Seismometrical Features

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Seismometrical Features

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1. Elements of the origin

Seismometrical observations of the main shock of the Niigata Earthquake were made by the seismological network of the Japan Meteorological Agency (JMA). The elements of the origin of the earthquake determined by JMA are as follows:[1)]

Origin time:	4h 01m 39.9s ± 0.1s, June 16, 1964 (GMT)
Epicenter:	Long. 139° 11' ± 00 E, Lat. 38° 21 ± 00'N
Focal depth:	40km
Magnitude:	$M = 7.5 \pm 0.2$

For the first three of the above results, the data used came from 18 stations whose epicentral distances were less than 250km, the computations being made by an IBM 704 on the bases of P and S travel time tables of Wadati, Sagisaka and Masuda, and the method of Geiger.

Estimation of the magnitude was made by means of the formulae of Tsuboi using maximum amplitudes observed at 18 stations where JMA type seismographs, with proper periods less than 5sec. are installed. The magnitudes of the same earthquake determined by Pasadena and Palisades are 7¼–7½ and 7¼ respectively.

Before announcing 7.5 for its magnitude, JMA had announced temporarily that it was 7.7 just after the earthquake occurrence, this being evaluated by a precursory method. Yoshiyama[2)] pointed out its overestimation by comparing the intensity-distance curve (cf. next section) of the present Niigata Earthquake with those obtained from the Tango earthquake (1927, M=7.4), the Tottori earthquake (1943, M=7.3) and the Fukui earthquake (1948, M=7.2), and drew a conclusion that its magnitude was about 7.3.

2. Seismic intensity

57 stations and 258 substations (Kunaikansokusho)[1)] under JMA reported

seismic intensities due to the earthquake (Table I.3.1). Their geographical distribution is shown in Fig. I.3.1. Except for a detached region of intensity V that appeared on the Pacific side involving parts of Miyagi and Yamagata Prefs., the areas of various intensities are as a whole arranged in a natural order.

Table I.3.1. Seismic intensities due to the Niigata Earthquake (at JMA stations)

V ;	Niigata · Sakata · Aikawa · Sendai · Shinjo
IV;	Yamagata · Fukushima · Akita · Shirakawa · Takada · Ishinomaki Mizusawa · Morioka · Nagano · Maebashi · Onahama · Wajima · Kakioka Wakamatsu
III;	Utsunomiya · Ōfunato · Karuizawa · Toyama · Kumagaya · Miyako Matsumoto · Chichibu · Tokyo · Kōfu · Yokohama · Omaezaki Suwa · Chūgūshi · Fukaura
II;	Matsushiro · Mito · Kanazawa · Aomori · Chōshi · Iida · Mishima Funatsu · Fushiki · Tanabe
I;	Takayama · Hachinohe · Tomisaki · Hakodate · Shizuoka · Hikone Muroran · Fukui · Toyooka · Tsu · Obihiro · Tsurugisan · Mori

The furthest station where residents felt the shock was at Tsurugisan whose epicentral distance was 680km. JMA also drew an intensity-distance curve as Yoshiyama did and compared it with ones from some previous large earthquakes as shown in Fig. I.3.2. The conclusion that JMA has drawn from this figure is a little different from Yoshiyama's. JMA thought the figure suggested that the magnitude of the present earthquake lay somewhere between those of the Kwanto earthquake (1923, M=7.9) and the Kita-Izu earthquake (1930, M=7.3), or a little above that of the Hyūga-nada earthquake (1941, M=7.4) which occurred beneath the sea bottom as in the present case, thus, M=7.5 being in accord with other ones. It seems inevitable that there should occur some discrepancies among magnitudes estimated by different methods.

