ELSEVIER

Physics of the Earth and Planetary Interiors 124 (2001) 1–7

PHYSICS OF THE EARTH AND PLANETARY INTERIORS

www.elsevier.com/locate/pepi

Centroid moment tensor solutions for intermediate-depth earthquakes of the WWSSN–HGLP era (1962–1975)

Po-fei Chen [a], Meredith Nettles [b], Emile A. Okal [a,*], Göran Ekström [b]

[a] Department of Geological Sciences, Northwestern University, Evanston, IL 60208, USA
[b] Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA

Received 28 June 2000; accepted 18 November 2000

Abstract

Centroid moment tensor solutions are presented for 76 intermediate-depth earthquakes (with reported depths between 130 and 300 km) covering the years 1962–1975. These solutions are obtained by applying the algorithm used for modern events to restricted datasets of analog (WWSSN) and digital (HGLP) seismograms.

Keywords: Centroid moment tensor; Intermediate-depth; Earthquakes; WWSSN; HGLP

1. Introduction

We present a catalogue of 76 centroid moment tensor solutions for intermediate-depth earthquakes, covering the years 1962–1975, obtained by applying the inversion algorithm routinely used in the Harvard CMT project to analog records from the world-wide standardized seismograph network (WWSSN; 1962–1974), and to digital high-gain long period (HGLP) records, as well as a few early international deployment of accelerometers (IDA) records, for the year 1975. This work follows in the steps of our similar catalogue for deep earthquakes (Huang et al., 1997) The catalogue is believed to be complete for moments $M_0 \geq 10^{26}$ dyn-cm, and more than doubles the population of reliable CMT solutions for these moment and depth windows.

We refer to Dziewonski et al. (2000) for the most recent update of the Harvard CMT catalogue, and to Dziewonski et al. (1999) for a complete set of references to the other CMT reports published by the Harvard group over the past 17 years. In a recent contribution, Ekström and Nettles (1997) have given a modern calibration of the HGLP instruments, and provided 108 new CMT solutions, essentially extending the CMT catalogue to include the year 1976.

A full discussion of the geophysical implications of the results of this experiment will be given elsewhere. We simply present, here, a brief outline of the operational procedure used to build the WWSSN–HGLP catalogue.

2. Rationale

Our continued research effort is aimed at alleviating any possible undersampling of the present-day CMT catalogue, which covers only 24 years. In Huang et al. (1994), we demonstrated the possibility of using a limited number of narrow-band records (such as WWSSN or HGLP seismograms) to invert for the moment tensors of deep earthquakes, and showed in particular

* Corresponding author. Tel.: +1-847-491-3194;
fax: +1-847-491-8060.
E-mail address: emile@earth.nwu.edu (E.A. Okal).

0031-9201/01/$ – see front matter
PII: S0031-9201(00)00220-X

Table 1
Centroid coordinates and parameters derived from moment tensor solutions for 76 earthquakes of 1962–1975[a]

