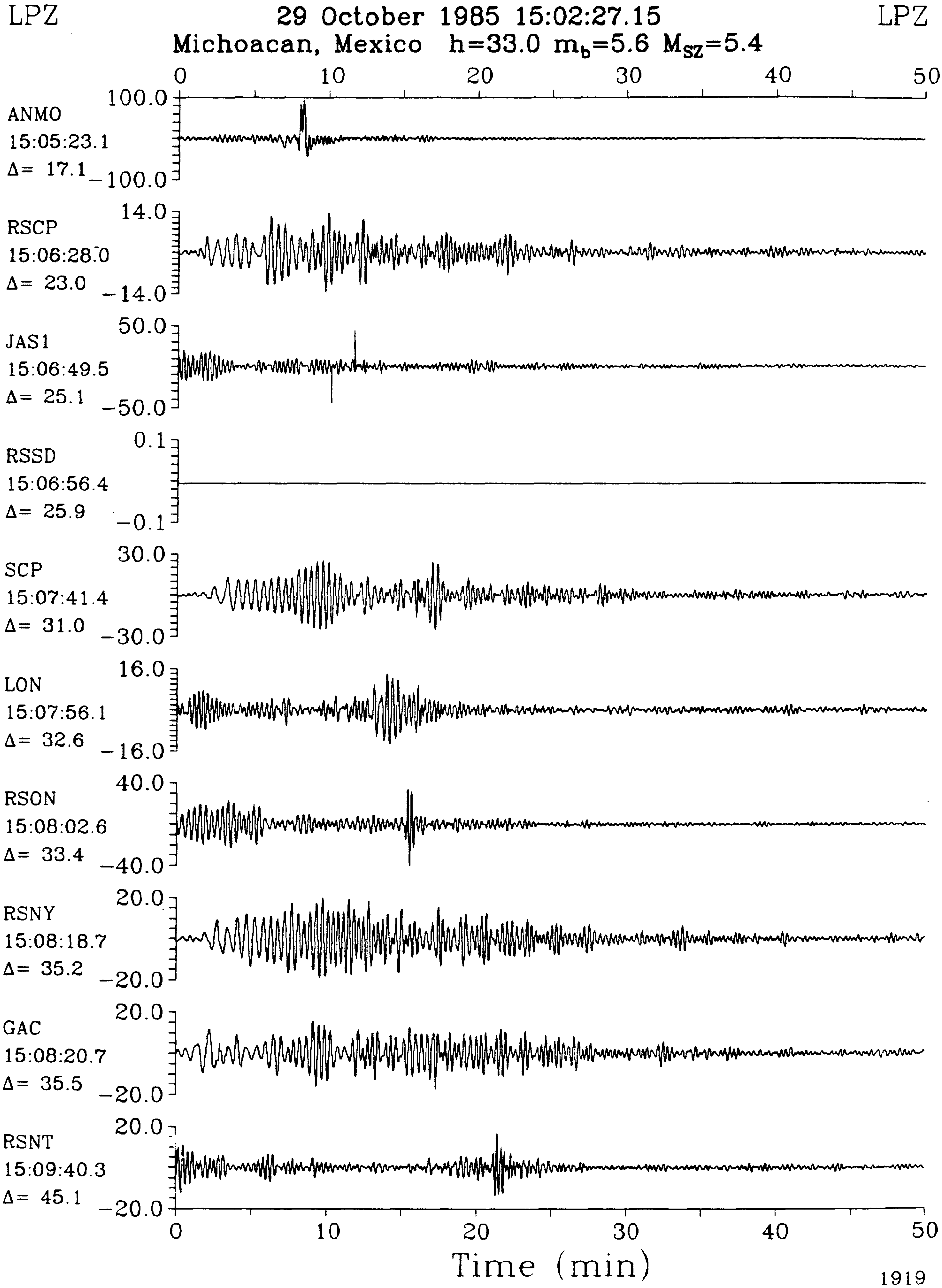


1917

SPZ 29 October 1985 15:02:27.15 SPZ

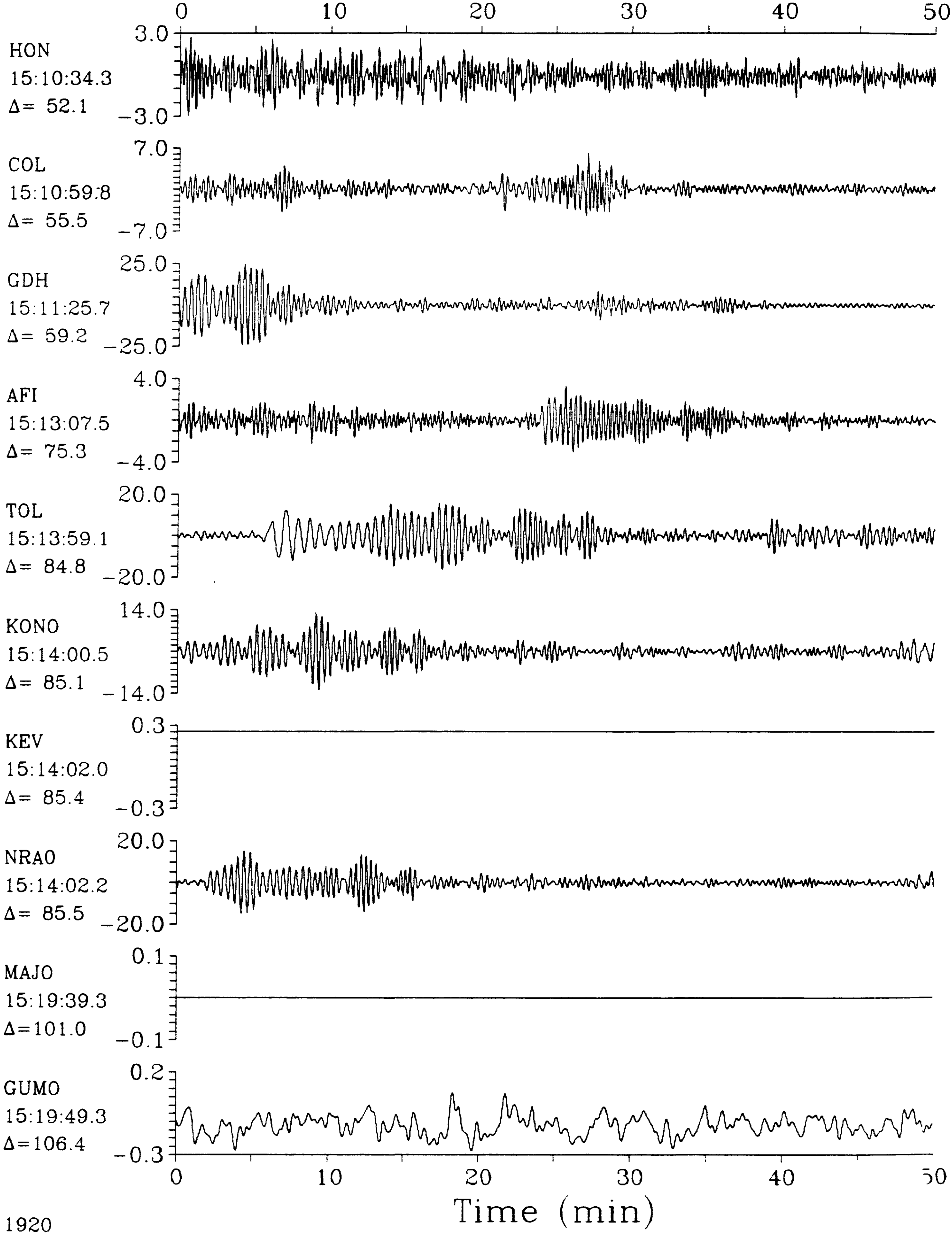
Michoacan, Mexico h=33.0 m_b=5.6 M_{SZ}=5.4




LPZ
29 October 1985 15:02:27.15
LPZ
Michoacan, Mexico h=33.0 m_b=5.6 M_{SZ}=5.4
0 10 20 30 40 50
ANMO
15:05:23.1
Δ= 17.1
100.0
−100.0
RSCP
15:06:28.0
Δ= 23.0
14.0
−14.0
JAS1
15:06:49.5
Δ= 25.1
50.0
−50.0
RSSD
15:06:56.4
Δ= 25.9
0.1
−0.1
SCP
15:07:41.4
Δ= 31.0
30.0
−30.0
LON
15:07:56.1
Δ= 32.6
16.0
−16.0
RSON
15:08:02.6
Δ= 33.4
40.0
−40.0
RSNY
15:08:18.7
Δ= 35.2
20.0
−20.0
GAC
15:08:20.7
Δ= 35.5
20.0
−20.0
RSNT
15:09:40.3
Δ= 45.1
20.0
−20.0
0 10 20 30 40 50
Time (min)

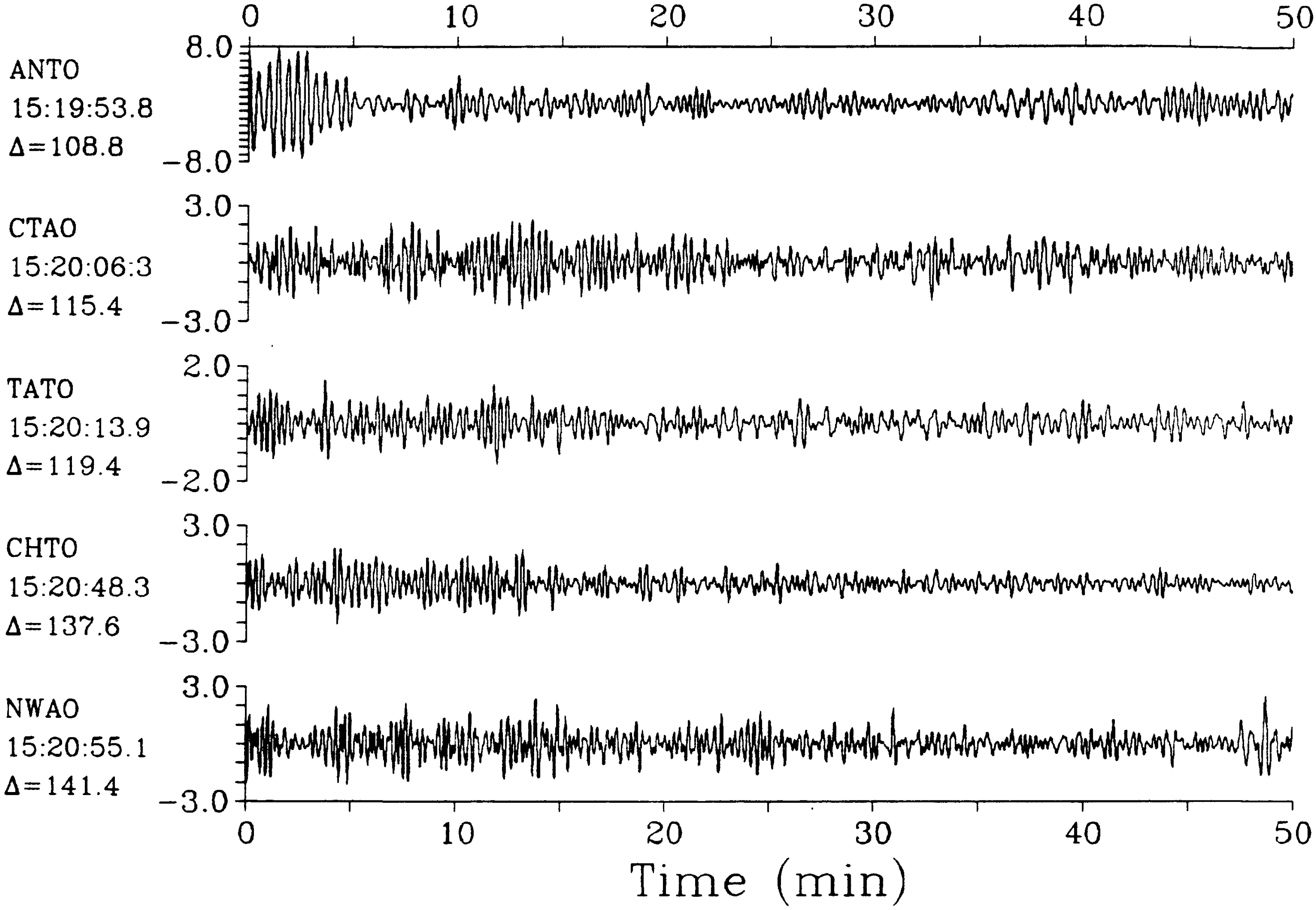
LPZ 29 October 1985 15:02:27.15 LPZ

Michoacan, Mexico h=33.0 m_b=5.6 M_{SZ}=5.4



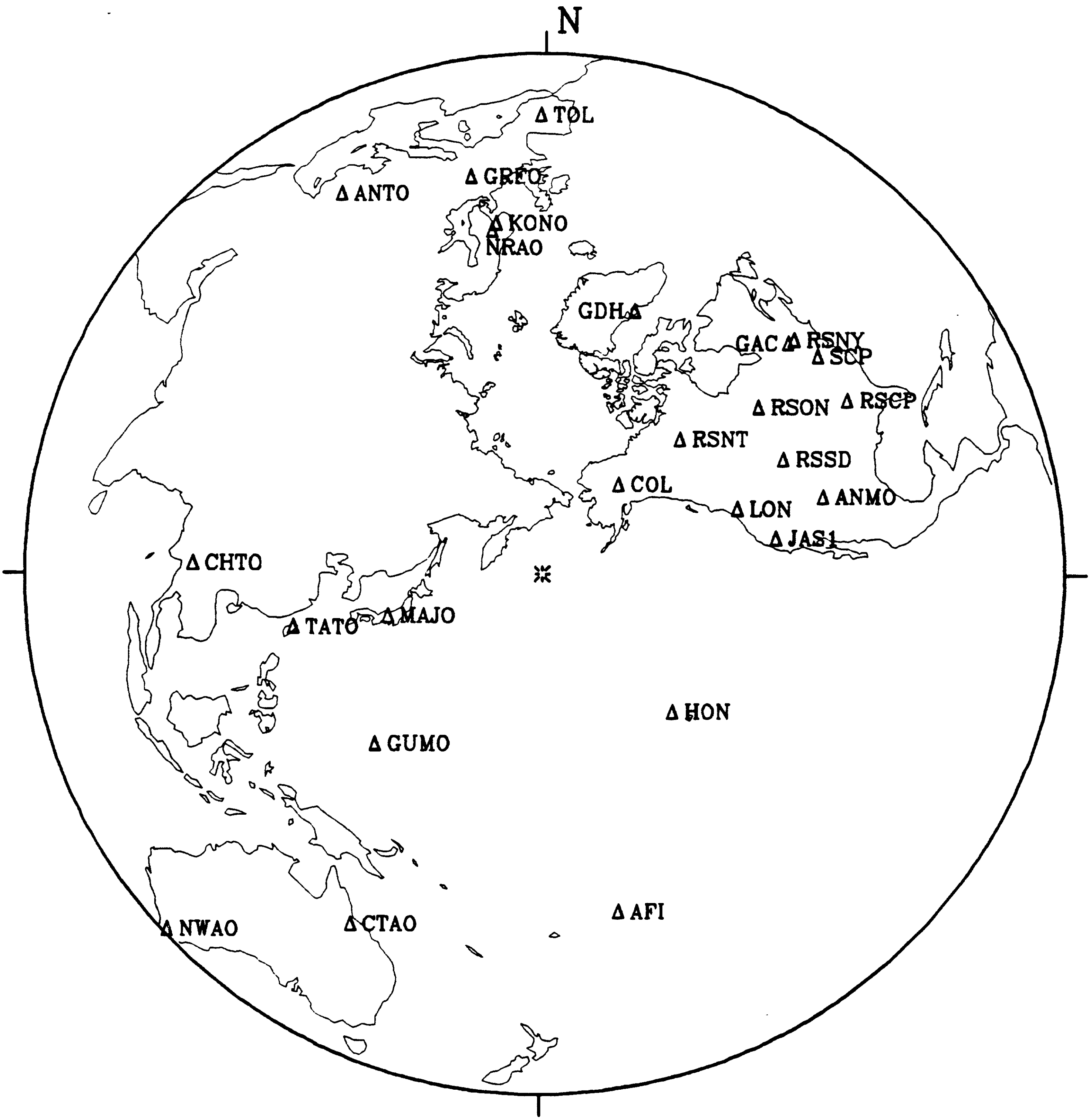
LPZ 29 October 1985 15:02:27.15 LPZ

Michoacan, Mexico h=33.0 m_b=5.6 M_{SZ}=5.4



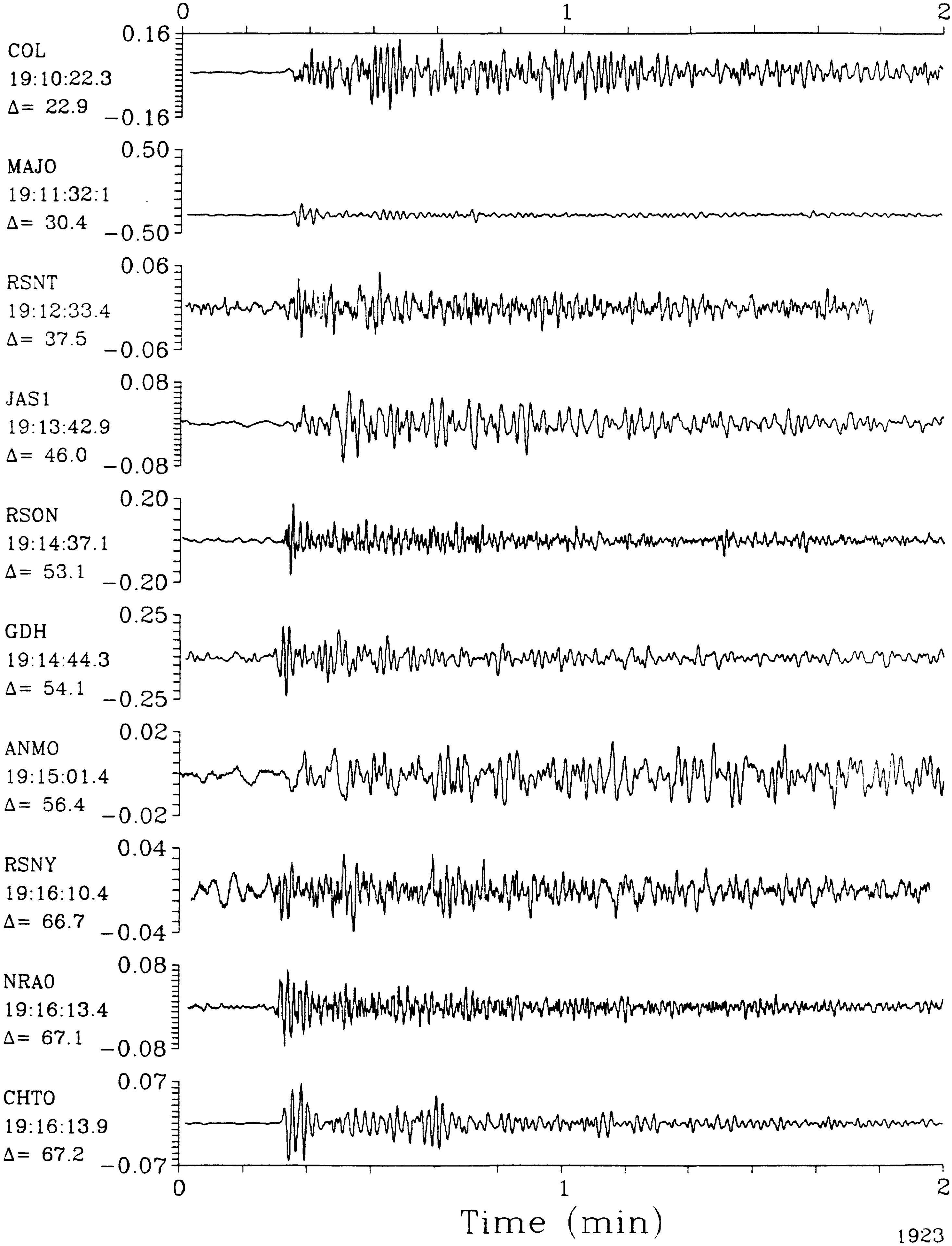
30 October 1985 19:05:37.46

Rat Islands, Aleutian Islands



SPZ 30 October 1985 19:05:37.46 SPZ

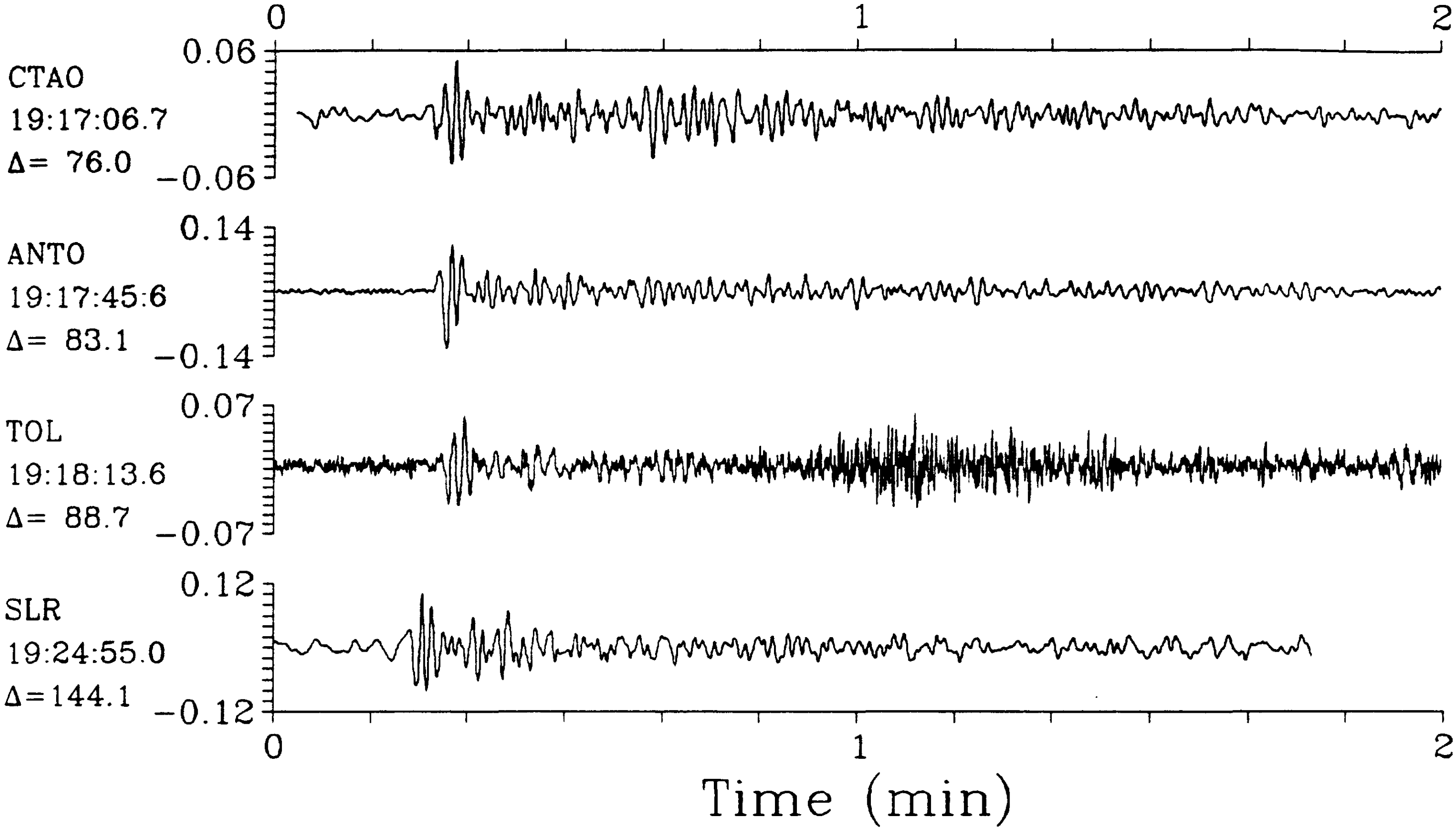
Rat Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.4



1923

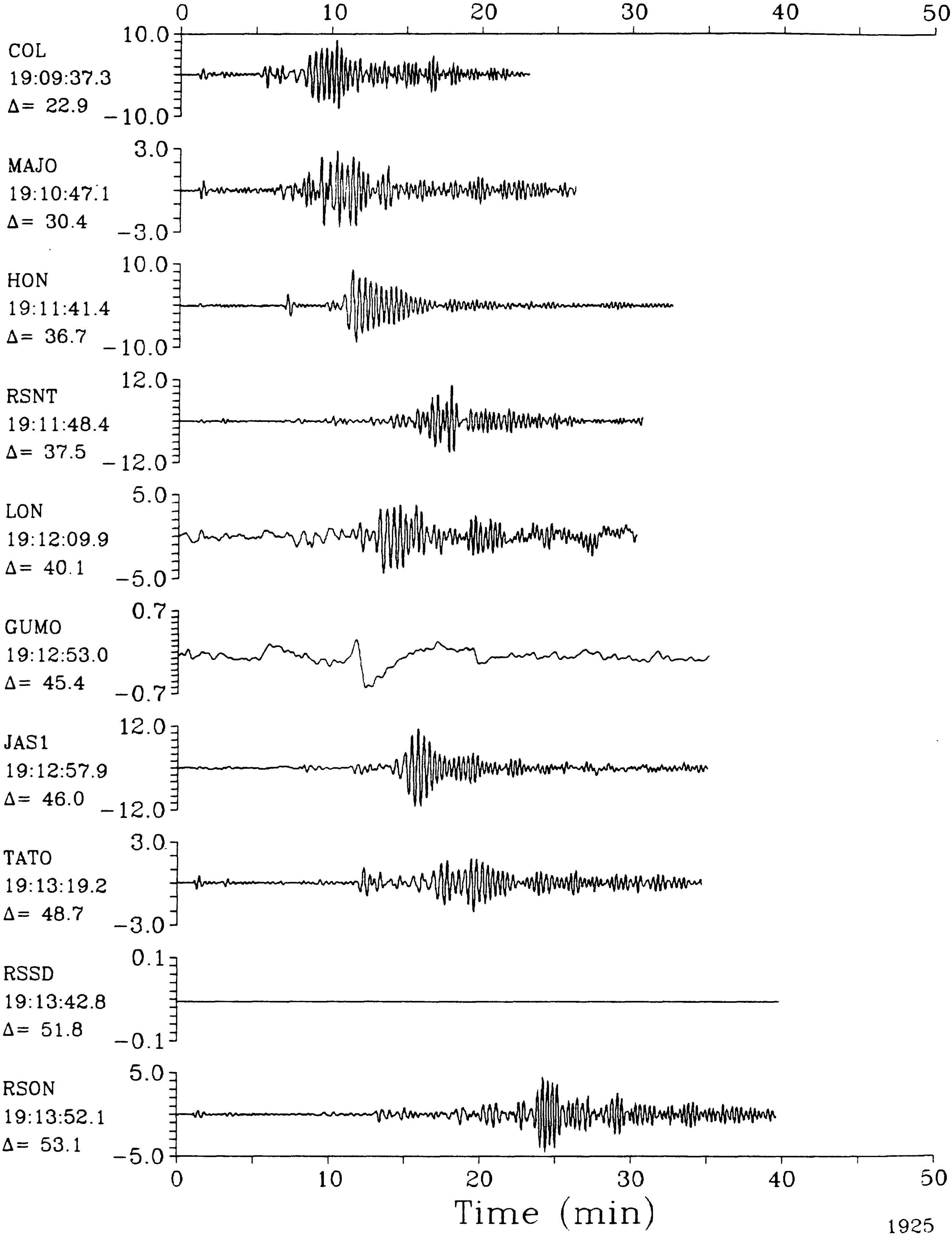
SPZ 30 October 1985 19:05:37.46 SPZ

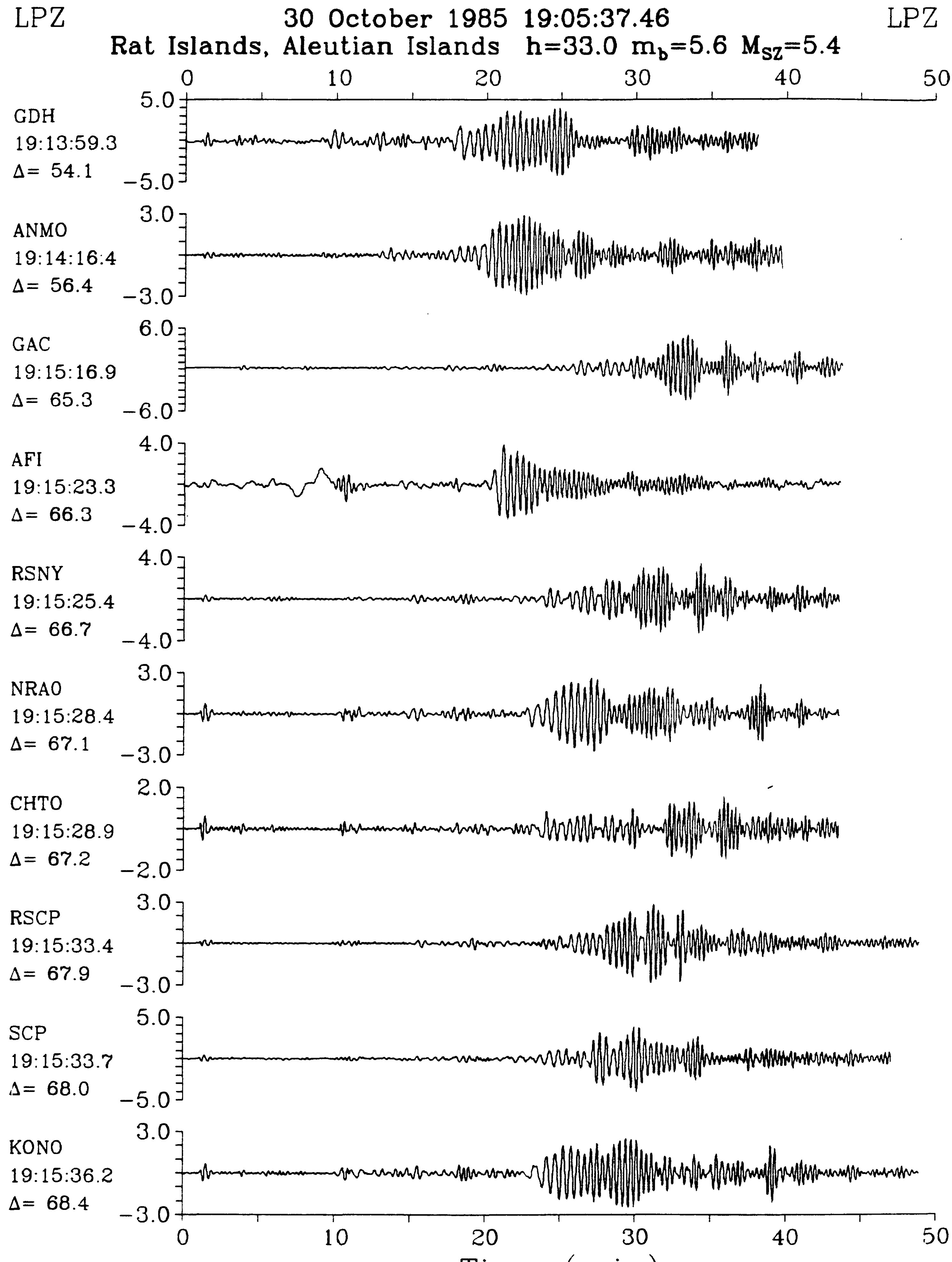
Rat Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.4



LPZ 30 October 1985 19:05:37.46 LPZ

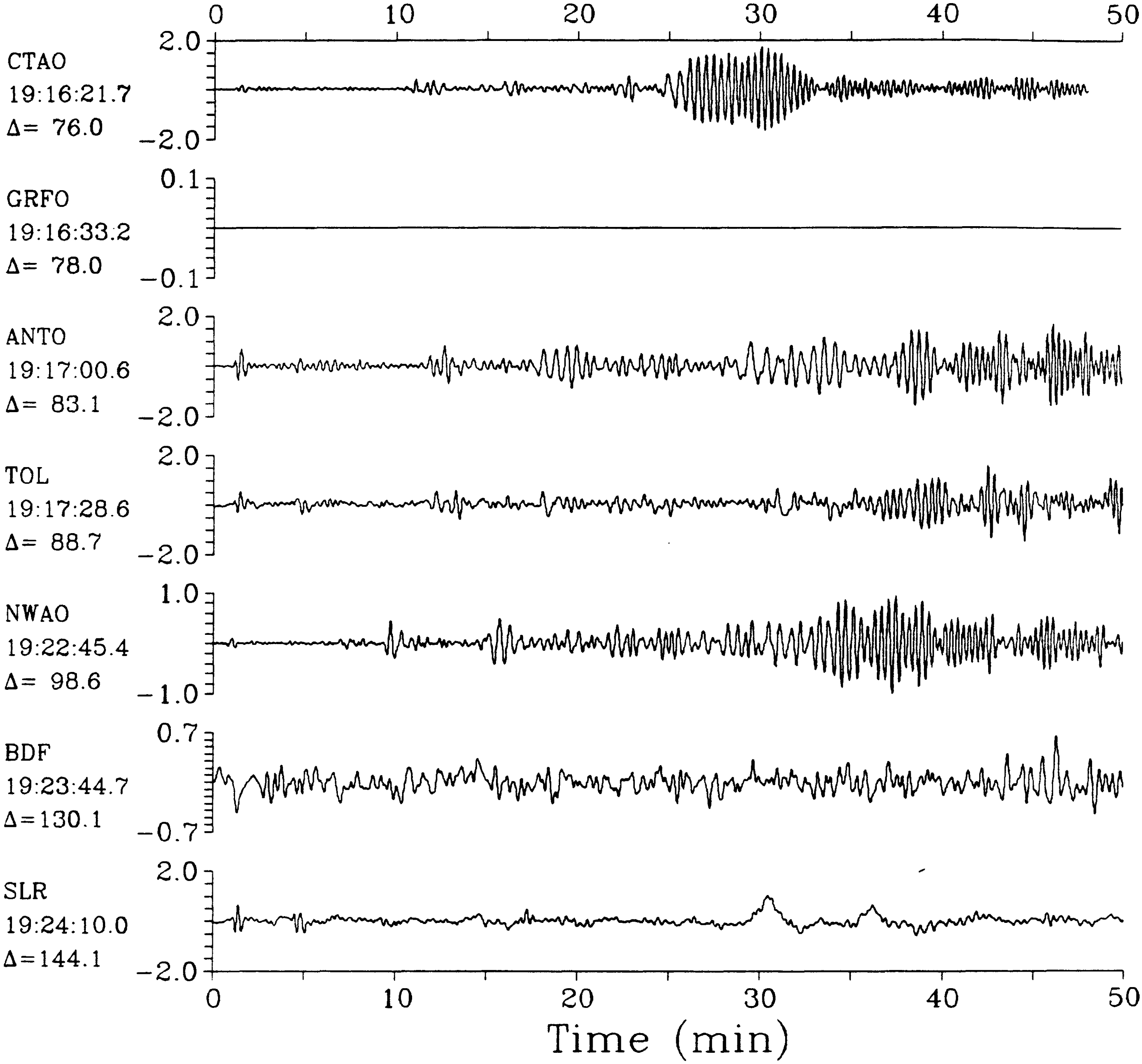
Rat Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.4




LPZ
30 October 1985 19:05:37.46
LPZ
Rat Islands, Aleutian Islands h=33.0 m$_b$=5.6 M$_{SZ}$=5.4
GDH
19:13:59.3
Δ= 54.1
ANMO
19:14:16:4
Δ= 56.4
GAC
19:15:16.9
Δ= 65.3
AFI
19:15:23.3
Δ= 66.3
RSNY
19:15:25.4
Δ= 66.7
NRAO
19:15:28.4
Δ= 67.1
CHTO
19:15:28.9
Δ= 67.2
RSCP
19:15:33.4
Δ= 67.9
SCP
19:15:33.7
Δ= 68.0
KONO
19:15:36.2
Δ= 68.4
Time (min)