3. Seismometric results

The results of the seismograph observations made at the stations under JMA are shown in Table I.3.2. Most of them were read by individual stations and reported to JMA, but not a few of them that had been either mistaken or doubtful were reread by JMA from the original records. The travel time are protted against the epicentral distances in Fig. I.3.3. For the sake of comparison Wadati-Sagisaka-Masuda's travel time curves for the focal depth 40km is drawn, too, in the figure. The figure shows that the observations for P are in good agreement with P curve as far as about 350km from the epicenter but they become later than the curve by 1 and 3 sec at around 500km (western part of Honshū) and 1,000km (Kyūshū), respectively. According to the report from JMA, even if the focal depth is changed to 20km, the tendency of the late arrival of P at these distances is not altered. Further, JMA pointed out that most of the points for P scattering widely from the P curve had resulted from records that show too vague a commencement of the phase to be read off accurately, and that the condition for S phase is also similar to it and contains something questionable both in accuracy and nature: the S phase as read might be some later phase than the real one suggesting a possibility that the focal depth is shallower than 40km.

The signs of initial motions are distributed as illustrated in Fig. I.3.4. The pull and push areas are divided by two nodal lines and a semicircle of inversion with a radius of 100–130km. Push senses of initial motions were very clear on

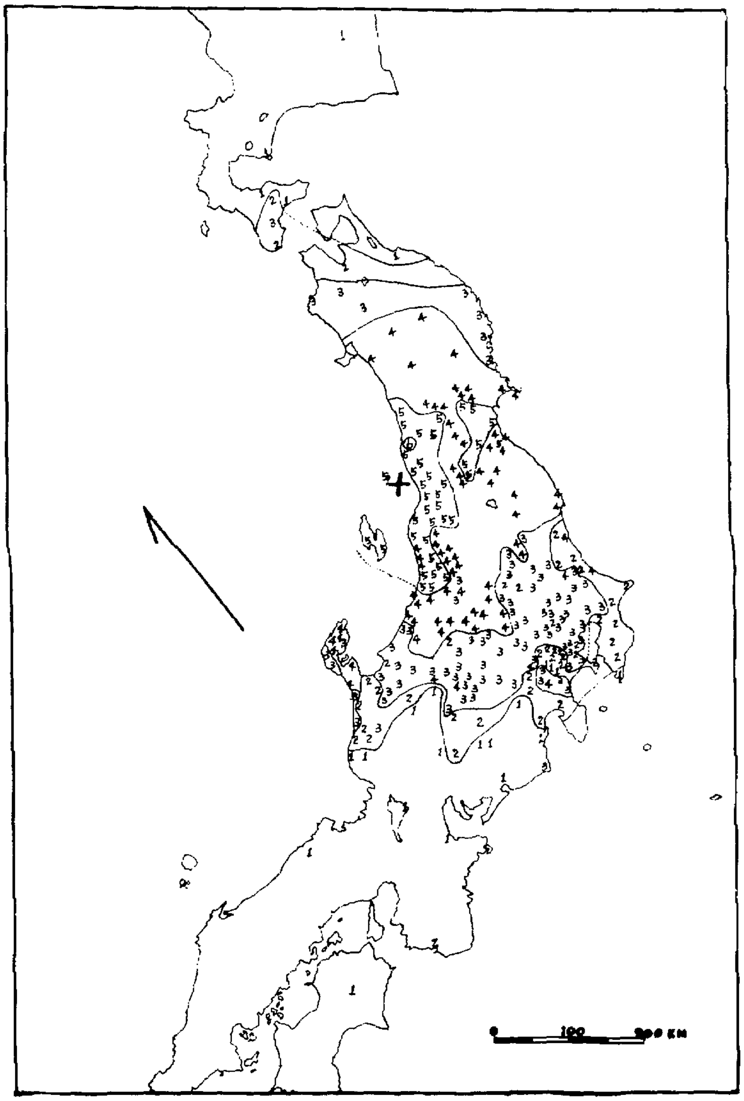

Fig. I.3.1. Distribution of seismic intensities due to the Niigata Earthquake.