No.	Centroid Parameters												
	Date			Time				Latitude		Longitude		Depth	
	D	M	Y	h	m	sec	δt_0	λ	$\delta\lambda_0$	ϕ	$\delta\phi_0$	h	δh_0
1	22	5	1962	8	6	44.4±0.7	6.4	-11.96±.09	0.28	166.30±.02	-0.36	117.6± 1.0	-3.4
2	31	5	1962	6	28	37.4±0.5	9.4	22.02±.05	0.01	142.72±.05	-0.09	265.2± 2.5	-12.8
3	6	7	1962	23	5	39.4±0.8	6.9	35.95±.14	-0.54	70.14±.15	-0.20	191.6± 4.6	-12.4
4	11	8	1962	8	15	46.6±0.6	4.1	24.72±.06	-0.47	123.44±.07	-0.01	136.8± 2.9	10.8
5	14	2	1963	7	4	51.1±0.5	-0.4	-7.19		127.85		361.6± 2.9	100.6
6	1	5	1963	10	3	22.9±0.5	2.9	-19.09		169.04		147.4± 1.9	13.4
7	28	1	1964	14	9	19.1±0.4	3.2	35.92±.07	-0.56	70.22±.07	-0.73	192.8± 2.2	-4.2
8	8	7	1964	11	55	50.3±0.3	9.2	-5.58±.05	-0.04	129.83±.03	0.04	189.2± 1.8	0.2
9	21	7	1964	3	49	2.5±0.5	5.1	-26.00		-177.88		212.3± 3.4	7.3
10	5	8	1964	11	6	11.5±0.5	10.1	-31.62±.06	0.60	-179.95±.04	-0.15	248.3± 1.8	32.3
11	14	3	1965	15	53	12.9±0.5	6.7	36.75±.20	0.33	70.79±.25	0.06	216.7± 2.2	11.7
12	16	9	1965	13	50	10.8±1.3	-1.4	7.13		126.58		167.4± 6.2	-10.6
13	17	9	1965	11	13	59.8±0.5	6.3	-1.40		-77.70		185.1± 2.2	24.1
14	21	9	1965	1	38	32.7±0.7	2.4	28.45±.07	-0.51	128.19±.05	-0.04	191.5± 1.5	-3.5
15	24	10	1965	14	32	15.4±1.0	1.5	4.17		125.81		179.0	
16	25	10	1965	22	34	30.1±0.3	7.7	43.89±.03	-0.32	145.95±.06	0.50	175.9± 1.3	16.9
17	21	11	1965	10	32	1.5±0.3	7.5	-5.98±.04	0.32	130.44±.04	0.14	131.5± 1.7	-0.5
18	8	12	1965	18	5	23.8±1.7	-0.8	-37.14±.10	-0.11	177.94±.15	0.42	167.1± 3.1	14.1
19	4	2	1966	10	39	12.5±0.6	1.0	-15.47±.06	0.46	168.05±.08	0.14	195.7± 3.8	12.7
20	1	5	1966	16	23	2.9±1.7	8.7	-8.30±.13	0.02	-73.95±.13	0.29	155.7± 1.7	18.7
21	6	6	1966	7	46	21.1±0.4	5.5	36.59±.04	0.16	71.27±.06	0.15	223.1± 2.2	9.1
22	13	6	1966	18	8	36.3±0.9	-0.3	-12.44±.04	-0.21	167.31±.08	0.29	237.9± 1.9	-4.1
23	7	10	1966	15	55	14.8±0.4	3.5	-21.40±.04	0.19	170.51±.06	-0.05	160.0± 1.7	-5.0
24	1	12	1966	4	57	0.7±0.9	1.8	-13.88±.07	0.15	166.78±.05	-0.26	123.1± 2.0	-12.9
25	21	12	1966	8	52	9.5±1.4	9.4	-19.47±.14	0.49	169.91±.06	0.17	248.4± 2.7	4.4
26	21	5	1967	18	45	18.1±0.5	4.9	-0.61±.06	0.35	101.49±.06	0.10	177.4± 2.3	-6.6
27	29	7	1967	10	24	30.8±1.1	6.1	7.34±.07	0.50	-73.29±.13	-0.20	157.2± 2.0	-2.8
28	12	8	1967	9	39	51.8±0.6	6.1	-24.25±.06	0.54	-177.21±.08	0.17	140.8± 2.9	-3.2
29	15	10	1967	8	0	57.6±0.3	5.0	11.72±.04	-0.19	-86.14±.05	-0.16	153.3± 1.7	-27.7
30	1	12	1967	13	57	6.2±0.8	2.8	49.11±.05	-0.34	154.40±.17	0.00	146.6± 2.1	2.6
31	14	5	1968	14	5	9.5±0.4	4.1	29.94±.04	0.01	129.67±.07	0.28	163.7± 2.0	1.7
32	19	1	1969	7	2	14.6±0.4	10.2	44.69±.03	-0.31	143.50±.06	0.30	254.0± 2.3	50.0
33	5	3	1969	19	33	27.1±0.6	4.2	36.91±.08	0.50	70.86±.07	0.13	211.8± 4.5	5.8
34	13	4	1969	23	33	17.3±1.0	0.0	-6.36±.10	-0.25	129.91±.06	0.00	163.6± 2.3	-6.4
35	17	6	1969	19	26	30.9±0.3	2.0	18.93±.04	-0.07	145.76±.03	0.26	201.1± 1.7	-4.9
36	8	8	1969	6	30	52.5±1.1	-4.0	36.44		70.86		179.1± 3.8	-13.9
37	8	8	1969	20	44	25.7±0.8	4.9	-6.21±.08	-0.07	130.02±.06	0.33	188.6± 3.0	-4.4
38	15	8	1969	8	42	0.1±1.1	5.2	21.62		143.04		279.1± 6.3	-39.9
39	17	10	1969	1	25	14.8±0.4	2.4	23.50±.05	0.40	94.78±.04	0.08	136.6± 1.7	12.6
40	8	1	1970	17	12	45.0±0.5	4.4	-34.84±.04	0.01	178.76±.06	-0.03	205.4± 1.8	16.4
41	28	2	1970	10	52	38.1±0.9	7.0	52.38±.06	-0.21	-174.93±.17	0.11	159.1± 1.7	-1.9
42	29	3	1970	10	8	25.1±0.7	4.7	-17.12±.06	-0.05	167.99±.06	-0.57	244.1± 2.5	12.1
43	20	4	1970	10	39	21.1±1.4	8.3	-18.58±.08	0.21	169.10±.12	-0.19	243.1± 2.5	0.1
44	8	7	1970	4	49	7.8±0.9	-2.8	18.00		-64.67		138.8± 4.6	-9.2
45	7	12	1970	21	35	25.3±0.3	3.4	29.77±.05	-0.02	139.98±.07	-0.13	178.1± 1.6	-4.9
46	21	2	1971	10	35	38.4±1.1	18.7	-23.47±.07	0.34	-66.75±.10	0.45	214.9± 3.0	48.9
47	17	5	1971	11	4	16.6±0.9	9.7	-1.16±.08	0.43	-77.82±.06	-0.13	168.3± 2.0	-3.7
48	17	7	1971	5	32	45.7±0.9	2.3	6.98		94.65		136.0± 4.1	-8.0
49	27	7	1971	2	2	59.0±1.3	14.5	-3.13±.08	-0.34	-77.07±.11	0.28	118.0± 3.4	30.0
50	7	3	1972	7	45	29.0±0.3	8.3	-28.12±.04	0.13	-178.07±.03	0.20	211.2± 2.0	30.2