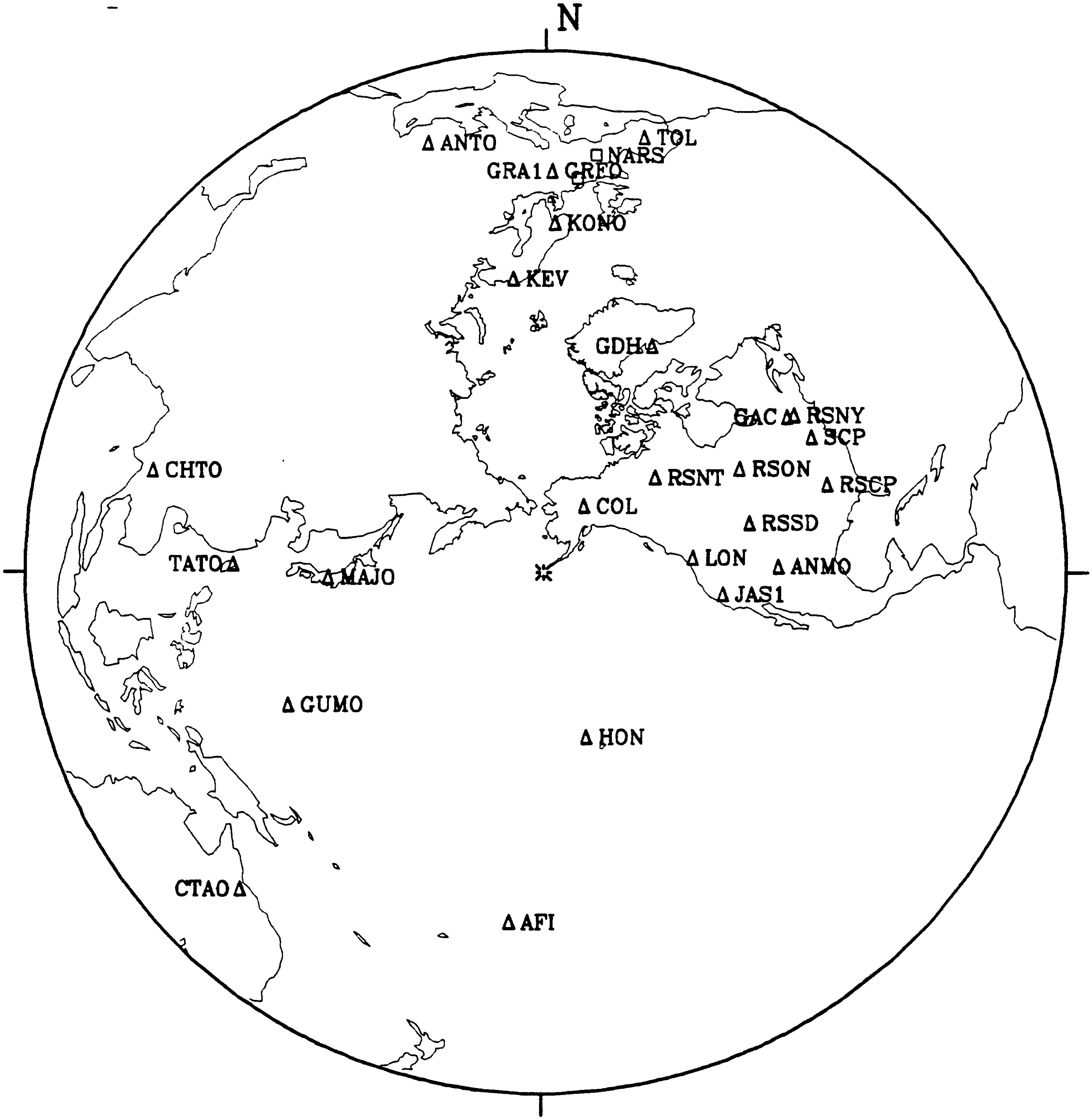
LPZ 30 October 1985 19:05:37.46 LPZ

Rat Islands, Aleutian Islands h=33.0 m_b=5.6 M_{SZ}=5.4



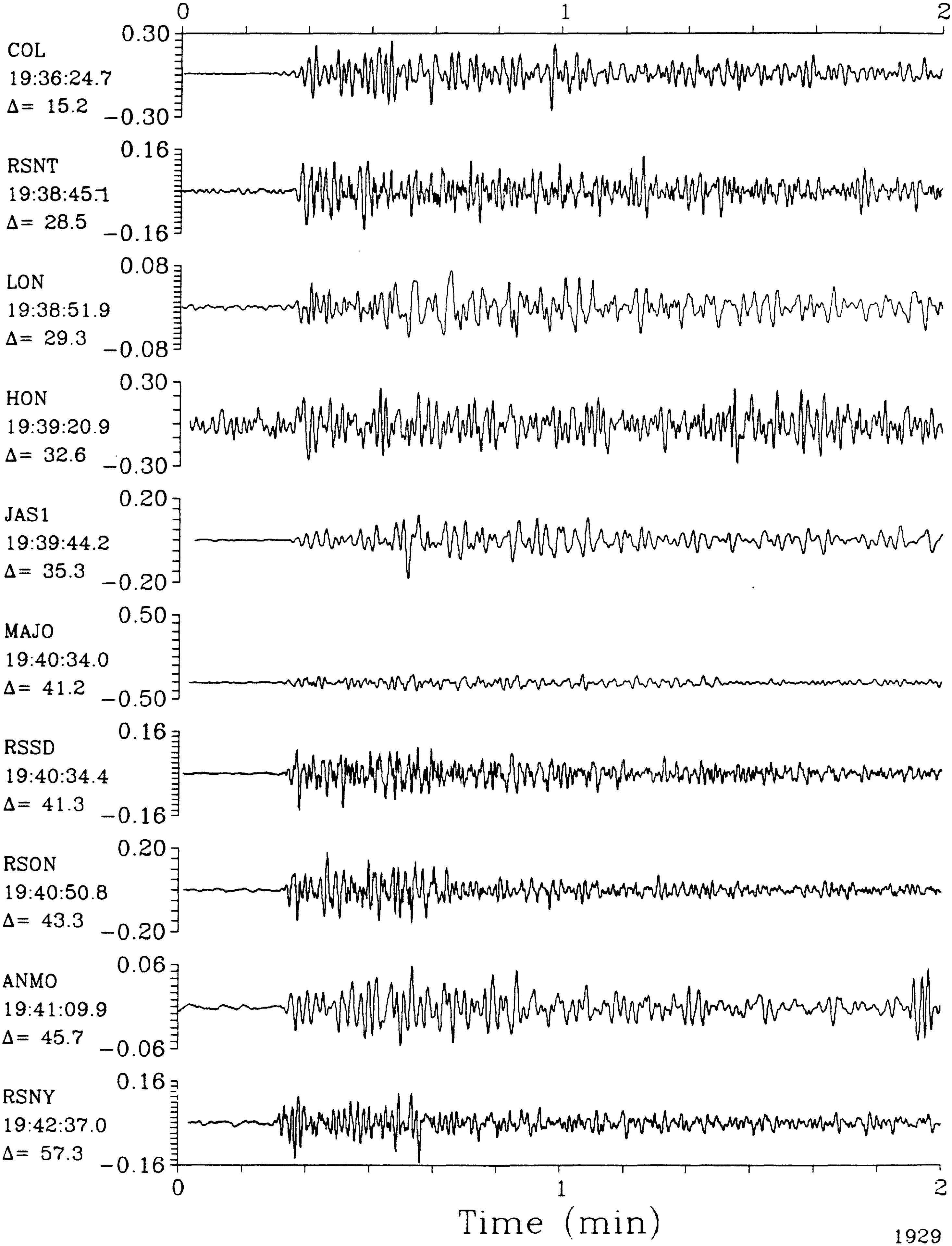
31 October 1985 19:33:07.12

Fox Islands, Aleutian Islands



SPZ 31 October 1985 19:33:07.12 SPZ

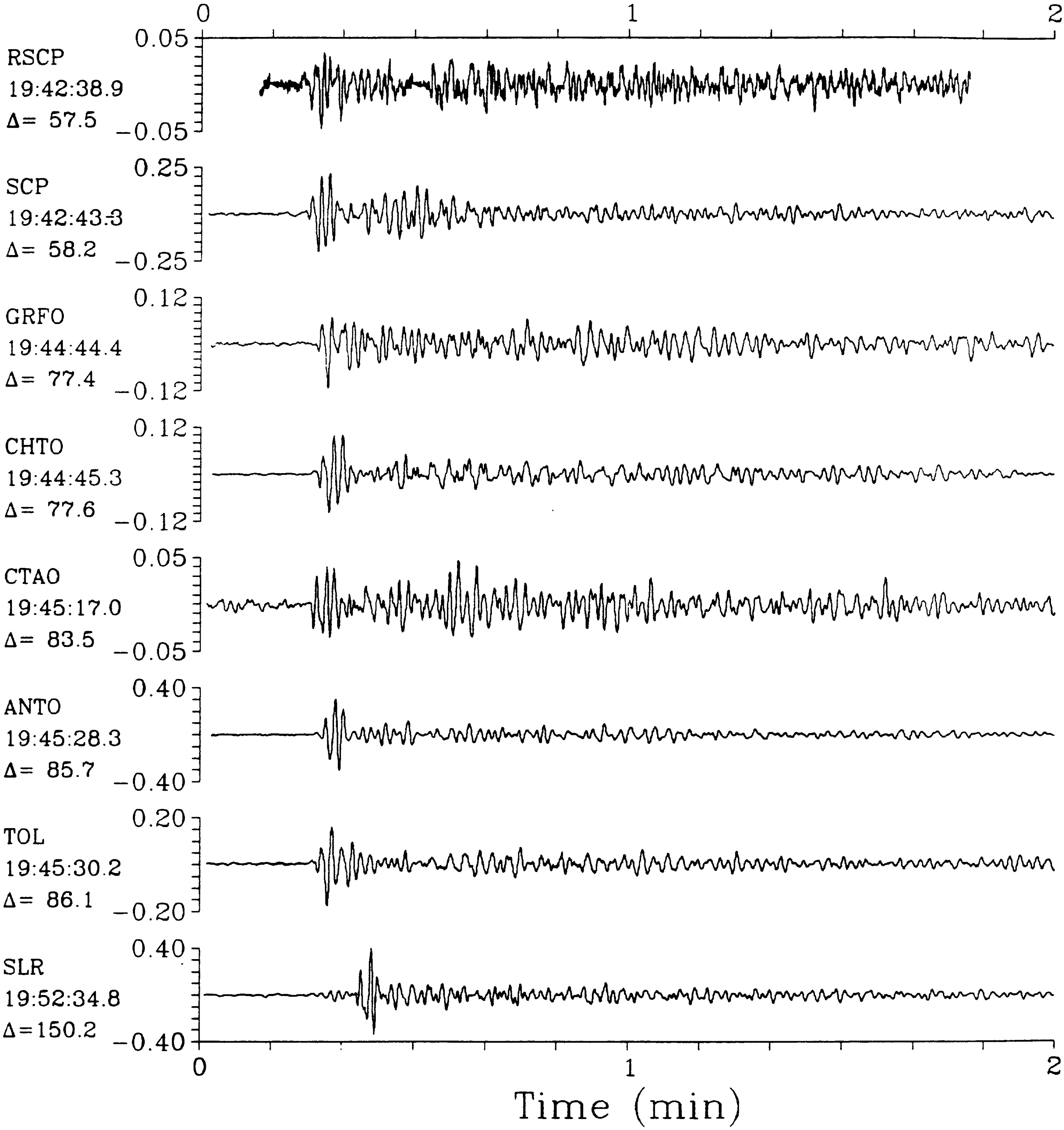
Fox Islands, Aleutian Islands h=33.0 m_b=5.8 M_{SZ}=5.7



1929

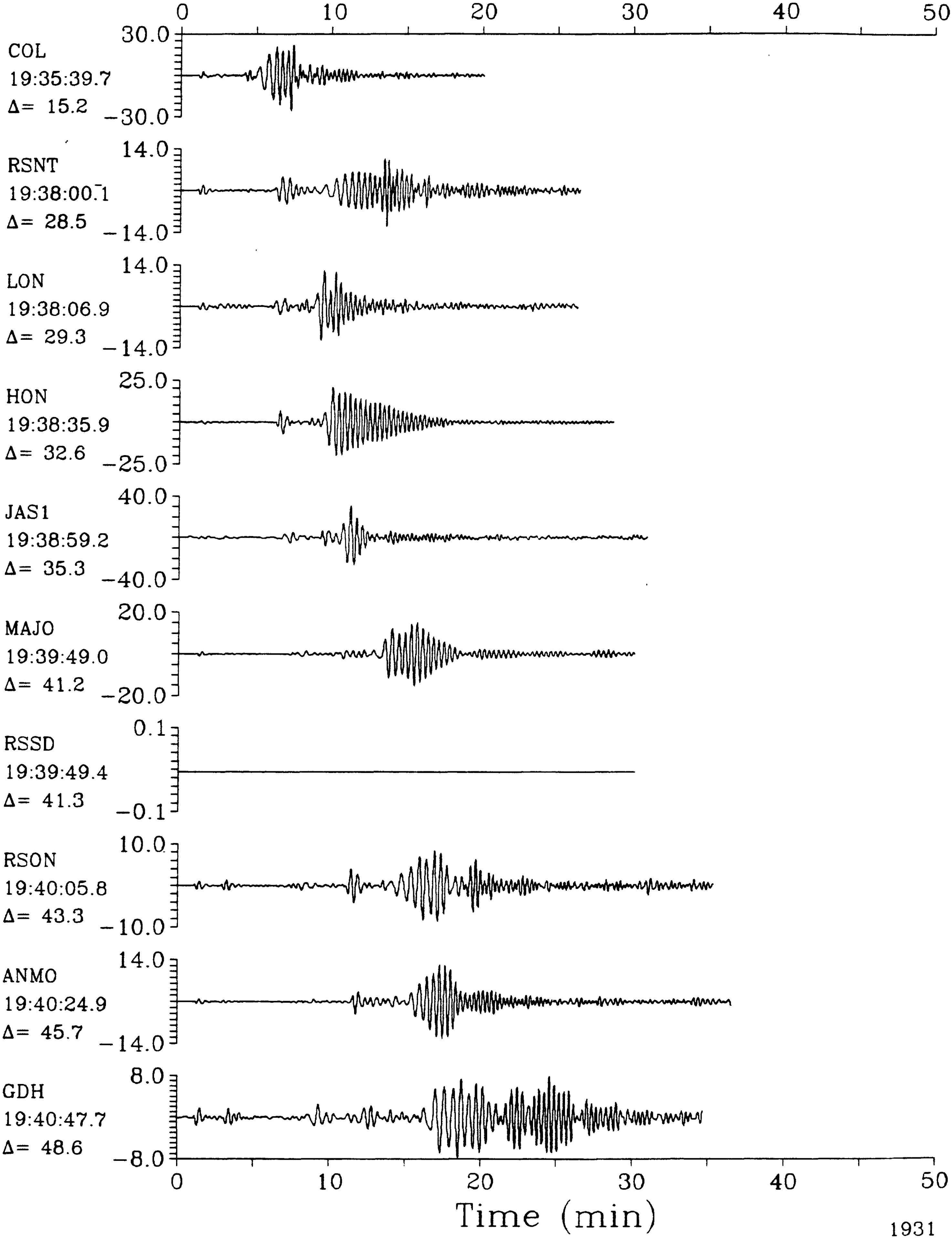
SPZ 31 October 1985 19:33:07.12 SPZ

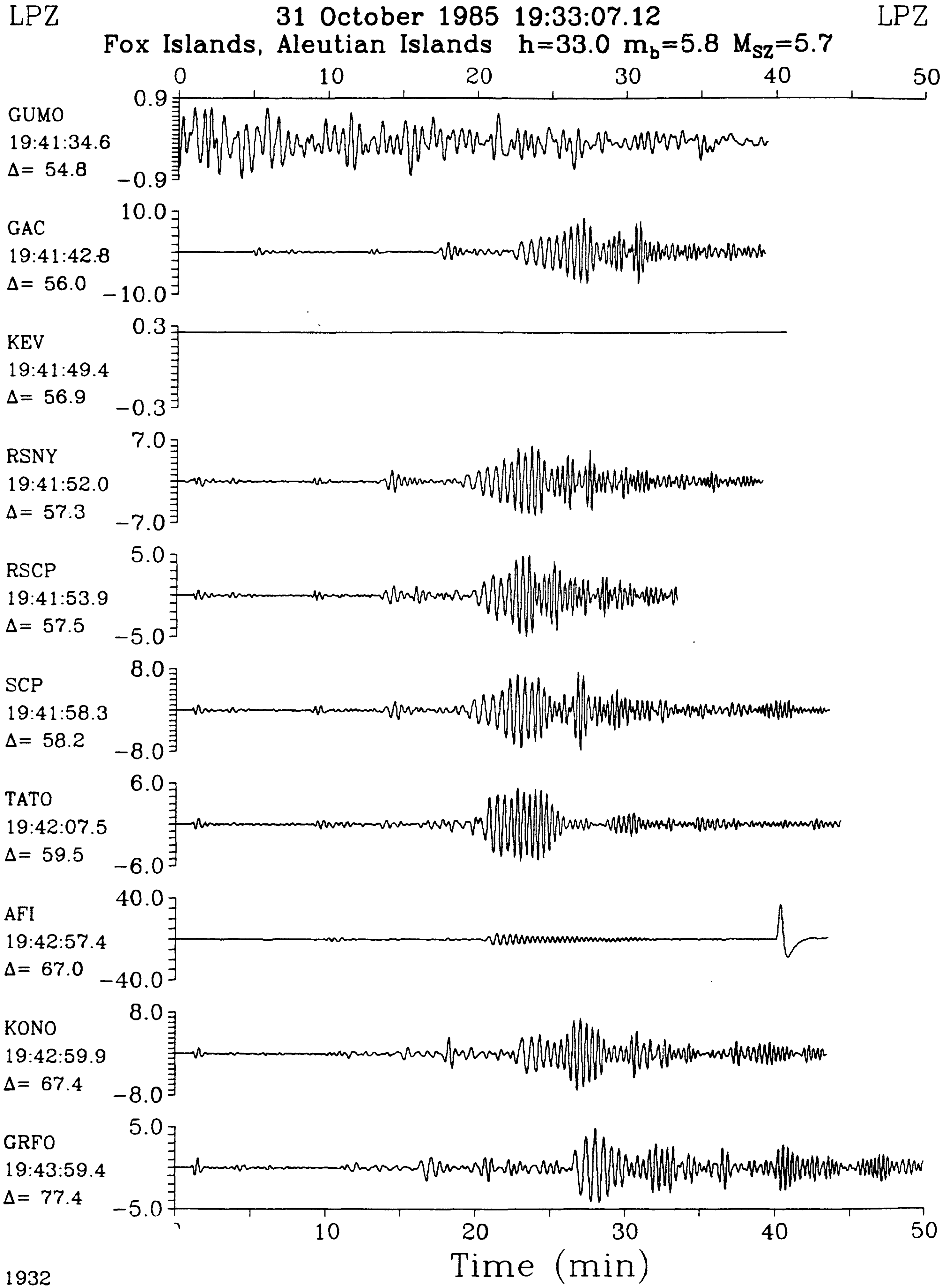
Fox Islands, Aleutian Islands h=33.0 m_b=5.8 M_{SZ}=5.7

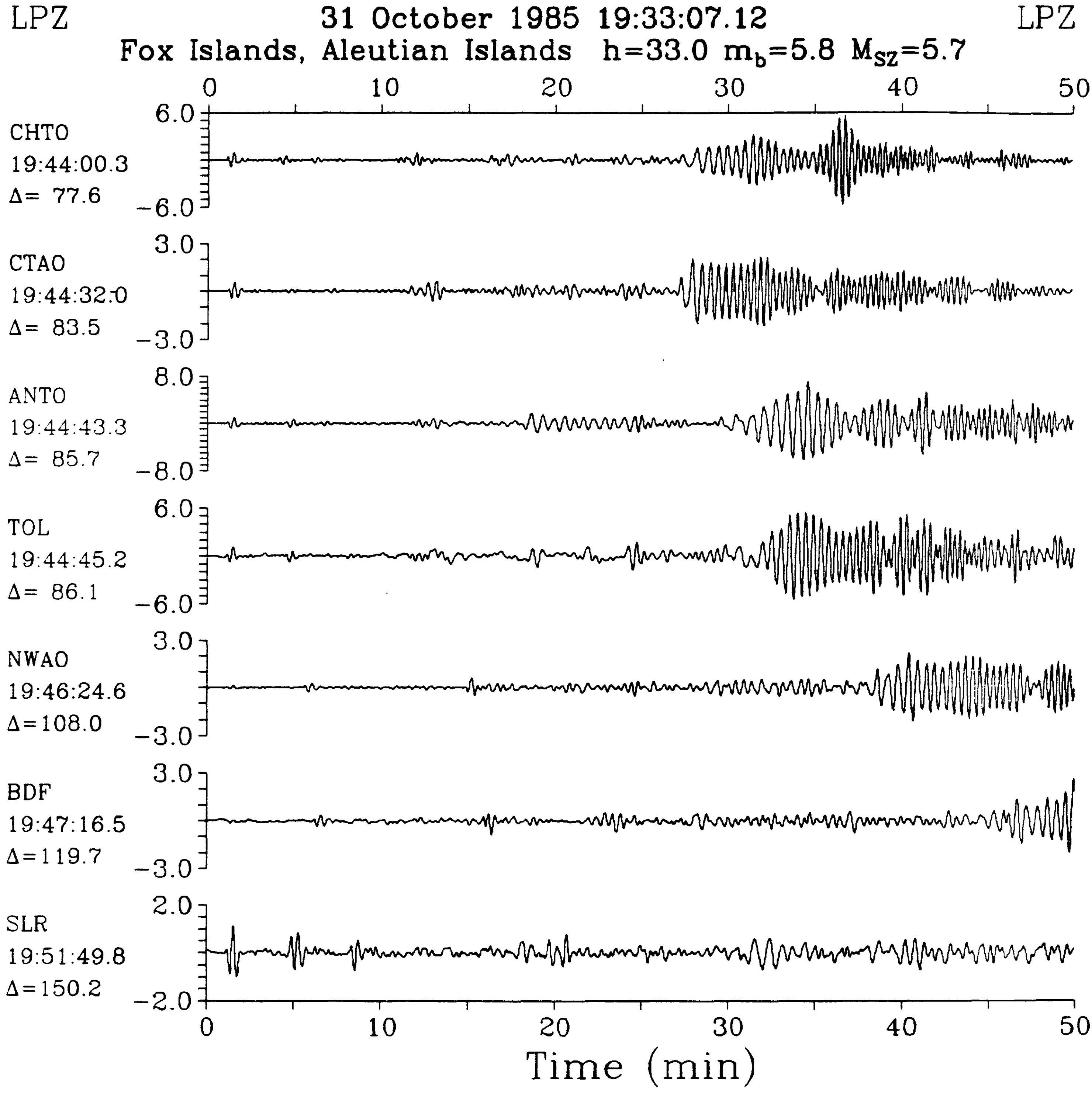


LPZ 31 October 1985 19:33:07.12 LPZ

Fox Islands, Aleutian Islands $h=33.0$ $m_b=5.8$ $M_{SZ}=5.7$

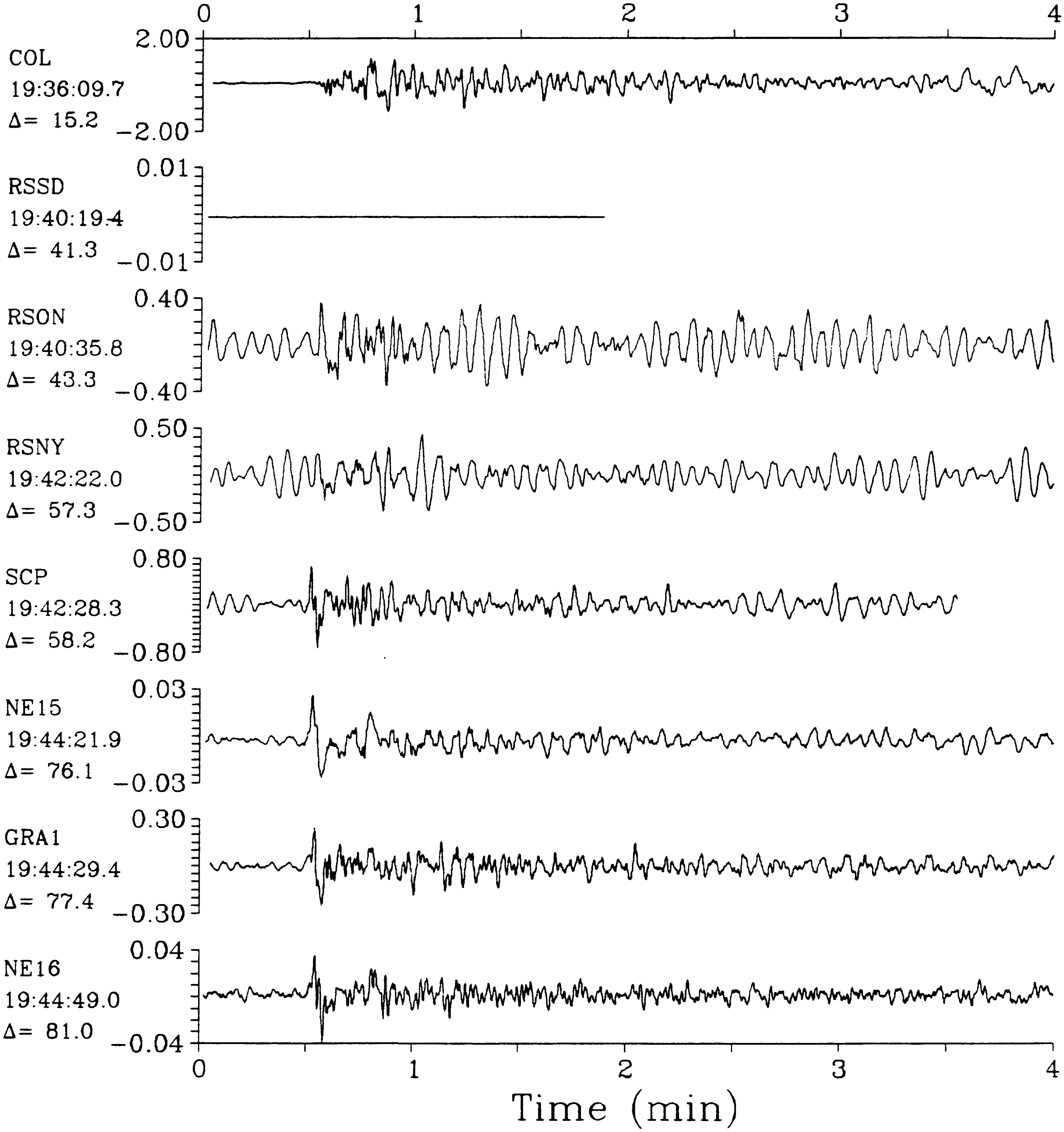



LPZ
31 October 1985 19:33:07.12
LPZ
Fox Islands, Aleutian Islands h=33.0 m_b=5.8 M_{SZ}=5.7
0
10
20
30
40
50
GUMO
19:41:34.6
Δ= 54.8
0.9
−0.9
GAC
19:41:42.8
Δ= 56.0
10.0
−10.0
KEV
19:41:49.4
Δ= 56.9
0.3
−0.3
RSNY
19:41:52.0
Δ= 57.3
7.0
−7.0
RSCP
19:41:53.9
Δ= 57.5
5.0
−5.0
SCP
19:41:58.3
Δ= 58.2
8.0
−8.0
TATO
19:42:07.5
Δ= 59.5
6.0
−6.0
AFI
19:42:57.4
Δ= 67.0
40.0
−40.0
KONO
19:42:59.9
Δ= 67.4
8.0
−8.0
GRFO
19:43:59.4
Δ= 77.4
5.0
−5.0
10
20
30
40
50
Time (min)


LPZ
31 October 1985 19:33:07.12
LPZ
Fox Islands, Aleutian Islands h=33.0 m_b=5.8 M_SZ=5.7
CHTO
19:44:00.3
Δ= 77.6
CTAO
19:44:32.0
Δ= 83.5
ANTO
19:44:43.3
Δ= 85.7
TOL
19:44:45.2
Δ= 86.1
NWAO
19:46:24.6
Δ=108.0
BDF
19:47:16.5
Δ=119.7
SLR
19:51:49.8
Δ=150.2
6.0
-6.0
3.0
-3.0
8.0
-8.0
2.0
-2.0
0
10
20
30
40
50
Time (min)

IPZ 31 October 1985 19:33:07.12 IPZ

Fox Islands, Aleutian Islands h=33.0 m_b=5.8 M_{SZ}=5.7

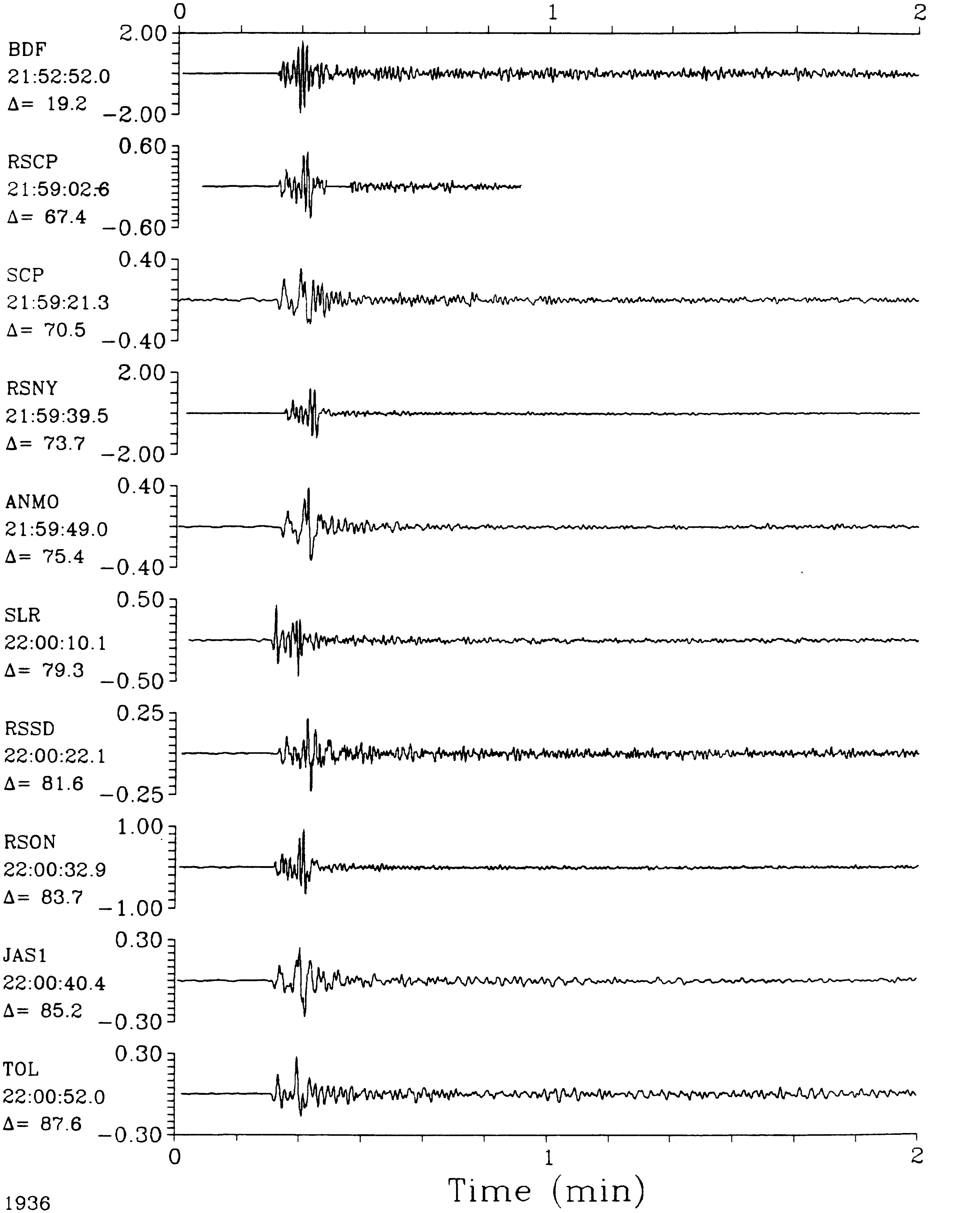


31 October 1985 21:49:20.01

Santiago Del Estero Prov., Arg.

SPZ 31 October 1985 21:49:20.01 SPZ

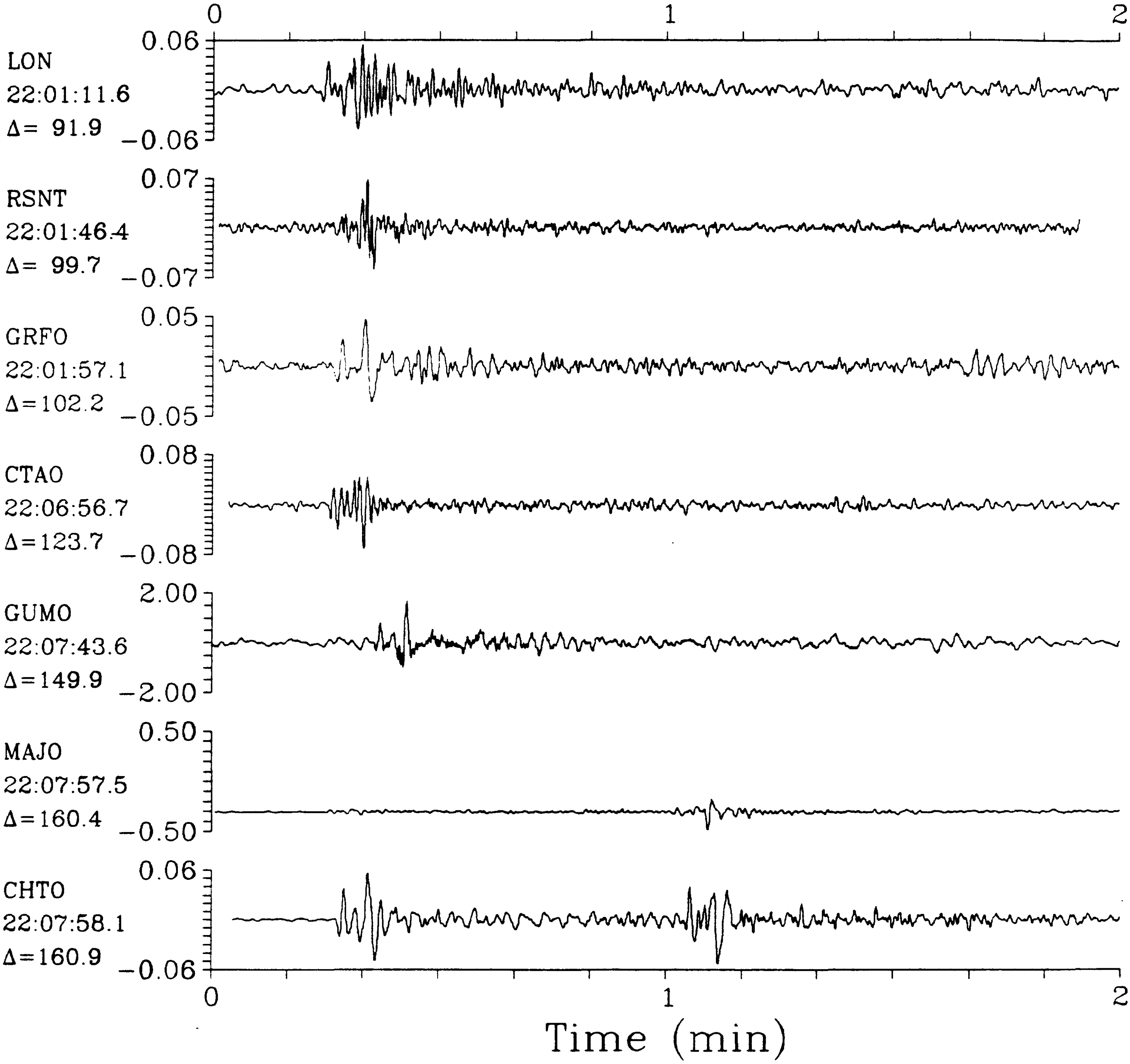
Santiago Del Estero Prov., Arg. h=594.5 m_b=5.8