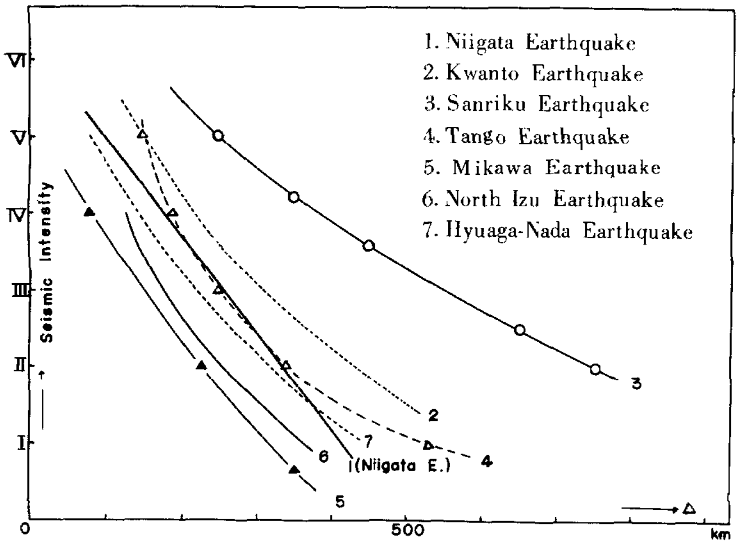

Fig. I.3.2. Intensity-distance curves.

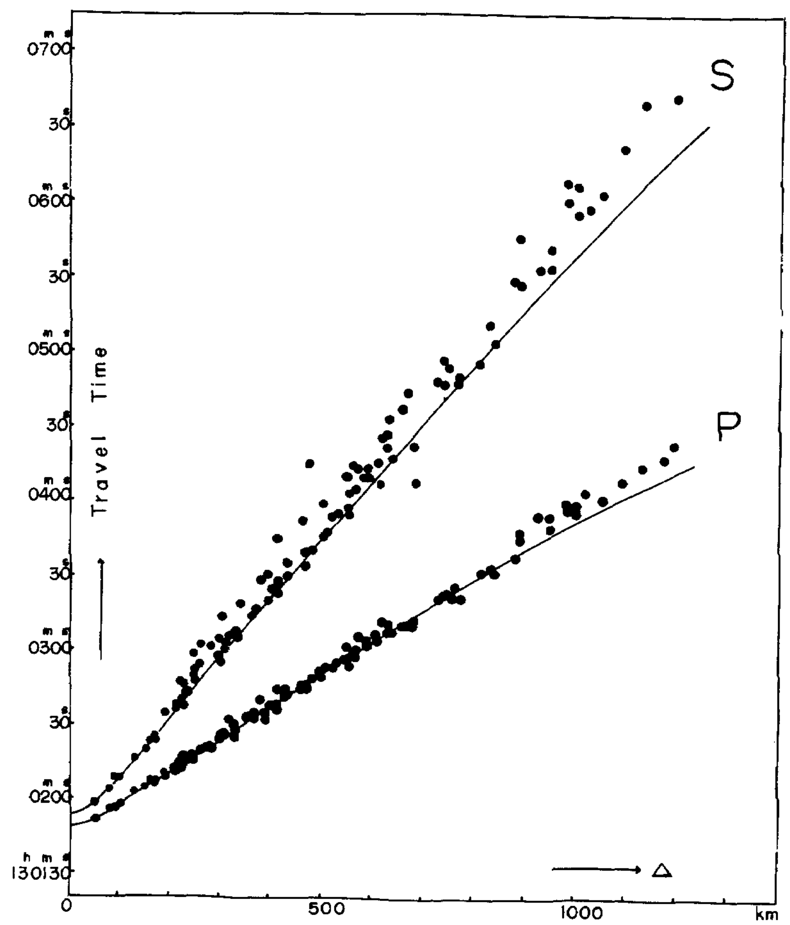

Fig. I.3.3. Travel times of the Niigata Earthquake.