No.	Half Drtn	Scale Factor 10^{ex}	Principal Axes									Best Double Couple						
			T-axis			N-axis			P-axis			M_0	Plane 1			Plane 2		
			σ	δ	ξ	σ	δ	ξ	σ	δ	ξ		φ_s	θ	λ	φ_s	θ	λ
1	5.6	26	1.30	84	44	-0.32	5	200	-0.98	2	290	1.1	26	43	98	195	48	83
2	5.2	26	1.07	67	272	-0.35	23	99	-0.72	2	8	0.9	76	47	58	299	52	120
3	5.3	26	1.45	52	65	-0.03	19	308	-1.43	31	205	1.4	250	23	30	132	79	110
4	3.9	25	5.87	33	43	1.58	19	146	-7.45	50	260	6.7	82	21	-155	329	81	-71
5	4.5	26	1.10	17	177	-0.14	35	74	-0.96	50	289	1.0	307	41	-30	60	71	-127
6	6.5	26	2.01	49	118	0.22	25	355	-2.24	30	250	2.1	292	28	24	180	79	115
7	5.0	26	0.93	62	314	0.06	10	65	-1.00	25	159	1.0	272	22	119	61	71	79
8	6.9	26	2.33	65	42	0.92	12	285	-3.25	21	190	2.8	258	26	61	110	67	103
9	3.0	25	1.68	47	110	0.62	13	214	-2.30	40	315	2.0	109	13	166	213	87	77
10	2.3	25	4.97	57	235	-0.43	13	344	-4.54	30	82	4.8	205	19	133	341	76	77
11	12.0	27	1.66	63	32	0.18	9	285	-1.84	26	191	1.8	262	21	65	108	71	99
12	2.7	25	1.33	43	342	-0.06	43	132	-1.27	16	237	1.3	10	48	157	116	73	45
13	2.7	25	7.06	24	65	0.76	26	323	-7.82	53	192	7.4	197	31	-32	315	74	-117
14	5.4	26	1.14	28	109	0.37	10	205	-1.52	59	313	1.3	173	19	-124	28	74	-79
15	2.2	24	8.42	54	200	-0.80	19	318	-7.62	30	60	8.0	192	23	146	314	77	70
16	5.5	26	1.38	59	319	-0.08	5	57	-1.30	30	150	1.3	255	15	109	56	76	85
17	5.1	25	9.78	48	286	-3.28	18	175	-6.49	37	71	8.1	103	19	18	357	84	108
18	2.8	25	1.45	65	263	-0.09	3	167	-1.35	25	76	1.4	159	20	82	348	70	93
19	2.1	25	5.55	29	142	-1.06	45	18	-4.49	31	252	5.0	287	45	-1	17	89	-135
20	3.7	25	4.49	25	119	-0.24	15	22	-4.25	60	264	4.4	238	24	-51	17	72	-106
21	4.8	26	0.88	76	302	0.19	12	93	-1.07	6	184	1.0	288	40	109	83	53	74
22	5.6	26	1.43	65	25	-0.10	24	194	-1.33	4	286	1.4	40	46	125	175	54	59
23	7.0	26	3.00	15	324	-0.45	73	118	-2.55	7	233	2.8	8	74	174	99	84	16
24	6.2	26	1.88	82	51	-0.48	7	201	-1.40	4	291	1.6	28	42	100	195	49	81
25	3.5	25	3.40	1	246	0.43	61	154	-3.82	29	337	3.6	18	69	-20	115	71	-158
26	6.0	26	1.75	56	71	-0.52	25	205	-1.23	22	305	1.5	72	32	142	195	71	64
27	6.2	26	1.82	49	103	-0.04	10	1	-1.78	40	262	1.8	296	11	24	182	85	100
28	2.3	26	1.16	53	127	0.42	30	270	-1.58	18	11	1.4	139	38	146	257	70	57
29	8.1	26	5.53	60	60	-0.85	5	322	-4.68	30	229	5.1	305	16	72	143	75	95
30	4.0	25	4.26	41	337	-0.16	11	237	-4.10	46	135	4.2	134	12	-13	237	87	-101
31	5.4	26	1.34	56	302	-0.25	5	39	-1.09	34	133	1.2	244	12	115	38	79	85
32	7.8	26	3.84	30	22	-0.25	56	171	-3.59	14	284	3.7	59	58	168	156	80	32
33	3.0	25	2.20	62	18	0.16	3	283	-2.35	28	192	2.3	275	17	81	104	73	93
34	2.5	25	3.88	1	117	2.33	77	22	-6.20	13	207	5.0	251	80	-9	343	82	-170
35	4.3	25	6.34	57	171	0.80	32	335	-7.14	7	70	6.7	190	47	136	314	59	52
36	2.0	24	9.23	54	238	-0.40	28	101	-8.83	20	359	9.0	50	35	34	291	71	120
37	4.8	26	0.88	22	115	0.12	68	293	-1.00	1	25	0.9	158	74	164	252	75	17
38	2.5	25	1.65	66	305	0.50	20	87	-2.15	14	182	1.9	297	36	125	76	62	68
39	3.6	25	3.77	57	160	0.33	18	280	-4.10	26	19	3.9	145	25	137	275	73	71
40	6.0	26	2.05	55	237	-0.31	32	33	-1.74	12	130	1.9	254	44	140	15	64	54
41	8.3	26	5.41	29	108	0.58	5	200	-5.99	60	298	5.7	184	16	-107	21	75	-85
42	4.9	25	9.08	31	79	0.26	54	224	-9.34	17	339	9.2	115	56	169	211	81	35
43	5.0	26	1.11	52	47	-0.11	25	174	-1.00	26	278	1.1	51	30	150	168	76	64
44	3.0	25	2.02	32	140	-0.62	0	230	-1.40	58	320	1.7	229	13	-91	50	77	-90
45	3.0	26	1.13	34	96	0.15	25	204	-1.28	45	322	1.2	130	26	-166	27	84	-65
46	6.3	26	3.02	12	72	-0.94	4	341	-2.08	78	233	2.5	167	33	-83	338	57	-95
47	5.1	26	1.44	21	58	-0.14	24	318	-1.30	57	185	1.4	183	32	-40	309	70	-115
48	2.1	25	2.24	43	75	-0.16	43	228	-2.08	14	331	2.2	103	49	155	209	72	44
49	7.6	27	1.78	5	60	-0.20	0	330	-1.58	85	238	1.7	150	40	-90	330	50	-90
50	4.9	26	0.87	2	270	0.53	46	178	-1.40	44	2	1.1	36	59	-33	145	62	-144

Table 1 (*Continued*)