1936

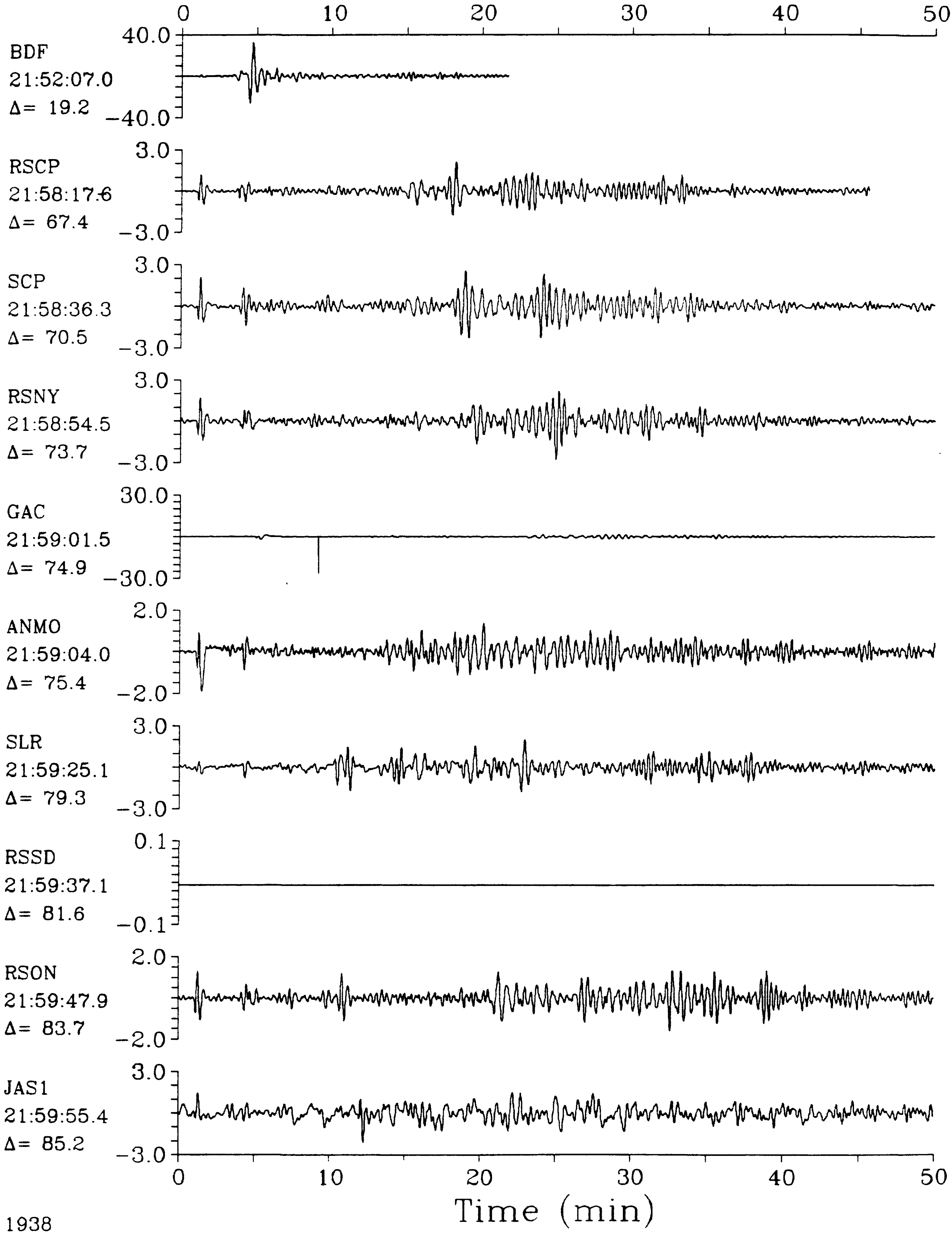
SPZ **31 October 1985 21:49:20.01** SPZ

Santiago Del Estero Prov., Arg. h=594.5 m_b=5.8

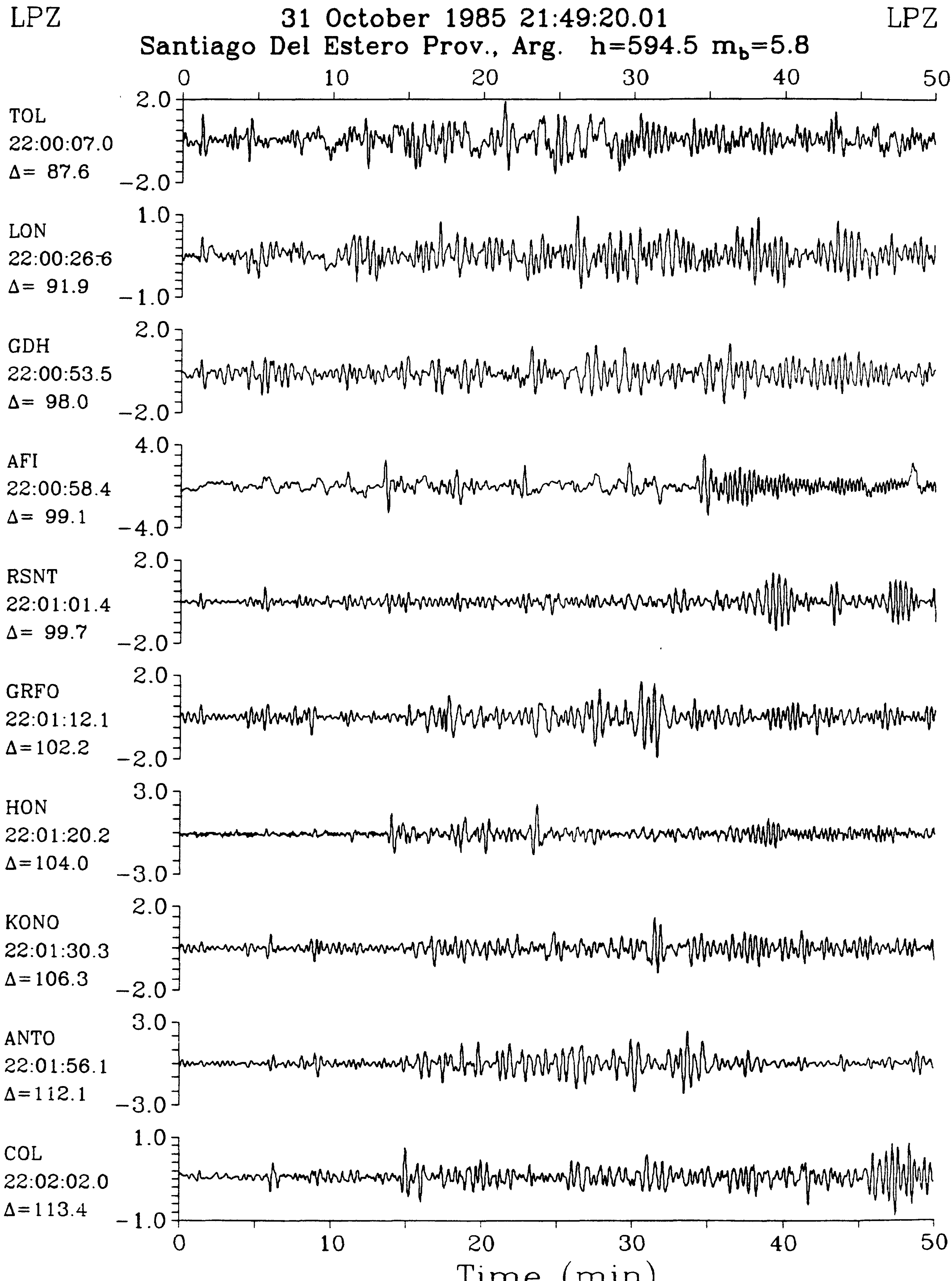


LPZ 31 October 1985 21:49:20.01 LPZ

Santiago Del Estero Prov., Arg. h=594.5 m_b=5.8



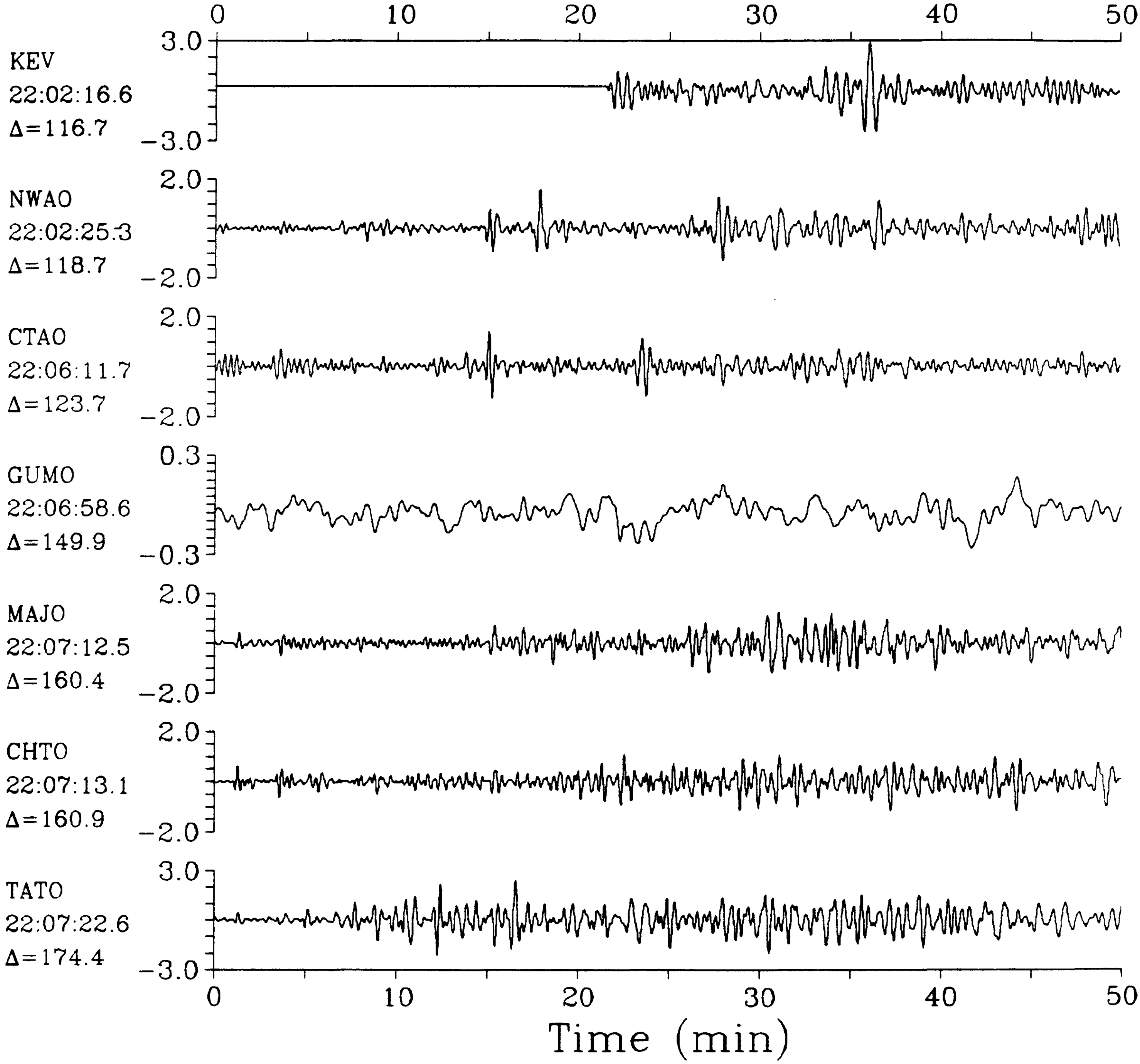
1938


LPZ
31 October 1985 21:49:20.01
Santiago Del Estero Prov., Arg. h=594.5 m_b=5.8
LPZ
TOL
22:00:07.0
Δ= 87.6
LON
22:00:26.6
Δ= 91.9
GDH
22:00:53.5
Δ= 98.0
AFI
22:00:58.4
Δ= 99.1
RSNT
22:01:01.4
Δ= 99.7
GRFO
22:01:12.1
Δ=102.2
HON
22:01:20.2
Δ=104.0
KONO
22:01:30.3
Δ=106.3
ANTO
22:01:56.1
Δ=112.1
COL
22:02:02.0
Δ=113.4
Time (min)

1939

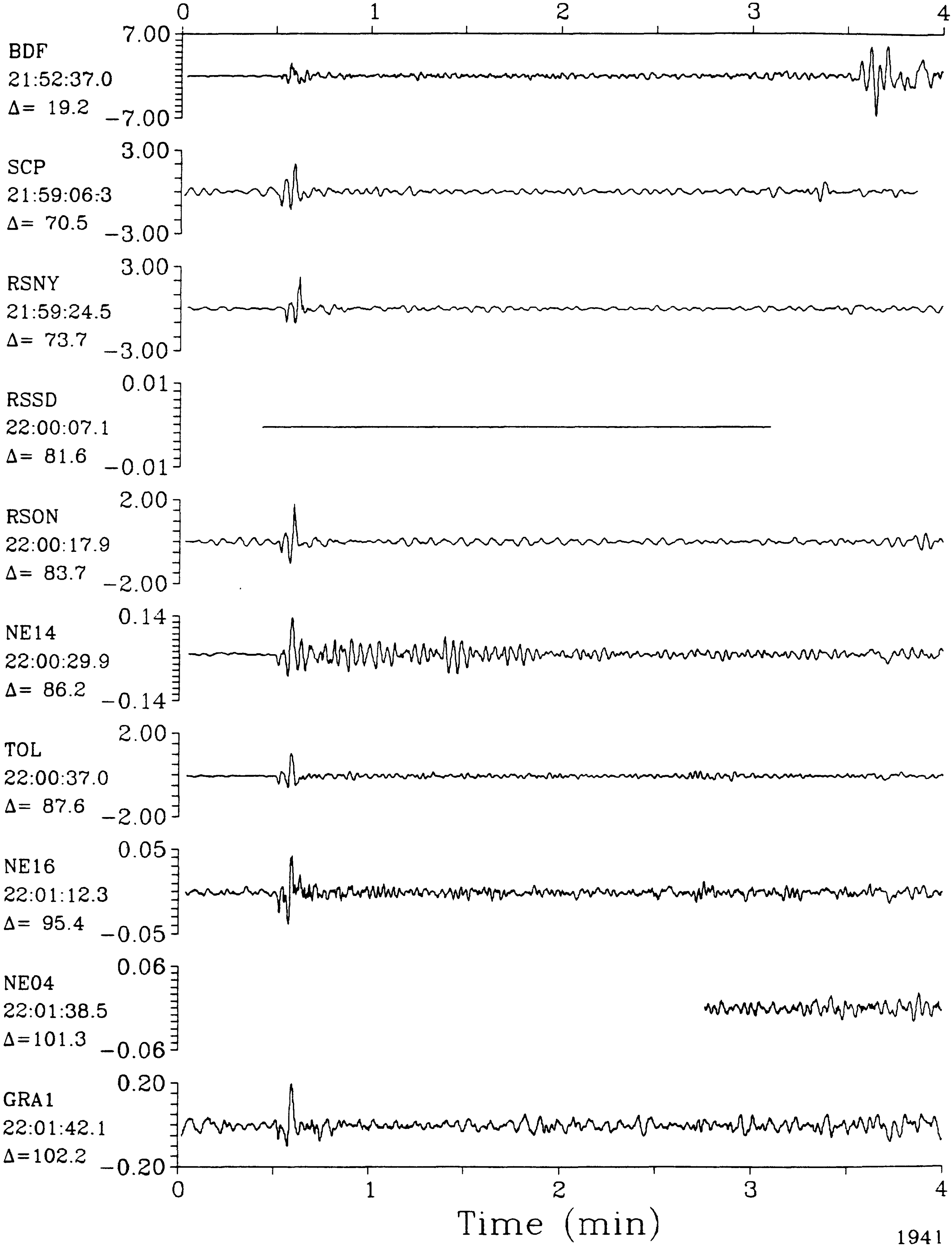
LPZ **31 October 1985 21:49:20.01** LPZ

Santiago Del Estero Prov., Arg. h=594.5 m_b=5.8



IPZ 31 October 1985 21:49:20.01 IPZ

Santiago Del Estero Prov., Arg. h=594.5 m_b=5.8



RESULTS OF A PREIMPOUNDMENT WATER-QUALITY STUDY

OF SWATARA CREEK, PENNSYLVANIA

By David K. Fishel and John E. Richardson

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4023

Prepared in cooperation with the

PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES,
BUREAU OF STATE PARKS

Harrisburg, Pennsylvania

1986

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey, WRD
P.O. Box 1107
Harrisburg, Pennsylvania 17108-1107

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225
(Telephone: (303) 234-5888)

CONTENTS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEMS OF UNITS (SI)

Multiply inch-pound unit	By	To obtain SI unit
	Length	
inch (in.)	2.540	centimeter (cm)
	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Volume	
gallon (gal)	3.785	liter (L)
	3,785	milliliter (mL)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Mass	
pound per day (lb/d)	0.4545	kilograms per day (Kg/d)
ton per day, short	0.9072	megagram per day (Mg/d)
ton per square mile per year [(ton/mi^2)/yr]	0.3503	metric ton per square kilometer per year [(t/km^2)/annum]
	Specific conductance	
micromhos per centimeter at 25° Celsius (µmho/cm at 25°C)	1.000	microsiemens per centimeter at 25° Celsius (µS/cm at 25°C)
	Temperature	
degree Fahrenheit (°F)	C=5/9 (°F-32)	degree Celsius (°C)
	Density	
pounds per cubic feet (lb/ft^3)	16.05	kilograms per cubic meter (Kg/m^3)

RESULTS OF A PREIMPOUNDMENT WATER-QUALITY STUDY

OF SWATARA CREEK, PENNSYLVANIA

By David K. Fishel and John E. Richardson

ABSTRACT

The water quality of Swatara Creek prior to impoundment by the proposed Swatara Creek Reservoir in south-central Pennsylvania was studied from July 1981 through October 1982. This report, done in cooperation with the Pennsylvania Department of Environmental Resources (PaDER), Bureau of State Parks, presents information on existing water-quality conditions. A discussion of possible water-quality conditions in and downstream from the planned impoundment is also included.

Precipitation measured near the study area at Lebanon, Pennsylvania from October 1981 through September 1982 was 8 percent below normal. Streamflow for the same period at Swatara Creek at Harper Tavern just downstream from the study area was 15 percent below the average annual flow. Swatara Creek above Highway 895 has been degraded by acid mine drainage. The main inflow to the planned impoundment has 2.1 times the discharge of Lower Little Swatara Creek--a forested and agricultural basin that is also tributary to the proposed impoundment. During the 1982 water year, 17,400 tons of suspended sediment were transported from the study area. About 46 percent of the annual load was transported during 3 days of high flow. Inflows to the planned impoundment from both Lower Little Swatara Creek and Swatara Creek above Highway 895 were poorly buffered. Measured concentrations of alkalinity and acidity were usually less than 10 mg/L (milligrams per liter) and 5 mg/L as $CaCO_3$, respectively. The inflows contain high concentrations of nutrients and metals that would probably stratify in a reservoir. Maximum concentrations of dissolved nitrate and total phosphorus were 2.6 mg/L and 0.31 mg/L, respectively, at Lower Little Swatara Creek; these concentratons are well above those needed for growth of algae. Maximum observed concentrations for total recoverable iron, aluminum, and manganese at Swatara Creek above Highway 895 at Pine Grove were 100,000 μg/L (micrograms per liter), 66,000 μg/L and 2,300 μg/L, respectively.

Large increases in metal concentrations along with simultaneous decreases in pH and increases in acidity confirm that mine drainage continues to degrade the water quality of Swatara Creek and may have a large impact on water quality of the planned impoundment. Iron, lead, copper, and zinc concentrations periodically exceeded the U.S. Environmental Protection Agency (U.S. EPA) criteria for freshwater aquatic life. Concentrations of manganese and lead also exceeded the U.S. EPA criteria for domestic water supplies and human health, respectively.

The water quality of the Swatara Creek Reservoir will depend on characteristics such as (1) the detention time of water in the lake, (2) the timing and extent of thermal and chemical stratification, (3) sedimentation,

and (4) the chemical loading and concentrations in the lake. Each of these characteristics may depend in part, on streamflow.

The impoundment will act as a sediment trap and thus reduce the concentrations of total phosphorus, iron, aluminum, lead, copper, and zinc immediately downstream from the impoundment. Large storm discharges and releases from the hypolimnion of the reservoir to attain the winter-pool level may contain low oxygen concentrations and elevated concentrations of iron, aluminum, lead, copper, and zinc. Unless conservation releases from the multilevel release gates are carefully controlled, low dissolved-oxygen levels and high metal concentrations may degrade the downstream water quality and be detrimental to the aquatic community.

INTRODUCTION

The PaDER (Pennsylvania Department of Environmental Resources), Bureau of State Parks plans to build a multipurpose reservoir in Swatara State Park in southcentral Pennsylvania (fig. 1). The primary uses of the reservoir will be for recreation and as a supplemental water supply for Lebanon and downstream communities. The reservoir's potential use for hydropower generation is also being investigated by the PaDER.

The proposed impoundment is to be built downstream from areas extensively mined for anthracite during the past two centuries. Large amounts of culm[1/] and sediment have been and continue to be transported by Swatara Creek from abandoned and active mines, culm piles and breaker plants. Acid mine drainage from the Swatara Creek headwaters and high nutrient loads from downstream tributaries flow into the proposed impoundment area.

The U.S. Geological Survey, in cooperation with the PaDER, Bureau of State Parks, began collecting hydrologic data in June 1981 to characterize the water and sediment entering the planned Swatara Creek impoundment and to estimate the effect of the impoundment on water quality. Data from the study will be used to design and operate an impoundment that will provide optimum water quality in and downstream from it.

Purpose and Scope

This report describes the results of a study to (1) determine the concentrations of sediment, nutrients, and constituents common to acid mine drainage in the waters of Swatara Creek, and the average annual load of the same constituents transported to the planned impoundment area; (2) determine the concentration of nutrients and metals in the streambed material and soils in the impoundment area; and (3) to estimate the future water quality in and downstream from the impoundment.

1/ Refuse coal screenings

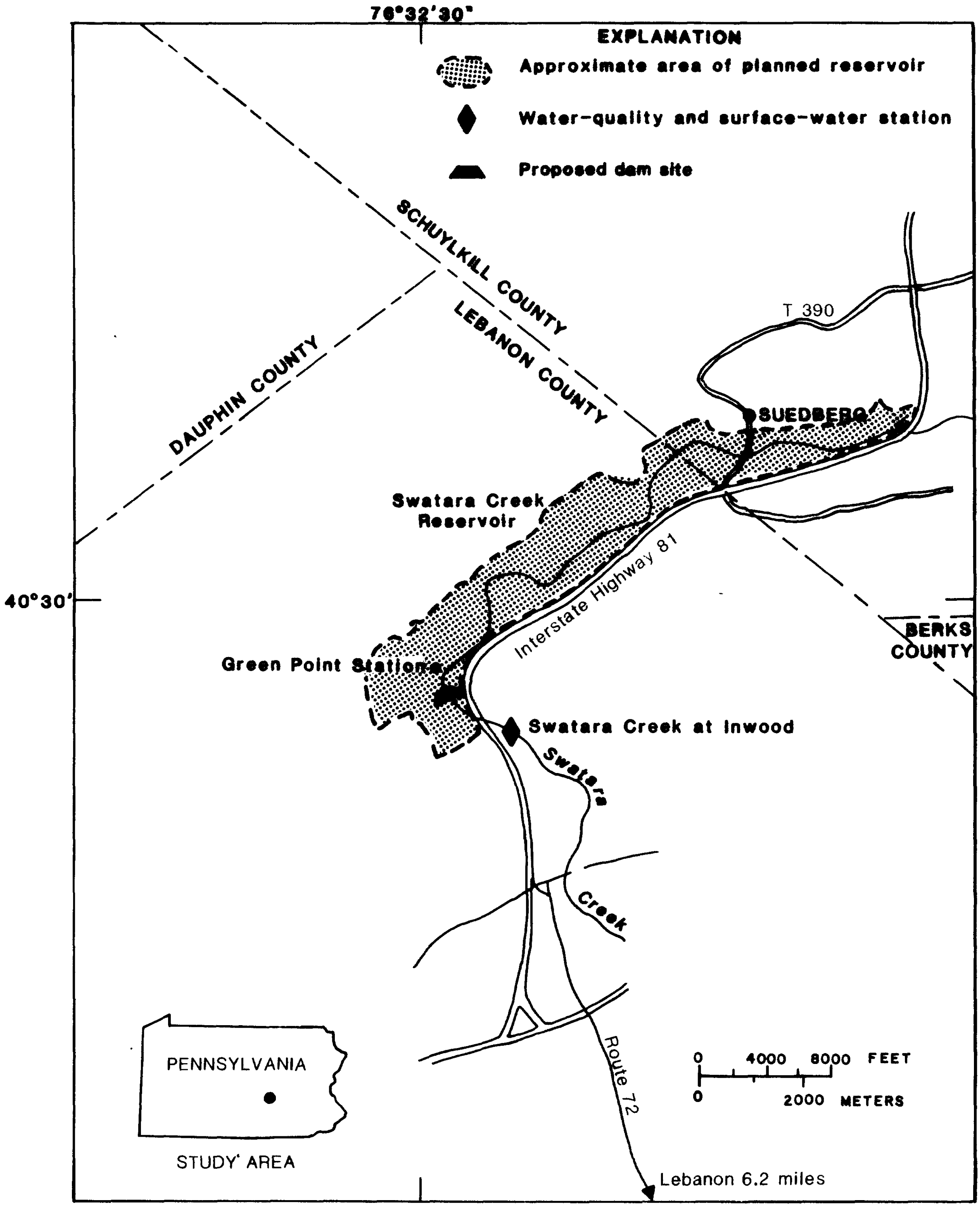


Figure 1.--Location of planned Swatara Creek Reservoir.

The report provides preliminary information on the concentrations of sediment, nutrients, dissolved ions, metals and bacteria transported by Swatara Creek to the planned impoundment area during July 1981 through October 1982. It includes discussions on the relation between chemical constituent concentrations and discharges, streamflow, and suspended sediment. Measured concentrations of nutrients and metals in streambed material also are included. Lastly, a preliminary estimation is made of the water quality of the planned reservoir, and the possible effects of streamflow, and effects of the reservoir on downstream water quality.

Proposed Swatara Creek Reservoir

Plans for Swatara Creek Reservoir began in July 1968 when $2 million was authorized by the Pennsylvania General Assembly legislation (Act 220) for dam and reservoir construction, to be administered by the Pennsylvania Department of General Services (DGS Project No. 152-1). The initial plans included building a multipurpose recreation and water-supply impoundment. Recreational activities included were boating, swimming, and fishing. Water supply was designated for Lebanon and downstream communities. More recently, designs for the reservoir have added the potential for hydropower generation, however, no additional water storage or release would be allocated for power generation.

The recommended location of the dam shown in figure 1 is at latitude 40°28'59" and longitude 76°32'07", approximately 0.6 mi upstream from Interstate Highway 81. The site is near the village of Green Point Station in Lebanon County.

The dam will be a concrete gravity type with a 445-foot non-gated spillway (Terraqua Resources Corporation, 1982). The spillway crest, at an elevation of 473.0 feet above sea level, will impound 10,500 acre-ft of water and create a lake area of 775 acres. About 7,000 acre-ft of water in the reservoir, below elevation 468 ft, will be allocated for sediment deposition, recreation, fish, and wildlife. Another 3,500 acre-ft, from elevation 468 to 473 ft, will be designated for a 10 Mgal/d water supply for Lebanon, low flow releases to Swatara Creek, and evaporation. Water may be released from the surface, from two intermediate levels, or from the bottom of the lake to enhance downstream water quality. The approximate reservoir depth at the dam will be 40 ft, and the reservoir length will be about 6.8 mi.

A subimpoundment was recommended by the Pennsylvania Fish Commission to reduce the suspended-sediment load to the reservoir (Hoopes 1981). This structure, with total drawdown capability, could be located near township road 390 at Suedberg. The subimpoundment could retard bedload transport and reduce the amount of suspended metals and nutrients transported to and trapped in the reservoir.

Previous Studies

Several investigators have reported on the hydrology of Swatara Creek basin. These investigations include water-quality studies, basin-wide hydrologic investigations, mine drainage abatement studies, and fisheries surveys.

McCarren and others (1961 and 1964) studied the water quality of the basin. They reported that ground water had a dominant influence on the quality of surface water during low flows. Their field tests also showed all ground water in the basin was non-acidic. However, the surface water above Ravine was found to be acidic. Sources of the acid drainage were identified as overflows from unworked coal mines. Water quality was reported to improve downstream near Pine Grove as acidic water was diluted and neutralized by inflows from Upper and Lower Little Swatara Creeks. Their study determined that a high percentage of the sediment load carried by streams in the Swatara Creek basin is transported during a few storms each year.

Stuart and others (1967) evaluated the hydrologic system of the Swatara Creek basin. Eight hydrologic zones, based on runoff, natural use of the water, and chemical characteristics of the water were defined in their study. Boundaries of the zones were generally the same as those for geologic formations transecting the basin.

Berger Associates Inc. (1972) determined sources and amounts of mine drainage entering the Swatara Creek headwaters. Their study identified five abandoned deep-mine pool overflows as the primary source of acid mine drainage in a 14.9-mi^2 area. The combined average acid discharge for the five overflows was 5,909 lb/d. Coal mine refuse piles were the second largest source of acid, and strip mines were the third largest source.

Potter and others (1976) surveyed fishes of the Swatara Creek as part of a study to determine effects due to operation of Three Mile Island Nuclear Station on aquatic life in the Susquehanna River. The surveys found no fish above Swatara Creek at Ravine where pH values below 6.0 were measured. They concluded that the moderate to low diversity indices throughout the Swatara drainage basin was probably due to poor water quality, and that the headwaters were biologically degraded by iron compounds, mine drainage, and coal dust.

Location of Study Area and Sampling Sites

The 169-mi^2 watershed for the Swatara Creek Reservoir lies in Schuylkill and Lebanon Counties in southcentral Pennsylvania (fig. 2). The headwaters originate in Broad Mountain and flow southwesterly about 29 mi before reaching Inwood, just below the proposed dam.

Streamflow and suspended-sediment data collection began in July 1981, and chemical-quality data collection began in December 1981 at three sites. Two of the sites were selected upstream of the proposed dam to characterize discharges entering the impoundment area. The most upstream site is on the mainstem of Swatara Creek, 0.3 mi. upstream from Highway 895 at Pine Grove. The predominant land use in this 72.6-mi^2 drainage basin is coal mining. The second site is on Lower Little Swatara Creek at Highway 501, about 0.6 mi. upstream from the confluence with Swatara Creek. This basin area is 34.3 mi^2 and is mostly forest and agriculture. A third site is located at Inwood, 11 mi. below the confluence of Swatara and Lower Little Swatara Creeks about 0.8 mi. downstream from the proposed dam. Data collected from this site reflect the suspended sediment and chemical constituents transported by Swatara Creek downstream of the impoundment prior to reservoir construction.

Bottom-material samples were collected from the streambed at three additional sites (fig. 2) on Swatara Creek. These sites are within the proposed impoundment area, and data at these sites will be used to characterize the initial chemistry of the proposed impoundment bottom.

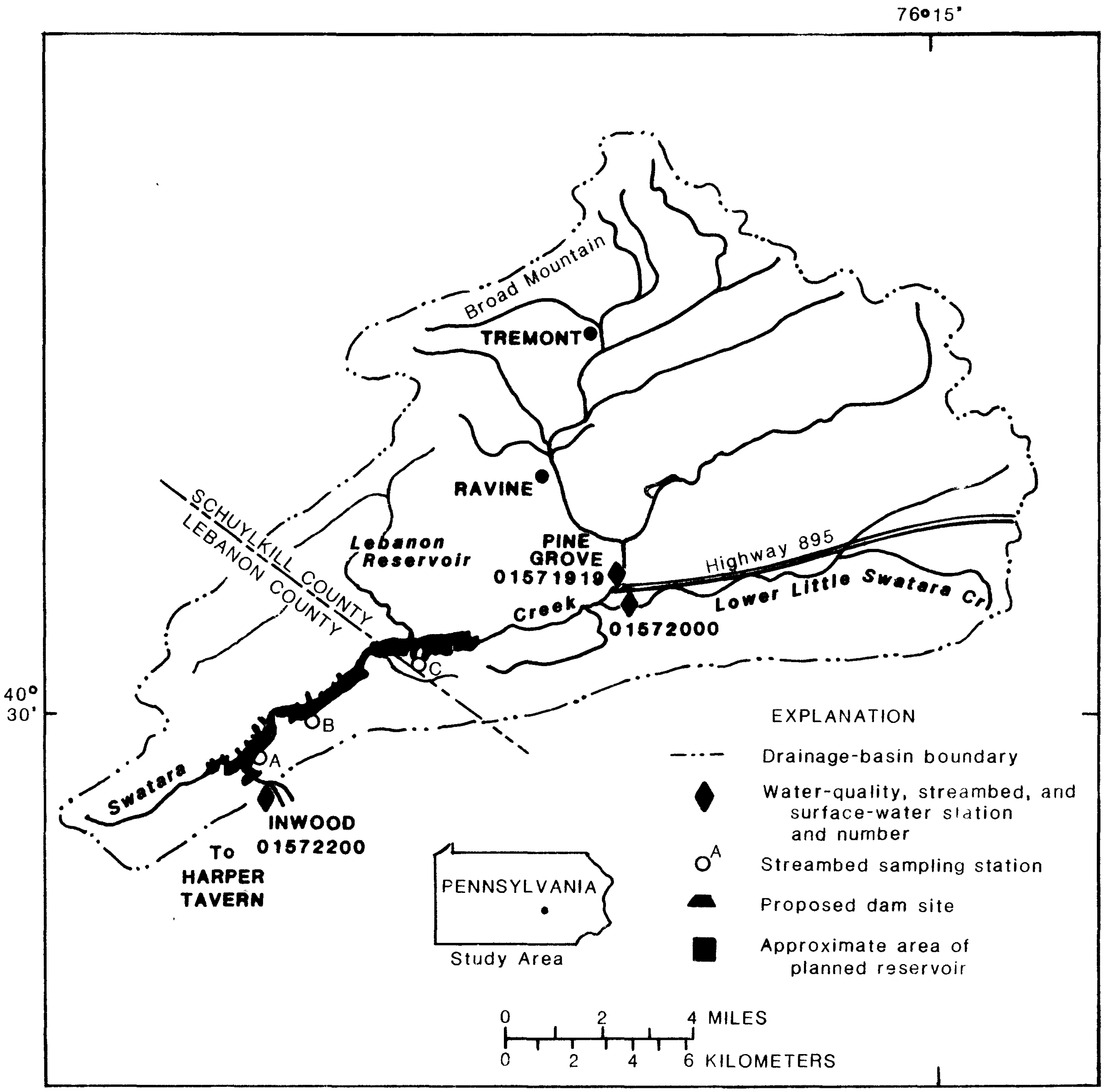


Figure 2.--Location of Swatara Creek Reservoir and sampling sites.

FACTORS AFFECTING WATER QUALITY OF SWATARA CREEK RESERVOIR STUDY AREA

Climate and Precipitation

Climate and precipitation are two factors which greatly affect the water quality of a stream. Climate is often described in terms of air temperature, which directly affects the water temperature and, therefore, the rates of chemical reactions occurring in a body of water. Warmer temperatures result in faster rates of chemical reactions. Precipitation through its relationship with runoff has a direct effect on water quality. Generally, the greater the precipitation, the greater the amount of runoff that increases chemical-constituent discharges to the streams.

The climate of the study area reflects the temperate conditions in Pennsylvania. Seasonal climatic differences are evident by a growing season beginning in April and ending in October. Air temperatures from winter to spring often differ by more than 100°F (56°C). Air temperatures for October 1981 to September 1982 ranged from -6°F (-21°C) to 94°F (34°C); the average was 51.7°F (10.9°C) at Lebanon. In the middle of the study area, at Pine Grove, the average air temperature for the same period was 49.1°F (9.5°C). The annual normal air temperature at Lebanon is 52.1°F (11.2°C) (National Oceanic and Atmospheric Administration, 1982).

Precipitation is greatly influenced by the orographic effects of the Appalachian Mountains. Table 1 gives a comparison of precipitation measured at Pine Grove near the middle of the study area in the valley and ridge area, with that measured at Lebanon just south of Blue Mountain and the study area. Precipitation data has not been collected long enough to determine a long-term annual precipitation for the Pine Grove station; however, total precipitation at Lebanon for the 1982 water year was 8 percent drier than that for 1931-60. About 30 percent more precipitation, 11.9 in. was measured at Pine Grove than at Lebanon in the 1982 water year. Much of the difference in total precipitation between the stations resulted from a local storm on August 8, 1982 which dropped 6.5 in. of rain at Pine Grove within 12 hours. A precipitation event of this intensity and duration has a 100-year recurrence interval. February, April, May and June 1982 were wetter than normal with June being 121 percent above normal (8.70 in. of precipitation measured at Lebanon).

Total precipitation for the three storms during which water-quality samples were collected and the antecedent soil conditions for each storm are listed in table 2. Although each storm had nearly the same amount of total precipitation, the streamflow hydrographs in figure 3 indicate gage heights and, therefore, corresponding runoff for each storm varied according to rainfall intensities, durations, and antecedent soil conditions. The sharp rise in gage height at Lower Little Swatara Creek (station 01572000) on February 2, 1982 was due to ice conditions that were present prior to the storm which began on February 3. As a result of the ice conditions, the gage height indicated flow greater than the actual discharge; Swatara Creek above Highway 895 (station 01571900) had no ice during this particular event.

Table 1.--Precipitation data for Swatara Creek study area
[National Oceanic and Atmospheric Administration, 1981-82]

	Pine Grove (inches)	Lebanon (inches)	Lebanon, normal-1931-60 (inches)	Lebanon, variation from normal (inches)	Lebanon, percent variation from normal
October 1981	4.09	2.61	3.55	-0.94	-26
November	1.34	1.17	3.36	-2.19	-65
December	2.75	2.10	3.28	-1.18	-36
January 1982	3.37	2.48	3.10	- .62	-20
February	3.02	3.12	2.59	.53	20
March	2.59	2.94	3.75	- .81	-22
April	5.43	4.51	3.65	.86	24
May	5.29	4.78	4.23	.55	13
June	8.28	8.70	3.93	4.77	121
July	3.05	2.80	4.39	-1.59	-36
August	9.66	1.30	4.27	-2.97	-70
September	3.29	3.75	3.89	- .14	- 4
Total	52.16	40.26	43.99	-3.73	- 8

Table 2.--Summary of storm precipitation tabulated from data collected in Pine Grove by the National Oceanic and Atmospheric Administration

Storm	Date	Total precipitation (inches)	Antecedent soil conditions
1	February 2-5, 1982	1.39	frozen ground
2	April 26-27, 1982	1.75	preplanting (dry-unplowed)
3	August 24-26, 1982	1.45	midsummer (dry, vegetative cover)

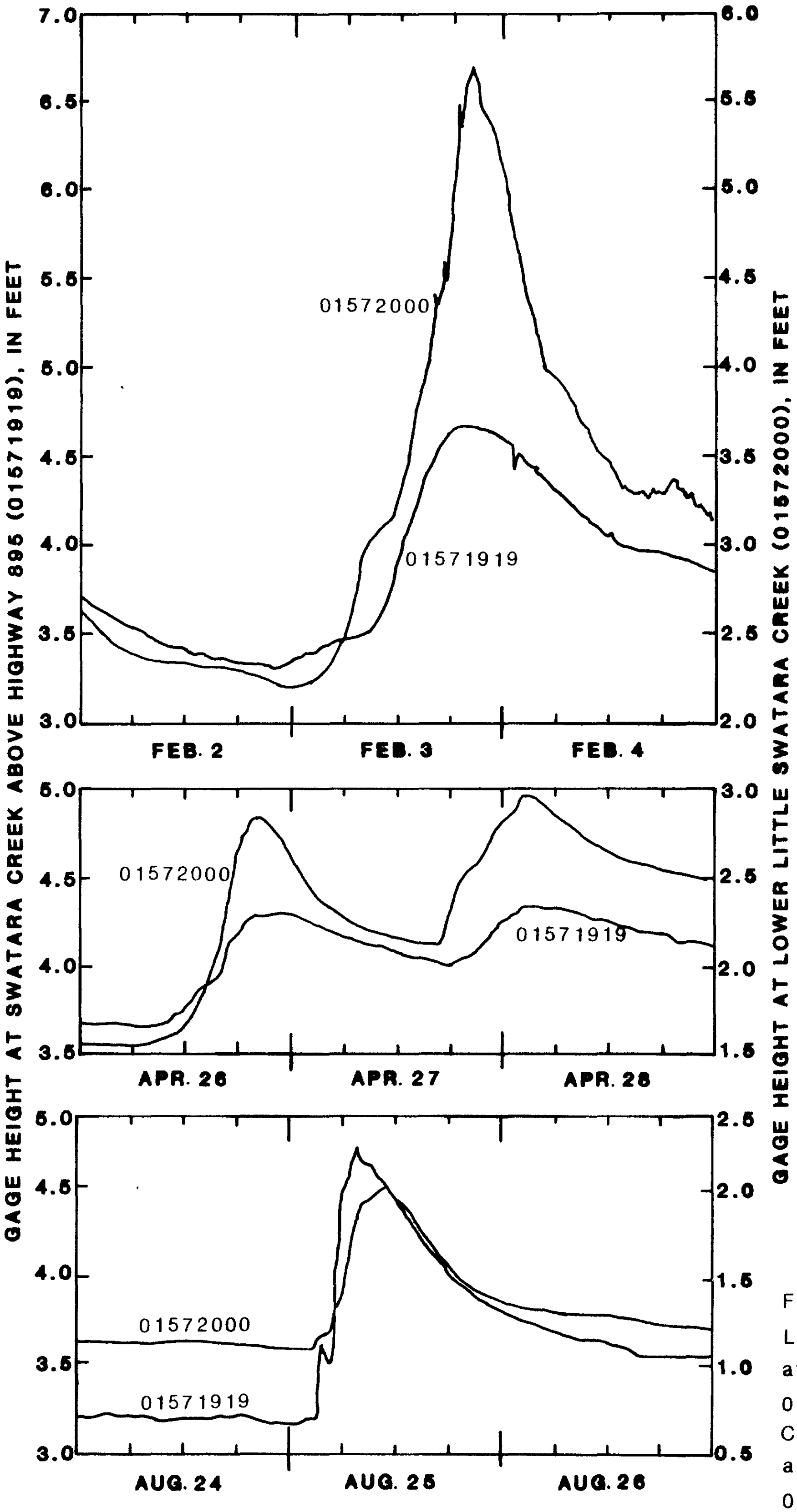


Figure 3.--Streamflow for Lower Little Swatara Creek at Pine Grove (station 01572000) and Swatara Creek above Highway 895 at Pine Grove (station 01571919) during storms.