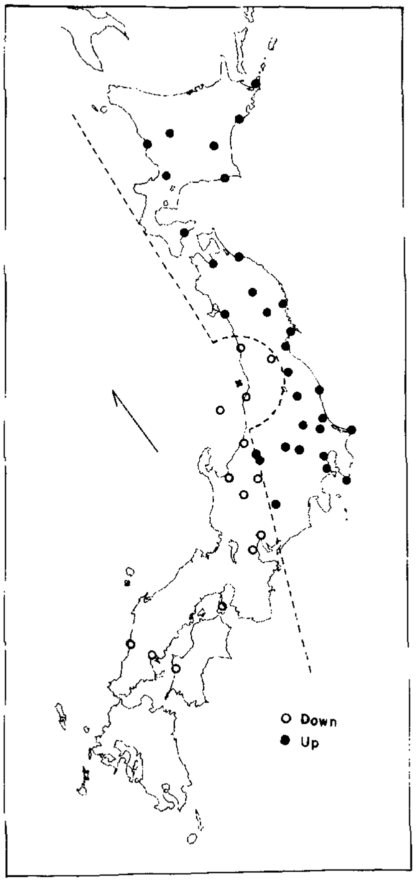

Fig. I.3.4. Distribution of initial motions for the Niigata Earthquake.

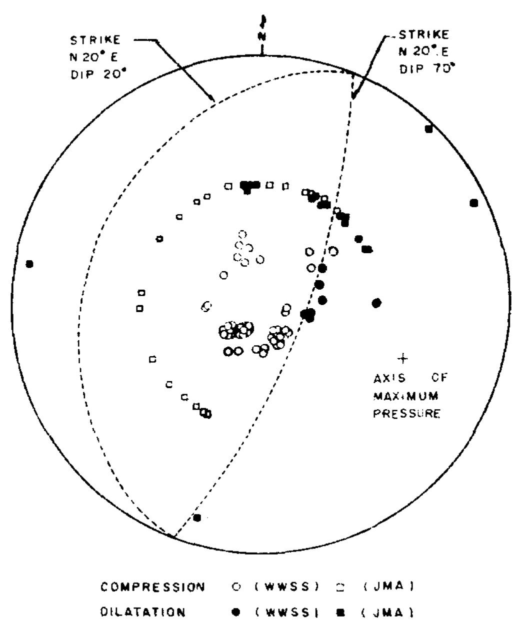

Fig. I.3.5. Stereographic projection of the upper focal hemisphere for the Niigata Earthquake.

Table I.3.2. Seismic data for the Niigata Earthquake

Station	Time of Occurrence	Initial Motion		
		N	E	Z
Niigata	$13^h\ 01^m\ 50.7^s$	–$^{\mu}$	–$^{\mu}$	- 21$^{\mu}$
Sakata	54.8	–	–	- 26
Aikawa	55.6	+ 48	+ 57	- 75
Yamagata	56.9	- 9	- 14	- 64
Fukushima	02 01.5	- 10	+ 27	+ 25
Sendai	03.8	+ 2	+ 49	+ 82
Shirakawa	05.9	- 8	+ 4	+ 9
Akita	06.4	+ 30	–	+ 3
Takada	06.8	+ 1	+ 1	- 2
Ishinomaki	09.1	- 0	+ 4	+ 5
Mizusawa	09.3	+125	+155	+ 40
Nagano	11.6	–	–	+ 2
Utsunomiya	11.8	- 6	+ 3	+ 7
Matsushiro	12.5	-	-	+
Onahama	13.0	- 17	+ 11	+ 18
Maebashi	13.6	–	–	+ 4
Morioka	13.6	+ 2	+ 2	+ 2
Ōfunato	14.4	+ 3	+ 6	+ 4
Wajima	14.4	+ 5	+ 6	- 13
Mito	16.2	–	–	+ 10
Kakioka	16.3	–	–	+
Karuizawa	16.6	–	–	–
Toyama	16.7	+ 2	+ 2	- 3
Kumagaya	16.8	-	–	+
Miyako	19.8	+ 13	+ 21	–
Matsumoto	20.1	+ 2	+	- 2
Chichibu	20.3	–	–	–
Takayama	23.6	+	+	-
Kanazawa	24.2	–	–	–
Aomori	24.5	+ 17	+ 13	+ 15
Tokyo	24.6	-	–	+
Kōfu	24.7	- 2	- 1	+
Chōshi	25.2	–	–	–
Hachinohe	25.9	+	+	+
Yokohama	27.1	–	–	+
Iida	29.3	-	-	+
Gifu	30.8	–	–	–
Funatsu	31.6	–	–	–
Fukui	32.0	–	–	–
Mishima	32.8	–	–	–
Tomisaki	33.6	–	–	+ 2
Ajiro	33.8	–	–	–