No.	Date D	Date M	Date Y	Time h	Time m	Time sec	Time δt_0	Latitude λ	Latitude $\delta\lambda_0$	Longitude ϕ	Longitude $\delta\phi_0$	Depth h	Depth δh_0	Half Drtn	Scale Factor 10^{e}[a]	T-axis σ	T-axis δ	T-axis ξ	N-axis σ	N-axis δ	N-axis ξ	P-axis σ	P-axis δ	P-axis ξ	M_0	Plane 1 φ_s	Plane 1 θ	Plane 1 λ	Plane 2 φ_s	Plane 2 θ	Plane 2 λ
51	22	3	1972	10	27	50.8±0.6	8.7	48.77±.05	-0.28	154.16±.09	0.56	131.3± 2.2	-3.7	6.5	26	2.09	29	110	-0.15	13	207	-1.94	57	318	2.0	166	20	-132	31	76	-77
52	22	5	1972	20	46	2.2±1.0	7.1	-17.48±.11	0.28	-174.88±.08	0.17	220.8± 4.1	12.8	7.3	26	4.83	9	25	-0.25	35	121	-4.58	54	283	4.7	81	47	-141	322	62	-50
53	5	9	1972	17	18	26.9±0.9	-2.6	1.90		128.20		141.0		3.2	25	2.90	79	328	0.90	8	191	-3.79	8	100	3.3	180	38	76	18	53	101
54	5	1	1973	13	54	32.8±0.4	3.6	-38.94±.06	0.08	175.29±.06	0.06	161.5± 1.5	14.5	4.3	26	1.03	46	22	-0.17	31	150	-0.86	28	259	0.9	39	33	162	144	80	58
55	3	4	1973	13	54	2.7±0.9	1.7	4.35±.09	-0.35	-75.60±.06	0.07	145.9± 1.6	-0.1	3.3	25	3.08	18	119	-0.28	7	211	-2.80	71	321	2.9	198	28	-105	35	63	-82
56	1	8	1973	1	31	35.4±0.8	4.3	-14.18±.06	0.15	166.92±.06	-0.37	210.6± 1.3	8.6	7.6	26	3.59	79	175	-0.22	11	338	-3.37	3	69	3.5	170	43	106	329	49	76
57	30	8	1973	18	25	51.1±1.0	8.7	7.97±.11	0.73	-72.60±.06	0.25	173.5± 1.7	-5.5	3.5	25	3.43	44	112	-0.15	24	356	-3.28	36	246	3.4	276	25	9	178	86	114
58	11	9	1973	23	18	54.6±1.1	4.2	25.44±.09	-0.21	124.61±.08	0.03	146.7± 1.5	9.7	3.0	25	2.18	18	65	1.07	28	165	-3.25	56	305	2.7	119	36	-142	356	69	-60
59	19	12	1973	12	56	5.1±0.5	14.0	-20.71±.06	-0.11	-176.28±.05	0.04	227.9± 2.0	36.9	5.1	26	1.15	42	116	-0.19	3	23	-0.96	48	290	1.1	248	4	-45	23	87	-93
60	11	3	1974	11	37	32.7±1.0	1.1	48.52±.07	0.21	153.11±.15	-0.05	145.8± 3.2	-8.2	2.7	25	1.47	31	267	0.46	22	11	-1.93	51	130	1.7	310	24	-154	195	79	-68
61	17	5	1974	20	55	14.3±0.7	2.2	-6.41±.08	0.14	106.34±.05	-0.43	121.6± 3.4	-19.4	3.6	25	3.97	20	17	0.72	55	138	-4.69	28	276	4.3	59	55	-174	325	85	-35
62	4	6	1974	4	14	22.9±0.4	9.1	-15.84±.05	0.05	-174.59±.05	0.45	283.8± 1.7	27.8	5.4	26	1.30	39	121	0.20	4	28	-1.50	50	293	1.4	245	7	-52	28	84	-94
63	30	7	1974	5	12	49.5±0.3	9.1	36.23±.04	-0.19	70.36±.04	-0.40	214.2± 1.6	5.2	7.9	26	4.09	58	15	-0.11	3	111	-3.97	32	203	4.0	305	13	104	110	77	87
64	7	10	1974	21	53	12.2±0.7	4.2	-58.13±.07	-0.05	-27.78±.10	-0.52	272.9± 2.9	-13.1	3.0	25	2.71	58	220	0.23	19	342	-2.94	25	81	2.8	206	26	137	336	73	71
65	8	11	1974	21	23	22.2±0.5	0.0	42.45±.05	-0.08	141.69±.14	-0.06	121.6± 4.2	-3.4	3.5	25	3.52	28	324	-0.37	3	55	-3.15	61	151	3.3	45	17	-101	236	74	-87
66	5	12	1974	11	57	32.9±2.5	1.8	-8.31±.21	-0.66	-74.33±.11	0.13	164.0± 3.1	8.0	2.0	26	1.07	6	86	-0.09	5	356	-0.98	82	225	1.0	182	39	-82	352	51	-97
67	15	1	1975	20	30	1.1±0.9	7.2	-7.98		112.30		142.9± 3.7	1.9	2.5	24	2.28	53	18	-0.14	30	238	-2.14	20	136	2.2	187	37	33	70	71	122
68*	17	1	1975	9	30	45.1±0.6	2.8	-17.87±.07	0.04	-174.33±.08	0.25	129.9± 1.9	-23.1	2.5	25	5.25	4	111	-0.37	26	19	-4.88	64	209	5.1	226	47	-53	358	54	-123
69*	25	3	1975	6	41	35.2±0.3	2.2	-27.96±.02	0.00	-66.57±.03	0.09	172.0± 1.1	-6.0	2.7	25	2.64	3	248	-0.44	22	339	-2.20	68	151	2.4	317	46	-121	178	52	-62
70*	9	4	1975	6	26	28.0±0.2	5.8	-4.04±.01	0.00	152.78±.02	0.09	104.2± 1.2	-28.8	3.9	25	8.66	50	211	0.69	0	121	-9.35	40	31	9.0	119	5	88	301	85	90
71*	8	7	1975	12	4	48.4±0.3	6.0	21.24±.02	-0.25	94.30±.03	-0.40	95.7± 1.0	-61.3	8.3	26	3.82	50	82	-0.53	39	276	-3.29	7	180	3.6	235	51	36	121	62	135
72*	10	8	1975	10	25	52.6±0.2	9.3	-22.95±.02	-0.30	-66.85±.02	-0.26	225.5± 1.3	59.5	3.6	25	6.92	23	63	0.06	1	333	-6.98	67	241	6.9	154	22	-88	332	68	-91
73*	23	8	1975	13	51	28.2±0.3	4.1	54.58±.02	-0.16	160.20±.04	0.15	137.3± 1.0	-3.7	2.7	25	1.13	39	305	0.14	8	208	-1.27	50	109	1.2	83	10	-35	207	85	-98
74	30	9	1975	3	51	7.6±0.5	8.3	-9.20±.04	0.35	-74.59±.06	0.06	135.0± 2.2	0.0	2.5	24	4.01	7	89	-0.80	41	185	-3.21	49	351	3.6	143	52	-146	31	64	-43
75	14	10	1975	14	53	12.5±0.6	5.7	-7.01±.07	0.05	128.95±.06	-0.07	182.9± 2.4	15.9	2.5	24	2.18	23	275	0.26	19	13	-2.43	59	139	2.3	332	28	-135	200	71	-70
76*	28	12	1975	15	24	57.8±0.2	7.0	-8.09±.01	-0.11	115.00±.02	-0.07	198.5± 0.8	2.5	2.7	25	2.33	53	28	0.35	5	291	-2.68	36	198	2.5	262	10	60	112	81	95