Topography, Geology, and Soils

The entire study area lies in the Valley and Ridge physiographic province, which is characterized by steep rugged ridges and valley terrain that trends to the northeast above Inwood. Elevations in the area range from 450 ft above sea level near Inwood to about 1,700 ft above sea level near Tremont. The Swatara Creek descends rapidly at a gradient of 78 ft/mi between the headwaters and Pine Grove. The gradient flattens to about 6 ft/mi from Pine Grove to Inwood. Deposition of suspended material occurs in this flat reach. The process of deposition is particularly visible during low-flow conditions in the late summer and early fall.

The geology and soils in the headwaters differ from those downstream and largely influence the water quality of Swatara Creek. In the headwaters, Swatara Creek flows primarily over Paleozoic sedimentary rocks of Pennsylvanian age. The rock layers consist of shale, sandstone, conglomerate, and anthracite. As the rocks weather, the residual and colluvial materials form soils that are then washed into the stream during storms. Soluble materials within the sedimentary rocks and soils include calcium, magnesium, carbonate, sulfate, aluminum, iron, manganese, copper, and phosphate. Their presence in Swatara Creek are reflected by the high dissolved solid concentrations, whereas low pH values, measured upstream of Tremont, indicate the presence of acidic discharges from the anthracite. Between Tremont and Inwood, alternating layers of sandstone, shale, and conglomerate form steep ridges and narrow valleys. Soils here are composed of residue from sandstone and siltstone. Tributaries in this area that contain low concentrations of dissolved solids enter Swatara Creek and begin to dilute and neutralize the acid mine drainage.

Land Use and Population

Changes in land use and population may increase sedimentation and, therefore, degrade water quality. As the study area becomes highly urbanized, the demand for potable water will increase. Previous investigations have predicted urbanization and water use to greatly increase east of Harrisburg and near Lebanon from 1960 to 2000. Population densities were expected to reach 500 people per square mile and water use to rise to 2.0 (Mgal/d)mi^2 (Stuart and others, 1967). Population in the Swatara Creek basin was expected to increase 60 percent, thus increasing demands for water from Swatara Creek. However, population densities have not reached predicted levels.

Table 3 lists total population and land use for the Swatara Creek basin from 1960 through 1980. The table shows a small shift in land use from agricultural, forested, and public uses to urban and mining uses as population increased 6 percent from 1960 through 1980. Note also that population increased by 59 percent for a density of about 349 people per square mile.

Table 3.--Population and land use changes in Swatara Creek basin, 1960-80

Year	Population	Land use, as percent of basin		
		Agricultural forested, and public	Urban (residential, commercial, and industrial)	Mining (strip and quarries)
1960 1/	126,200	95.3	3.3	1.4
1970 2/	156,000	----	---	---
1980 3/	201,100	91.2	6.4	2.4

1/ Stuart, W. T., Schneider, W. V., and Crooks, J. W., (1967, p. 18-21).
2/ Wright, S. K., (1976, p. 58).
3/ Commonwealth of Pennsylvania (1982, p. V-25).

Streamflow

The effects of streamflow on the water quality of the Swatara Creek Reservoir study area is especially important during periods of high and low flows. The Swatara Creek has a long history of repeated flooding. Streamflow records from 1919-81 indicate that overbank flooding, beginning at a discharge of 5,000 ft^3/s, has occurred 187 times in Swatara Creek at Harper Tavern, 16 mi. downstream of the study area. Floods at Harper Tavern often occur in March, April, and May and are associated with basin-wide frontal storms. Local flooding occurs in the summer and is due to heavy precipitation accompanying local thunderstorms. This was the case during the study on August 8, 1982 when 6.5 in. of rain fell within 12 hours causing extensive flooding of homes and businesses in Pine Grove. Most of the suspended metals and nutrients are transported from the study area during high flows.

Low flows in the study area often occur from August through November. Inflow to the planned impoundment during this period may not be capable of completely exchanging the water in the planned reservoir, and thermal and chemical stratification may intensify. For example, at a typical flow of 40 ft^3/s, as recorded during October and November 1981 and September 1982, the planned reservoir would require 204 days for a complete exchange of water.

DATA COLLECTION AND METHODOLOGY

Streamflow Data

Streamflow data were collected at the three stations shown in figure 2, and are published in the Survey's "Water Resources Data for Pennsylvania, Volume 2, Water Year 1982." Continuous streamflow data were collected beginning July 1981 for Lower Little Swatara Creek at Pine Grove and October 1981 for Swatara Creek above highway 895 at Pine Grove. These gaging stations are equipped with analog to digital-stage recorders and continuous strip-chart stage recorders. A partial-record station was established at Swatara Creek at Inwood in November of 1981.

Stage-discharge relationships were defined at each station by measuring streamflow over a wide range of stream stages including base flow and storm conditions using a Price current meter. Stage-discharge relations were used to determine instantaneous streamflows when water-quality samples were collected. These streamflows were then used to compute chemical constituent discharges.

Streamflow data for Lower Little Swatara Creek and Swatara Creek at Harper Tavern have been collected for 13 and 63 years, respectively. Streamflow records from these stations were used to characterize the flow conditions during the study period.

Water-quality Data

Suspended-sediment data collection began in July 1981 at Lower Little Swatara Creek at Pine Grove and in October 1981 at Swatara Creek above Highway 895 at Pine Grove. Daily suspended-sediment samples were collected manually at these stations during baseflow conditions. During storms, samples were collected more frequently with a U.S. Geological Survey PS-69 automatic pumping sampler. Suspended-sediment samples were collected manually each month and during storms at Swatara Creek at Inwood. During storms at each station, additional samples were collected manually for analysis of percentages of sand and fine particles or for a complete particle-size analysis.

Analyses for suspended sediment were done in the Survey's sediment laboratory in Harrisburg, PA., by methods described by Guy (1969). Daily values for suspended-sediment concentration and discharge were computed using the techniques of Porterfield (1972).

Chemical-quality data collection began in December 1981 at each of the three stations. Samples were collected monthly during base-flow conditions and at selected stages during storms to develop transport curves for chemical constituents. Storms were selected so that the water quality at each station could be related to different phases of the growing season. Chemical-quality samples were collected using depth-integrating samplers and the equal-width increment procedure (Guy and Norman, 1970). Bacteriological and dissolved oxygen samples, and water temperature measurements were taken at the centroid of flow at each station.

Chemical-quality samples were analyzed or preserved for analysis immediately after collection at the sampling location. Field analyses included measurements of water temperature, pH, alkalinity, acidity, specific conductance, dissolved oxygen, fecal coliform, and fecal streptococcal bacteria. Samples analyzed for dissolved constituents were filtered in the field using a 0.45 micron membrane filter mounted in a peristaltic filter assembly. Samples for dissolved organic carbon were filtered through a 0.45 micron silver filter in a stainless steel pressure filtration unit. Bacteriological analyses were done during base flow in the field by techniques described by Greeson and others (1977). Bacteriological samples collected during base flow and storms also were packed on ice and delivered to the PaDER, Bureau of Laboratories in Harrisburg, PA for analysis within 24 hours of sample collection. Table 4 lists the physical, chemical, and bacteriological analyses performed on water-quality samples.

Statistical analysis of water-quality data was performed using the computer package "Statistical Analysis System" (Helwig, 1978). Basic univariate statistics for water-quality characteristics were calculated, including maximum, minimum, and median concentrations, and maximum and minimum instantaneous discharges. Preliminary regression statistics using the least-squares method were computed for constituents determined to be normally distributed and whose means and variances were not directly related. Logarithmic transformations using log (X) or log (X+1) were used when needed to meet the assumption of normal distributions. Chemical constituent hydrographs were plotted to determine trends during the study period. Storm hydrographs were used to show relationships between chemical concentrations and streamflow.

HYDROLOGY OF SWATARA CREEK

Water quality is highly variable and either beneficial or detrimental depending on the designated use of the water. Because the water in the proposed Swatara Creek Reservoir is designated for water supply, fishing, swimming, and boating, the impoundment's influence on the physical, sediment, chemical, and bacteriological characteristics of the water will be important. Although no additional water is designated for possible hydro-power generation, current plans call for an intake which will draw water from the bottom of the reservoir for this function; therefore, the impact of this operation on the water-quality charcteristics also may be important. The results presented in this report are those observed prior to impoundment construction. The data are listed in the back of the report in table 9.

Streamflow

Streamflow records at Harper Tavern were examined to determine flow conditions during the study since the stations in the study area did not have long records. Annual flow for 1982 at Swatara Creek at Harper Tavern was 15 percent below the average annual flow computed for the previous 63 years. Based on this analysis, it is assumed that the annual flows measured in the study area during the 1982 water year are about 15 percent less than that expected over a long period.

Table 4.-- Physical, chemical, and bacteriological analyses performed on water-quality samples

Physical and other related analyses

acidity (mg/L as $CaCO_3$)
alkalinity (mg/L as $CaCO_3$)
oxygen, dissolved (mg/L)
pH (units)
specific conductance (µS/cm at 25°C)
water temperature (°C)
chemical oxygen demand (mg/L)
turbidity (FTU)

Chemical Analyses

Nutrients (mg/L)

nitrogen, nitrite dissolved
nitrogen, nitrite total
nitrogen, nitrate dissolved
nitrogen, nitrate total
nitrogen, ammonia dissolved
nitrogen, ammonia total
nitrogen, Kjeldahl dissolved
nitrogen, Kjeldahl total
phosphorus, orthophosphate dissolved
phosphorus, orthophosphate total
phosphorus, dissolved
phosphorus, total
carbon, organic

Dissolved ions (mg/L)

calcium
chloride
magnesium
silica
sodium
sulfate
potassium

Metals (µg/L)

aluminum, dissolved
aluminum, total-recoverable
chromium, total-recoverable
copper, total-recoverable
iron, dissolved
iron, total-recoverable
lead, total-recoverable
manganese, dissolved
manganese, total-recoverable
mercury, total-recoverable
zinc, total-recoverable

Bacteriological Analyses

fecal coliform (colonies/100 mL)
fecal streptococci (colonies/100 mL)

Daily mean streamflow hydrographs and monthly streamflow bar charts for Lower Little Swatara Creek and Swatara Creek above Highway 895, shown in figures 4 and 5, reflect the similarity in streamflow characteristics of these two stations. Annual discharge from Swatara Creek above Highway 895 was 2.1 times greater than that from Lower Little Swatara Creek during the 1982 water year. This ratio is nearly equal to the 2.12 ratio for the drainage areas of the two basins, so the discharge per square mile from each stream is about equal. About 47 percent of the annual flows for both stations occurred during April, May, and June. Maximum and minimum monthly flows occured during June and October, respectively, for both stations. Maximum daily flows during the study for both stations occured on June 6; streamflow was 526 ft^3/s at Lower Little Swatara Creek and 884 ft^3/s at Swatara Creek above Highway 895. Minimum daily flows for both stations occurred in October and were 3.1 ft^3/s for Lower Little Swatara Creek, and 21 ft^3/s for Swatara Creek above Highway 895.

A flow-duration curve (fig. 6) was computed for Lower Little Swatara Creek based on 14 years of records (1920-32, 1982). The 1982 flow-duration curve is similar to the 1920-32 curve. The maximum daily flow of 526 ft^3/s measured at Lower Little Swatara Creek on June 6 will recur less than 0.6 percent of the time based on the flow-duration curve. However, this figure could be slightly higher when a long-term record is considered since Swatara Creek at Harper Tavern annual flow for 1982 was 15 percent below the average annual flow.

Instantaneous flows at Lower Little Swatara Creek were compared for 1982 and the period of record. A maximum instantaneous flow of 1,370 ft^3/s for 1982 occurred on August 8; this flow was only 9 percent less than the maximum flow for the period of record.

Results of regression analysis using the least-squares method show a good relationship ($r^2 = 0.95$) exists between the common logarithm of the instantaneous flow measured at Swatara Creek at Inwood and the common logarithm of the flow recorded at Swatara Creek above Highway 895 at Pine Grove for a range of flows at Inwood from 53.5 ft^3/s to 1770 ft^3/s. Figure 7 shows the relation between the flows at the two stations based on 15 measurements over a range of flows. The equation for the regression line in figure 7 based on preliminary data was used to determine the daily discharges at Inwood and is as follows:

$$\text{Log } Q_I = 1.1756 (\text{Log } Q_{895}) - 0.0286 \qquad (1)$$

where Log Q_I = the logarithim of the instantaneous flow of Swatara Creek at Inwood, in ft^3/s

1.1756 = the slope of the regression line,

Log Q_{895} = the logarithim of the instantaneous flow of Swatara Creek, above Highway 895 at Pine Grove, in ft^3/s

-0.0286 = the intercept of the regression line

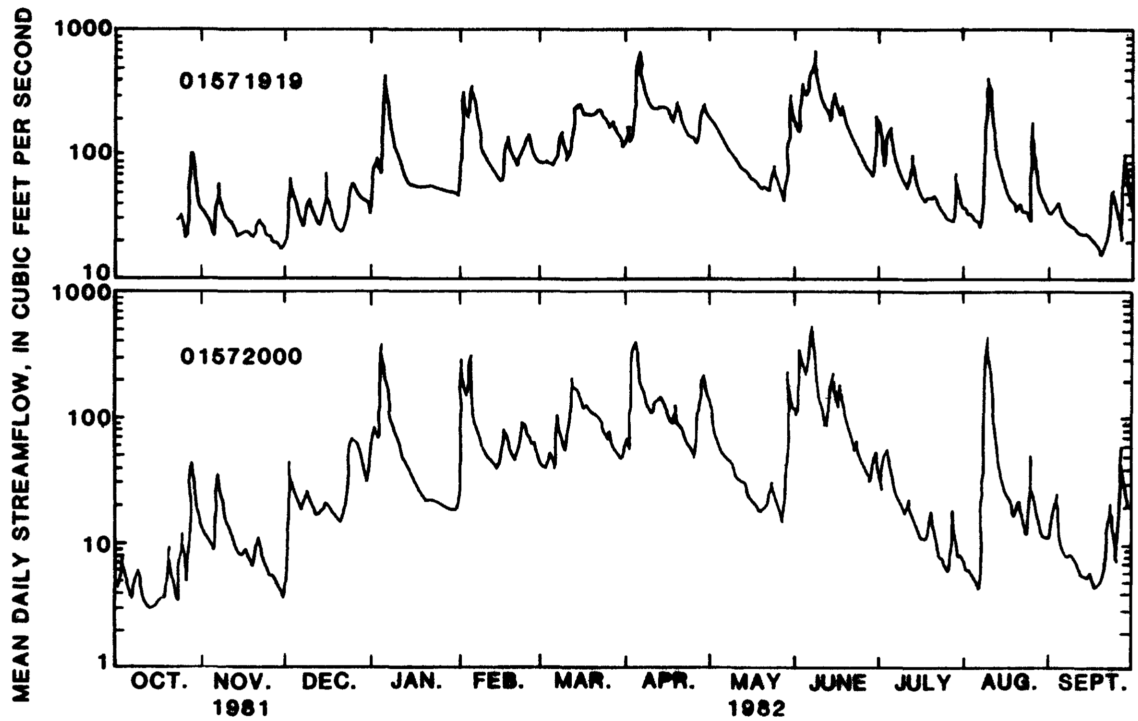


Figure 4.--Mean daily streamflow for Swatara Creek above Highway 895 (station 01571919) and Lower Little Swatara Creek at Pine Grove (station 01572000), 1982 water year.

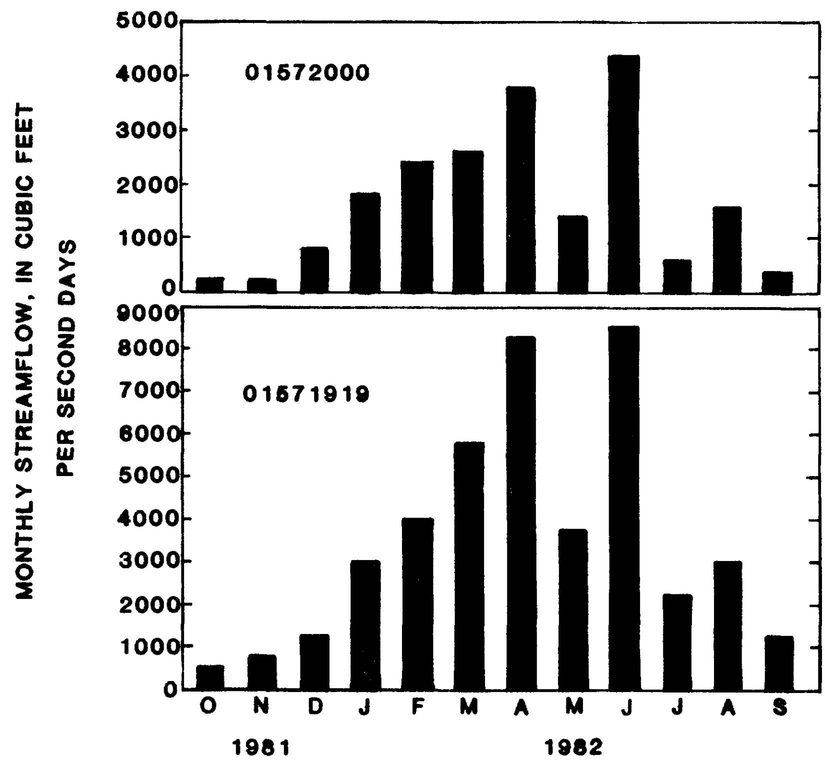


Figure 5.--Monthly streamflow for Lower Little Swatara Creek at Pine Grove (station 01572000) and Swatara Creek above Highway 895 (station 01571919), 1982 water year.

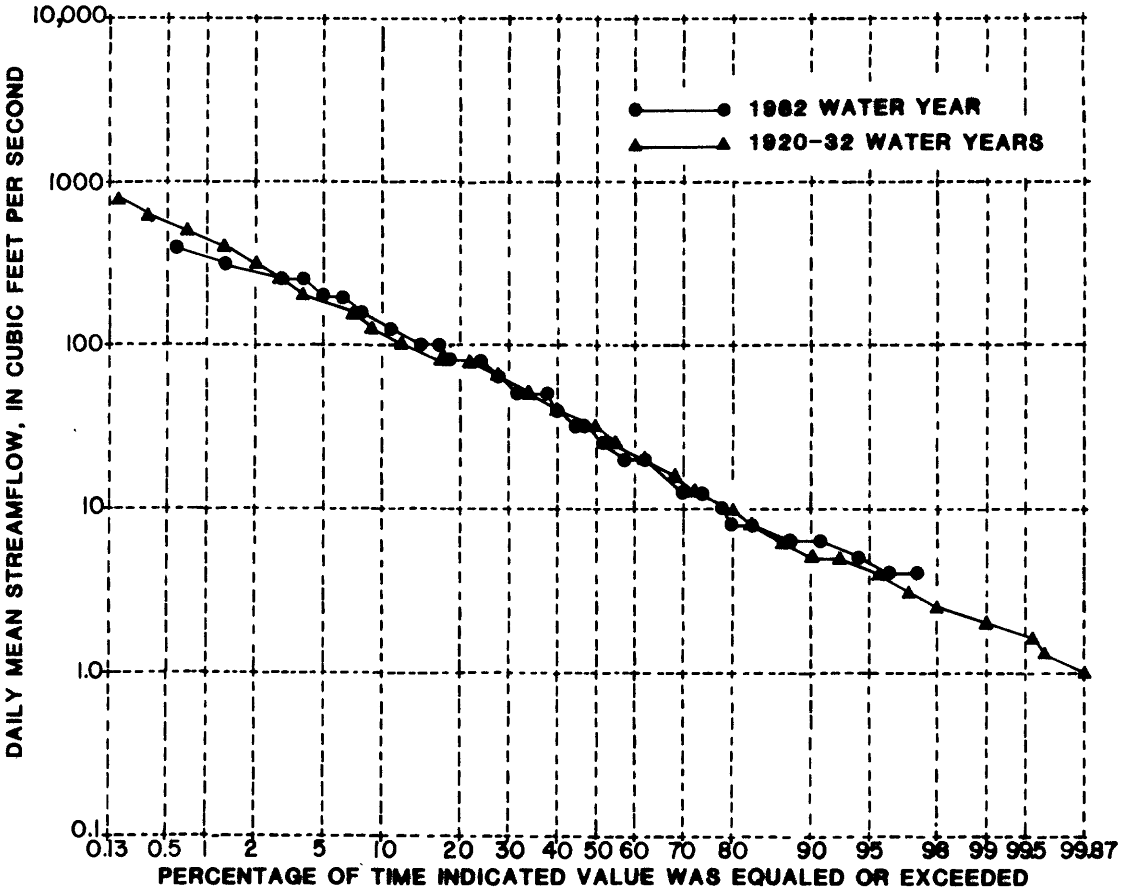


Figure 6.--Flow-duration curves for Lower Little Swatara Creek at Pine Grove.

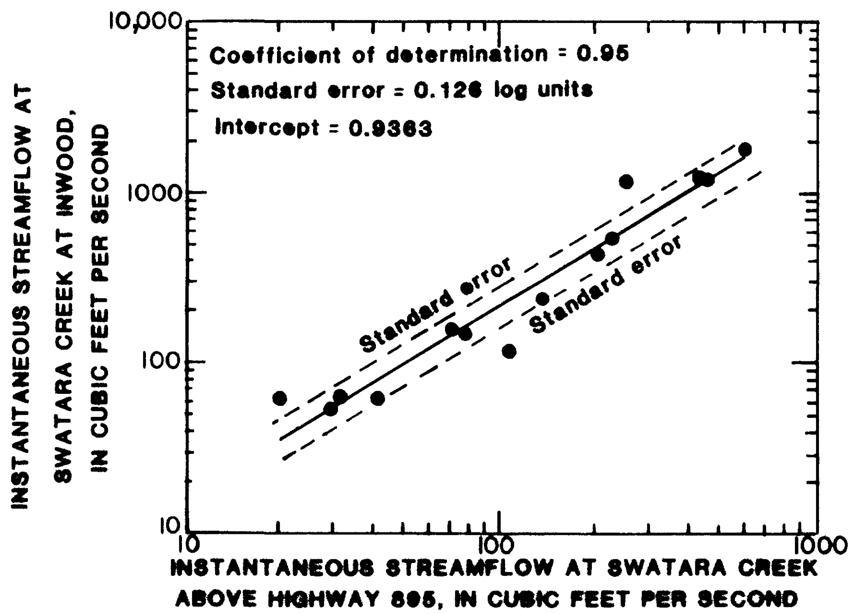


Figure 7.--Relation between instantaneous streamflow at Swatara Creek at Inwood and instantaneous streamflow at Swatara Creek above Highway 895 at Pine Grove.

Water Quality

Table 5 lists basic statistics for instantaneous water-quality concentrations and discharges measured at each station from October 1981 to September 1982. Concentrations and discharges listed in these tables are from manually collected depth-integrated composite samples and are used for discussions throughout this report. Qualitative relationships between water-quality constituents and streamflow are given, but available data are inadequate to report results quantitatively.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Swatara Creek above highway 895 at Pine Grove	Location: Lower Little Swatara Creek at Pine Grove	Location: Swatara Creek at Inwood
Acidity	Median concentration	4.0	2.0	3.0
	Number of samples	19	21	16
	Min - max concentration	.0 - 21.0	.0 - 10.0	0.0 - 12.0
	Min - max discharge	.00 - 21.09	.00 - 17.98	0.00 - 13.91
Alkalinity	Median concentration	4.0	7.0	6.0
	Number of samples	21	21	16
	Min - max concentration	.0 - 8.0	1.0 - 15	1.0 - 9.0
	Min - max discharge	0 - 6.39	.15 - 4.88	.46 - 13.82
pH	Median	6.5	7.0	6.6
	Number of samples	21	21	16
	Minimum - maximum	5.6 - 7.2	6.2 - 8.4	6.3 - 6.9
Specific conductance (μS/cm at 25°C)	Median	164	72	132
	Number of samples	21	21	16
	Minimum - maximum	123 - 348	59 - 88	93 - 205
Water temperature (°C)	Median	12.0	12.0	13.0
	Number of samples	21	21	16
	Minimum - maximum	.5 - 22.0	.5 - 23.5	.5 - 24.5
Dissolved oxygen	Median	10.4	10.2	10.3
	Number of samples	21	21	16
	Minimum - Maximum	5.6 - 13.5	7.0 - 14.0	7.2 - 13.6
Chemical oxygen demand	Median concentration	22	15	10
	Number of samples	16	15	12
	Min - max concentration	<10 - 405	<10 - 56	<10 - 556
	Min - max discharge	.73 - 407	.15 - 46.75	1.46 - 967

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Swatara Creek above highway 895 at Pine Grove	Location: Lower Little Swatara Creek at Pine Grove	Location: Swatara Creek at Inwood
	Median	16.5	13	9.0
Turbidity (FTU)	Number of samples	20	19	15
	Minimum - maximum	3.0 - 840	2.5 - 120	1.4 - 230
Sediment, suspended	2/ Median concentration	26	22	14
	Number of samples	21	21	16
	Min - max concentration	6 - 3,900	1 - 201	2 - 652
	Min - max discharge	.44 - 3,920	.06 - 361	.40 - 1,130
Streamflow (ft^3/s)	2/ Median	225	68	219
	Number of samples	21	21	16
	Minimum - maximum	27.1 - 592	5.69 - 666	54 - 1,280
Nitrate, dissolved	Median concentration	0.79	1.4	0.90
	Number of samples	21	20	16
	Min - max concentration	.31 - 1.80	.53 - 2.6	.47 - 1.70
	Min - max discharge	.03 - 2.88	.01 - 2.52	.08 - 5.53
Nitrate, total	Median concentration	.79	1.4	.90
	Number of samples	21	21	16
	Min - max concentration	.31 - 1.80	.53 - 2.6	.47 - 1.70
	Min - max discharge	.03 - 2.88	.01 - 2.52	.08 - 5.53
Nitrite, dissolved	Median concentration	.01	.01	.01
	Number of samples	21	20	16
	Min - max concentration	< .01 - .02	< .01 - .02	< .01 - .01
	Min - max discharge	< .01 - .02	< .01 - .02	< .01 - .03
Nitrite, total	Median concentration	.01	.01	.01
	Number of samples	21	21	16
	Min - max	< .01 - .02	< .01 - .02	< .01 - .02
	Min - max discharge	< .01 - .03	< .01 - .05	< .01 - .07
Ammonia, dissolved	Median concentration	.15	.03	.08
	Number of samples	21	21	16
	Min - max concentration	.07 - .82	.01 - .26	.01 - .18
	Min - max discharge	.03 - .40	< .01 - .47	< .01 - .62

2/ Values for these characteristics were determined for samples which were collected manually.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Swatara Creek above highway 895 at Pine Grove	Location: Lower Little Swatara Creek at Pine Grove	Location: Swatara Creek at Inwood
Ammonia, total	Median concentration	0.15	0.04	0.09
	Number of samples	21	21	16
	Min - max concentration	.07 - .82	.02 - .30	.01 - .20
	Min - max discharge	.03 - .04	< .01 - .54	< .01 - .69
Organic nitrogen, dissolved	Median concentration	.70	.75	.60
	Number of samples	20	21	16
	Min - max concentration	.23 - 1.20	.19 - 1.2	.01 - 1.0
	Min - max discharge	.03 - 1.24	.01 - .51	.05 - 3.18
Organic nitrogen, total	Median concentration	.78	.80	.77
	Number of samples	20	21	15
	Min - max concentration	.23 - 2.20	.29 - 1.4	.23 - 2.4
	Min - max discharge	.05 - 2.21	.01 - 1.07	.08 - 4.17
Ammonia + organic nitrogen, dissolved	Median concentration	.85	.83	.70
	Number of samples	20	21	16
	Min - max concentration	.30 - 1.60	.30 - 1.3	.30 - 1.20
	Min - max discharge	.06 - 3.80	.01 - .81	.06 - 3.80
Ammonia + organic nitrogen, total	Median concentration	.98	.83	.90
	Number of samples	20	21	15
	Min - max concentration	.30 - 2.40	.35 - 1.5	.30 - 2.60
	Min - max discharge	.08 - 4.52	.01 - 1.34	.08 - 4.52
Nitrogen, dissolved	Median	1.7	2.1	1.9
	Number of samples	19	19	7
	Min - max concentration	.45 - 2.9	.94 - 3.3	1.3 - 2.7
	Min - max discharge	.11 - 3.68	.02 - 3.42	.38 - 9.33
Nitrogen, total	Median	1.9	2.3	2.0
	Number of samples	19	20	7
	Min - max concentration	.49 - 2.9	.94 - 3.5	1.4 - 2.7
	Min - max discharge	.14 - 4.00	.02 - 3.78	.40 - 9.33
Ortho-phosphate, dissolved	Median concentration	<.01	.01	<.01
	Number of samples	20	20	16
	Min - max concentration	<.01 - .01	<.01 - .04	<.01 - .01
	Min - max discharge	<.01 - .02	<.01 - .05	<.01 - .03
Ortho-phosphate, total	Median concentration	<.01	.01	<.01
	Number of samples	20	19	15
	Min - max concentration	<.01 - .06	.01 - .05	<.01 - .03
	Min - max discharge	<.01 - .10	<.01 - .09	<.01 - .04

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations and instantaneous discharges, 1982 water year--continued

[Concentration in milligrams per liter and dischsrge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Swatara Creek above highway 895 at Pine Grove	Location: Lower Little Swatara Creek at Pine Grove	Location: Swatara Creek at Inwood
Phosphorus, dissolved	Median concentration	0.02	0.03	0.02
	Number of samples	21	21	16
	Min - max concentration	.01 - .06	<.01 - .10	.01 - .04
	Min - max discharge	<.01 - .07	<.01 - .18	<.01 - .10
Phosphorus, total	Median concentration	.05	.07	.04
	Number of samples	21	21	16
	Min - max concentration	.03 - .28	.02 - .31	.02 - .25
	Min - max discharge	<.01 - .32	<.01 - .56	<.01 - .55
Organic carbon, dissolved	Median concentration	2.3	2.0	2.0
	Number of samples	15	16	11
	Min - max concentration	<1.0 - 7.0	1.1 - 7.0	1.0 - 4.4
	Min - max discharge	.17 - 7.67	.02 - 12.6	.20 - 15.2
Organic carbon, total	Median concentration	2.2	2.1	1.3
	Number of samples	13	15	11
	min - max concentration	<1.0 - 7	<1.0 - 8.8	<1.0 - 4.9
	Min - max discharge	.10 - 8.95	.02 - 15.82	.17 - 16.93
Aluminum, * dissolved	Median concentration	100	110	100
	Number of samples	20	19	16
	Min - max concentration	30 - 500	<10 - 330	20 - 560
	Min - max dischage	< .01 - .53	< .01 - .16	.01 - .81
Aluminum, * total	Median concentration	1,100	670	450
	Number of samples	21	21	16
	Min - max concentration	300 - 66,000	70 - 3,400	90 - 13,000
	min - max discharge	.02 - 66.29	< .01 - 6.11	.03 - 22.6
Chromium, * total	Median concentration	10	10	10
	Number of samples	12	11	7
	Min - max concentration	<10 - 40	<10 - 50	<10 - 20
	Min - max discharge	< .01 - .04	< .01 - .09	< .01 - .07
Copper, * total	Median concentration	20	20	20
	Number of samples	12	12	7
	Min - max cncentration	10 - 220	10 - 30	10 - 60
	Min - max discharge	.01 - .22	< .01 - .05	.01 - .10
Iron, * dissolved	Median concentration	430	85	70
	Number of samples	21	20	16
	Min - max concentration	40 - 1,500	40 - 210	30 - 270
	Min - max discharge	.01 - 8.0	< .01 - .18	.01 - .38

* Concentrations for these constituents are in micrograms per liter.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

[Concentration in micrograms per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Swatara Creek above highway 895 at Pine Grove	Location: Lower Little Swatara Creek at Pine Grove	Location: Swatara Creek at Inwood
Iron, total	Median concentration	2,200	850	760
	Number of samples	21	21	16
	Min - max concentration	410 - 100,000	100 - 7,900	70 - 21,000
	Min - max discharge	.03 - 100	< .01 - 14.2	.01 - 36.5
Lead, total	Median concentration	19	5.8	9.3
	Number of samples	12	12	7
	Min - max concentration	4 - 172	< 5 - 40	5 - 52
	Min - max discharge	< .01 - .17	< .01 - .02	< .01 - .08
Manganese, dissolved	Median concentration	640	20	330
	Number of samples	21	20	16
	Min - max concentration	350 - 2,000	10 - 150	210 - 610
	Min - max discharge	.10 - 2.31	< .10 - .27	.05 - .73
Manganese, total	Median concentration	740	50	350
	Number of samples	21	21	16
	Min - max concentration	410 - 2,300	30 - 670	230 - 710
	Min - max discharge	1.02 - 7.53	< .01 - .56	.05 - 1.28
Mercury, total	Median concentration	< 2.0	< 2.0	< 2.0
	Number of samples	12	12	7
	Min - max concentration	< 2.0 - 2.0	< 2.0 - < 2.0	< 2.0 - < 2.0
	Min - max discharge	< .01 - < .01	< .01 - < .01	< .01 - .01
Zinc, total	Median concentration	85	20	60
	Number of samples	12	11	7
	Min - max concentration	<10 - 310	10 - 50	<10 - 120
	Min - max discharge	.01 - .31	< .01 - .07	.01 - .38
Calcium, ** dissolved	Median concentration	11	4.6	8.6
	Number of samples	21	20	16
	Min - max concentration	7.9 - 20	2.5 - 6.1	5.7 - 14
	Min - max discharge	1.46 - 12.6	.06 - 6.83	2.04 - 19.7
Chloride, ** dissolved	Median concentration	8.0	6.0	7.5
	Number of samples	21	21	16
	Min - max concentration	6.0 - 21	5.0 - 8.0	6.0 - 12
	Min - max discharge	.66 - 23.6	.09 - 12.59	1.17 - 34.6

** Concentrations for these constituents are in milligrams per liter.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Swatara Creek above highway 895 at Pine Grove			Location: Lower Little Swatara Creek at Pine Grove			Location: Swatara Creek at Inwood		
Magnesium, dissolved	Median concentration	6.8			2.2			5.0		
	Number of samples	21			20			16		
	Min - max concentration	3.9	-	18	1.6	-	5.1	2.7	-	12
	Min - max discharge	.10	-	.79	.03	-	2.88	1.22	-	9.33
Potassium, dissolved	Median concentration	1.2			1.2			1.2		
	Number of samples	21			20			16		
	Min - max concentration	.80	-	3.4	.70	-	3.8	.78	-	2.8
	Min - max discharge	.13	-	4.64	.01	-	6.83	.20	-	8.99
Silica, dissolved	Median concentration	5.9			4.5			5.5		
	Number of samples	21			20			16		
	Min - max concentration	2.9	-	7.1	.50	-	6.2	2.4	-	6.9
	Min - max discharge	.52	-	6.76	.03	-	3.78	.49	-	12.4
Sodium, dissolved	Median concentration	5.8			3.0			5.3		
	Number of samples	21			20			16		
	Min - max concentration	4.0	-	13	2.3	-	4.7	3.4	-	8.3
	Min - max discharge	.73	-	14.6	.05	-	6.83	.82	-	21.1
Sulfate, dissolved	Median	50			5			30		
	Number of samples	21			21			16		
	Min - max concentration	25	-	130	< 5	-	25	15	-	60
	Min - max discharge	6.59	-	50.2	.08	-	18.0	5.83	-	52.2
Hardness, dissolved	Median	55			21			40		
	Number of samples	21			21			16		
	Min - max concentration	36	-	140	16	-	43	25	-	71
Fecal Coliform (colonies/ 100 mL)	Median concentration	31			140			25		
	Number of samples	10			10			9		
	Min - max concentration	K3	-	570	16	-	800	< 2	-	180
Fecal Streptococci (colonies/ 100 mL)	Median concentration	105			185			78		
	Number of samples	10			10			10		
	Min - max concentration	K21	-	3,500	K61	-	2,000	K4	-	240

K = Value based on non-ideal colony count

Physical and Other Related Characteristics

Physical and other related characteristics measured include water temperature, dissolved oxygen, pH, alkalinity, acidity, specific conductance, chemical oxygen demand and turbidity. Figures 8 to 15 show monthly variations of the physical characteristics measured during base flow.

Water temperatures for all three sites (fig. 8) were very similar ranging from 0°C at Lower Little Swatara Creek to 24.5°C at Swatara Creek at Inwood. Maximums occurred in July and minimums in December and January.

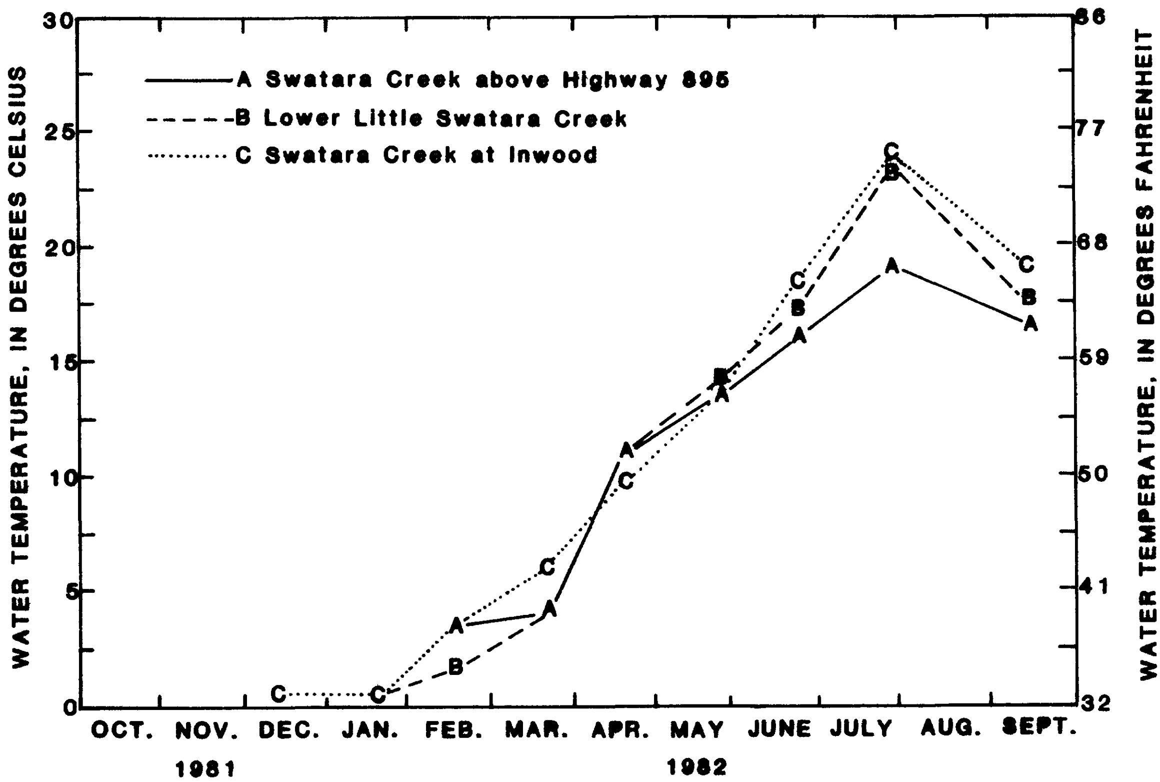


Figure 8.--Monthly variation of water temperature during baseflow.