Maximum Amplitude			Period			P - S	Epicentral Distance
N	E	Z	N	E	Z		
–$^{\mu}$	–$^{\mu}$	–$^{\mu}$	–^{s}	–^{s}	–^{s}	00^{m} 07.1^{s}	51^{km}
–	–	–	–	–	–	08.2	83
–	–	25000			4	12.2	91
15000	30000	12000	3	5	7	11.5	102
16000	17000	7500	1	1	2	13.9	131
18000	23000	8000	5	8	2	16.0	150
31000	25000	8300	6	6	3	17.0	165
21000	20000	11000	5	2	4	18.1	171
34000	30000	6900	2	3	4	16.2	161
16000	11000	7900	7	7	6	24.5	185
–	–	–	–	–	–	–	190
25000	23000	14000	4	3	5	24.4	207
18000	21000	8000	6	6	6	25.1	209
4800	3200	3000	9	6	6	–	219
24000	25000	10000	4	5	7	25.6	218
15000	23000	11000	5	5	5	33.8	217
6500	7800	7600	9	9	9	23.1	227
6900	6000	6100	5	8	9	28.5	234
14000	12000	4500	5	5	4	30.4	228
31000	29000	5500	6	7	5	31.1	247
11000	10000	6800	8	6	8	32.7	252
19000	17000	6700	5	5	4	26.4	230
16000	16000	–	5	6	–	35.7	253
24000	38000	18000	5	6	6	40.8	245
7000	4900	5000	10	12	11	41.0	280
13000	13000	5000	5	5	4	33.7	258
5900	9000	6200	4	5	4	42.1	262
4600	4100	3900	8	6	6	49.6	298
10000	10000	4700	5	5	4	32.2	301
18000	6200	3700	10	3	10	35.0	306
34000	35000	3600	6	7	6	30.8	300
5000	8500	2200	5	6	5	38.8	303
7600	8200	4700	7	7	8	40.1	327
5100	5600	5400	9	12	10	35.7	314
21000	24000	8500	7	4	5	39.4	326
5800	4100	3200	6	5	5	48.5	338
6400	6000	4000	5	6	6	50.1	393
5700	5800	3900	5	5	5	33.3	319
2900	2800	1600	7	6	6	44.2	366
9000	9000	3000	4	6	5	40.2	360
22000	14000	5000	6	7	6	45.6	385
19000	7800	4000	6	6	5	41.8	367

Station	Time of Occurrence	Initial Motion N	Initial Motion E	Initial Motion Z
Tsuruga	02^m 35.5^s	μ	$-\mu$	$-\mu$
Hakodate	37.1	-	-	+
Nagoya	37.9	+	+	-
Ōshima	38.0	–	–	–
Shizuoka	39.4	–	–	–
Omaezaki	40.9	–	–	–
Hamamatsu	42.0	–	–	–
Hikone	42.6	–	–	–
Nagatsuro	43.8	–	–	-
Muroran	44.1	-	–	–
Tsu	45.1	-	-	–
Kameyama	46.2	+ 3	+ 1	- 2
Maizuru	46.9	–	–	-
Kyoto	48.4	-	–	–
Suttsu	49.4	–	–	-
Toyooka	50.5	–	–	–
Tottori	52.7	–	–	–
Nara	52.9	-	-	–
Urakawa	53.0	+	+	+
Osaka	54.9	–	–	-
Kobe	56.0	–	–	–
Sapporo	56.5	+ 2	+ 1	+ 2
Himeji	57.8	–	–	–
Hiroo	58.1	–	–	–
Saigo	59.6	-	–	-
Owase	03 01.3	-	–	–
Sumoto	01.9	+ 1	+ 1	-
Hachijojima	03.0	–	–	–
Yonago	03.4	–	-	–
Obihiro	04.7	–	-	+
Wakayama	04.9	–	–	–
Shionomisaki	07.1	–	–	–
Takamatsu	07.3	–	–	–
Tokushima	08.4	–	–	–
Kushiro	08.8	+ 1	+ 1	+ 2
Matsue	09.8	-	–	–
Asahikawa	10.0	+ 1	+	+ 1
Rumoi	10.1	–	–	+ 2
Okayama	10.5	-	-	–
Tsurugisan	10.9	–	–	–
Murotomisaki	19.5	–	–	–
Nemuro	19.6	+ 2	+ 4	+ 2
Kochi	20.1	+ 2	+ 2	–
Hamada	20.8	–	–	- 2