[a] For explanation of headings see Dziewonski et al. (1987).

Table 2
Elements of the moment tensors obtained in CMT inversions

No.	Scale	Elements of Moment Tensor					
	10^{e*}	M_{rr}	$M_{\theta\theta}$	$M_{\phi\phi}$	$M_{r\theta}$	$M_{r\phi}$	$M_{\theta\phi}$
1	26	1.28±0.03	-0.39±0.06	-0.89±0.05	0.11±0.02	-0.14±0.02	-0.22±0.04
2	25	8.51±0.57	-7.12±0.81	-1.39±0.74	0.06±0.95	5.11±0.63	0.61±0.99
3	25	5.27±1.25	-7.67±1.83	2.40±1.78	8.65±1.18	-9.12±1.25	1.83±2.07
4	25	-2.43±0.39	3.09±0.53	-0.66±0.50	2.21±0.41	-5.72±0.33	-0.87±0.55
5	25	-5.05±0.45	9.48±0.66	-4.43±0.80	-4.78±0.56	-4.01±0.55	-0.44±0.59
6	26	0.65±0.09	0.17±0.10	-0.82±0.08	-0.05±0.07	-1.77±0.08	0.92±0.09
7	25	5.50±0.41	-6.03±0.58	0.53±0.54	6.35±0.34	4.00±0.35	-1.89±0.59
8	26	1.53±0.09	-2.45±0.12	0.93±0.12	1.80±0.07	-0.60±0.08	0.48±0.10
9	25	-0.05±0.11	-0.17±0.19	0.22±0.14	-1.20±0.12	-1.52±0.10	-0.68±0.17
10	25	2.31±0.13	0.05±0.22	-2.36±0.18	-1.69±0.12	3.78±0.14	-0.33±0.19
11	27	0.97±0.09	-1.17±0.10	0.21±0.09	1.29±0.06	-0.47±0.06	0.16±0.12
12	24	4.95±1.23	2.86±1.35	-7.82±1.68	8.33±1.39	-0.54±1.69	7.23±1.72
13	25	-3.63±0.34	-1.33±0.46	4.96±0.47	5.03±0.40	-3.00±0.31	-1.35±0.49
14	25	-8.54±0.43	2.08±0.68	6.46±0.65	-6.75±0.45	-9.06±0.49	-0.55±0.62
15	24	3.51±0.96	0.74±0.73	-4.25±0.77	-5.62±0.96	4.04±0.85	1.21±0.81
16	25	6.84±0.35	-5.41±0.50	-1.43±0.57	9.45±0.39	6.90±0.37	-1.99±0.52
17	25	2.68±0.29	-3.06±0.41	0.38±0.44	1.28±0.27	7.70±0.28	2.22±0.44
18	25	0.94±0.12	-0.15±0.13	-0.79±0.08	-0.19±0.11	1.06±0.08	0.21±0.16
19	25	-0.35±0.30	1.83±0.53	-1.48±0.44	-1.77±0.26	-3.16±0.25	3.18±0.34
20	25	-2.43±0.21	0.64±0.27	1.79±0.28	-0.68±0.19	-3.30±0.18	1.74±0.23
21	26	0.82±0.04	-1.03±0.06	0.21±0.07	0.22±0.05	0.13±0.05	0.11±0.05
22	26	1.16±0.05	0.02±0.08	-1.18±0.07	0.50±0.05	-0.32±0.05	-0.43±0.07
23	26	-0.24±0.06	0.91±0.08	-0.67±0.09	0.87±0.07	0.31±0.07	2.52±0.10
24	26	1.83±0.07	-0.58±0.11	-1.25±0.09	0.17±0.07	-0.30±0.07	-0.33±0.11
25	25	-0.55±0.11	-1.87±0.17	2.42±0.22	-1.67±0.14	-0.64±0.11	-2.27±0.17
26	26	0.94±0.08	-0.65±0.12	-0.29±0.11	0.20±0.09	-1.20±0.08	-0.50±0.12
27	26	0.30±0.12	-0.02±0.16	-0.28±0.19	-0.09±0.11	-1.74±0.11	0.31±0.13
28	26	0.70±0.07	-1.22±0.10	0.52±0.11	-0.80±0.06	-0.17±0.07	0.46±0.10
29	26	2.94±0.17	-1.67±0.31	-1.27±0.27	2.46±0.20	-3.67±0.16	0.72±0.22
30	25	-0.30±0.26	1.01±0.37	-0.72±0.34	3.41±0.21	2.24±0.20	-0.04±0.28
31	25	5.73±0.51	-3.77±0.69	-1.96±0.77	6.51±0.53	9.14±0.56	-0.61±0.65
32	26	0.56±0.09	2.22±0.15	-2.79±0.18	1.45±0.13	-1.43±0.10	-1.79±0.10
33	25	1.19±0.12	-1.31±0.19	0.12±0.17	1.83±0.14	-0.47±0.16	0.25±0.19
34	25	1.88±0.27	-3.72±0.27	1.85±0.31	1.68±0.25	-0.91±0.25	3.93±0.32
35	25	4.62±0.23	1.42±0.37	-6.04±0.35	-2.81±0.27	0.46±0.26	2.80±0.38
36	24	4.84±0.78	-6.88±0.88	2.04±0.90	-5.16±1.01	3.87±0.95	-1.62±1.05