Base flow dissolved oxygen values ranged from 8.0 to 14.0 mg/L, and showed the expected inverse relationship with water temperature as maximums occurred in December and minimums in July (fig. 9). Dissolved oxygen concentations were generally higher at Lower Little Swatara Creek because depths were shallower allowing greater reaeration and photosynthetic activity. The percent saturation of oxygen was greater than 84 percent at each station at every measurement during base flow. However, during high flow on August 25, the percent saturation dropped as low as 64 percent at Swatara Creek above Highway 895, 76 percent at Lower Little Swatara Creek, and 78 percent at Swatara Creek at Inwood due to high concentrations of chemical oxygen demand. Detecting these sudden decreases in oxygen will be important to the successful management of the aquatic biota in the study area. Continuous monitoring for dissolved oxygen upstream from and within the impoundment area would be helpful in detecting these sudden changes.

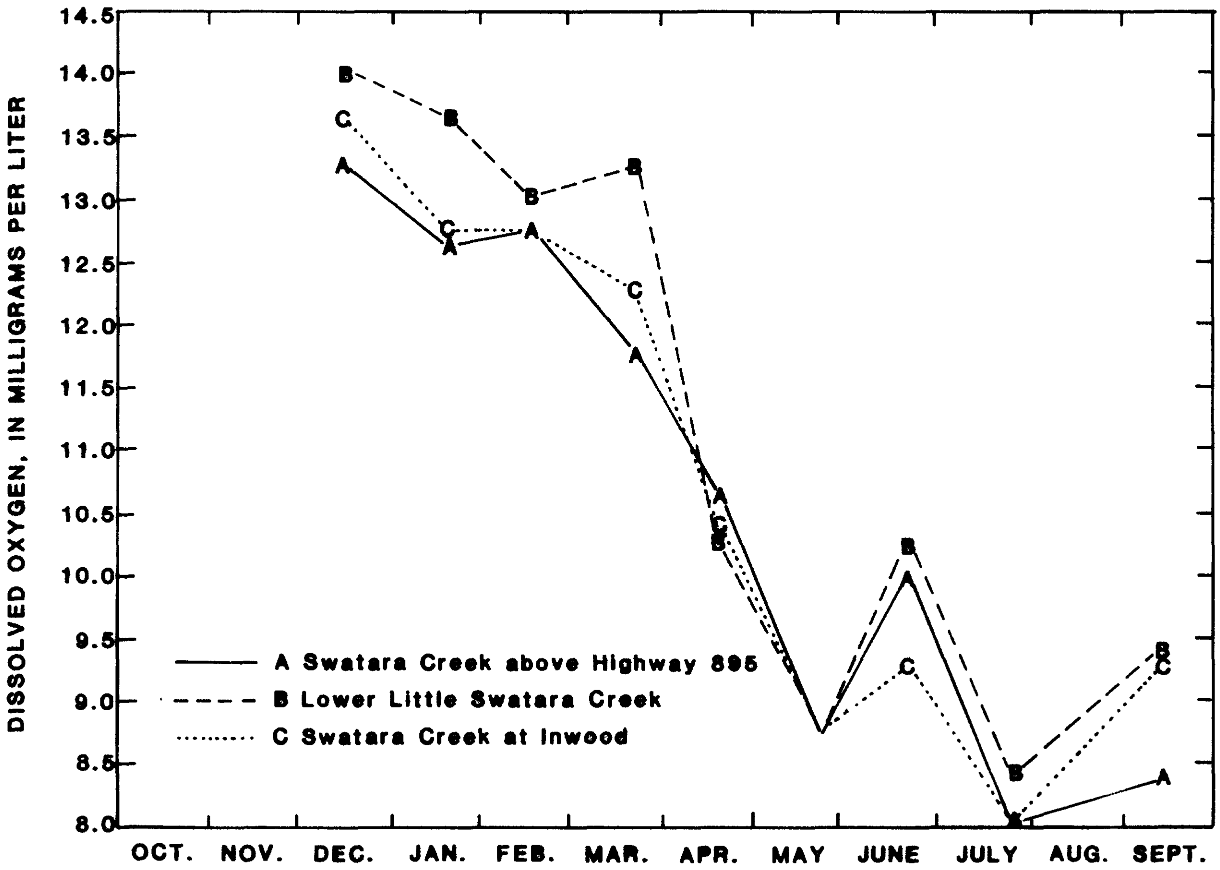


Figure 9.--Monthly variation of dissolved oxygen during baseflow.

Alkalinity, acidity, and pH are important in determining buffer capacity or the ability to neutralize an acid or base discharged into a given body of water (figs. 10-12). Water with a pH between 4.5 and 8.3 has both alkalinity and acidity, and therefore, can neutralize both acids and bases. Because the Swatara Creek headwaters originate in an area heavily mined for anthracite, the ability of the water to neutralize the acidic mine drainage is important. The buffering capacity of Swatara Creek and Lower Little Swatara Creek is low; alkalinity was usually less than 10 mg/L as $CaCO_3$, and acidity was less than 5.0 mg/L as $CaCO_3$. The addition of any acid or base into the Swatara Creek may rapidly alter the pH and, therefore, be detrimental to the aquatic biota. Preliminary data indicate that a pH of 6.0, necessary to support a warm-water fishery (Moran and Wentz, 1974), is narrowly met at all three stations during base-flow conditions. At Lower Little Swatara Creek the pH steadily increased during the warmer months when photosynthetic activity increased and dissolved carbon dioxide was taken up by aquatic organisms. During periods of high flow, pH dropped to 5.6, at Swatara Creek above Highway 895, whereas corresponding alkalinity and acidity were 4.0 mg/L and 21.0 mg/L as $CaCO_3$, respectively. The simultaneous decrease in pH and increase in acidity, sulfate, iron, aluminum, and manganese concentrations above Highway 895 are indicative of the acidic discharges from the mining areas entering Swatara Creek during storms.

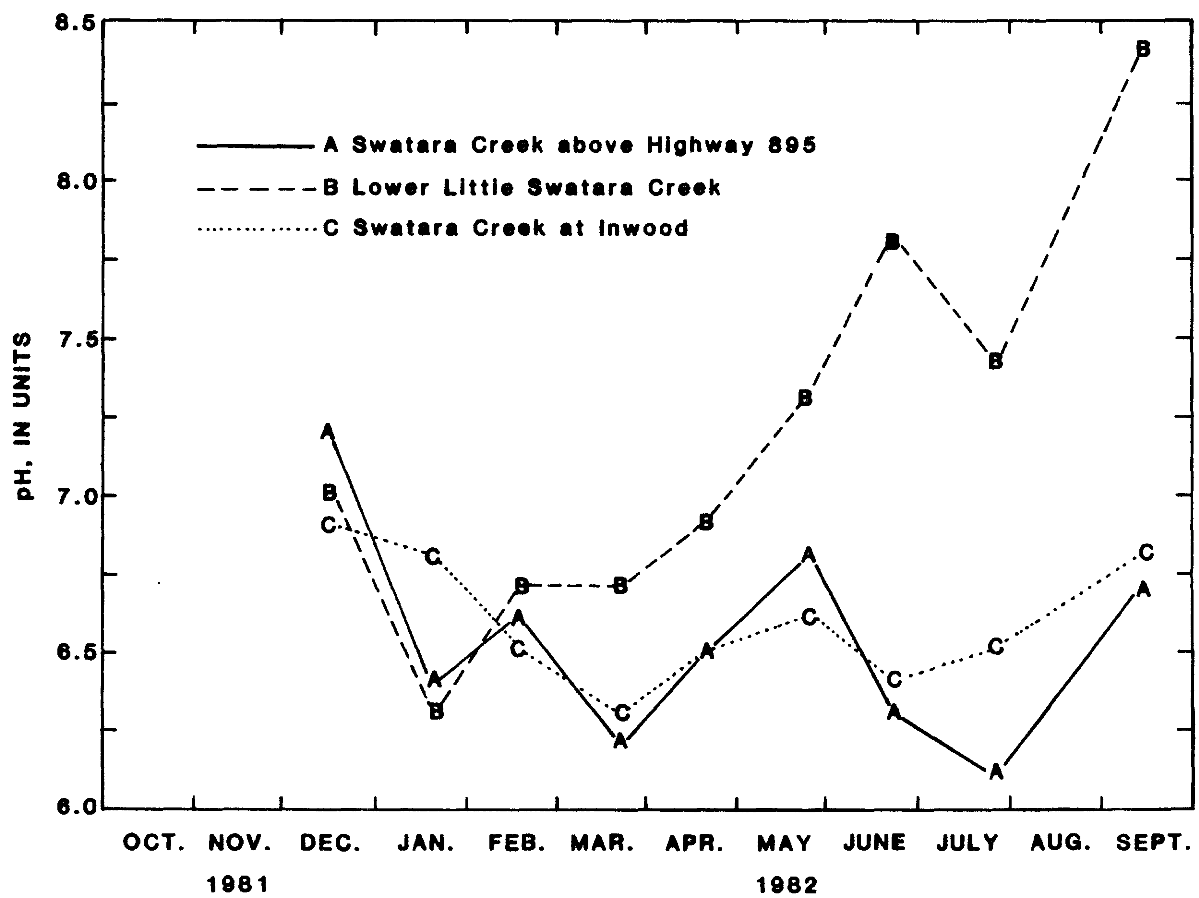


Figure 10.--Monthly variation of pH during baseflow.

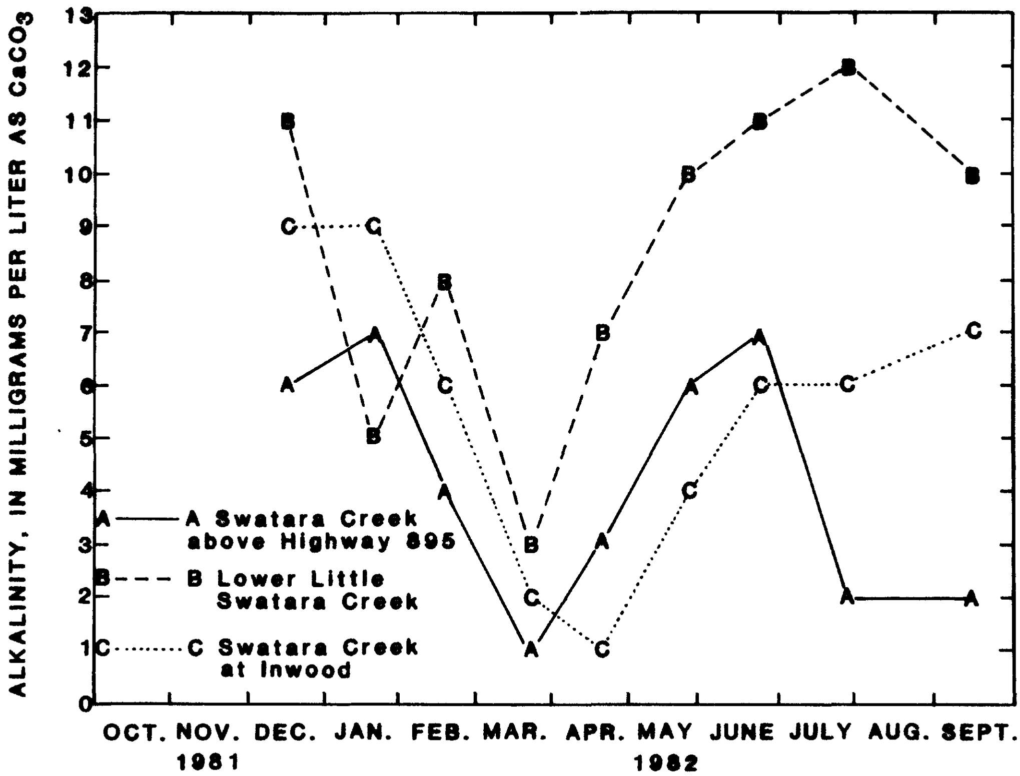


Figure 11.--Monthly variation of alkalinity during baseflow.

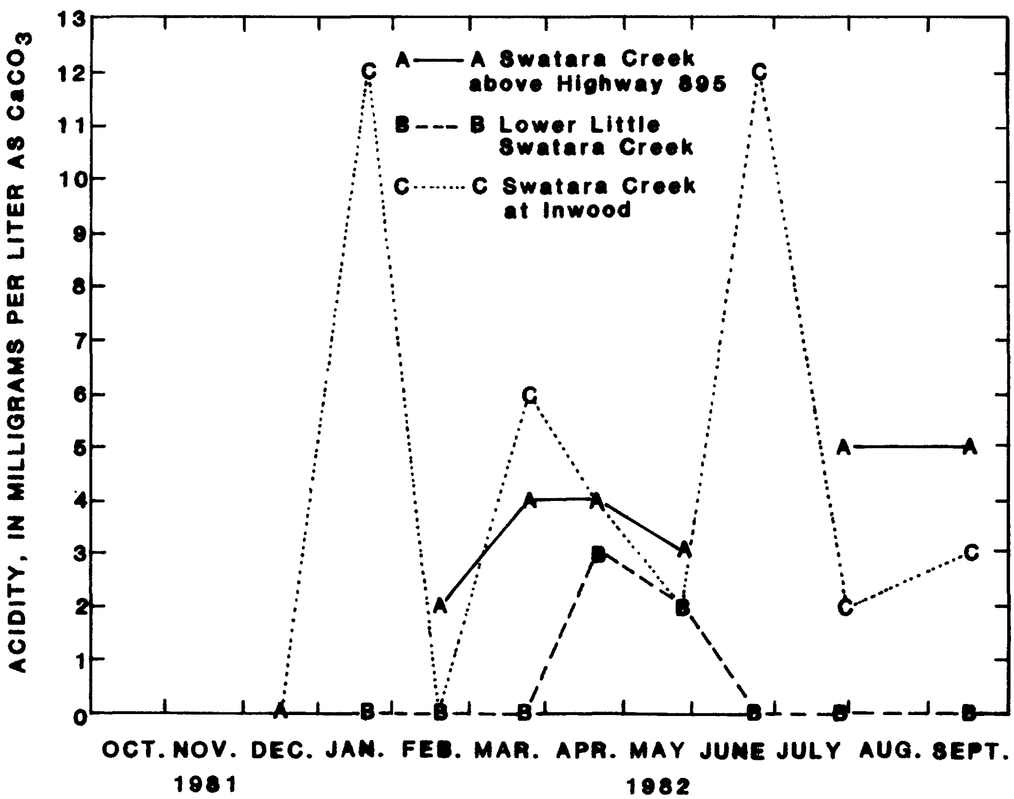


Figure 12.--Monthly variation of acidity during baseflow.

Specific conductance--the ability of a substance to conduct an electrical current--is an indication of the presence of ions such as calcium, magnesium, sodium, potassium, chloride, sulfate, and metallic ions in solution. Specific conductance for Swatara Creek above Highway 895 (fig. 13) was about three times greater than Lower Little Swatara Creek during base flow due to the discharges from the mining areas. The median value for Swatara Creek above Highway 895 was 164 μS/cm compared to 72 μS/cm at Lower Little Swatara Creek. Dilution by Lower Little Swatara Creek and other tributaries resulted in a median value of 132 μS/cm downstream at Swatara Creek at Inwood.

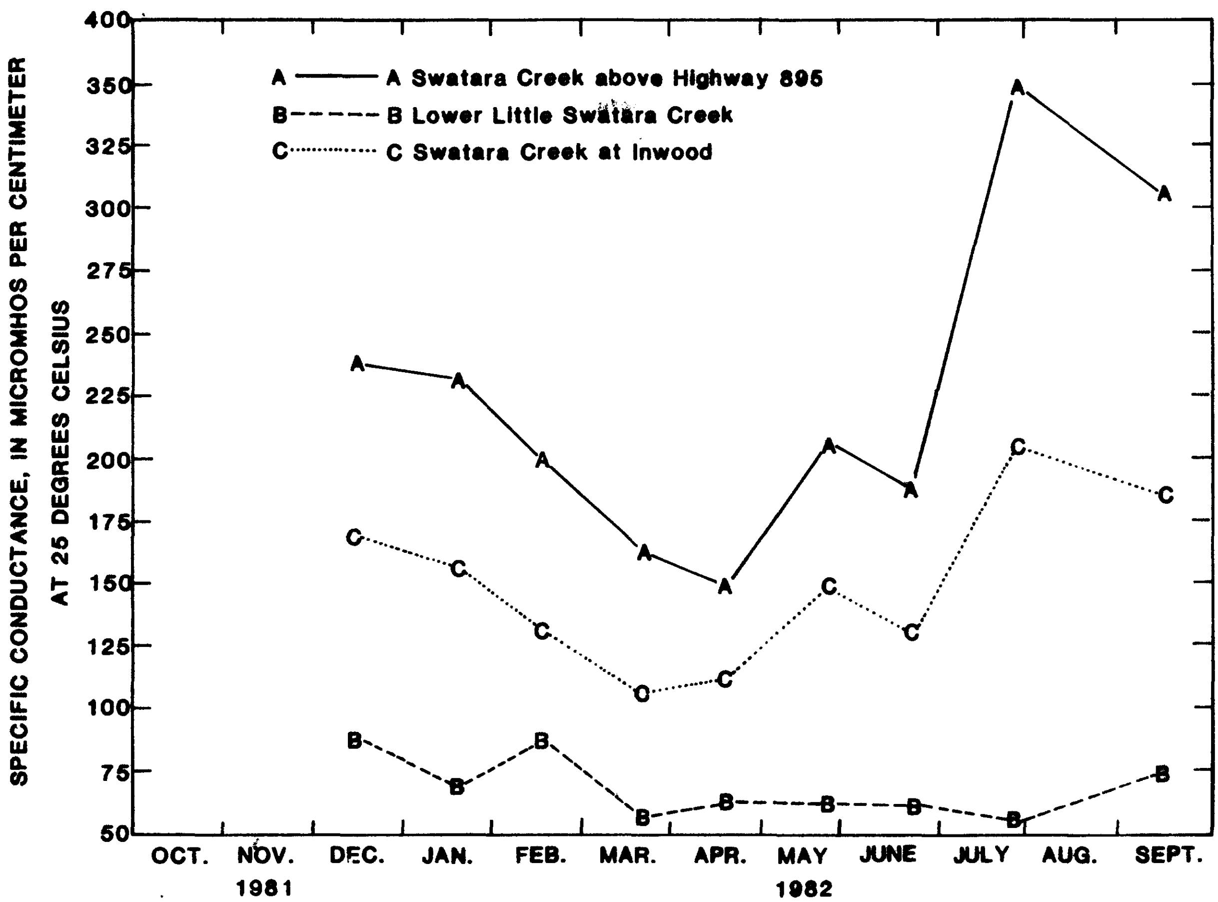


Figure 13.--Monthly variation of specific conductance during baseflow.

Chemical oxygen demand is a measure of the materials that can be oxidized in the waters, and is a helpful tool in determining the amount of organic and reducing material present. The high chemical oxygen demand concentrations at all three sites on June 22 (fig. 14), were measured during a high base flow when large amounts of organic material, sewage, were observed floating in the streams. Preliminary data also indicate substantial organic material is discharged into the Swatara Creek above Highway 895 during high flows. On August 25, a maximum chemical oxygen demand of 405 mg/L was measured at Swatara Creek above Highway 895 and 556 mg/L at Swatara Creek at Inwood. These values were 40 to 50 times greater than the 10 mg/L commonly measured during base flow.

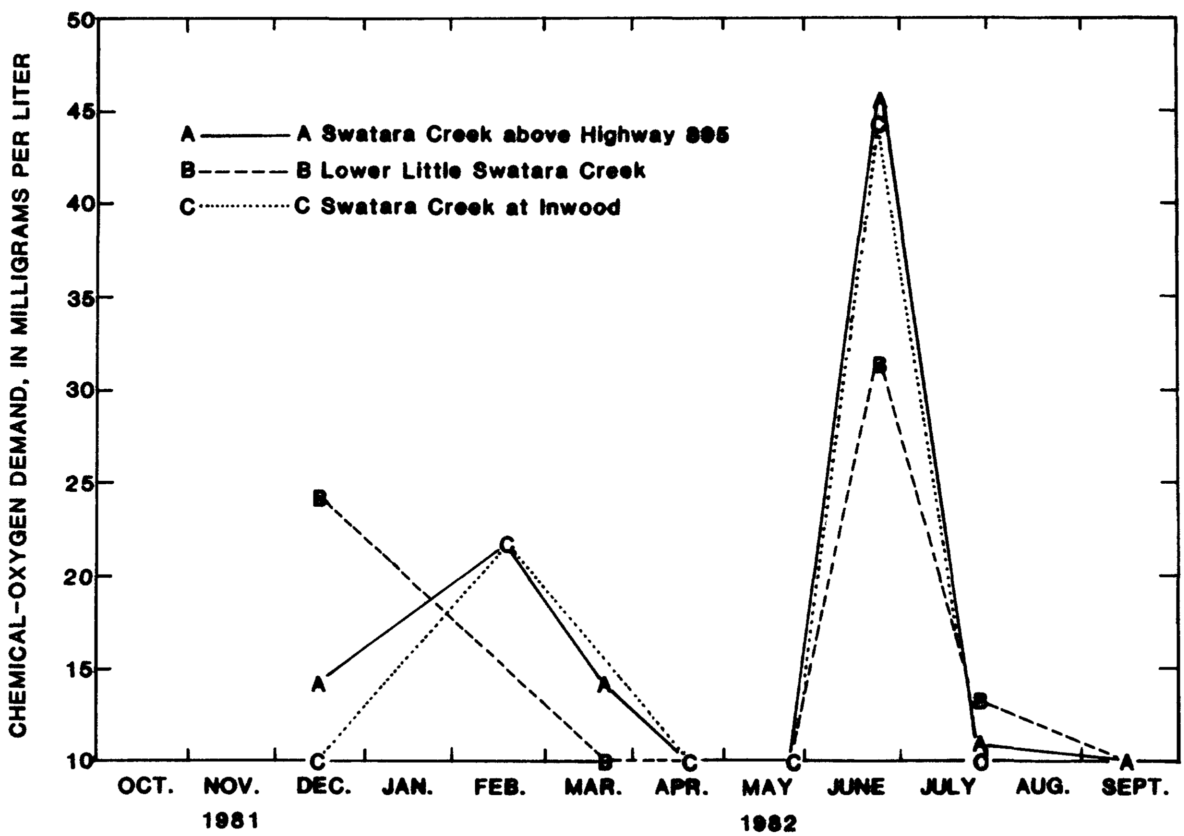


Figure 14.--Monthly variation of chemical oxygen demand during baseflow.

Turbidity is a measure of the ability of the suspended or colloidal material in a solution to reduce light penetration. Excessive turbidity degrades the aesthetic value of recreational water, is a safety hazard in swimming, diving, and boating, and interferes with light penetration required for photosynthesis and plant growth. Turbidity of the Swatara Creek and Lower Little Swatara Creek during base flow (fig. 15) was usually below 15 NTU (Nephelometric turbidity units). Turbidity increased to a maximum of 840 NTU during high flow on August 25, 1982 at Swatara Creek at Inwood.

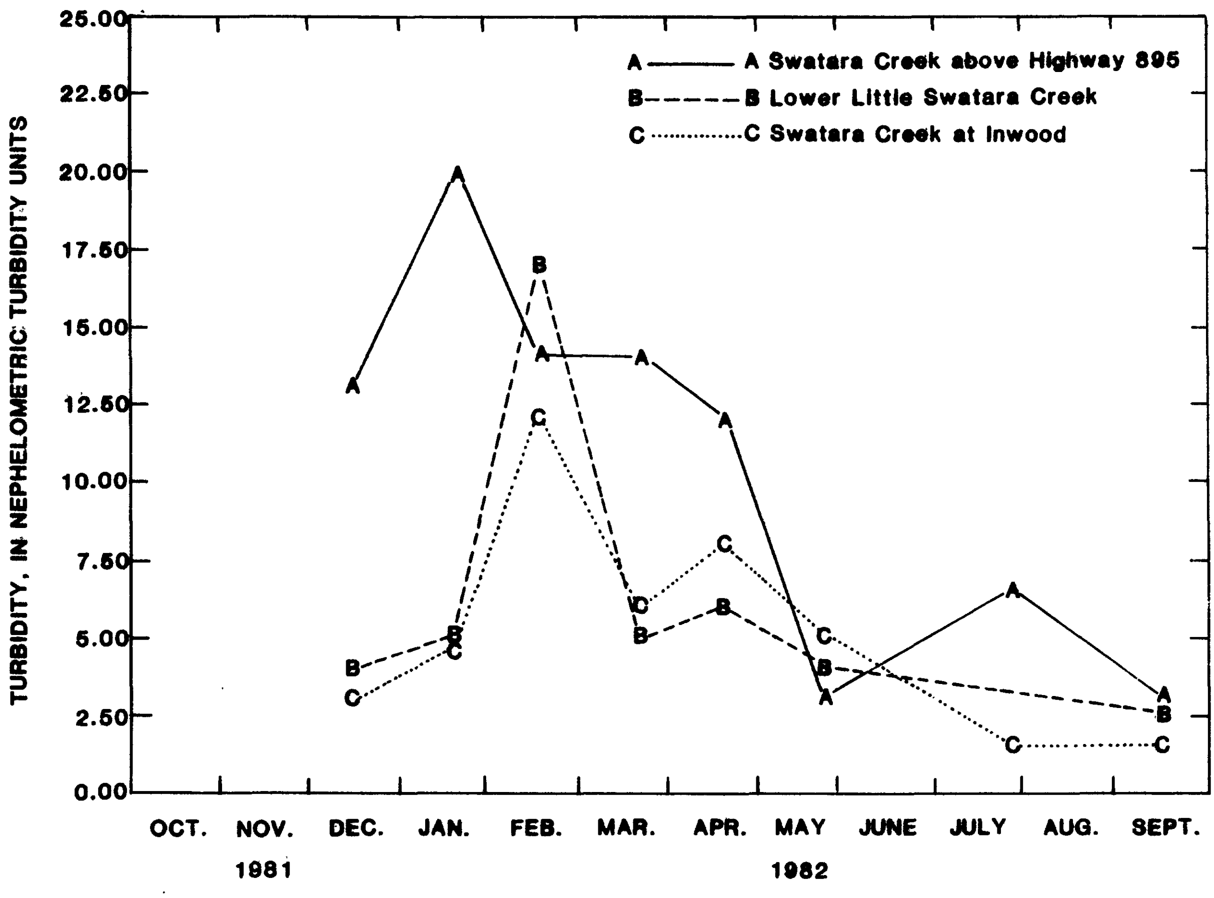


Figure 15.--Monthly variation of turbidity during baseflow.

Sediment

Most fluvial sediment studies report the concentrations and discharges of suspended sediment transported in a given time period. However, the amount of bedload transported by a stream is also important in reservoir studies. A significant amount of the total sediment load transported to the Swatara Creek impoundment may be the result of bedload transport, because much of the sediment is coal and its low specific gravity (1.65) permits it to be transported readily.

Recently, O'Leary and Beschta (1981) measured the bedload of a small forested watershed, and made several observations that apply to the Swatara Creek study area. They stated, "....large fluctuations in bedload transport rates over time intervals during which streamflow did not appreciably change seems an important characteristic of bedload transport in a mountain stream. Our data further indicate that these temporal fluctuations occur rapidly - within minutes." Their study found that stream characteristics that influence bedload fluctuations include nonuniform channel geometry, nonuniform particle size, and nonuniform streamflows. Each of these characteristics are evident in Swatara Creek and greatly affect the sediment available for bedload transport. Pool and riffle channel configurations result in sudden changes in stream velocities and cause some deep stream reaches with slow velocities to fill with organic debris and culm while other reaches are shallow, have faster velocities, and have only bedrock present. Bed material ranges from sand to coarse gravel and cobbles. The size of particles transported and streamflows sharply rise and fall within several hours in response to precipitation. Thus, the amount of bedload measured and used to develop a bedload transport curve for one storm will not necessarily estimate the bedload accurately for another storm even at similar flow conditions.

As no actual measurements of bedload transport during the preliminary study have been made for Swatara Creek or Lower Little Swatara Creek, a bedload transport rating curve has not been made for Swatara Creek. Bedload transport in Swatara Creek probably occurs only during large storms of short duration.

Suspended-Sediment Concentrations and Loads

Daily mean suspended-sediment concentrations from October 1981 through September 1982 (table 5) ranged from 1 to 947 mg/L at Swatara Creek above Highway 895 and from 1 to 614 mg/L at Lower Little Swatara Creek. Suspended-sediment discharges for the same period ranged from 0.14 to 2,620 ton/d at Swatara Creek above Highway 895 and 0.02 to 1,260 ton/d at Lower Little Swatara Creek. During this 1-year period the combined suspended-sediment load from the study area above the planned reservoir was about 16,000 tons.

The streamflow relation developed earlier between the continuous recording station at Swatara Creek above Highway 895 and the partial record station at Inwood, was used to estimate daily flows for Inwood. These daily streamflows, along with the preliminary equation (2) developed by regressing instantaneous sediment discharge versus streamflow at Inwood, were used to determine the sediment discharges for Swatara Creek at Inwood. The ranges of flows and suspended-sediment discharges used to develop the equation were from 54 to 1,280 ft^3/s and 0.40 to 1,130 ton/d, respectively, and therefore the equation should not be used to estimate discharges above these values. The annual sediment load was then calculated by summing the estimated daily sediment discharges, by the following relationship:

$$\text{Log } S_I = 2.1982 (\text{Log } Q_I) - 4.1988 \qquad (2)$$

where Log S_I = the logarithim of the daily sediment discharge at Inwood in tons/d

2.1982 = the slope of the regression line

Log Q_I = the logarithim of the water (average daily) discharge at Inwood in ft^3/s

and -4.1988 = the intercept of the regression line

Results from this method are not accurate for short periods of record particularily if high flow days are to subdivided as in this case; however, they do indicate that at least 17,400 tons of suspended sediment were transported by Swatara Creek at Inwood from October 1981 to September 1982. These results are about half the 35,000 ton average annual sediment load estimated by Terraqua Resources Corporation (1982), and are due in part to the 15-percent below-normal streamflows during the study. The quantities and yields of sediment for the stations are listed below in table 6.

Table 6.--Summary of annual suspended-sediment loads and yields, 1982 Water Year

Station	Drainage area (mi^2)	Load (tons)	Yield (ton/mi^2)
Swatara Creek above Highway 895	72.6	11,300[1/]	157
Lower Little Swatara Creek at Pine Grove	34.3	4,700	137
Swatara Creek at Inwood	169	17,400	103

1 Sediment records at this station began on October 23, 1981. However, no storms occurred between October 1 and October 23, 1981; therefore the annual sediment load would not have been significantly different.

The low sediment yield at Inwood compared to that at the other stations is due to several factors. First, there is a large increase in forest cover between Pine Grove and Inwood that reduces the amount of sheet erosion and the amount of sediment transported from tributaries entering below Pine Grove. Secondly, some of the sediment discharged by Lower Little Swatara Creek and Swatara Creek at Pine Grove may be deposited in the relatively flat stretch of channel between Pine Grove and Inwood. Thirdly, the main tributary entering Swatara Creek below Pine Grove at Suedberg flows through Lebanon Reservoir, which traps much of the suspended material before it reaches Swatara Creek and the planned impoundment area at Inwood. In summary, about 17,400 tons of suspended sediment were transported to the planned impoundment area in the 1982 water year, and 65 percent of the suspended sediment was transported by Swatara Creek above Highway 895 which occupies 43 percent of the drainage area.

Particle-Size Distribution

Assuming that the discharge weighted particle-size analyses (table 9) are representative, 32 percent of the suspended sediment is clay, 37 percent is silt, and 31 percent is sand at Swatara Creek above Highway 895. Sand and silt analyses of the suspended sediment from Swatara Creek at Inwood also show a similar composition. At Lower Little Swatara Creek, 41 percent of the suspended sediment is clay, 51 percent silt, and only 8 percent is sand. Therefore, of the 17,400 ton suspended-sediment load transported from the study area, about 6,000 consisted of clay, 7,100 tons of silt, and 4,300 tons of sand.

Chemistry of Bottom Material

The streambed at and above Inwood contains high concentrations of metals that are contributed primarily by the Swatara Creek headwaters (table 7 and fig. 2). As shown in the table, concentrations of aluminium, iron, and manganese were 7, 4, and 2 times greater, respectively, at Swatara Creek above Highway 895 than at Lower Little Swatara Creek. These conditions are caused by acid mine drainage and the associated precipitation and sorption of metals to bottom material in Swatara Creek. Concentrations of these metals are not conducive to aquatic biota.

Table 7.--Metals and nutrients associated with bottom material on September 14, 1982
[constituent concentrations in μg/g except as footnoted]

Location	Aluminum	Iron	Manganese	Carbon 1/ inorganic as C	Carbon 1/ organic as C	Nitrogen organic as N	Nitrogen nitrite plus nitrate as N	Nitrogen Ammonia as N	Phosphorus as P
Swatara Creek above highway 895	5,600	13,000	650	<0.1	420	7,800	5	11	170
Lower Little Swatara Creek at Pine Grove	900	2,900	340	.2	16	2,000	4	4	250
Swatara Creek at Suedberg (site C on fig. 2)	580	2,500	220	< .1	97	1,400	<2	<0.4	72
Swatara Creek 2.3 miles upstream from Inwood site (site B on fig. 2)	660	2,800	370	< .1	69	1,900	<2	.6	260
Swatara Creek 1.6 miles upstream from Inwood (site A on fig. 2)	1,700	5,700	1,000	.5	290	1,400	3	2	130
Swatara Creek at Inwood	870	3,300	720	< .1	280	6,000	<2	0.5	51

1/ Concentrations for these constituents are g/Kg.

In addition to the metals, substantial quantities of nutrients are found in the bottom material in the study area. The highest concentrations of organic nitrogen were found in the bottom material at Swatara Creek above Highway 895 and Swatara Creek at Inwood (table 7). Organic nitrogen and ammonia nitrogen concentrations were at least 2.5 times greater at Swatara Creek above Highway 895 than at any other site except for organic nitrogen at Inwood. Organic carbon was also significantly higher at Swatara Creek above Highway 895 than any other site. Phosphorous was highest at site B on Swatara Creek, 2.3 miles upstream of Inwood and at Lower Little Swatara Creek.

The sewage-treatment plant at Pine Grove has secondary treatment facilities, but untreated sewage from outside the borough is discharged into Swatara Creek. Visible quantities of sewage have been observed during routine visits to Swatara Creek above Highway 895. Presence of this sewage accounts for the high nutrient content of bottom material in Swatara Creek.

Chemical Characteristics

Nutrients

The two major nutrients required for algal growth are dissolved nitrogen and phosphorus. When these two constituents are coupled with proper light intensities and water temperatures, excessive algal growth may occur. The literature suggests 0.3 mg/L of inorganic nitrogen and 0.01 mg/L of phosphorus are critical concentrations which, when exceeded, can stimulate excessive growth of algae (McKee and Wolf, 1963; Harms and others, 1974). The U.S. Environmental Protection Agency (1976) recommends that total phosphorus should not exceed 0.05 mg/L at the point where it enters any lake or reservoir.

Measured nitrogen concentrations for discharges from both Swatara Creek above 895 and Lower Little Swatara Creek exceeded the critical values during the entire study period. Most nitrogen at both Swatara Creek above Highway 895 and Lower Little Swatara Creek was transported as dissolved nitrate; however, the concentrations varied greatly between the two stations as indicated by the median values in table 5 and figure 16. The median concentration for dissolved ammonia nitrogen of 0.15 mg/L at Swatara Creek above Highway 895 was five times greater than the median for Lower Little Swatara Creek, and the median concentration for dissolved nitrate nitrogen of 1.4 mg/L at Lower Little Swatara Creek was almost twice the median of Swatara Creek above Highway 895. Median total organic nitrogen concentrations were similar at both Lower Little Swatara Creek and Swatara Creek above Highway 895 as values were 0.80 mg/L and 0.78 mg/L, respectively. Median dissolved organic and ammonia nitrogen concentrations measured downstream at Swatara Creek at Inwood indicate both decrease between Pine Grove and Inwood. The median concentration at Inwood was 0.90 mg/L for dissolved nitrate nitrogen and 0.08 mg/L for dissolved ammonia nitrogen. The median total organic nitrogen concentration of 0.77 mg/L for Inwood was similar to that calculated for both upstream stations.

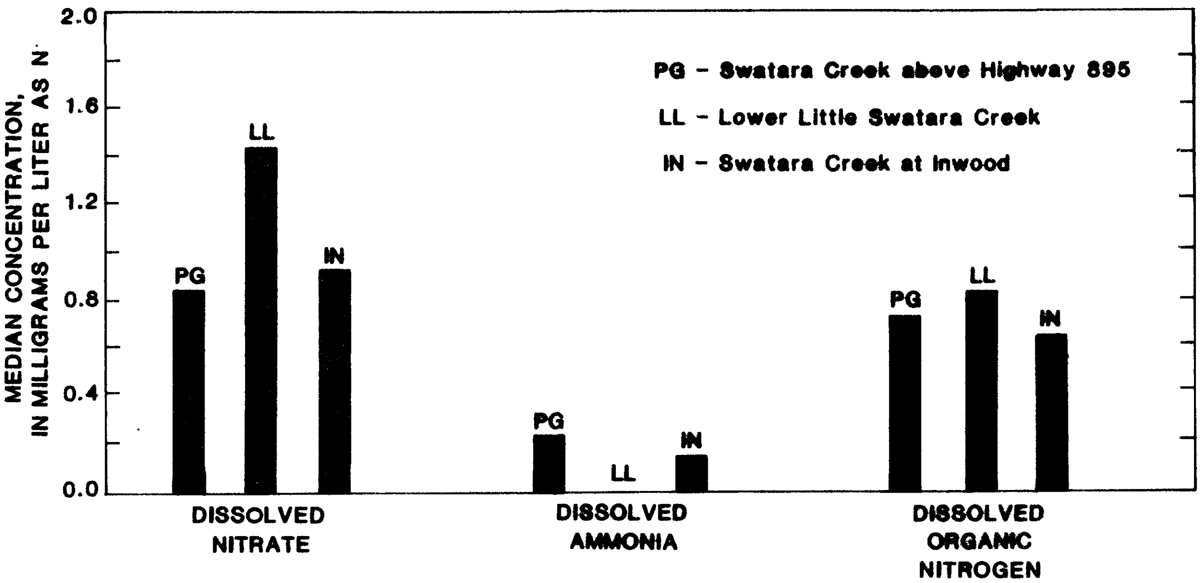


Figure 16.--Median concentrations of dissolved nitrate, ammonia, and organic nitrogen.