Maximum Amplitude			Period			P - S	Epicentral Distance
N	E	Z	N	E	Z		
2000^{μ}	1900^{μ}	1200^{μ}	6^{s}	8^{s}	5^{s}	00^{m} 51.5^{s}	409^{km}
2500	2200	1700	12	10	11	48.5	407
4900	6800	1800	5	6	6	43.6	405
11000	6000	4000	5	7	6	46.3	399
3000	6000	3300	6	5	5	47.5	381
9900	13000	6000	5	6	6	–	425
6700	8500	2500	4	5	5	52.0	425
3100	3800	1400	5	11	7	46.2	431
4000	8700	2300	6	6	5	01 00.2	411
2400	1500	2200	12	13	11	00 49.0	466
5600	6000	2700	5	7	6	01 29.2	470
5400	5800	1900	7	6	5	04.9	458
1000	1100	1100	8	11	6	00 51.8	466
1900	1900	1500	5	8	6	50.3	482
3900	2600	3600	10	11	10	55.8	501
1000	800	950	6	4	4	01 07.5	499
1800	1000	600	7	12	6	01.2	546
4400	1800	1700	6	6	7	00 54.0	506
3500	3700	2600	6	6	12	01 00.2	522
12000	15000	2800	5	5	4	00 58.7	525
2100	2300	1200	6	7	6	01 14.4	542
2400	2700	1700	13	10	14	00 58.9	553
900	900	500	6	6	6	01 14.7	560
1100	1100	1000	13	15	6	06.0	560
1400	2400	350	7	11	5	12.3	571
–	–	–	–	–	–	01.4	546
2900	1500	820	8	5	7	10.4	588
6000	6800	2200	7	6	4	06.4	585
950	900	160	5	10	4	04.9	613
2300	3200	4400	4	4	8	10.0	611
870	1000	1600	7	11	8	04.3	583
5200	2500	1400	9	7	6	13.9	626
5000	4500	7500	7	7	5	08.9	642
350	310	140	3	2	3	18.3	631
420	380	360	13	15	15	12.2	676
1100	1200	350	8	8	5	21.8	633
470	400	210	4	4	3	26.4	659
3200	1900	1800	13	16	15	33.1	672
1400	750	1100	10	8	6	14.0	623
1100	1200	1300	6	7	9	00 57.2	678
2900	4000	900	10	11	4	01 27.2	725
160	210	260	11	14	14	29.8	772
950	1600	1200	8	7	7	25.7	737
490	560	500	12	17	11	35.6	743

Station	Time of Occurrence	Initial Motion		
		N	E	Z
Abashiri	03^{m} 20.9^{s}	$-\mu$	$-\mu$	$-\mu$
Hiroshima	21.5	–	+ 3	- 2
Matsuyama	23.5	–	–	-
Ashizurimisaki	30.1	–	–	–
Wakkanai	30.5	–	–	–
Uwajima	31.5	–	–	–
Torishima	37.4	–	–	–
Oita	43.5	–	–	–
Shimonoseki	46.5	–	–	–
Fukuoka	48.8	–	–	–
Asosan	52.6	–	–	–
Nobeoka	54.4	–	–	–
Miyazaki	54.7	–	–	–
Kumamoto	55.5	–	–	–
Izuhara	58.3	–	–	–
Saga	59.4	–	–	–
Nagasaki	04 01.0	–	–	–
Onsendake	03.0	–	–	–
Kagoshima	06.6	–	–	–
Fukue	13.3	–	–	–
Yakushima	22.1	–	–	–

the records at most stations in eastern Japan while pull senses of initial motions were most vague at many stations in western Japan.