37	25	2.30±0.47	-6.92±0.54	4.63±0.53	-1.26±0.39	-2.37±0.38	6.75±0.54
38	25	1.31±0.23	-1.93±0.28	0.63±0.33	0.86±0.28	0.33±0.30	0.19±0.27
39	25	1.92±0.12	-1.97±0.19	0.05±0.17	-3.12±0.13	0.04±0.11	1.44±0.17
40	26	1.23±0.07	-0.66±0.10	-0.57±0.10	-0.41±0.05	1.15±0.05	-1.02±0.10
41	26	-3.21±0.20	0.56±0.29	2.65±0.34	-1.96±0.19	-4.46±0.24	0.38±0.24
42	25	1.76±0.26	-7.12±0.40	5.36±0.41	-1.72±0.31	-4.77±0.30	-4.23±0.38
43	25	4.83±0.51	0.89±0.86	-5.72±0.60	3.56±0.40	-7.81±0.54	-3.24±0.63
44	25	-0.43±0.11	0.35±0.14	0.08±0.16	-1.18±0.11	-1.00±0.17	0.82±0.19
45	25	-2.62±0.43	-2.84±0.60	5.47±0.64	-6.06±0.46	-8.92±0.42	-2.75±0.66
46	26	-1.87±0.13	-0.59±0.19	2.46±0.19	0.39±0.11	-0.94±0.12	-1.10±0.19
47	25	-7.47±0.52	-0.87±0.68	8.33±0.68	8.12±0.58	-4.99±0.54	-5.89±0.70
48	25	0.86±0.17	-1.46±0.22	0.61±0.19	-0.08±0.18	-1.37±0.17	-1.09±0.24
49	27	-1.56±0.10	0.29±0.16	1.26±0.14	0.14±0.13	-0.24±0.10	-0.85±0.15
50	25	-3.96±0.39	-4.71±0.63	8.66±0.59	-9.61±0.31	0.43±0.38	0.31±0.65
51	26	-0.87±0.08	-0.25±0.12	1.12±0.12	-0.93±0.08	-1.45±0.08	0.28±0.11
52	26	-2.97±0.32	3.76±0.56	-0.79±0.52	0.25±0.32	-2.34±0.39	-2.22±0.46
53	25	2.73±0.33	0.81±0.29	-3.54±0.35	0.44±0.24	0.82±0.26	-0.77±0.42
54	25	2.89±0.40	3.19±0.53	-6.08±0.47	6.09±0.36	-5.08±0.39	-1.07±0.48
55	25	-2.22±0.11	0.27±0.16	1.95±0.15	-1.08±0.15	-1.34±0.11	1.17±0.21
56	26	3.44±0.10	-0.50±0.16	-2.94±0.16	-0.78±0.10	0.11±0.11	1.08±0.18
57	25	0.46±0.14	-0.22±0.15	-0.23±0.14	-0.06±0.14	-3.04±0.13	1.38±0.21
58	25	-1.79±0.12	0.80±0.16	0.99±0.15	-1.01±0.12	-1.93±0.12	-1.02±0.15
59	25	-0.21±0.39	-0.88±0.63	1.09±0.45	-4.21±0.30	-9.60±0.38	1.86±0.52
60	25	-0.70±0.16	0.06±0.17	0.63±0.20	0.73±0.14	1.34±0.14	-0.51±0.18
61	25	-0.09±0.21	3.30±0.35	-3.21±0.28	0.76±0.20	-2.53±0.20	-1.24±0.30
62	26	-0.37±0.04	0.28±0.06	0.09±0.06	-0.61±0.05	-1.23±0.05	0.05±0.05
63	26	1.81±0.10	-1.37±0.16	-0.44±0.16	3.43±0.11	-1.17±0.12	0.68±0.14
64	25	1.41±0.09	0.58±0.16	-2.00±0.16	-1.05±0.13	1.93±0.12	0.04±0.13
65	25	-1.63±0.20	1.10±0.26	0.53±0.37	2.34±0.14	1.53±0.17	1.16±0.24
66	26	-0.95±0.07	-0.09±0.09	1.04±0.11	0.09±0.07	-0.20±0.09	-0.07±0.09
67	24	1.16±0.14	-0.26±0.21	-0.90±0.18	1.57±0.18	0.08±0.13	-1.15±0.28
68*	25	-3.96±0.12	-0.35±0.09	4.30±0.11	1.43±0.08	-1.24±0.09	2.24±0.13
69*	25	-1.94±0.04	-0.21±0.04	2.15±0.04	0.48±0.03	0.44±0.04	-1.16±0.05
70*	25	1.21±0.12	-1.25±0.09	0.04±0.09	-7.63±0.09	4.52±0.09	1.12±0.07
71*	26	2.02±0.05	-3.22±0.06	1.21±0.05	0.60±0.04	-2.12±0.04	-0.22±0.05
72*	25	-4.80±0.08	1.01±0.08	3.79±0.08	2.38±0.06	-4.47±0.06	-1.89±0.10
73*	25	-0.29±0.02	0.27±0.02	0.02±0.02	0.50±0.02	1.05±0.02	0.10±0.02
74	24	-2.08±0.11	-1.84±0.17	3.92±0.19	-1.17±0.10	-0.75±0.11	-0.21±0.16
75	24	-1.43±0.11	-0.13±0.13	1.56±0.13	0.95±0.14	1.47±0.12	-0.22±0.17
76*	25	0.58±0.03	-0.90±0.03	0.32±0.03	2.21±0.02	-0.89±0.02	0.28±0.03