The maximum instantaneous ammonia nitrogen concentration of 0.82 mg/L at Swatara Creek above Highway 895 occurred during low flow in September and was 40 times greater than the concurrent concentration measured at Lower Little Swatara Creek and 80 times greater than the concurrent concentration measured at Swatara Creek at Inwood. The source of these high ammonia concentrations may be due to sewage discharges or other point sources upstream from Highway 895. Maximum ammonia nitrogen concentrations at Lower Little Swatara Creek occurred during high flow in February. Maximum concentrations for dissolved nitrate of 2.6 mg/L were measured in January and February at Lower Little Swatara Creek, whereas, corresponding measurements at Swatara Creek above Highway 895 were 1.1 and 1.6 mg/L, respectively. The maximum total organic nitrogen concentration, however, was much higher at Swatara Creek above Highway 895 (2.2 mg/L); whereas a maximum of 1.4 mg/L was measured at Lower Little Swatara on the same day, August 25, 1982.

Instantaneous discharges for nitrogen constituents ranged from less than 0.01 ton/d for total nitrite nitrogen at all three stations to 5.53 ton/d for dissolved nitrate nitrogen at Swatara Creek at Inwood. Maximum nitrite, nitrate, and ammonia nitrogen discharges at Swatara Creek above Highway 895 were nearly equal to those at Lower Little Swatara Creek (table 5). However, the maximum dissolved and total organic nitrogen discharges of Swatara Creek above Highway 895 of 1.24 ton/d and 2.21 ton/d were over two times greater than the maximum discharges at Lower Little Swatara Creek.

In summary, most of the nitrogen transported by the Swatara Creek above Highway 895 and Lower Little Swatara Creek is dissolved nitrate, which will be available for biological uptake. The high ammonia concentrations in Swatara Creek above Highway 895 indicate the presence of sewage discharges or other point-source discharges upstream from the sampling site. Substantial quantities of dissolved and suspended organic nitrogen will be transported to the impoundment from the Swatara Creek above Highway 895.

Measured dissolved phosphorus concentrations were commonly 0.01 mg/L or less, indicating that phosphorus may be the limiting nutrient for plant growth. Total phosphorus concentrations measured at both the Swatara Creek above Highway 895 and Lower Little Swatara Creek were usually two to three times greater than dissolved concentrations, indicating that much of the phosphorus transported in the study area is associated with the suspended sediment. The median total phosphorus concentrations for Lower Little Swatara Creek and Swatara Creek above Highway 895 were 0.07 mg/L and 0.05 mg/L, respectively; while corresponding median dissolved phosphorus concentrations were 0.03 mg/L and 0.02 mg/L. Similar results were seen downstream at Inwood where the median total phosphorus concentration was 0.04 mg/L and the median dissolved phosphorus concentration was 0.02 mg/L. Conservation efforts to reduce the phosphorus, especially that attached to the suspended sediment, discharged from Lower Little Swatara Creek probably would greatly reduce the phosphorus available for algal growth.

The maximum instantaneous total phosphorus concentrations for both upstream stations occurred during the storm of February 2 to 5, 1982 when 0.31 mg/L was measured at Lower Little Swatara Creek and 0.28 mg/L at Swatara Creek above Highway 895. The maximum total phosphorus concentration measured for Swatara Creek at Inwood was 0.25 mg/L during the storm of August 24 to 26, 1982.

Instantaneous total phosphorus discharges ranged from less than 0.01 ton/d at all three stations to 0.56 ton/d at Lower Little Swatara Creek. Dissolved phosphorus discharges ranged from less than 0.01 ton/d at all three stations to 0.18 ton/d at Lower Little Swatara Creek at Pine Grove.

Thus, unlike nitrogen, most of the phosphorus transported by Swatara Creek is suspended, and therefore may deposit to the stream bottom. During high flows, resuspension and resolution of this phosphorus may occur, making it available as nutrients for plant growth. Brown and others (1983) say that generally 20 to 40 percent of sediment phosphorus from agricultural watersheds is bioavailable, and Young and others (1982) indicate 55 percent of particulate phosphorus in municipal wastewaters is avaible in the short term and 63 percent is ultimately available.

Metals

Aluminum, iron, and manganese are often contained within coal-bearing formations, and therefore are common to acid-mine drainage. Iron and manganese concentrations measured in Swatara Creek at both Pine Grove and Inwood exceeded the recommended U.S. EPA criteria (U.S. Environmental Protection Agency, 1976, 1980) and Pennsylvania water-quality standards (PaDER, 1979). The concentrations and discharges in table 5 reflect the large differences in metal concentrations between the mine drainage of Swatara Creek above Highway 895 and the forested and agricultural drainage of Lower Little Swatara Creek. These results confirm that mine drainage affects the water quality at both Pine Grove and Inwood.

In the past, aluminum was thought to be harmless because it is the most abundant metal on earth and usually occurs as complex aluminum silicates such as feldspar. By using treatment processes, these suspended forms of aluminum can readily be removed from water to be used for drinking. Subsequently, no criterion for aluminum has been established by the U.S. EPA, and the Pennsylvania water-quality standard states that aluminum should not be greater than 0.1 of the 96-hr LC 50 (lethal concentration for 50 percent of the specific species if maintained for 96 hours) for representative important species. The 96-hr LC 50 value has not been determined for many fish species and may be quite different depending on other characteristics of the native water such as pH. Thus, water with high suspended aluminum concentrations, like that which enters the planned impoundment area, is generally felt to be safe for drinking after treatment. However, recent investigations at Cornell University, Darmouth College, and the University of Vermont, have linked free aluminum, caused by the effects of acid rain, with potentially toxic concentrations in mountain soil, water, and streams (Davis, 1983). Further studies need to be done to determine what concentrations constitute toxic levels and the possible effects on public health.

Differences between the median dissolved and total aluminum concentrations in table 5 indicate most aluminum is transported in the suspended phase and is deposited on the streambed before reaching Inwood. The median total aluminum concentration at Inwood of 450 μg/L was less than half the median for Swatara Creek above Highway 895 (fig. 17 and table 5). The median concentration of 1,100 μg/L for total aluminum at Swatara Creek above Highway 895 was nearly twice the median concentration of 670 μg/L at Lower Little Swatara Creek. The median concentration for dissolved aluminum was about 100 μg/L for all three stations. Figure 18 illustrates the direct relation between concentrations of total aluminum and suspended sediment during high flows at each station. Maximum concentrations for total aluminum at Swatara Creek above Highway 895 and at Inwood of 66,000 μg/L and 13,000 μg/L, respectively, were measured during the storm of August 25, 1982, which occurred during the mid-summer growing phase. The maximum total aluminum concentration of 3,400 μg/L for Lower Little Swatara Creek was measured during the storm in February when the ground was frozen. Conversely, the maximum dissolved aluminum concentrations were highest at the mine drainage sites above Highway 895 and at Inwood during the colder months, and highest at Lower Little Swatara Creek during the storm in August.

The maximum instantaneous discharge for total aluminum at Swatara Creek above Highway 895 was 66.3 ton/d, more than 10 times greater than the maximum for Lower Little Swatara Creek and three times greater than the maximum of 22.6 ton/d measured at Swatara Creek at Inwood.

The U.S. EPA criteria (U.S. Environmental Protection Agency, 1976, 1980) for iron concentrations are 0.3 mg/L for domestic water supplies and 1.0 mg/L for freshwater aquatic life. The Pennsylvania water-quality standard states, "total iron concentrations should not be more than 1.5 mg/L and dissolved iron concentrations more than 0.3 mg/L." The U.S. EPA criteria for domestic water supplies were exceeded by 100 percent and 71 percent of the samples, respectively, for total and dissolved iron at Swatara Creek above Highway 895. The U.S. EPA criteria for freshwater aquatic life were exceeded by 90 percent and 10 percent of the samples, respectively, for total and dissolved iron at Swatara Creek above Highway 895, whereas 71 percent of the samples for both total and dissolved iron exceeded the Pennsylvania water-quality standard. At both Lower Little Swatara Creek and Swatara Creek at Inwood,

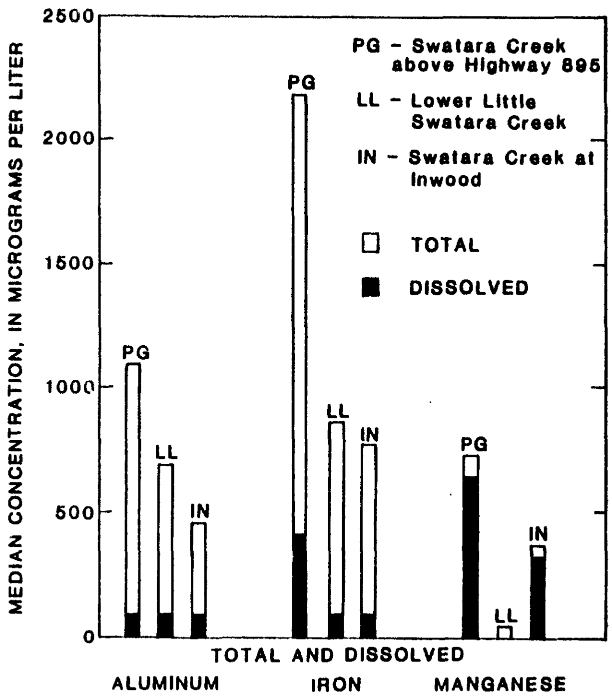


Figure 17.--Median concentrations of total and dissolved aluminum, iron, and manganese.

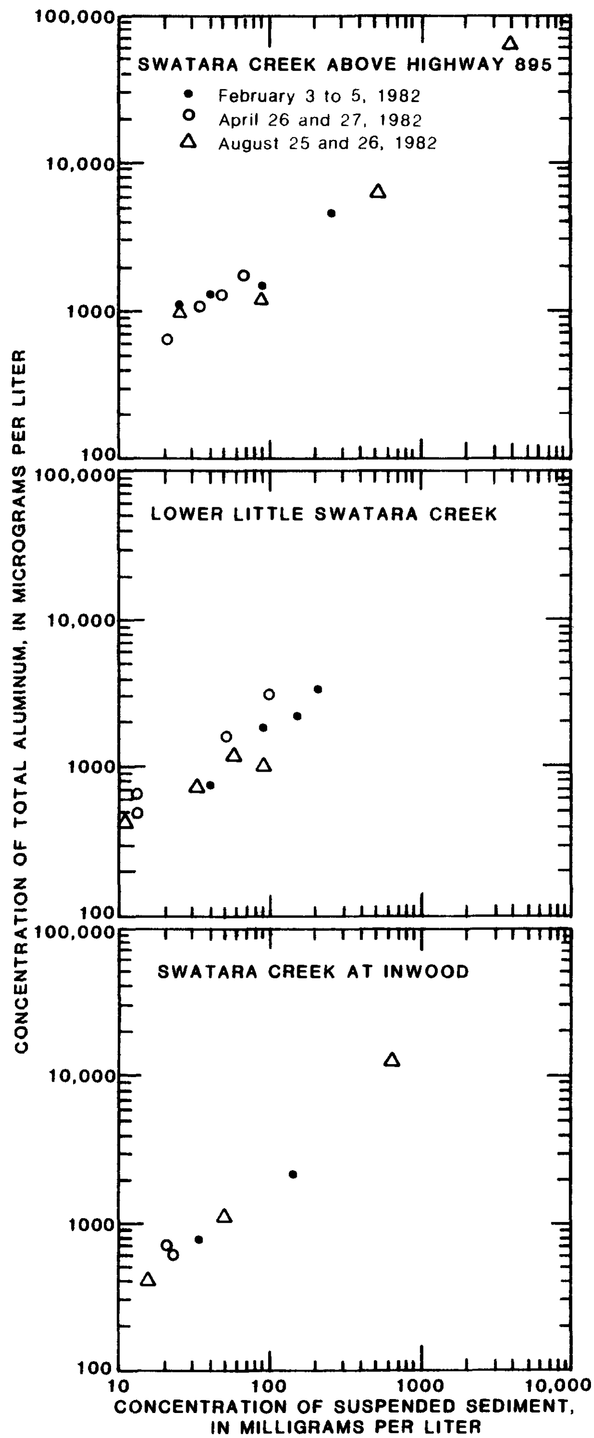


Figure 18.--Relation between concentrations of total aluminum and suspended sediment during high flows.

25 percent of the total iron samples exceeded the Pennsylvania standard and 75 percent of the samples exceeded the U.S. EPA criterion for domestic water supplies.

Like aluminum, differences between the total and dissolved median iron concentrations indicate most of the iron is transported in the suspended phase (fig. 17). The median total iron concentration measured at Inwood was less than one-third of that measured above Highway 895 (fig. 16), indicating that iron may be deposited on the streambed between Pine Grove and Inwood. The median concentrations for total iron at Swatara Creek above Highway 895 (2,200 µg/L) was significantly higher than the median concentration at Lower Little Swatara Creek (850 µg/L). The median concentration for dissolved iron was over five times greater at Swatara Creek above Highway 895 (430 µg/L) than at Lower Little Swatara Creek at Pine Grove (85 µg/L).

Figure 19 illustrates the direct relation between total iron and suspended sediment during high flows at each station. The maximum total iron concentration for Swatara Creek above Highway 895 of 100,000 µg/L was measured during the midsummer storm of August 25, 1982, whereas the maximum for Lower Little Swatara Creek (7,900 µg/L) was measured during the storm of February 3, 1982.

Dissolved-iron concentrations, also like aluminum, were highest during the colder months at Swatara Creek above Highway 895 and at Inwood, whereas dissolved iron concentrations at Lower Little Swatara Creek showed less variation throughout the year.

The maximum instantaneous discharge for total iron of 100 ton/d measured at Swatara Creek above Highway 895 was more than seven times greater than the maximum of 14 ton/d measured for Lower Little Swatara Creek and 2.7 times greater than that measured for Swatara Creek at Inwood.

The U.S. EPA criterion for manganese is 50 µg/L for domestic water supplies. The Pennsylvania water-quality standard states, "manganese should not be greater than 1.0 mg/L." These values were not established on toxicological basis, but were established primarily to reduce aesthetic damage and prevent objectional tastes in beverages. Removal of manganese from water for domestic uses requires special treatment such as pH adjustment, aeration, superchlorination, or chemical precipitation.

All measured concentrations of dissolved and total manganese at Swatara Creek above Highway 895 and at Inwood exceeded the U.S. EPA criterion. Forty-five percent of the samples for total manganese and 19 percent of the samples for dissolved manganese from Lower Little Swatara Creek exceeded U.S. EPA criteria.

Median total and dissolved manganese concentrations in figure 17 and table 5 show that most manganese transported at Swatara Creek above Highway 895 and at Inwood is dissolved and most at Lower Little Swatara Creek is suspended. The median concentrations for total and dissolved manganese were 740 µg/L and 640 µg/L, respectively, at Swatara Creek above Highway 895. They were about two times greater than median concentrations at Inwood and more than 14 times greater than the median at Lower Little Swatara Creek. Figure 20 illustrates that the relation between total manganese and suspended-sediment at Lower Swatara Creek is well defined, but the relations at Swatara

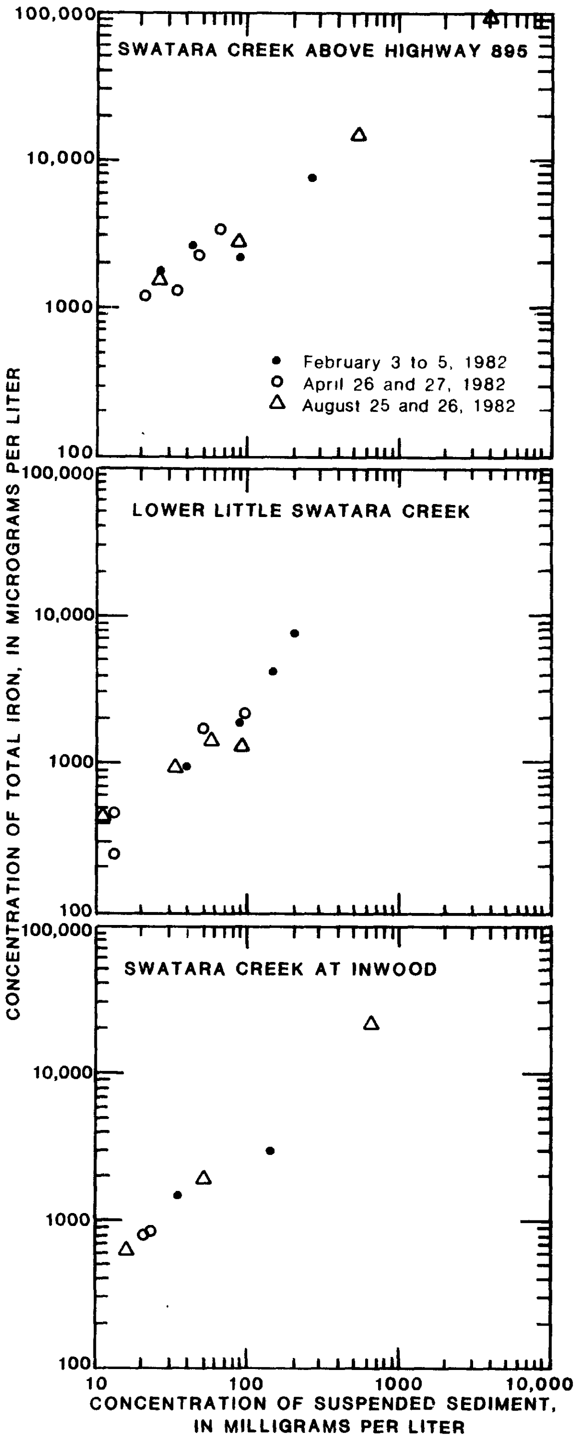


Figure 19.--Relation between concentrations of total iron and suspended sediment during high flows.

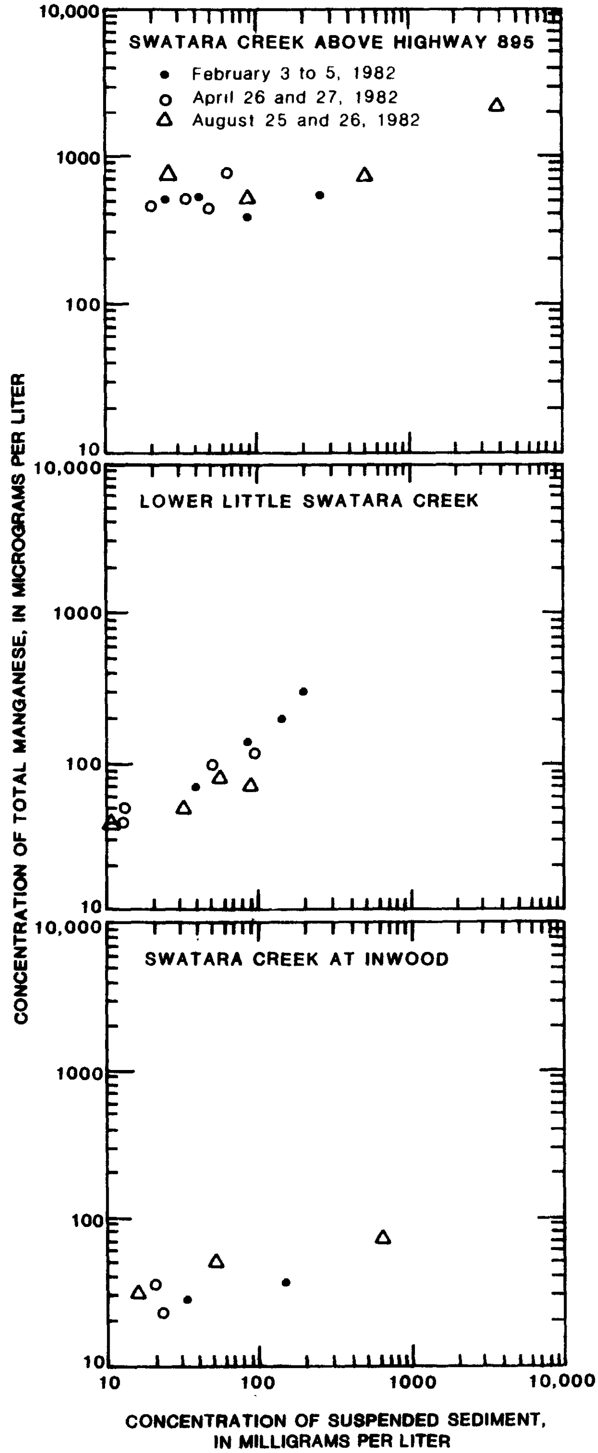


Figure 20.--Relation between concentrations of total manganese and suspended sediment during high flows.

Creek above Highway 895 and at Inwood are not well defined. These results may be due in part to the changes in the solubility of manganese at the mine-drainage sites where pH is lower and the oxidation potential higher and is consistent with work presented by Hem (1970). Maximum concentrations for total manganese at Swatara Creek above highway 895 and at Inwood were 2300 μg/L and 710 μg/L, respectively, and occurred during the midsummer storm of August 25, 1982. The maximum for Lower Little Swatara Creek was 670 μg/L and occurred in June.

The maximum instantaneous total manganese discharge at Swatara Creek above Highway 895 (7.53 ton/d) was more than 13 times greater than the maximum for Lower Little Swatara Creek at Pine Grove and almost 6 times greater than that for Swatara Creek at Inwood.

The U.S. EPA criterion for total lead for freshwater aquatic life in water with a hardness of 100 mg/L as $CaCO_3$ is 3.8 μg/L, and the human-health criterion is 50 μg/L. At both Swatara Creek above Highway 895 and Lower Little Swatara Creek, more than 50 percent of the samples analyzed for total lead exceeded the U.S. EPA criterion for freshwater aquatic life. The human-health criterion was exceeded at both Swatara Creek above Highway 895 and at Inwood during a storm on August 25, 1982. Preliminary data in figure 21 suggest that the primary source of lead is from Swatara Creek above Highway 895, and a direct relationship exists between total lead and suspended sediment during particular storms. Median lead concentrations (fig. 22) were greatest at Swatara Creek above Highway 895 (19.0 μg/L) and decreased from dilution downstream to Swatara Creek at Inwood (9.3 μg/L). Because lead does not naturally occur in the concentrations measured, there may be a point source that contributes lead to Swatara Creek above Highway 895.

Maximum instantaneous concentrations for total lead measured at Swatara Creek above Highway 895 and at Inwood were 172 μg/L and 52 μg/L, respectively, and occurred during the August 25, 1982 storm. The maximum total lead concentration measured at Lower Little Swatara Creek (40 μg/L) also occurred during the August 25, 1982 storm.

The maximum instantaneous total lead discharge at Swatara Creek above Highway 895 of 0.17 ton/d was 8 times greater than the maximum measured for Lower Little Swatara Creek at Pine Grove and 2 times greater than that at Swatara Creek at Inwood.

Copper and zinc concentrations at Swatara Creek above Highway 895 and at Inwood also occasionally exceeded the respective U.S. EPA criteria for fresh-water aquatic life. The U.S. EPA criterion for total copper states, that copper concentrations should not exceed 22 μg/L at any time, if water has a hardness of 100 mg/L as $CaCO_3$, and total zinc should not exceed 47 μg/L as a 24-hour average (U.S. Environmental Protection Agency 1980). The maximum concentrations for copper measured at Swatara Creek above Highway 895 and at Inwood were 220 and 60 μg/L, respectively. Median concentrations were below the U.S. EPA criterion. Maximum zinc concentrations measured at Swatara Creek above Highway 895 and at Inwood were 310 and 120 μg/L, respectively. The median concentrations for total zinc of 85 μg/L and 60 μg/L, at these sites, respectively, also exceeded the criterion.

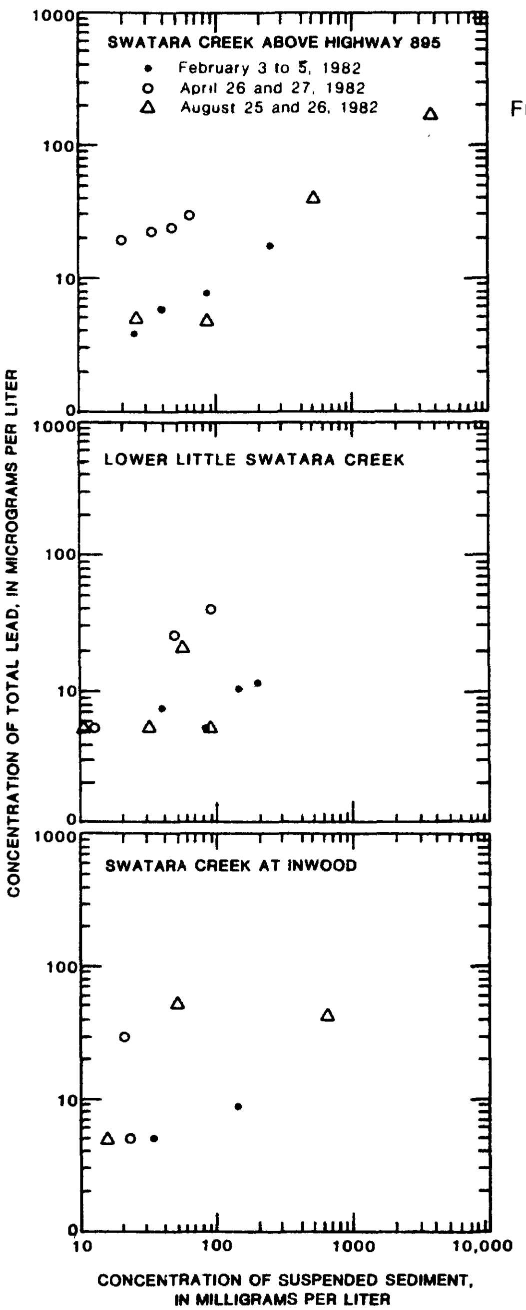


Figure 21.--Relationship between concentrations of total lead and suspended sediment during high flows.

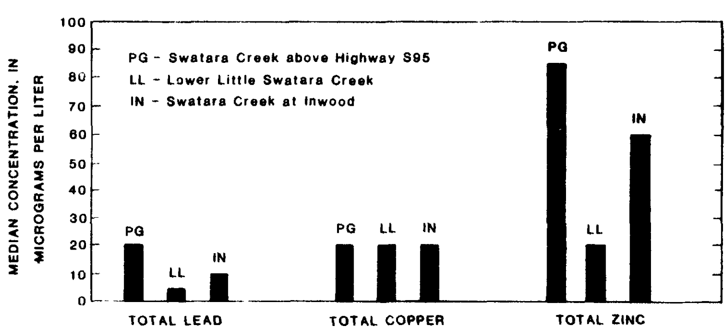


Figure 22.--Median concentrations of total lead, copper, and zinc.

Major Dissolved Ions

The ionic composition of Swatara Creek changes from above Highway 895 to Inwood. These changes result mostly from dilution of Swatara Creek by the inflow of Lower Little Swatara Creek. The median sulfate concentration is 10 times higher for mine drainage from Swatara Creek above Highway 895 than agricultural and forested drainage from Swatara Creek (table 5). Stiff diagrams that depict the median concentrations of each major ion (fig. 23), show the differences in ionic composition at the three sites. The water at Swatara Creek above Highway 895 is a mixed cation-sulfate type, whereas Lower Little Swatara Creek is a mixed cation and mixed anion type. Lower Little Swatara Creek water mixes with Swatara Creek, thereby reducing the concentrations of all ions, particularly sulfate, at Inwood.

Major-ion concentrations at all three sites indicate that water in the Swatara Creek State Park Reservoir is generally soft, with hardness values usually less than 70 mg/L as $CaCO_3$ for Swatara Creek and 30 mg/L as $CaCO_3$ for Lower Little Swatara Creek. No ions exceeded U.S. EPA criteria or Pennsylvania water-quality standards. However, instantaneous and median sulfate concentrations and discharges (table 5) indicate that most sulfate in

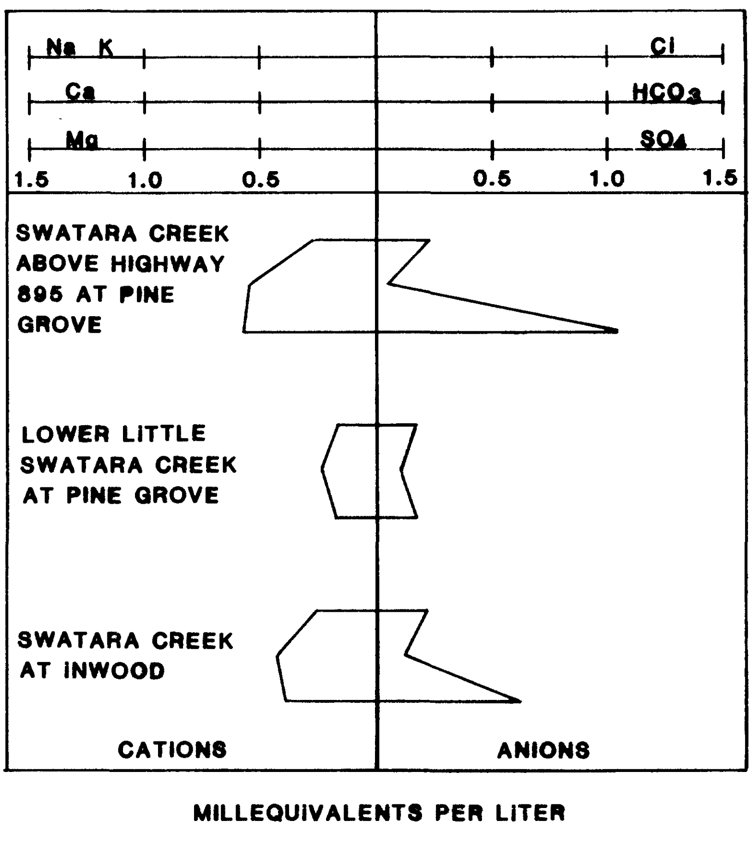


Figure 23.--Stiff diagrams of major ions for Swatara Creek Reservoir sampling sites.

Swatara Creek originates from the mine drainage upstream from Highway 895. The maximum measured sulfate concentration was 130 mg/L at Swatara Creek above Highway 895 and 25 mg/L at Lower Little Swatara Creek. Median concentrations were 50 and 5 mg/L, respectively. Downstream at Inwood, the maximum concentration was 60 mg/L and the median concentration was 30 mg/L. Instantaneous maximum sulfate discharges for Swatara Creek above Highway 895, Lower Little Swatara Creek, and Swatara Creek at Inwood were 50.2, 18.0, and 52.2 ton/d, respectively.

Bacteriological Characteristics

Fecal coliform concentrations in Swatara Creek and Lower Little Swatara Creek were usually below the U.S. EPA criterion of 200 colonies per 100 mL of water for bathing waters. Bacteria concentrations, however, exceeded the criterion and persisted at high levels for several days during and after a storm.

Table 8 lists bacteriological data collected during the 1982 water year. Samples analyzed in the field commonly had higher bacteria concentrations, probably due to the increased die off of bacteria in samples that were held up to 24 hours before being analyzed by PaDER laboratory personnel. Concentrations for both FC (fecal coliform) and FS (fecal streptococci bacteria) were usually higher at Lower Little Swatara Creek than at Swatara Creek above highway 895 and at Inwood. Although the FC:FS ratio[1/] is commonly used to differentiate animal and human sources of bacteria, it cannot be used for these sites because the acid mine drainage in Swatara Creek probably reduces the survival rate of the bacteria (Hackney and Bissonnette, 1978). If conservation measures are taken to reduce or neutralize the acid mine drainage entering the Swatara Creek headwaters, bacteria concentrations at Swatara Creek above Highway 895 and at Inwood may significantly increase, and the FC:FS ratio may be useful in determining the sources of bacterial contamination.

PRELIMINARY ESTIMATION OF THE WATER QUALITY OF THE PLANNED SWATARA CREEK RESERVOIR

In order to predict the water quality of the planned Swatara Creek Reservoir, numerous characteristics of the lake must be considered. These characteristics include the detention time of water in the lake, the timing and extent of thermal and chemical stratification, sedimentation within the lake, the chemical loads entering the lake, and the chemical concentrations in the lake. These factors, which are at least partly related to streamflow, are discussed below.

Any land use or water treatment above the lake may significantly affect future water quality in the lake. For example, if mine drainage into Swatara Creek is reduced and if corresponding improvements in sewage treatment are not made, fecal coliform and fecal streptococci bacteria concentrations above Highway 895 may increase and have a detrimental impact on the lake.

1/ If FC:FS is less than 0.7, then animal source is suspected; if FC:FS is greater than 4.0, then human source is suspected.

Table 8.--Summary of bacteriological data, 1982 water year

		Fecal coliform (colonies/100 mL)		Fecal Streptococci (colonies/100 mL)	
Date	Time	Field	Laboratory	Field	Laboratory
Swatara Creek above Highway 895 at Pine Grove					
December 15, 1981	0850	34	40	220	40
January 20, 1982	1230	K8	10	80	40
February 3, 1982	1345		900		4,200
February 3, 1982	2130		1,000		3,600
February 4, 1982	1050		600		3,100
February 5, 1982	1400	K570		K3500	
February 16, 1982	1135	32	140	240	50
March 23, 1982	0900	<4	10	K21	10
April 20, 1982	1130	K3	25	54	25
April 26, 1982	1630		25		300
April 26, 1982	2345		420		620
April 27, 1982	0220		120		380
April 27, 1982	0945		340		340
May 25, 1982	1150	K39	30	100	80
June 22, 1982	0900	30	10	88	50
July 27, 1982	0945	K4	10	110	50
August 25, 1982	0615		9,200		2,200
August 25, 1982	1030				
August 25, 1982	1815		2,400		4,800
August 26, 1982	1415		40		40
September 14, 1982	0900	44	20	800	3
Lower Little Swatara Creek at Pine Grove					
December 15, 1981	1115	25	80	100	20
January 20, 1982	1500	16	110	84	60
February 3, 1982	1830		2,900		22,000
February 4, 1982	0150		1,900		21,000
February 4, 1982	1245		1,000		2,700
February 5, 1982	1110	K260	340	2,000	340
February 16, 1982	0915	800	2,100	>240	5,100
March 23, 1982	1130	100	10	K61	10
April 20, 1982	1345	K32	75	170	25
April 26, 1982	1430		180		120
April 26, 1982	2000		2,800		2,200
April 27, 1982	0100		2,400		1,500
April 27,1982	1215		780		2,500
May 25, 1982	1330	400	410	200	220
June 22, 1982	1200	260	260	280	20
July 27, 1982	1300	160	140	270	
August 25, 1982	0430		1,400		4,000
August 25, 1982	1110				48,000
August 25, 1982	1635		21,000		23,000
August 26, 1982	1145		6,100		1,800
September 14, 1982	1130	120	120	67	190
Swatara Creek at Inwood					
December 15, 1981	1330	K6	10	18	10
January 20, 1982	1000	<2	10	K6	10
February 4, 1982	0745		1,000		5,200
February 5, 1982	1615	K130		42	370
February 16, 1982	1435	K25	100	>240	280
March 3, 1982	1455	<4	10	K4	10
April 20, 1982	0745	K9	25	160	25
April 26, 1982	1830		600		100
April 27, 1982	1500		270		110
May 25, 1982	0845	180	200	110	50
June 22, 1982	1400		30	94	90
July 27, 1982	1445	39	50	200	10
August 25, 1982	0745		7,000		17,000
August 25, 1982	1430		3,500		4,000
August 26, 1982	1645		1,700		100
September 14, 1982	1445	K67	70	62	40

< = less than   > = greater than   K = based on non-ideal colony count

Detention Time

The detention time of water in the planned lake will be much longer than in the fast-moving water of Swatara Creek. This will allow slow physical and chemical reactions to come closer to completion (Hem, 1970). The detention time in the Swatara Creek Reservoir will be longest during low flows, which usually occur from August through November. For example, at a typical flow of 40 ft^3/s, recorded during October and November 1981, and September 1982, the planned lake will require 204 days for a complete exchange of water. As a result, the lake will become a holding basin in which thermal and chemical stratification may occur. At high flows of about 1,000 ft^3/s an exchange would occur in about 8 days.

Thermal and Chemical Stratification

As the morphometric characteristics of the planned Swatara Creek Reservoir will be similar to those at nearby Blue Marsh Lake, the lake's processes of thermal stratification are expected to be similar (Barker, J. L., oral commun. 1983). However, because the chemical composition of the inflows for these impoundments is different, chemical stratification in Swatara Creek Reservoir will probably be different from Blue Marsh Lake and can only be discussed qualitatively as suggested by Flippo (1970).

Like many lakes in the temperate zone, the planned Swatara Creek Reservoir can be expected to thermally stratify in response to the seasonal conditions found in this area. Base-flow water temperatures reflected these seasonal differences in the 1982 water year. Water temperatures ranged from 0.0° C in the winter to 24.5° C in the summer. During spring base flow, as the detention time of the water in the lake increases and the lake becomes calm, solar radiation will be absorbed by the surface of the lake. As the surface water of the lake becomes warmer and less dense, a thermal resistance to mixing will develop. Gradually, three regions of different temperatures and densities (epilimnion-upper, metalimnion-middle, hypolimnion-lower) can be expected to form. Wetzel (1975) states, "When streamflow enters a lake or reservoir, the incoming water will flow into the density layer in the lake which is most similar to its density; this process is governed by temperature, dissolved material and suspended sediment." In early summer, warm base flow will flow over top of the denser, cooler impounded water. In contrast, the winter base flow will be cooler and denser than summer base flow, and will create little mixing in the shallow upstream part of the lake. The main part of these discharges flow down the slope of the reservoir bed, to a depth where its density is in equilibrium with that of the impounded water, and then flow horizontally to the point of outflow.

In the narrow Swatara Creek Reservoir, the introduction of the cooler base flows during the winter and late spring will result in an accumulation of organic nitrogen, phosphorus, and metals in the hypolimnion. If large amounts of oxidizable material are transported to the planned lake during storms and base flow, and if organic material is deposited in the spring and summer from the epilimnion, dissolved oxygen in the hypoliminion may be depleted as early as mid-June. Hydrogen sulfide may also be generated in the anaerobic part of the lake as organic material decomposes in the summer and winter. Dissolved-metal concentrations in the hypolimnion can be expected to increase as anoxic conditions persist and increased retention times during low flows permit reduction and leaching of the lake sediments. As low base flows persist during the summer, dissolved nitrate and phosphorus concentrations may decrease in the warmer epilimnion due to consumption by algae and other aquatic plants. As the algae die and settle into the hypolimnion, decomposition of the organic matter will use oxygen.