JMA reported that it showed a cone type mechanism. But Aki[4], assuming it to be a fault type mechanism, calculated its dip and direction. He projected the positions of the stations belonging to WWSS (World Wide Standard Seismograph) network as well as those to JMA on the upper half of a focal hemisphere with marks of their senses of initial motions (Fig. I.3.5). A pair of apparent fault planes are thus determined, one of which is N 70°W in dipping direction and 70° in dip angle, the other one is N 110°E and 20° respectively.

If we try to fix a fault plane from the nodal line and inversion circle given in Fig. I.3.2, its dipping angle is easily obtained to be N 74°W. Further, if we[3] assume that the velocities of P wave in the upper and the lower layers of Moho discontinuity are 6.1 and 7.5km/sec respectively, then, the dip of the fault may be obtained to be 67°. The thickness of the upper layer (crust) is calculable too if the depth of the origin is given. And if the focal depth is assumed to vary from 0 to 40km it varies from 30 to 50km.

Aki[4] also estimated the focal depth and considered 40km a little too

Maximum Amplitude			Period			P - S	Epicentral Distance
N	E	Z	N	E	Z		
1300$^{\mu}$	850$^{\mu}$	400$^{\mu}$	4^{s}	4^{s}	5^{s}	01^{m} 18.1^{s}	760^{km}
1300	1100	780	13	11	6	31.2	750
530	590	850	8	9	9	24.0	764
2700	2300	550	16	10	5	32.2	839
600	400	–	10	10	–	23.2	811
1600	900	500	6	11	7	39.2	826
1400	1000	450	8	6	10	49.4	879
4400	3200	1100	7	7	5	59.4	888
89	77	110	10	11	10	38.0	888
850	750	950	7	11	11	43.4	954
–	–	–	–	–	–	47.0	953
1400	740	500	6	5	5	37.6	934
1600	750	230	5	10	6	02 10.5	1004
1300	2000	300	7	13	13	03.8	983
–	–	–	–	–	–	01 57.1	1000
1700	1700	130	5	7	8	02 08.1	982
700	800	500	9	9	12	01.0	1048
–	–	–	–	–	–	01 53.0	1021
1900	2000	800	17	9	10	02 13.4	1088
300	250	90	7	12	12	24.3	1128
190	300	220	15	18	13	18.2	1185

deep. He used the JMA data but employed three crustal models in which the P wave velocities are represented by $v = v_0 (r/r_0)^{z_0}$ for the crust and $v = v_1 (r/r_1)^{z_1}$ for the mantle(5), where r is the distance from the earth's center, v_0 and v_1 are 5.78 and 7.75km/sec and z_0 and z_1 are - 2.4 and - 2.3 respectively. The results are that the thickness of the crust varies from 29 to 35km while focal depth varies from 10.6 to 18.6km.

The origin times that were derived by Aki from the same assumptions mentioned above differ from that of JMA by +(0.7 - 0.9) sec with standard errors ±(0.39 - 0.47) sec.

Some typical seismograms of the Niigata Earthquake are shown here in Fig. I.3.6. They are selected from among the records obtained by the stations under JMA. The first two plates show those of the strong motion seismograph of JMA Type (V=1, T=6 sec (H), 5 sec (V), v=8), and the following two, those of the electromagnetic seismograph of JMA 59 visual type (V=100, T=5 sec, h=0.55). The order in which the components of the records are arranged in the figure is from top to bottom N-S, E-W, U-D, and D-U, W-E, S-N, respectively.