that under favorable conditions, reliable moment tensor solutions could be derived from as few records as two components at a single station. This approach was successfully applied to 104 deep-focus earthquakes ($h \geq 300$ km) for the years 1962–1976 (Huang et al., 1997), and later to a dataset of 35 older deep events, reaching back to 1907 (Huang et al., 1998).

Huang et al. (1994) gave a detailed explanation of the feasibility of inverting depleted datasets, based on the efficient excitation of overtone surface waves by deep earthquakes, which makes up (in terms of the richness of resolving kernels) for restricted azimuthal coverage or for poor sampling in the frequency domain due to the narrow-band character of

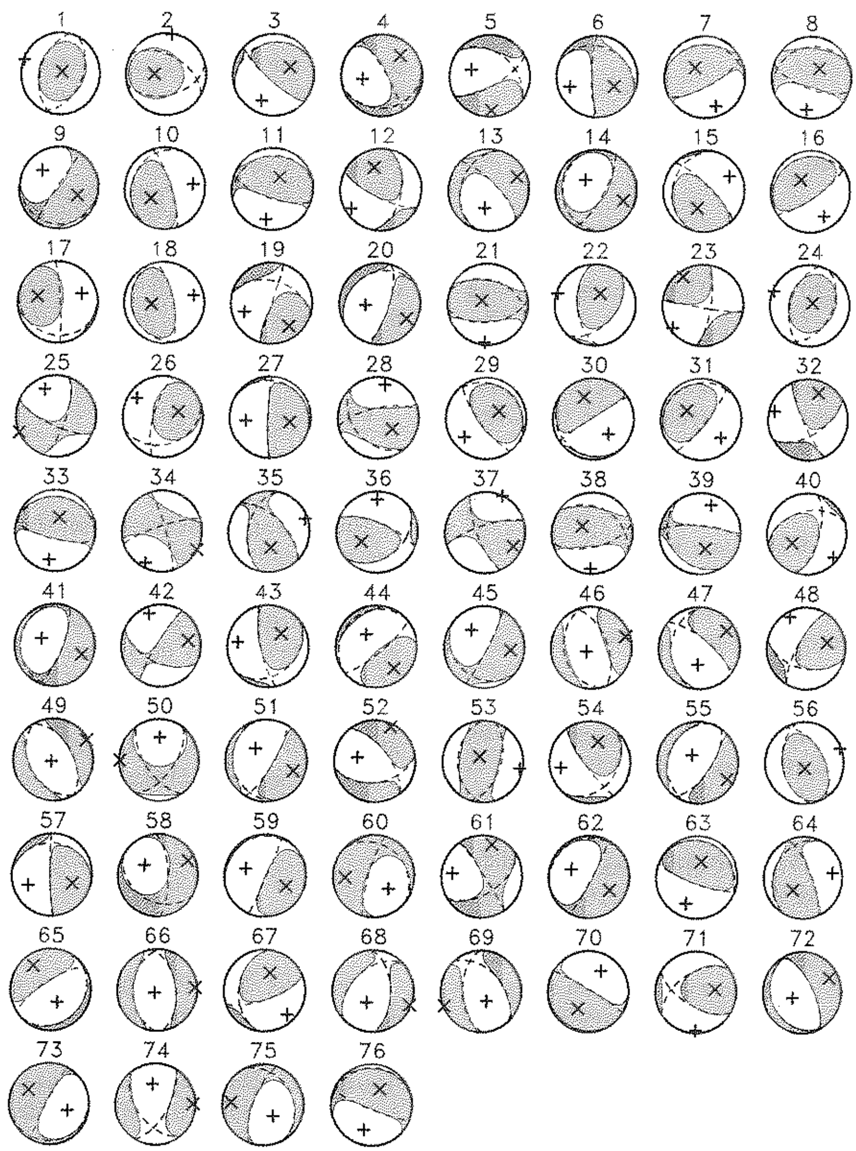

Fig. 1. Equal-area representation of the moment tensors listed in Table 2. Solid lines are the projections of the nodal surfaces of the full moment tensors; dashed lines represent the fault planes of the best double-couples, as listed in the last columns of Table 1. The compression and tension axes are shown by plus signs and crosses, respectively.

the older instruments. As the depth of the earthquake is reduced, this situation becomes less favorable, and thus, a larger number of stations must be used. In a series of systematic tests run on modern-day digital data, Huang (1996) found that the minimum number of stations necessary for a stable inversion grew from 1 at 450 to 8 at 20 km. For the intermediate depth range, these numbers would be 3 at 300 km and 5 at 130 km, further reduced to 1 and 4, respectively, if source depth is constrained in the inversion.