Sedimentation

Data from the investigation showed 46 percent of the annual suspended-sediment load at both Swatara Creek above Highway 895 and Lower Little Swatara Creek was transported during three days: April 3, June 29, and August 28, 1982; these results support McCarren's (1964) conclusion that a high percentage of suspended sediment carried by streams in the Swatara Creek basin is transported during a few storms each year. Therefore, during storms, the proposed impoundment will be impacted by sudden discharges of suspended material. During base flow, much of the suspended material may be trapped in the lake.

The amount of sedimentation that would have occurred in the planned Swatara Creek Reservoir during the 1982 water year was estimated using techniques described by Brune (1953). Assuming the suspended sediment has a density of 55 lb/ft^3 and the reservoir has a 78 percent trap efficiency, 494,000 ft^3 or 11.4 acre-ft of suspended sediment would have been trapped in the impoundment from October 1981 to September 1982. Because 7,000 acre-ft of the reservoir is designated for sediment deposition, the preliminary data indicate that life expectancy of the lake would be about 614 years. Because streamflows for this part of the study were 15 percent below normal, the average annual suspended-sediment load transported to the planned impoundment may be higher, which would shorten the life expectancy of the lake. Although preliminary data indicate a subimpoundment is not necessary to reduce the suspended-sediment load to the reservoir, a subimpoundment may provide other beneficial water-quality improvements. The deposition and precipitation of sediment, coal fines, and associated metals during low flows will probably be greater in the shallow inflow sections of the lake where velocities are insufficient to keep the particulate matter suspended. As a result, the lake bottom probably will be largely covered by particulate coal. Preliminary data indicate that storm discharges and wave action along the shore line of the lake may resuspended this material and increase the turbidity of the lake substantially.

Initial information also indicates that large storms probably transport significant quantities of coal as bedload in the Swatara Creek. The impact of bedload transport into the planned impoundment will probably be sudden but infrequent.

Chemical Loads and Concentrations

Water-quality data collected during this preliminary investigation show the chemical loads entering and chemical concentrations in the planned impoundment area will largely depend on flow conditions. Base flow water-quality data indicate that the lake will probably be poorly buffered because measured concentrations of alkalinity and acidity were usually less than 10 mg/L and 5 mg/L as $CaCO_3$, respectively. As a consequence, the lake may be impacted by acid mine discharges from Swatara Creek above Highway 895, like those measured during storms when the pH dropped to 5.6 and acidity and metal concentrations simultaneously increased. In the absence of acid mine drainage and in response to the consumption of carbon dioxide by photosynthesis in the epilimnion, the pH of portions of the lake may increase substantially higher than the median of 6.5 measured at Inwood.

Nitrogen concentrations measured during both base flows and storms at inflows to the planned lake exceeded the critical values necessary for algal growth during the entire study period. As most of the nitrogen was dissolved, it will be available for biological uptake in and downstream from the planned impoundment. Dissolved phosphorus concentrations were commonly 0.01 mg/L or less, indicating that phosphorus may become a limiting nutrient for plant growth in the lake, especially during base flows from March through July. However, a significant loading of phosphorus and organic nitrogen associated with the suspended sediment occurs during storms. Storms of sufficient magnitude, as those measured in February, April, and August 1982, may resuspend these nutrients and transport them to the planned lake, where they may be trapped along with sediments in the lake's bottom material. Ultimately, these nutrients may become available for resolution, plant enrichment, and algal growth. Brown and others (1983) report that generally 20 to 40 percent of sediment phosphorus from agricultural watersheds is available to aquatic life, and Young and others (1982) indicate 55 percent of particulate phosphorus in municipal wastewaters is available in the short term; 63 percent is ultimately available. Measured base-flow concentrations of dissolved and suspended organic and ammonia nitrogen and bottom-material data indicate that most of the organic and ammonia nitrogen is transported from Swatara Creek above Highway 895. Although sewage from the borough of Pine Grove undergoes secondary treatment, visible discharges of untreated sewage from outside the borough were observed during base flows in Swatara Creek. The high biological oxygen demand created from such high concentrations of nutrients may result in low dissolved oxygen concentrations similar to the case on August 25, 1982 at 6:15 a.m. when 5.6 mg/L (64 percent saturation) of dissolved oxygen was measured.

Water-quality data collected during the 1982 water year indicated that most metal loads to the planned impoundment area were transported during storms and associated with suspended sediment. High concentrations of aluminum, iron, and manganese transported from the Swatara Creek headwaters to the study area were also measured in the bottom material of Swatara Creek at low flows. Like phosphorus, much of the iron, aluminum, lead, copper, and zinc was suspended and may be trapped in the lake and deposited on the lake bottom.

HYPOTHETICAL EFFECTS OF THE RESERVOIR ON DOWNSTREAM WATER QUALITY

As suggested during the preceeding discussion, the water quality of Swatara Creek in and downstream from the impoundment will need to be monitored closely. Because the reservoir will stratify thermally and chemically in the summer and autumn, releases during this part of the year will have the most impact on downstream water quality. Conservation releases need to be carefully controlled from the release gates, so that water from the hypolimnion with low dissolved oxygen levels and high dissolved metal concentrations will not degrade the downstream water-quality conditions and be detrimental to the aquatic community.

The reservoir will act as a sediment trap and, therefore, reduce the concentrations of total phosphorus, iron, aluminum, lead, copper, and zinc discharged immediately downstream of the impoundment during low and medium flows. Because streamflows at Harper Tavern and other points downstream of Inwood will be affected by the impoundment, and peak flows will probably be reduced, the reservoir is expected to reduce the frequency of large discharges of nutrients and metals such as those currently being measured at Inwood.

When storm discharges are large or when the winter-pool level is to be maintained by releasing water from the hypolimnion, rapid flushing of high concentrations of iron, aluminum, lead, copper, and zinc that may occur could have an adverse effect on the downstream aquatic community.

Acid conditions similar to those reported by the Pennsylvania Fish Commission for Tioga-Hammond Lakes (Baltimore Corps of Engineers, oral commun., 1984) also may occur in the Swatara Creek reservoir. If severe ice buildup occurs on the lake, little mixing may occur because the inflow current will be constricted. When acidic storm discharges from Swatara Creek above Highway 895 enter the lake, they may be trapped in pockets or accumulate near the release structure. This acid buildup may be detrimental to fish in the lake, and release of this water may kill fish downstream.

SUMMARY AND CONCLUSIONS

The preimpoundment water-quality of the proposed Swatara Creek Reservoir was studied and preliminary results for the period June 1981 to October 1982 are summarized below.

Precipitation and streamflow data for the 1982 water year indicate that preliminary data collection was performed during atypical conditions. Near the study area at Lebanon, precipitation in Pennsylvania was 8 percent below normal. Streamflow for the same period just downstream at Swatara Creek at Harper Tavern was 15 percent below the average annual flow.

During this 1-year period, about 2.1 times more discharge entered the planned impoundment area from the coal mining region of the Swatara Creek headwaters above Highway 895 than that from the forested and agricultural area of Lower Little Swatara Creek.

Swatara Creek reservoir will probably result in a poorly buffered lake with inflows containing high concentrations of nutrients and metals that will probably chemically stratify during the summer. Measured concentrations of alkalinity and acidity for Lower Little Swatara Creek and Swatara Creek above Highway 895 were usually less than 10 and 5 mg/L as $CaCO_3$, respectively. Dissolved inorganic nitrogen and phosphorus concentrations flowing to the planned impoundment area were measured as high as 2.6 and 0.10 mg/L, respectively. The critical concentrations for dissolved inorganic nitrogen and phosphorus of 0.3 mg/L and 0.01 mg/L, respectively, which are necessary to stimulate excessive algal growth, were commonly exceeded. Phosphorus may become the limiting nutrient for algal growth from March through July; however, phosphorus in the bottom material will be available for re-solution, plant enrichment, and algal growth. Even if substantial amounts of organic nitrogen are prevented from being discharged into the Swatara Creek and transported to the planned impoundment area, oxygen depletion may occur which will be harmful to the acquatic life in and downstream of the impoundment. High metal concentrations, including maximums of 66,000 μg/L for total aluminum, 100,000 μg/L for total iron, and 2,300 μg/L for total manganese, along with simultaneous decreases in pH and increases in acidity, indicate that mine drainage continues to degrade the water-quality of Swatara Creek. Concentrations of iron, lead, copper, and zinc concentrations in inflows to the planned impoundment occasionally exceeded U.S. EPA freshwater aquatic-life criteria. Concentrations of manganese and lead also exceeded U.S. EPA water-qualtiy criteria for domestic water supplies and human health, respectively. The water quality of the planned Swatara Creek reservoir will depend largely on the (1) detention time of water in the lake; (2) the timing and extent of thermal and chemical stratification; (3) sedimentation; and (4) chemical loads to, and concentrations in the lake; each factor is influenced, in part, by the frequency of occurrence of particular streamflows.

The impoundment will act as a sediment trap and, therefore, reduce the concentrations of total phosphorus, iron, aluminum, lead, copper, and zinc immediately downstream from the impoundment. Large storm discharges from the Swatara Creek headwaters, and releases from the hypolimnion to maintain a winter-pool level, may contain low oxygen concentrations and high concentrations of iron, aluminum, lead, copper, and zinc. Unless conservation releases are controlled carefully from the multilevel release gates, low dissolved-oxygen levels and high metal concentrations may degrade the downstream water quality and be detrimental to the aquatic community.

REFERENCES

Berger Associates, Inc. 1972, Swatara Creek mine drainage pollution abatement project, part two, Operation Scarlift, Commonwealth of Pennsylvania, SL-126-2, 168 p.

Brune, G. M., 1953, Trap efficiency of reservoirs: American Geophysical Union Transactions, v. 34, no.3, p. 407-418.

Brown, M. P., Rafferty, M. R., and Longabucco, P., 1983, Nonpoint source control of phosphorus - a watershed evaluation, Volume 3. Phosphorus transport in the West Branch of the Delaware River watershed: New York State Department of Environmental Conservation, Albany, New York, CR 806839, P 002137-01, 112 p.

Commonwealth of Pennsylvania, 1982, Proposed Comprehensive Water Quality Management Plan, Lower Susquehanna Area, Bureau of Water Quality Management, Department of Environmental Resources, Publication no. 64, chapter V, p. V-25.

Davis, H., 1983, Acid Rain, Aluminum Link Found, The Washington Post, May 24, 1983, p. A9.

Flippo, H. N., Jr., 1970, Chemical and biological conditions in Bald Eagle Creek and prognosis of trophic characteristics of Foster Joseph Sayers Reservoir, Centre County, Pennsylvania: U.S. Geological Survey Open-File Report, 48 p.

Greeson, P. E., Ehlke, T. A., Irwin, G. A., Lium, B. W., and Slack, K. V., 1977, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Water-Resources Investigations, Book 5, Chapter A4, 332 p.

Guy, H. P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water Resources Investigations, Book 5, Chapter Cl, 58 p.

Guy, H. P., and Norman, V. W., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter C2, 59 p.

Hackney, C. R., and Bissonnette, G. K., 1978, Recovery of indicator bacteria in acid mine streams, Journal of Water Pollution Control Federation, v. 50, p. 775-780.

Harms, L. L., Darnbush, J. N., and Anderson, J. R. 1974, Physical and chemical quality of agricultural land runoff, Journal Water Pollution Control Federation, V. 46, no. 11, 2,460 p.

Helwig, J. T., 1978, SAS Introductory Guide, SAS Institute Inc., Raleigh, North Carolina, 83 p.

Hem, J. D., 1970 Study and interpretation of the chemical characteristics of natural water, U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Hoopes, R. L., 1981, Swatara Lake (707D) Swatara State Park, preimpoundment design and operations specifications - a contribution from the Pennsylvania Fish Commission, 4 p.

McCarren, E. F., Wark, J. W., and George, J. R., 1961, Hydrologic processes diluting and neutralizing acid streams of the Swatara Creek basin, Pa., in Geological Survey Research, 1961: U.S. Geological Survey Prof. Paper 424-D, p. D64-D67.

__________, 1964, Water quality of the Swatara Creek Basin, Pa.: U.S. Geological Survey Open-File Report., 88 p.

McKee, J. E., and Wolf, H. W., 1963, Water quality criteria: The Resources Agency of California, State Water Quality Control Board, Pub. No. 3-A, 300 p.

Moran, R. E., and Wentz, D. S., 1974, Effects of metal-mine drainage on water quality in selected areas of Colorado, 1972-73: Colorado Resources Circular no. 25, 38 p.

National Oceanic and Atmospheric Administration, 1981-1982: Climatological data, Pennsylvania.

O'Leary, S. J., and Beschta, R. L., 1981, Bedload transport in an Oregon coast range stream: Water Resources Bulletin, v. 17, no. 5, p. 886-894.

Pennsylvania Department of Environmental Resources, 1979, Water quality standards, PA. Bulletin, 9(36), p. 3051-3183.

Porterfield, George, 1972, Computation of fluvial-sediment discharge: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter C3, 66 p.

Potter, W. A., Malick, R. W., Jr., and Polk, J. L., 1976, The composition and Distribution of ifshes of the Swatara Creek drainage, Pennsylvania, Proceedings of the Pennsylvania Academy of Science, v. 50., p. 136-140.

Stiff, H. A., Jr., 1951, The interpretation of chemical water analysis by means of patterns: Journal of Petroleum Technology, v. 3, no. 10, p. 15-17.

Stuart, W. T., Schneider, W. J., and Crooks, J. W., 1967, Swatara Creek basin of southeastern Pennsylvania: U.S. Gelogical Survey Water-Supply Paper 1829, 79 p.

Terraqua Resources Corporation, 1982, Feasibility study report, dam and reservoir project, Swatara State Park: Commonwealth of Pennsylvania, Department of General Services, Project Number 152-1, 66 p.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: Washington, D.C. 256 p.

__________, 1980, Water quality criteria documents: Availability, Federal Register, v. 45, no. 231, p. 79318-79341.

Wetzel, R. G., 1975, Limnology, W. B. Saunders Company, Philadelphia, Pennsylvania, 743 p.

Table 9.--Surface-water and water-quality data, July 1981 through September 1982

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µS/cm)	pH (Units)	Temper-ature (°C)	Tur-bid-ity (FTU)	Oxygen, dis-solved (mg/L)	Oxygen demand, chem-ical (high level) (mg/L)	Coli-form, fecal, 0.7 UM-MF (Cols./ 100 mL)	Strep-tococci fecal, KF Agar (Cols. per 100 mL)	Hard-ness (mg/L as $CaCO_3$)
DEC											
15...	0850	86	237	7.2	0.5	13	13.2	14	34	220	94
JAN											
20...	1230	60	231	6.4	.5	20	12.6	--	K8	80	104
FEB											
03...	1345	417	154	6.3	1.0	90	13.2	68	--	--	38
03...	2130	592	123	6.6	1.0	27	12.0	34	--	--	36
04...	1050	388	145	6.3	2.0	22	13.0	15	--	--	41
05...	1400	224	157	6.2	2.0	18	13.6	<10	K570	K3,500	45
16...	1135	106	199	6.6	4.0	14	12.8	22	32	240	62
MAR											
23...	0900	225	164	6.2	4.5	14	11.8	14	<4	K21	55
APR											
20...	1130	196	147	6.5	11.5	12	10.6	<10	K3	K54	53
26...	1630	239	193	6.4	12.5	29	10.4	--	--	--	55
26...	2345	333	125	6.7	12.0	17	10.4	--	--	--	40
27...	0220	314	134	6.6	12.0	15	10.4	--	--	--	49
27...	0945	298	130	6.8	14.0	10	10.4	--	--	--	46
MAY											
25...	1150	73	208	6.8	14.0	3.0	8.8	10	K39	100	69
JUN											
22...	0900	126	190	6.3	16.5	--	10.0	46	30	88	69
JUL											
27...	0945	34	348	6.1	19.5	6.4	8.0	11	K4	110	140
AUG											
25...	0615	372	188	5.6	22.0	840	5.6	405	--	--	68
25...	1030	393	156	6.5	18.5	125	7.6	258	--	--	48
25...	1815	230	158	6.7	20.0	21	7.4	86	--	--	47
26...	1415	99	204	6.4	19.5	16	7.6	388	--	--	65
SEP											
14...	0900	27	305	6.7	17.0	3.0	8.4	<10	44	800	110

K = Results based on non-ideal colony count.

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Acidity (mg/L as $CaCO_3$)	Calcium dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as mg)	Sodium, dis-solved (mg/L as Na)	Percent Sodium	Sodium ad-sorp-tion ratio	Potas-sium, dis-solved (mg/L as K)	Alka-linity field (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Silica, dis-solved (mg/L as SiO_2)
DEC											
15...	0.0	18	12	6.9	14	0.3	1.4	6	80	10	6.9
JAN											
20...	--	12	18	9.8	17	.4	.9	7	80	10	7.1
FEB											
03...	4.0	8.2	4.3	13	40	.9	3.4	0	30	21	6.0
03...	5.0	7.9	3.9	8.3	31	.6	2.9	4	25	13	3.9
04...	8.0	8.3	5.0	7.3	26	.5	2.8	4	35	11	3.9
05...	4.0	9.2	5.4	6.1	22	.4	2.5	3	35	10	4.2
16...	2.0	12	7.6	10	26	.6	.9	4	55	12	6.7
MAR											
23...	4.0	11	7.0	5.3	17	.3	.9	1	54	8.0	5.9
APR											
20...	4.0	11	6.8	4.8	16	.3	.9	3	50	8.0	6.2
26...	6.0	11	6.8	5.5	17	.3	1.0	4	55	8.0	6.0
26...	3.0	8.4	4.7	4.2	18	.3	1.0	4	30	6.0	5.5
27...	4.0	10	5.8	4.0	15	.2	.8	5	35	6.0	5.5
27...	3.0	9.1	5.6	4.0	16	.3	.9	5	30	6.0	5.7
MAY											
25...	3.0	14	9.8	6.8	16	.3	.8	6	60	7.0	6.5
JUN											
22...	--	14	9.2	5.8	15	.3	1.0	7	60	6.0	3.4
JUL											
27...	5.0	20	18	9.2	14	.4	1.4	2	130	8.0	6.8
AUG											
25...	21	12	7.5	4.1	12	.2	1.5	4	50	7.0	5.2
25...	5.0	10	5.3	4.2	16	.3	1.3	6	35	7.0	5.9
25...	3.0	10	5.4	4.8	18	.3	1.2	8	30	8.0	6.6
26...	5.0	13	7.8	5.3	15	.3	1.4	6	75	7.0	2.9
SEP											
14...	5.0	20	14	10	16	.4	3.3	2	90	9.0	7.1

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitrogen, nitrate total (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, organic dissolved (mg/L as N)	Nitrogen, ammonia + organic t)tal (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, total (mg/L as N)
DEC											
15...	0.81	0.79	0.010	0.010	0.200	0.200	0.30	0.30	0.50	0.50	1.3
JAN											
20...	1.1	1.10	.010	.010	.180	.180	.65	.43	.83	.61	1.9
FEB											
03...	1.5	1.50	.020	.020	.290	.290	1.1	1.1	1.40	1.4	2.9
03...	1.8	1.80	.020	.010	.250	.250	.35	.28	.70	.53	2.5
04...	1.6	1.60	.020	.010	.290	.290	.31	.31	.60	.60	2.2
05...	1.2	1.20	.010	.010	.150	.150	.62	.62	.77	.77	2.0
16...	1.1	1.10	.020	.020	.110	.110	.69	.49	.80	.60	1.9
MAR											
23...	.58	.56	<.010	<.010	.070	.070	.23	.23	.30	.30	.90
APR											
20...	.89	.89	.010	.010	.120	.120	1.1	1.1	1.20	1.2	2.1
26...	.63	.61	.010	.010	.250	.250	1.0	1.0	1.20	1.2	1.8
26...	.79	.79	.010	.010	.120	.120	.83	.83	.95	.95	1.8
27...	.65	.65	.010	.010	.120	.120	.78	.78	.90	.90	1.6
27...	.75	.75	.010	.010	.080	.080	.72	.72	.80	.80	1.6
MAY											
25...	.35	.35	.010	.010	.220	.220	1.4	1.2	1.60	1.4	2.0
JUN											
22...	1.1	1.10	<.010	<.010	.130	.130	.87	.87	1.00	1.0	--
JUL											
27...	.31	.31	.010	.010	.620	.620	.60	.30	1.20	.92	1.5
AUG											
25...	.51	.49	.010	.010	.170	.170	2.2	.83	2.40	1.0	2.9
25...	.58	.58	.020	.010	.130	.130	.87	.67	1.00	.80	1.6
25...	.78	.78	.020	.020	.110	.110	1.2	.69	1.30	.80	2.1
26...	.89	.87	.010	.010	.150	.150	--	--	--	--	--
SEP											
14...	.45	.45	.010	.010	.820	.820	.78	.78	1.60	1.6	2.1

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitrogen dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, total recoverable (µg/L) as Al)	Aluminum, dissolved (µg/L) as Al)	Chromium, total recoverable (µg/L) as Cr)	Copper, total recoverable (µg/L) as Cu)	Iron, total recoverable (µg/L) as Fe)	Iron, dissolved (µg/L) as Fe)
DEC											
15...	1.3	0.070	0.040	<0.010	--	1,000	100	--	--	2,500	860
JAN											
20...	1.7	.060	.030	.010	.010	1,200	40	--	--	3,100	1,500
FEB											
03...	2.9	.280	.060	.010	.010	4,700	470	30	20	7,700	440
03...	2.3	.130	.040	.060	.010	1,500	90	20	20	2,200	210
04...	2.2	.120	.020	.020	.010	1,300	140	10	20	2,600	760
05...	2.0	.070	.020	.030	.010	1,100	100	20	30	1,700	630
16...	1.7	.040	.020	.010	.010	680	100	--	--	1,800	1,000
MAR											
23...	.90	.030	.010	<.010	<.010	660	70	--	--	2,600	1,100
APR											
20...	2.1	.040	.020	.010	.010	620	90	--	--	1,800	650
26...	1.8	.060	.010	<.010	<.010	1,800	130	<10	10	3,400	800
26...	1.8	.050	.020	<.010	<.010	1,300	500	<10	10	2,200	340
27...	1.6	.040	.010	<.010	<.010	1,100	--	40	20	1,300	400
27...	1.6	.040	.020	--	<.010	640	330	<10	30	1,200	430
MAY											
25...	1.8	.030	.010	<.010	<.010	580	90	--	--	970	310
JUN											
22...	--	.040	.020	<.010	<.010	500	50	--	--	1,100	300
JUL											
27...	1.2	.050	.010	<.010	<.010	690	30	--	--	1,200	430
AUG											
25...	1.5	.280	.020	<.010	<.010	66,000	120	40	220	100,000	40
25...	1.4	.250	.020	.010	<.010	6,700	240	<10	60	15,000	90
25...	1.6	.120	.020	<.010	<.010	1,200	150	<10	20	2,800	120
26...	--	.030	.030	.010	.010	960	60	<10	20	1,600	460
SEP											
14...	2.1	.040	.040	.010	.010	300	40	--	--	410	70

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Lead, total recov-erable (µg/L as Pb)	Manga-nese, total recov-erable (µg/L as Mn)	Manga-nese, dis-solved (µg/L as Mn)	Mercury total recov-erable (µg/L as Hg)	Zinc, total recov-erable (µg/L as Zn)	Carbon, organic total (mg/L as C)	Carbon, organic dis-solved (mg/L as C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment, dis-charge, sus-pended (ton/d)	Sed. susp. sieve diam. percent finer than 0.062 mm
DEC										
15...	--	1,200	1,200	--	--	1.7	1.3	22	5.1	--
JAN										
20...	--	1,100	1,100	--	--	2.2	2.2	28	4.5	--
FEB										
03...	18	570	400	<2.0	100	5.0	--	265	298	77
03...	8	410	350	<2.0	60	5.6	4.8	89	142	68
04...	6	550	540	<2.0	90	4.5	4.5	42	44	91
05...	4	540	530	<2.0	80	--	7.0	26	9.8	93
16...	--	740	720	--	--	2.6	2.5	14	4.0	--
MAR										
23...	--	640	640	--	--	--	--	20	12	--
APR										
20...	--	580	550	--	--	1.7	1.7	21	12	--
26...	30	790	790	<2.0	60	--	2.2	66	43	77
26...	24	460	460	<2.0	<10	--	2.4	48	43	66
27...	23	540	510	<2.0	60	--	2.4	34	29	70
27...	20	470	460	<2.0	90	1.3	<1.0	21	17	61
MAY										
25...	--	830	830	--	--	<1.0	<1.0	8	1.6	--
JUN										
22...	--	770	670	--	--	<1.0	--	22	7.5	--
JUL										
27...	--	2,000	2,000	--	--	1.1	--	9	.83	--
AUG										
25...	172	2,300	790	<2.0	310	7.0	--	3,900	3,920	82
25...	40	770	530	<2.0	130	--	--	523	555	73
25...	<5	540	540	<2.0	80	--	3.2	88	55	82
26...	<5	800	720	<2.0	110	4.0	1.4	26	6.9	88
SEP										
14...	--	1,300	1,300	--	--	--	2.3	6	.44	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED SEDIMENT, OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Temper-ature (°C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment, dis-charge, sus-pended (ton/d)	Sed. susp. fall. diam. percent finer than 0.004 mm	Sed. susp. fall diam. percent finer than 0.008 mm
JAN							
04...	1325	650	--	233	409	26	36
04...	1326	612	--	233	385	26	36
FEB							
03...	1830	592	2.0	135	216	39	40
APR							
03...	1850	836	10.5	1,150	2,600	30	41
MAY							
29...	0640	566	--	42	64	66	75
AUG							
25...	1400	314	22.5	251	213	46	62

Date	Sed susp. fall diam. percent finer than 0.016 mm	Sed. susp. fall diam. percent finer than 0.031 mm	Sed. susp. sieve diam. percent finer than 0.062 mm	Sed. susp. sieve diam. percent finer than 0.125 mm	Sed. susp. sieve diam. percent finer than 0.250 mm	Sed. susp. sieve diam. percent finer than 0.500 mm	Sed. susp. sieve diam. percent finer than 1.00 mm
JAN							
04...	48	67	78	88	95	99	100
04...	48	67	78	88	95	99	100
FEB							
03...	57	69	78	86	94	99	100
APR							
03...	51	61	65	74	88	96	99
MAY							
29...	81	82	86	89	92	95	98
AUG							
25...	77	86	91	95	99	100	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

ONCE-DAILY

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	13.0	3.0	3.5	1.5	3.0	11.5	---	17.0	22.0	---	19.0
2	---	14.0	3.0	2.5	1.0	2.5	12.0	17.0	---	---	---	23.5
3	---	12.0	4.0	2.0	1.5	2.0	10.5	---	15.0	16.0	---	21.0
4	---	11.0	5.0	4.0	2.5	1.5	5.0	17.5	15.0	---	---	17.0
5	---	11.0	4.5	4.0	3.0	2.0	6.0	---	---	22.0	---	19.5
6	---	10.5	3.0	3.5	2.5	2.5	6.0	15.0	14.0	---	---	21.0
7	---	9.0	3.5	4.0	1.0	1.5	6.5	---	16.5	21.0	---	17.0
8	---	10.0	4.5	1.5	2.0	1.5	9.0	16.0	14.0	---	---	17.0
9	---	8.5	3.0	1.0	1.5	1.0	---	---	16.0	20.5	---	20.5
10	---	7.5	2.0	.5	1.5	1.5	8.0	13.5	14.5	---	---	22.0
11	---	9.5	1.5	.5	2.0	3.0	---	---	---	22.5	21.0	21.5
12	---	7.5	2.5	.5	2.0	3.5	10.5	18.5	14.0	---	---	21.0
13	---	7.0	2.0	.5	1.5	4.0	---	---	12.5	23.0	22.0	22.5
14	---	8.0	1.0	.5	2.5	6.0	11.5	19.5	12.5	---	---	21.5
15	---	9.0	1.5	.5	2.0	4.5	---	---	19.0	20.0	---	21.5
16	---	9.0	1.5	.5	3.0	4.0	14.0	22.0	17.5	---	23.5	19.5
17	---	9.0	1.0	.5	2.5	4.0	---	---	19.0	24.5	22.0	18.5
18	---	9.0	1.0	.5	2.0	6.5	13.5	22.0	---	---	23.0	18.5
19	---	9.5	1.0	.5	2.0	6.0	---	---	19.0	21.5	23.0	17.0
20	---	9.0	1.0	.5	2.0	6.0	11.5	18.5	---	---	20.0	14.5
21	---	6.5	.5	.5	2.0	6.0	---	---	18.0	24.5	17.5	16.5
22	---	5.5	1.0	.5	2.5	7.0	13.0	16.5	16.5	---	18.5	14.5
23	12.5	5.5	1.5	.5	4.5	9.0	---	---	15.0	26.5	19.5	15.5
24	8.5	5.0	1.5	.5	4.0	8.0	16.0	12.0	---	---	23.0	17.5
25	7.0	4.0	2.0	.5	2.5	9.5	---	14.0	21.0	---	22.5	16.0
26	11.0	4.5	2.0	.5	1.5	7.0	12.5	21.5	---	---	22.0	15.5
27	13.0	6.0	2.5	.5	1.0	8.0	12.0	---	19.5	27.0	19.0	16.5
28	12.0	5.0	1.0	.5	2.0	8.0	16.0	16.5	---	---	18.5	17.0
29	10.0	5.0	2.0	.5	---	6.5	---	14.5	20.0	25.0	17.0	18.5
30	11.5	4.5	1.5	.5	---	12.0	14.5	19.0	---	---	19.0	17.0
31	10.0	---	2.0	.5	---	9.0	---	19.0	---	---	20.0	---
Mean	10.5	8.0	2.0	1.0	2.0	5.0	11.0	17.5	16.5	22.5	20.5	18.5

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)
		OCTOBER			NOVEMBER			DECEMBER	
1	---	---	---	36	8	0.78	27	16	1.2
2	---	---	---	34	8	.73	68	25	4.6
3	---	---	---	28	8	.60	57	7	1.1
4	---	---	---	23	11	.68	48	5	.65
5	---	---	---	22	8	.48	41	5	.55
6	---	---	---	56	70	12	36	9	.87
7	---	---	---	45	9	1.1	31	8	.67
8	---	---	---	36	6	.58	47	26	3.3
9	---	---	---	31	12	1.0	49	13	1.7
10	---	---	---	28	14	1.1	41	6	.66
11	---	---	---	28	13	.98	38	7	.72
12	---	---	---	26	13	.91	33	6	.53
13	---	---	---	23	10	.62	32	5	.43
14	---	---	---	22	12	.71	49	13	2.5
15	---	---	---	24	10	.65	68	19	3.5
16	---	---	---	26	12	.84	41	11	1.2
17	---	---	---	26	14	.98	31	8	.67
18	---	---	---	25	16	1.1	28	6	.45
19	---	---	---	24	9	.58	25	6	.41
20	---	---	---	33	19	1.7	30	5	.41
21	---	---	---	33	8	.71	26	6	.42
22	---	---	---	29	5	.39	31	9	.75
23	---	---	---	28	5	.38	42	7	.79
24	42	16	1.8	25	4	.27	56	7	1.1
25	27	3	.22	24	5	.32	56	7	1.1
26	30	13	1.6	22	4	.24	49	6	.79
27	115	122	35	23	4	.25	48	4	.52
28	86	46	12	22	6	.36	45	12	1.5
29	59	13	2.1	21	5	.28	45	11	1.3
30	49	12	1.6	21	3	.17	41	10	1.1
31	41	12	1.3	---	---	---	36	10	.97
Total	478	---	55.62	844	---	31.49	1,295	--	36.46

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)
		JANUARY			FEBRUARY			MARCH	
1	72	23	4.5	360	54	52	92	12	3.0
2	86	28	6.5	180	48	23	97	12	3.1
3	68	21	3.9	339	111	145	99	13	3.5
4	458	288	416	424	46	53	90	15	3.6
5	403	46	50	239	25	16	103	21	5.8
6	246	25	17	177	18	8.6	106	16	4.6
7	171	15	6.9	140	20	7.6	144	29	11
8	136	11	4.0	110	16	4.8	174	27	13
9	111	11	3.3	100	16	4.3	126	25	8.5
10	88	9	2.1	97	15	3.9	103	26	7.2
11	72	20	3.9	86	15	3.5	113	44	13
12	66	20	3.6	78	16	3.4	262	224	172
13	62	11	1.8	72	22	4.3	275	177	139
14	60	18	2.9	66	12	2.1	288	69	54
15	59	17	2.7	70	13	2.5	268	35	25
16	58	16	2.5	133	30	11	236	24	15
17	57	21	3.2	153	19	7.8	246	19	13
18	57	13	2.0	108	19	5.5	236	33	21
19	58	13	2.0	99	18	4.8	243	31	20
20	60	23	3.7	88	16	3.8	239	17	11
21	59	17	2.7	108	19	5.5	262	47	33
22	58	16	2.5	136	20	7.3	249	33	22
23	57	20	3.1	159	19	8.2	220	23	14
24	56	20	3.0	168	19	8.6	202	16	8.7
25	55	15	2.2	123	13	4.3	189	23	12
26	54	15	2.2	101	19	5.2	214	36	21
27	53	16	2.3	97	14	3.7	186	22	11
28	52	18	2.5	94	10	2.5	162	22	9.6
29	51	18	2.5	---	---	---	142	14	5.4
30	50	25	3.4	---	---	---	131	16	5.7
31	60	27	4.4	---	---	---	165	139	76
TOTAL	3,053	---	573.3	4,105	---	412.2	5,662	---	764.7

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)
		APRIL			MAY			JUNE	
1	196	88	47	217	11	6.4	177	82	71
2	147	24	9.5	202	10	5.5	473	84	112
3	476	838	1,770	177	10	4.8	375	75	81
4	764	200	413	162	11	4.8	379	28	29
5	477	51	66	147	12	4.8	488	250	529
6	403	33	36	131	12	4.2	884	114	274
7	333	25	22	123	12	4.0	613	56	93
8	294	18	14	120	12	3.9	428	34	39
9	278	19	14	118	11	3.5	339	22	20
10	265	17	12	106	10	2.9	285	20	15
11	285	15	12	94	12	3.0	262	18	13
12	285	14	11	92	15	3.7	227	16	9.8
13	278	16	12	92	12	3.0	362	64	77
14	262	18	13	84	8	1.8	389	23	24
15	233	21	13	77	10	2.1	291	19	15
16	211	22	13	75	13	2.6	252	29	21
17	214	69	50	72	11	2.1	307	28	23
18	301	101	83	66	9	1.6	233	29	18
19	217	35	21	64	8	1.4	199	20	11
20	199	13	7.0	66	8	1.4	174	25	12
21	177	8	3.8	62	8	1.3	150	16	6.5
22	165	8	3.6	77	10	2.1	126	19	6.5
23	165	8	3.6	99	8	2.1	133	14	5.0
24	156	9	3.8	88	7	1.7	113	18	5.5
25	150	9	3.6	75	7	1.4	101	13	3.5
26	214	58	44	62	2	.33	94	16	4.1
27	281	34	26	53	1	.14	90	11	2.7
28	310	43	36	90	136	66	84	17	3.9
29	259	14	9.8	443	151	220	249	947	860
30	233	13	8.2	233	14	8.8	211	66	42
31	---	---	---	193	25	13	---	---	---
TOTAL	8,228	---	2,780.9	3,760	---	384.37	8,488	---	2,426.5

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean Concentration (mg/L)	Sediment discharge (ton/d)
		JULY			AUGUST			SEPTEMBER	
1	118	26	8.3	45	11	1.3	42	11	1.2
2	97	24	6.3	41	13	1.4	49	20	2.6
3	144	168	101	41	13	1.4	53	12	1.7
4	208	64	43	38	10	1.0	38	7	.72
5	128	16	5.5	37	7	.70	35	6	.57
6	106	11	3.1	33	6	.53	33	8	.71
7	90	10	2.4	34	6	.55	33	8	.71
8	84	11	2.5	421	787	2,620	33	9	.80
9	74	12	2.4	528	94	156	31	9	.75
10	66	10	1.8	291	38	30	30	7	.57
11	66	15	2.7	174	21	9.9	29	10	.78
12	128	116	49	131	20	7.1	29	17	1.3
13	79	18	3.8	88	6	1.4	29	8	.63
14	62	15	2.5	72	6	1.2	29	6	.47
15	57	11	1.7	62	8	1.3	28	4	.30
16	54	13	1.9	57	10	1.5	28	3	.23
17	51	10	1.4	54	8	1.2	26	8	.56
18	56	18	2.7	54	9	1.3	26	5	.35
19	54	13	1.9	46	8	.99	26	5	.35
20	59	16	2.5	48	15	1.9	27	6	.44
21	57	15	2.3	53	7	1.0	28	3	.23
22	48	10	1.3	41	10	1.1	42	24	2.7
23	43	4	.46	41	15	1.7	72	29	5.6
24	41	3	.33	38	10	1.0	38	8	.82
25	38	5	.51	233	607	572	32	8	.69
26	38	7	.72	111	27	8.1	28	5	.38
27	37	10	1.0	72	14	2.7	126	141	60
28	90	257	93	61	11	1.8	68	22	4.0
29	62	18	3.0	53	11	1.6	48	11	1.4
30	48	11	1.4	43	10	1.2	38	8	.82
31	48	12	1.6	41	9	1.0	---	---	---
TOTAL	2,331	---	352.02	3,082	---	3,433.87	1174	---	92.38
YEAR	42,500		11,343.81						

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

DATE	Time	Stream-flow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (Units)	Temperature (°C)	Turbidity (FTU)	Oxygen, dissolved (mg/L)	Oxygen demand, chemical (high level) (mg/L)	Coliform, fecal, 0.7 UM-MF (Cols./100 mL)	Streptococci fecal, KF Agar (Cols. per 100 mL)	Hardness (mg/L as $CaCO_3$)
DEC											
15...	1115	24	88	7.0	0.5	4.0	14.0	24	25	100	20
JAN											
18...	1015	--	85	7.6	.0	--	10.0	<10	17	73	18
20...	1500	21	68	6.3	.5	5.0	13.6	--	16	84	27
FEB											
03...	1830	666	72	6.2	.5	120	10.4	26	--		15
04...	0150	452	72	6.3	.5	78	13.0	19	--		18
04...	1245	244	78	6.2	1.0	30	13.0	<10	--	--	21
05...	1110	123	83	6.5	1.0	13	13.6	<10	K260	2,000	22
16...	0915	55	86	6.7	2.0	17	13.0	--	800	>240	24
MAR											
23...	1130	78	59	6.7	4.5	5.0	13.2	<10	100	K61	<20
APR											
20...	1345	80	65	6.9	11.0	6.0	10.2	<10	K32	170	20
26...	1430	68	61	7.0	13.0	8.0	10.0	--	--	--	16
26...	2000	228	64	6.9	12.0	35	10.0	--	--	--	17
27...	0100	198	62	6.6	12.0	24	10.0	--	--	--	18
27...	1215	116	63	7.1	13.5	9.0	10.8	--	--	--	18
MAY											
25...	1330	21	63	7.3	14.5	4.0	8.8	<10	400	200	<20
JUN											
22...	1200	57	63	7.8	17.5	--	10.2	32	260	280	43
JUL											
27...	1300	6.0	59	7.4	23.5	--	8.4	13	160	270	20
AUG											
25...	0430	17	81	7.1	18.0	28	7.6	15	--	--	9
25...	1110	90	76	7.2	18.5	33	7.2	32	--	--	5
25...	1635	53	9	7.2	20.0	23	7.0	28	--	--	25
26...	1145	25	88	7.5	18.0	11	8.6	56	--	--	26
SEP											
14...	1130	5.7	75	8.4	18.0	2.5	9.4	<10	120	67	30

K = Results based on non-ideal colony count.

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Acidity (mg/L as $CaCO_3$)	Calcium dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as Mg)	Sodium, dis- solved (mg/L as Na)	Percent sodium	Sodium ad- sorp- tion ratio	Potas- sium, dis- solved (mg/L as K)	Alka- linity field (mg/L as $CaCO_3$)	Sulfate dis- solved (mg/L as SO_4)	Chlo- ride, dis- solved (mg/L as CL)	Silica, dis- solved (mg/L as SIO_2)
DEC											
15...	0.0	6.1	2.8	4.5	26	0.4	1.1	11	5.0	8.0	5.1
JAN											
18...	1.0	3.8	2.0	3.3	28	.3	.9	7	25	7.0	6.2
20...	.0	2.5	5.1	3.0	19	.3	.9	5	5.0	6.0	.5
FEB											
03...	10	3.8	1.6	3.8	28	.4	3.8	2	10	7.0	2.1
04...	4.0	4.2	1.8	3.8	27	.4	3.2	4	10	7.0	2.6
04...	2.0	4.8	2.2	4.2	27	.4	2.5	4	10	8.0	3.9
05...	.0	5.2	2.3	4.3	27	.4	2.1	3	5.0	8.0	3.9
16...	.0	5.3	2.5	4.7	27	.4	2.7	8	10	8.0	4.4
MAR											
23...	.0	--	--	--	--	--	--	3	6.0	6.0	--
APR											
20...	3.0	4.3	1.9	2.6	23	.3	.7	7	10	6.0	4.6
26...	.0	3.8	1.7	2.4	23	.3	.8	1	<5.0	5.0	4.3
26...	4.0	4.1	1.6	2.7	25	.3	1.0	7	<5.0	6.0	4.4
27...	2.0	4.4	1.7	2.3	21	.2	1.1	6	5.0	5.0	4.6
27...	.0	3.9	1.9	3.0	26	.3	.9	7	5.0	6.0	5.0
MAY											
25...	2.0	4.3	2.1	3.1	25	.3	.7	10	5.0	6.0	5.4
JUN											
22...	.0	4.7	2.3	3.1	23	.3	.7	11	10	5.0	5.4
JUL											
27...	.0	4.0	1.8	3.1	27	.3	.9	12	15	6.0	4.3
AUG											
25...	3.0	5.4	2.4	2.5	18	.2	1.4	5	5.0	7.0	4.6
25...	2.0	5.3	2.2	2.4	18	.2	1.5	13	5.0	7.0	5.4
25...	2.0	5.9	2.5	2.9	19	.3	1.8	12	5.0	8.0	6.2
26...	2.0	6.0	2.7	2.6	17	.2	1.7	15	10	7.0	5.9
SEP											
14...	.0	5.2	2.5	3.8	23	.3	2.9	10	5.0	6.0	4.2

Table 9.—Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitro-gen, nitrate total (mg/L as N)	Nitro-gen, nitrate dis-solved (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, nitrite dis-solved (mg/L as N)	Nitro-gen, ammonia total (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Nitro-gen, organic total (mg/L as N)	Nitro-gen, organic dis-solved (mg/L as N)	Nitro-gen,am-monia + organic total (mg/L as N)	Nitro-gen,am-monia + organic dis. (mg/L as N)	Nitro-gen, total (mg/L as N)
DEC											
15...	2.2	2.00	0.010	0.010	0.030	0.020	0.58	0.58	0.61	0.60	2.8
JAN											
18...	2.6	1.80	<.010	<.010	.110	.110	.49	.48	.60	.59	--
20...	2.6	--	.010	--	.030	.030	.80	.80	.83	.83	3.5
FEB											
03...	1.4	1.40	.030	.010	.300	.260	.40	.19	.70	.45	2.1
04...	1.7	1.70	.020	.010	.220	.180	.89	.27	1.10	.45	2.9
04...	2.6	2.60	.010	.010	.140	.130	.56	.56	.70	.69	3.3
05...	2.3	1.80	.010	.010	.080	.080	.62	.53	.70	.61	3.0
16...	1.9	1.90	.020	.010	.180	.150	.75	.75	.93	.90	2.8
MAR											
23...	1.7	1.70	<.010	<.010	.060	.010	.29	.29	.35	.30	2.0
APR											
20...	1.6	1.60	.010	.010	.030	.030	.87	.87	.90	.90	2.5
26...	1.2	1.20	.010	.010	.060	.050	.75	.75	.81	.80	2.0
26...	1.0	1.00	.010	.010	.080	.070	.92	.83	1.00	.90	2.0
27...	1.1	1.10	.020	.010	.100	.090	.86	.86	.96	.95	2.1
27...	1.2	1.20	.010	.010	.030	.030	.80	.80	.83	.83	2.0
MAY											
25...	.91	.91	.010	.010	.030	.030	1.3	1.2	1.30	1.2	2.2
JUN											
22...	1.9	1.90	<.010	<.010	.040	.040	.96	.86	1.00	.90	--
JUL											
27...	.53	.53	.010	.010	.020	.020	.38	.38	.40	.40	.94
AUG											
25...	1.4	1.40	.010	.010	.070	.070	1.4	1.2	1.50	1.3	2.9
25...	1.3	1.30	.020	.010	.020	.020	.78	.68	.80	.70	2.1
25...	1.4	1.40	.030	.020	.040	.010	.99	.99	1.00	1.0	2.4
26...	1.6	1.60	.010	.010	.020	.010	.99	.99	1.00	1.0	2.6
SEP											
14...	.87	.87	.010	.010	.020	.020	.40	.40	.42	.42	1.3

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitrogen dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, total recoverable (μg/L as AL)	Aluminum, dissolved (μg/L as AL)	Chromium, total recoverable (μg/L as Cr)	Copper, total recoverable (μg/L as Cu)	Iron, total recoverable (μg/L as Fe)	Iron, dissolved (μg/L AS Fe)
DEC											
15...	2.6	0.050	0.040	<0.010	<0.010	410	110	--	--	850	210
JAN											
18...	--	.030	.010	<.010	<.010	90	30	--	--	120	40
20...	--	.030	.030	.010	<.010	70	30	--	--	100	50
FEB											
03...	1.9	.310	.100	.050	.020	3,400	90	50	30	7,900	100
04...	2.2	.220	.080	.040	.040	2,200	70	30	30	4,300	50
04...	3.3	.110	.040	.020	.020	1,900	30	30	20	1,900	50
05...	2.4	.070	.030	.030	--	760	80	--	30	990	80
16...	2.8	.100	.060	.050	.040	990	60	--	--	980	80
MAR											
23...	2.0	.020	.010	<.010	<.010	80	--	--	--	170	--
APR											
20...	2.5	.070	.020	--	<.010	140	110	--	--	790	40
26...	2.0	.040	.020	<.010	<.010	670	140	<10	10	250	80
26...	1.9	.100	.030	.010	.010	3,100	200	<10	20	2,200	150
27...	2.1	.080	.040	.010	.010	1600	--	40	30	1,700	170
27...	2.0	.040	.030	--	<.010	490	160	10	10	470	80
MAY											
25...	2.1	.030	.020	<.010	<.010	400	160	--	--	200	110
JUN											
22...	--	.030	.020	<.010	<.010	160	<10	--	--	400	90
JUL											
27...	.94	.050	.020	<.010	<.010	380	70	--	--	310	100
AUG											
25...	2.7	.090	.040	<.010	<.010	1,000	90	10	30	1,000	80
25...	2.0	.120	.030	.010	<.010	1,200	320	10	20	1,400	150
25...	2.4	.080	.040	.010	.010	710	330	<10	10	940	180
26...	1.0	.050	.040	.010	.010	420	160	<10	20	450	60
SEP											
14...	1.3	.030	.030	.010	.010	240	160	--	--	130	90

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Lead, total recov-erable (μg/L as Pb)	Manga-nese, total recov-erable (μg/L as Mn)	Manga-nese, dis-solved (μg/L as Mn)	Mercury total recov-erable (μg/L as Hg)	Zinc, total recov-ersble (μg/L as Zn)	Carbon, organic total (mg/L as C)	Carbon, organic dis-solved (mg/L as C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment, dis-charge, sus-pended (ton/d)	Sed. susp. sieve diam. percent finer than 0.062 mm
DEC										
15...	--	80	10	--	--	1.5	1.1	1	0.06	--
JAN										
18...	--	30	30	--	--	<1.0	<1.0	--	--	--
20...	--	30	20	--	--	1.8	1.8	3	.17	--
FEB										
03...	11	310	150	<2.0	40	8.8	7.0	201	361	91
04...	10	200	100	<2.0	30	5.9	5.0	149	182	87
04...	<5	140	80	<2.0	30	4.6	3.7	89	59	91
05...	7	70	40	<2.0	--	3.3	2.6	40	13	82
16...	--	40	10	--	--	5.7	5.2	27	4.0	--
MAR										
23...	--	30	--	--	--	--	--	5	1.1	--
APR										
20...	--	30	10	--	--	2.1	1.7	11	2.4	--
26...	5	50	50	<2.0	<10	--	2.2	13	2.4	77
26...	40	120	90	<2.0	<10	--	3.9	96	59	82
27...	25	100	50	<2.0	20	--	4.3	51	27	84
27...	<5	40	30	<2.0	20	1.5	1.5	13	4.1	86
MAY										
25...	--	30	20	--	--	1.1	1.1	5	.28	--
JUN										
22...	--	670	20	--	--	1.1	--	9	1.4	--
JUL										
27...	--	40	20	--	--	<1.0	--	22	.36	--
AUG										
25...	<5	70	30	<2.0	50	2.6	--	91	4.2	52
25...	20	80	20	<2.0	20	3.3	--	58	14	93
25...	<5	50	20	<2.0	20	--	4.4	33	4.7	89
26...	<5	40	10	<2.0	30	--	4.0	11	.74	85
SEP										
14...	--	40	20	--	--	1.4	1.4	5	.08	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED-SEDIMENT, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Temper-ature (°C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment, dis-charge, sus-pended (ton/d)	Sed. susp. fall diam. percent finer than 0.004 mm	Sed. susp. fall diam. percent finer than 0.008 mm
JAN							
04...	1315	536	4.5	364	527	37	52
FEB							
03...	1900	984	--	218	579	43	56
APR							
03...	1820	824	10.0	1,360	3,030	41	55
MAY							
29...	0615	335	--	67	61	60	72
AUG							
25...	1330	77	--	40	8.3	74	--

Date	Sed. susp. fall diam. percent finer than 0.016 mm	Sed. susp. fall diam. percent finer than 0.031 mm	Sed. susp. seive diam. percent finer than 0.062 mm	Sed. susp. seive diam. percent finer than 0.125 mm	Sed. susp. sieve diam. percent finer than 0.250 mm	Sed. susp. sieve diam. percent finer than 0.500 mm	Sed. susp. sieve diam. percent finer than 1.00 mm
JAN							
04...	68	80	89	96	99	100	--
FEB							
03...	65	73	93	95	97	99	100
APR							
03...	72	82	92	97	99	100	--
MAY							
29...	84	92	96	97	99	100	--
AUG							
25...	--	--	95	--	--	--	100

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SPECIFIC CONDUCTANCE (MICROSIEMENS/CM at 25°C), WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

ONCE-DAILY

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1										---	58	123
2										---	57	77
3										---	59	70
4										---	60	67
5										---	58	63
6										---	59	64
7										---	56	64
8										---	56	64
9										---	61	69
10										75	57	85
11										---	55	72
12										---	55	71
13										68	56	70
14										66	58	67
15										66	56	71
16										66	58	68
17										63	58	70
18										63	59	76
19										61	56	72
20										65	55	73
21										75	53	75
22										66	56	73
23										66	53	75
24										65	52	71
25										64	52	71
26										63	54	72
27										62	58	71
28										62	60	68
29										62	81	68
30										64	65	67
31										60	60	---
MEAN										65	58	72

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SPECIFIC CONDUCTANCE (MICROSIEMENS/CM AT 25°C), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982
ONCE-DAILY

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	68	102	78									
2	66	98	85									
3	67	98	96									
4	74	96	94									
5	74	93	95									
6	72	98	94									
7	70	101	90									
8	73	101	90									
9	72	98	89									
10	---	97	90									
11	74	94	91									
12	72	93	90									
13	72	92	90									
14	70	89	90									
15	70	87	82									
16	71	91	112									
17	72	90	81									
18	72	94	111									
19	70	93	113									
20	75	90	107									
21	79	90	113									
22	83	91	---									
23	82	91	112									
24	78	90	107									
25	94	90	112									
26	90	90	115									
27	87	85	107									
28	116	84	---									
29	118	83	---									
30	111	83	---									
31	106	---	---									
MEAN	80	92	97									

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

ONCE-DAILY

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1										---	24.0	22.0
2										---	24.5	21.0
3										---	21.5	21.0
4										---	24.0	20.5
5										---	23.5	21.0
6										---	22.0	22.0
7										---	23.5	21.0
8										---	20.5	20.5
9										---	24.0	19.5
10										25.5	26.0	18.5
11										---	26.0	21.0
12										---	25.0	22.0
13										25.0	24.5	21.0
14										25.0	24.5	23.5
15										23.5	22.0	21.0
16										22.0	23.5	18.0
17										24.0	22.0	19.0
18										24.5	21.5	18.0
19										26.0	22.0	16.5
20										24.5	21.5	17.5
21										24.0	21.5	17.0
22										21.5	20.5	17.5
23										21.5	17.5	15.0
24										20.0	21.0	15.0
25										20.5	21.0	15.5
26										21.0	21.5	16.5
27										24.0	23.0	17.0
28										21.5	23.0	16.5
29										21.5	23.0	14.0
30										22.5	21.0	13.0
31										23.0	22.5	---
MEAN										23.0	22.5	18.5

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

ONCE-DAILY

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	12.5	11.5	2.0	3.0	0.5	2.0	11.0	---	17.5	21.0	---	20.5
2	12.5	13.0	2.0	2.0	.5	2.0	10.5	17.5	16.0	---	---	24.0
3	11.5	11.5	3.5	2.0	1.0	1.0	10.0	---	15.5	17.0	---	22.5
4	12.0	10.5	4.5	4.5	2.0	1.0	5.5	17.0	15.0	---	---	18.0
5	15.0	10.0	4.5	3.5	2.0	1.0	7.0	---	---	22.5	---	19.5
6	14.5	10.0	2.5	3.0	2.0	1.5	6.0	16.0	14.5	---	---	20.5
7	12.5	9.0	3.0	4.5	1.0	1.5	4.0	---	17.0	19.5	---	18.0
8	12.5	8.0	4.0	1.5	1.0	1.0	6.0	16.0	14.0	---	---	17.0
9	11.0	7.5	2.5	1.0	1.0	1.0	---	---	16.0	23.0	---	20.0
10	---	6.5	1.5	.5	1.0	1.0	5.5	15.5	15.0	---	---	21.0
11	9.5	8.5	1.0	.5	1.0	2.5	---	---	---	23.5	20.5	20.0
12	11.0	6.5	1.5	.5	1.0	2.5	10.0	19.0	15.0	---	---	21.5
13	10.0	5.5	1.0	.5	1.0	3.0	---	---	13.0	24.5	21.0	22.5
14	10.0	6.5	1.0	.5	1.5	5.0	10.5	20.0	13.0	---	---	22.0
15	10.5	8.0	1.0	.5	1.5	4.0	---	---	18.0	22.0	---	21.0
16	11.0	8.0	1.0	.5	2.0	4.0	13.0	21.5	17.5	---	22.0	20.0
17	11.0	8.0	1.0	.0	2.0	4.5	---	---	19.0	26.0	22.0	19.0
18	10.0	8.0	1.0	.0	1.5	5.0	12.0	22.0	---	---	21.5	18.5
19	9.0	8.5	.5	.0	1.5	6.0	---	---	18.0	24.5	22.0	17.5
20	9.0	8.5	.5	.0	1.5	5.5	10.0	20.0	---	---	20.5	15.0
21	9.5	6.5	1.0	.0	1.5	6.0	---	---	17.5	25.0	18.5	17.0
22	12.0	5.0	1.0	.0	2.0	6.5	13.0	19.0	17.5	---	20.5	15.0
23	12.0	4.5	1.5	.0	3.0	8.0	---	---	16.5	26.0	19.5	15.5
24	9.0	4.0	2.0	.0	3.0	6.0	15.5	13.0	---	---	22.0	16.5
25	7.0	3.0	2.0	.0	1.5	9.5	---	14.5	20.0	---	21.0	16.5
26	9.5	3.0	1.5	.0	1.0	7.5	13.5	21.0	---	---	21.5	16.0
27	13.0	4.5	1.5	.0	1.0	5.5	13.0	---	20.5	26.5	19.0	17.0
28	13.0	4.5	1.5	.0	1.5	5.0	15.5	17.0	---	---	19.5	17.0
29	10.0	4.5	1.5	.0	---	4.0	---	15.5	21.0	24.0	17.0	18.0
30	10.5	3.5	1.0	.0	---	9.0	15.0	19.0	---	---	19.5	18.0
31	9.5	---	1.5	.5	---	9.5	---	18.0	---	---	20.5	---
MEAN	11.0	7.0	2.0	1.0	1.5	4.0	10.5	18.0	16.5	23.0	20.5	19.0

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

Day	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)
		JULY			AUGUST			SEPTEMBER	
1	---	---	---	11	7	0.21	6.9	7	0.13
2	---	---	---	9.8	8	.21	6.0	5	.08
3	---	---	---	9.8	9	.24	5.4	4	.06
4	---	---	---	11	10	.30	4.9	5	.07
5	---	---	---	9.8	7	.19	4.9	5	.07
6	---	---	---	8.6	6	.14	4.9	5	.07
7	---	---	---	8.0	8	.17	4.4	6	.07
8	---	---	---	11	10	.30	6.5	17	.30
9	---	---	---	9.8	8	.21	11	12	.36
10	---	---	---	8.0	5	.11	5.4	6	.09
11	---	---	---	7.4	6	.12	4.4	5	.06
12	---	---	---	7.4	7	.14	3.9	6	.06
13	---	---	---	6.9	6	.11	3.9	4	.04
14	---	---	---	6.5	5	.09	3.9	4	.04
15	---	---	---	6.9	5	.09	4.9	9	.12
16	17	---	---	7.4	5	.10	9.2	10	.25
17	15	---	---	6.0	4	.06	7.4	7	.14
18	14	---	---	4.9	8	.11	6.5	5	.09
19	13	---	---	4.9	8	.11	11	7	.21
20	50	---	---	4.4	5	.06	7.4	6	.12
21	96	---	---	3.9	4	.04	5.4	5	.07
22	61	---	---	3.9	5	.05	4.9	8	.11
23	32	---	---	4.4	5	.06	4.9	9	.12
24	23	9	0.56	4.4	5	.06	3.9	9	.09
25	21	11	.62	4.4	5	.06	3.5	10	.09
26	20	8	.43	4.4	5	.06	3.5	8	.08
27	19	8	.41	4.4	5	.06	3.5	7	.07
28	15	7	.28	3.9	5	.05	3.5	9	.09
29	16	7	.30	3.5	6	.06	3.2	8	.07
30	13	9	.32	3.5	5	.05	3.2	7	.06
31	12	9	.29	8.6	7	.16	---	---	---
TOTAL	437	---	3.21	208.8	---	3.78	162.3	---	3.28

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concentration (mg/L)	Sediment discharge (ton/d)
		OCTOBER			NOVEMBER			DECEMBER	
1	3.9	10	.11	9.8	2	0.05	8.6	1	0.02
2	7.4	15	.30	8.6	1	.02	45	6	.73
3	4.9	6	.08	8.0	3	.06	29	2	.16
4	3.9	6	.06	7.4	1	.02	24	3	.19
5	3.5	6	.06	7.4	2	.04	22	3	.18
6	3.9	7	.07	29	15	1.2	19	2	.10
7	6.0	9	.15	17	4	.18	17	3	.14
8	4.9	10	.13	13	3	.11	26	5	.35
9	3.9	8	.08	11	2	.06	24	7	.45
10	3.1	6	.05	11	2	.06	19	5	.26
11	3.1	7	.06	9.8	2	.05	17	3	.14
12	3.1	7	.06	8.6	1	.02	16	3	.13
13	3.1	6	.05	7.4	2	.04	16	5	.22
14	3.1	7	.06	7.4	1	.02	17	4	.18
15	3.5	8	.08	7.4	1	.02	22	3	.18
16	3.5	8	.08	8.6	1	.02	18	8	.39
17	3.9	7	.07	8.0	4	.09	17	6	.28
18	4.9	8	.11	7.4	4	.08	16	7	.30
19	9.2	7	.17	7.4	2	.04	15	6	.24
20	4.9	7	.09	11	2	.06	15	4	.16
21	3.9	7	.07	11	1	.03	14	5	.19
22	3.5	7	.07	8.6	1	.02	18	6	.29
23	6.5	9	.16	7.4	1	.02	30	6	.49
24	12	10	.32	7.4	1	.02	67	5	.90
25	4.9	5	.07	7.4	1	.02	64	6	1.0
26	4.9	8	.11	7.4	1	.02	58	6	.94
27	34	20	1.8	6.9	1	.02	55	3	.45
28	34	12	1.1	6.9	1	.02	51	6	.83
29	[illegible]	[illegible]	.21	6.5	1	.02	37	8	.80
30	13	3	.11	6.5	1	.02	29	8	[illegible]
31	11	2	.06	---	---	---	41	10	1.1
TOTAL	234.4	---	6.00	281.2	---	2.45	866.6	---	12.42

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)
		JANUARY			FEBRUARY			MARCH	
1	79	26	5.5	280	67	51	39	2	0.21
2	81	25	5.5	140	29	11	39	3	.32
3	66	15	2.7	260	180	126	36	3	.29
4	362	221	280	300	118	96	51	7	.96
5	267	55	46	94	48	12	47	7	.89
6	153	15	6.2	82	13	2.9	39	9	.95
7	111	9	2.7	72	11	2.1	99	108	48
8	79	7	1.5	62	18	3.0	77	26	5.4
9	70	5	.95	52	3	.42	57	7	1.1
10	60	8	1.3	48	4	.52	52	26	3.7
11	52	12	1.7	45	8	.97	80	70	22
12	46	7	.87	43	20	2.3	196	133	76
13	42	4	.45	41	8	.89	163	58	28
14	37	6	.60	39	8	.84	159	29	12
15	33	4	.36	46	15	1.9	132	9	3.2
16	29	4	.31	78	43	10	115	7	2.2
17	26	4	.28	71	14	2.7	121	7	2.3
18	24	5	.32	50	1	.14	111	7	2.1
19	23	4	.25	47	2	.25	109	6	1.8
20	22	3	.18	44	2	.24	101	5	1.4
21	21	1	.06	57	6	.92	98	6	1.6
22	20	1	.05	87	12	2.8	89	4	.96
23	20	1	.05	87	13	3.1	77	5	1.0
24	20	4	.22	83	10	2.2	68	3	.55
25	19	5	.26	60	3	.49	63	1	.17
26	19	2	.10	60	10	1.6	75	7	1.4
27	19	1	.05	63	4	.68	59	3	.48
28	19	1	.05	43	2	.23	50	2	.27
29	18	5	.24	---	---	---	47	2	.25
30	18	2	.10	---	---	---	44	2	.24
31	20	2	.11	---	---	---	56	7	1.3
TOTAL	1,875	---	358.96	2,434	---	337.19	2,549	---	221.04

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	mean discharge (ft^3/s)	Mean Concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean Concentration (mg/L)	Sediment discharge (ton/d)
		APRIL			MAY			JUNE	
1	68	22	4.0	94	5	1.3	102	57	50
2	56	6	.91	80	5	1.1	358	153	179
3	316	614	1,260	69	5	.93	242	44	29
4	370	244	289	58	5	.78	215	23	13
5	189	35	18	54	5	.73	288	71	80
6	163	16	7.0	49	6	.79	526	73	109
7	130	10	3.5	45	7	.85	326	31	27
8	110	8	2.4	44	9	1.1	213	22	13
9	106	8	2.3	40	8	.86	150	14	5.7
10	107	11	3.2	35	6	.57	115	11	3.4
11	131	12	4.2	31	5	.42	109	16	4.7
12	136	10	3.7	30	5	.41	86	9	2.1
13	142	8	3.1	30	5	.41	192	54	43
14	130	7	2.5	26	5	.35	223	25	15
15	105	6	1.7	23	6	.37	153	13	5.4
16	90	6	1.5	22	7	.42	118	15	4.8
17	85	13	3.0	20	6	.32	178	56	33
18	123	23	9.4	19	5	.26	110	12	3.6
19	84	6	1.4	18	6	.29	90	10	2.4
20	78	11	2.3	19	6	.31	75	8	1.6
21	72	9	1.7	19	6	.31	65	5	.88
22	63	6	1.0	26	9	.63	55	5	.74
23	57	4	.62	30	12	.97	62	21	3.5
24	53	6	.86	25	7	.47	46	7	.87
25	49	5	.66	21	4	.23	40	4	.43
26	109	34	18	17	1	.05	36	4	.39
27	145	26	12	15	3	.12	33	4	.36
28	208	38	23	39	88	18	30	4	.32
29	144	14	5.4	242	139	120	50	38	9.8
30	113	7	2.1	118	31	10	53	53	9.0
31	---	---	---	107	31	10	---	---	---
TOTAL	3,732	---	1,688.45	1,465	---	173.35	4,339	---	650.99

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft^3/s)	Mean concen-tration (mg/L)	Sediment discharge (ton/d)
		JULY			AUGUST			SEPTEMBER	
1	33	8	0.71	6.9	6	0.11	11	1	0.03
2	27	7	.51	6.2	5	.08	15	8	.68
3	48	31	6.0	6.3	5	.09	26	22	1.9
4	56	32	5.6	5.8	4	.06	12	4	.13
5	34	23	2.1	5.2	4	.06	9.2	2	.05
6	29	16	1.3	4.6	4	.05	8.2	3	.07
7	25	6	.41	4.3	5	.06	7.7	6	.12
8	23	6	.37	217	190	552	8.3	3	.07
9	20	6	.32	441	137	261	8.0	5	.11
10	18	7	.34	225	48	37	7.4	4	.08
11	17	8	.37	111	20	6.0	6.8	7	.13
12	22	8	.48	73	14	2.8	6.0	4	.06
13	16	14	.60	48	8	1.0	5.5	3	.04
14	14	13	.49	37	7	.70	5.4	4	.06
15	12	4	.13	30	7	.57	5.4	2	.03
16	11	9	.27	24	8	.52	5.7	3	.05
17	11	8	.24	23	7	.43	4.7	3	.04
18	11	12	.36	21	8	.45	4.4	3	.04
19	11	11	.33	17	7	.32	4.8	2	.03
20	18	22	1.5	17	11	.50	5.2	6	.08
21	14	13	.49	22	7	.42	6.3	5	.09
22	9.0	6	.15	14	6	.23	13	11	.39
23	7.9	10	.21	12	6	.19	22	12	.71
24	7.5	8	.16	12	6	.19	11	6	.18
25	6.5	5	.09	49	45	7.0	7.9	4	.09
26	6.2	3	.05	24	13	.84	7.1	3	.06
27	5.9	10	.16	19	3	.15	62	81	17
28	18	15	.72	16	4	.17	31	16	1.3
29	11	10	.30	12	3	.10	22	6	.36
30	7.7	8	.17	11	2	.06	17	3	.14
31	7.9	7	.15	11	2	.06	---	---	---
TOTAL	557.6	---	25.08	1,525.3	---	873.21	366.0	---	24.12
YEAR	2,022.51		4,721.26						

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (μS/cm)	pH (Units)	Temper-ature (°C)	Tur-bid-ity (FTU)	Oxygen, dis-solved (mg/L)	Oxygen demand, chem-ical (high leve) (mg/L)	Coli-form, fecal, 0.7 UM-MF (Cols./ 100 mL)	Strep-tococci fecal, KF Agar (Cols. per 100 mL)	Hard-ness (mg/L as $CaCO_3$)
DEC											
15...	1330	75	166	6.9	0.5	3.0	13.6	10	K6	18	66
JAN											
20...	1000	114	159	6.8	.5	5.0	12.8	--	<2	K6	55
FEB											
04...	0745	1,280	98	6.4	.5	40	11.2	50	--	--	25
05...	1615	538	110	6.3	1.0	14	13.4	10	K130	42	30
16...	1435	236	jgd	b$1	x$d	jv	jv$o	vv	†vl	fvxd	go
+>"											
vg$$$	jxl1	lgr	jdb	b$g	b$1	b$d	jv$v	nn	w4	K4	28
APR											
20...	0745	169	115	6.5	10.0	8.0	10.4	<10	K9	160	34
26...	1830	436	94	6.7	12.5	10	10.4	--	--	--	33
27...	1500	568	93	6.8	13.0	9.0	10.2	--	--	--	30
MAY											
25...	0845	145	149	6.6	14.0	5.0	8.8	<10	180	110	46
JUN											
22...	1400	274	130	6.4	19.0	--	9.2	44	--	94	40
JUL											
27...	1445	62	205	6.5	24.5	1.4	8.0	<10	39	200	71
AUG											
25...	0745	169	162	6.8	18.5	27	7.6	<10	--	--	52
25...	1430	644	146	6.5	20.0	230	7.6	556	--	--	44
26...	1645	202	134	6.9	20.0	11	7.2	68	--	--	41
SEP											
14...	1445	54	190	6.8	19.5	1.6	9.2	<10	K67	62	70

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Acidity (mg/L as $CaCO_3$)	Calcium dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Percent sodium	Sodium ad-sorp-tion ratio	Potas-sium, dis-solved (mg/L as K)	Alka-linity field (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Silica, dis-solved (mg/L) as SIO_2)
DEC											
15...	0.0	12	6.8	6.2	19	0.4	1.1	9	45	10	2.4
JAN											
20...	12	6.9	12	6.9	18	.4	.8	9	40	9.0	5.4
FEB											
04...	3.0	5.7	2.7	6.1	32	.5	2.6	4	15	10	3.6
05...	2.0	6.6	3.4	6.0	28	.5	2.0	4	20	9.0	4.0
16...	.0	8.1	4.4	8.3	31	.6	2.0	6	25	12	5.5
MAR											
23...	6.0	6.8	4.0	3.9	20	.3	.8	2	26	6.0	5.6
APR											
20...	4.0	8.3	5.0	4.0	17	.3	.8	1	30	7.0	5.3
26...	2.0	6.7	3.9	3.8	20	.3	.8	4	25	6.0	5.5
27...	3.0	6.5	3.3	3.4	19	.3	.8	5	15	6.0	5.1
MAY											
25...	2.0	9.9	6.3	5.5	19	.3	.8	4	35	6.0	5.8
JUN											
22...	12	9.7	5.7	5.1	18	.3	1.0	6	35	6.0	6.9
JUL											
27...	2.0	14	8.7	6.8	17	.4	1.2	6	60	8.0	5.8
AUG											
25...	3.0	11	6.7	4.9	16	.3	1.3	8	35	7.0	6.3
25...	8.0	10	5.1	4.0	15	.3	1.5	6	30	8.0	5.4
26...	2.0	8.8	4.6	3.5	15	.2	1.2	8	25	6.0	6.2
SEP											
14...	3.0	14	8.4	5.6	14	.3	2.8	7	40	8.0	5.8

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitrogen, nitrate total (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, organic dissolved (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, total (mg/L as N)
DEC											
15...	1.2	1.20	0.010	0.010	0.080	0.080	0.72	0.62	0.80	0.70	2.0
JAN											
20...	1.2	1.20	.010	.010	.120	.120	.55	.55	.67	.67	1.9
FEB											
04...	1.6	1.60	.020	.010	.200	.180	.93	.93	1.10	1.1	2.7
05...	1.4	1.30	.010	.010	.080	.080	.58	.52	.66	.60	2.0
16...	1.3	1.20	.010	.010	.140	.130	.77	.77	.90	.90	2.2
MAR											
23...	1.7	1.70	.010	.010	.070	.070	.23	.23	.30	.30	2.0
APR											
20...	.84	.80	<.010	<.010	.090	.090	--	.86	--	.95	--
26...	.61	.59	.010	.010	.090	.080	.71	.62	.80	.70	1.4
27...	.72	.72	.010	<.010	.030	.030	.87	.77	.90	.80	--
MAY											
25...	.50	.50	<.010	<.010	.150	.150	1.0	1.0	1.20	1.2	--
JUN											
22...	1.2	1.20	<.010	<.010	.110	.110	1.0	1.0	1.10	1.1	--
JUL											
27...	.47	.47	.010	<.010	.050	.050	.45	.30	.50	.35	--
AUG											
25...	.89	.89	.010	.010	.080	.070	1.0	.01	1.10	1.1	--
25...	.69	.69	.010	.010	.170	.090	2.4	.56	2.60	.65	--
26...	.90	.90	.010	<.010	.100	.100	1.3	.55	1.40	.65	--
SEP											
14...	.60	.60	<.010	<.010	.010	.010	.59	.59	.60	.60	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitrogen dis-solved (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, dis-solved (mg/L as P)	Phos-phorus, ortho, total (mg/L as P)	Phos-phorus, ortho, dis-solved (mg/L as P)	Alum-inum, total recov-erable (µg/L as Al)	Alum-inum, dis-solved (µg/L as Al)	Chro-mium, total recov-erable (µg/L as Cr)	Copper, total recov-erable (µg/L as Cu)	Iron, total recov-erable (µg/L as Fe	Iron, dis-solved (µg/L as Fe)
DEC											
15...	1.9	0.040	0.040	<0.010	<0.010	170	170	--	--	220	40
JAN											
20...	1.9	.030	.030	.010	<.010	90	30	--	--	400	270
FEB											
04...	2.7	.160	.030	.010	<.010	2,200	110	20	20	3,000	70
05...	1.8	.070	.020	.030	.010	800	560	10	20	1,500	90
16...	2.1	.060	.010	.020	<.010	610	100	--	--	1,200	180
MAR											
23...	2.0	.020	.020	<.010	<.010	490	70	--	--	880	260
APR											
20...	--	.040	.020	<.010	<.010	410	70	--	--	740	30
26...	1.3	.030	.010	<.010	<.010	710	140	<10	10	780	80
27...	--	.040	.020	--	<.010	610	210	10	10	840	90
MAY											
25...	--	.020	.010	<.010	<.010	270	90	--	--	280	70
JUN											
22...	--	.030	.010	<.010	<.010	290	20	--	--	500	30
JUL											
27...	--	.030	.010	<.010	<.010	210	40	--	--	200	60
AUG											
25...	--	.090	.020	.010	<.010	1100	410	<10	20	1900	60
25...	--	.250	.020	.010	<.010	13,000	220	<10	60	21,000	70
26...	--	.030	.030	.010	<.010	400	90	20	30	620	60
SEP											
14...	--	.030	.030	<.010	<.010	180	100	--	--	70	50

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Lead, total recov- erable (µg/L as Pb)	Manga- nese, total recov- erable (µg/L as Mn)	Manga- nese, dis- solved (µg/L as Mn)	Mercury total recov- erable (µg/L as Hg)	Zinc, total recov- erable (µg/L as Zn)	Carbon, organic total (mg/L as C)	Carbon, organic dis- solved (mg/L as C)	Sedi- ment, sus- pended (mg/L)	Sedi- ment, dis- charge, sus- pended (ton/d)	Sed. susp. sieve diam. percent finer than 0.062 mm
DEC										
15...	--	650	610	--	--	1.0	1.0	2	0.40	--
JAN										
20...	--	560	550	--	--	1.3	1.3	6	1.8	--
FEB										
04...	9	370	210	<2.0	110	4.9	4.4	143	494	63
05...	5	290	280	<2.0	50	3.7	2.8	34	49	81
16...	--	340	320	--	--	3.7	2.7	16	10	--
MAR										
23...	--	310	310	--	--	--	--	11	16	--
APR										
20...	--	330	310	--	--	2.0	2.0	12	5.5	--
26...	30	350	350	<2.0	<10	--	2.0	21	25	69
27...	<5	230	220	<2.0	40	--	1.5	23	35	68
MAY										
25...	--	470	470	--	--	1.1	1.1	4	1.6	--
JUN										
22...	--	340	320	--	--	<1.0	--	10	7.4	--
JUL										
27...	--	350	340	--	--	<1.0	--	4	.67	--
AUG										
25...	52	500	430	<2.0	90	2.0	--	51	23	93
25...	46	710	350	<2.0	120	<1.0	--	652	1,130	97
26...	5	300	270	<2.0	60	--	2.4	16	8.7	88
SEP										
14...	--	370	370	--	--	--	1.5	5	.73	--

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED SEDIMENT, DECEMBER 1981 to SEPTEMBER1982

Date	Time	Stream- flow, instan- taneous (ft^3/s)	sedi- ment, sus pended (mg/L)	Sedi- ment, Dis- charge, sus pended (ton/d)	Sed. susp. fall diam. percent finer than 0.004 mm	Sed. susp. fall diam. percent finer than 0.008 mm	Sed. susp. fall diam. percent finer than 0.016 mm	Sed. susp. fall diam. percent finer than 0.031 mm	Sed. susp. sieve diam. percent finer than 0.062 mm	Sed. susp. sieve diam. percent finer than 0.125 mm
AUG										
25...	1520	629	586	995	51	68	86	95	99	100