3. Selection of events

We targeted for inversion all events spanning the "WWSSN–HGLP years" (1962–1975) with a reported depth h between 130 and 300 km, and at least one reported magnitude M (most often m_b) $\geq$ 5.8. Our experience was that smaller events could not be reliably inverted. Records from all 159 such earthquakes were visually inspected; 78 events were processed and 75 successfully inverted, among which 10 were determined from HGLP records. Unfortunately, we could not find records of sufficient quality to invert the large earthquake of 26 February 1963 in New Guinea (7.5°S; 146.1°E; h = 156 km); we refer the reader to Fukao and Abe (1971) for a non-CMT moment tensor solution, based on long-period Love waves. For each event to be processed, stations well distributed in azimuth were selected after inspection of the individual records, their number varying from 3 to 7 for the WWSSN (1962–1974) events, and from 3 to 12 for the HGLP-IDA (1975) events. In the case of the WWSSN records, a processing window consisting of the generalized body waves (P group, S group, and the mantle reverberations such as PS, SS, etc.) was isolated, lasting from 2 min before the P arrival to 2 min after the arrival of fundamental Love waves. Records were digitized and equalized to a common sampling δt = 1 s, identical to that used on long-period channels of present-day digital networks. In the case of the HGLP records, we followed the procedure described by Ekström and Nettles (1997). The inversion proceeded by using exactly the same algorithm as utilized in the routine CMT determination of Dziewonski et al. (1981). Tables 1 and 2 and Fig. 1 present our dataset in the same format as used throughout the quarterly reports and in Huang et al. (1997). Events for which mantle waves were included in the inversion (Dziewonski and Woodhouse, 1983) are identified by a star next to their number in Column 1. The format of the tables is described in detail in Dziewonski et al. (1987), to which the reader is referred. In the case of a few small earthquakes, a blank entry for the precision of the coordinates λ, ϕ of the centroid indicates that the epicenter was fixed during the inversion. In two instances (Events 15 and 53; identified by a blank entry for δh_0), we had also to constrain the depth during the inversion. With the goal of eventually merging the present catalogue with Huang et al. (1997), we keep the solution for Event 5, which converged to 361 km, and we incorporate Event 38, previously inverted to 279 km by Huang et al. (1997), but dropped from their catalogue. This brings the total number of solutions in the present dataset to 76. We also kept in the catalogue those events (numbers 1, 24, 49, 61, 65, 70 and 71) which converged to depths shallower than 130 km.

4. Conclusion

The total moment release for the 76 events in the catalogue is 1.20×10^{28} dyn-cm. We estimate that the catalogue is complete for $M_0 \geq 10^{26}$ dyn-cm on the basis of frequency–moment statistics. This threshold is also supported by the observation that the number of solutions above the threshold (32) is comparable to that of available solutions (59) in the main CMT catalogue (1976–1999) for the relevant ranges of depth and moment, once prorated for a common sampling duration.

Acknowledgements

We thank Don Helmberger at Caltech and Paul Richards at Lamont for lending us their precious WWSSN films and chips covering the years 1962–1963. Petra Pančošková printed and digitized a large fraction of the WWSSN data. This research is supported by the National Science Foundation, under grants EAR-97-06152 (Northwestern) and EAR-98-05172 (Harvard), and by an NSF Graduate Fellowship to Meredith Nettles.

References

Dziewonski, A.M., Woodhouse, J.H., 1983. An experiment in the systematic study of global seismicity: centroid-moment tensor solutions for 201 moderate and large earthquakes of 1981. J. Geophys. Res. 88, 3247–3271.

Dziewonski, A.M., Chou, T.-A., Woodhouse, J.H., 1981. Determination of earthquake source parameters from waveform data for studies of global and regional seismicity. J. Geophys. Res. 86, 2825–2852.

Dziewonski, A.M., Ekström, G., Franzen, J.E., Woodhouse, J.H., 1987. Centroid moment tensor solutions for January–March 1986. Phys. Earth Planet. Inter. 45, 1–10.

Dziewonski, A.M., Ekström, G., Maternovskaya, N., 1999. Centroid-moment tensor solutions for October–December 1998. Phys. Earth Planet. Inter. 115, 1–16.

Dziewonski, A.M., Ekström, G., Maternovskaya, N., 2000. Centroid-moment tensor solutions for January–March 2000. Phys. Earth Planet. Inter. 121, 175–187.

Ekström, G., Nettles, M., 1997. Calibration of the HGLP seismograph network and centroid-moment tensor analysis of significant earthquakes of 1976. Phys. Earth Planet. Inter. 101, 219–243.

Fukao, Y., Abe, K., 1971. Multi-mode Love waves excited by shallow and deep earthquakes. Bull. Earthq. Res. Inst. Tokyo Univ. 49, 1–12.

Huang, W.-C., 1996. Centroid-moment tensor solutions from analog seismograms of deep earthquakes (1907–1976). Ph.D. Dissertation, Northwestern University, Evanston, 196 pp.

Huang, W.-C., Ekström, G., Okal, E.A., Salganik, M.P., 1994. Application of the CMT algorithm to analog recordings of deep earthquakes. Phys. Earth Planet. Inter. 83, 283–297.

Huang, W.-C., Okal, E.A., Ekström, G., Salganik, M.P., 1997. Centroid-moment-tensor solutions for deep earthquakes predating the digital era: the WWSSN dataset (1962–1976). Phys. Earth Planet. Inter. 99, 121–129.

Huang, W.-C., Okal, E.A., Ekström, G., Salganik, M.P., 1998. Centroid moment tensor solutions for deep earthquakes predating the digital era: the historical dataset (1907–1961). Phys. Earth Planet. Inter. 106, 181–190.