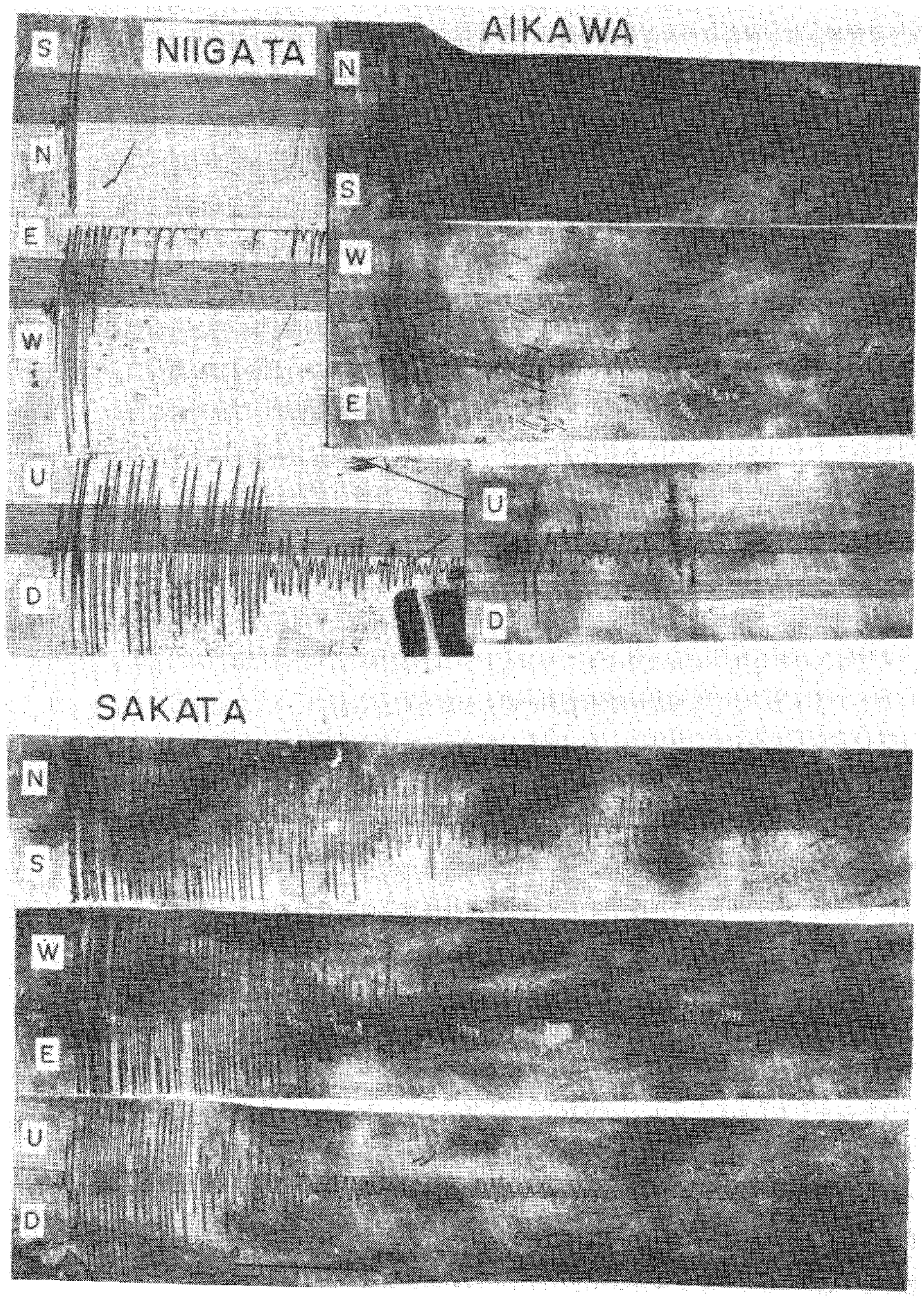

Fig. I.3.6(a) Strong-motion seismograms of the Niigata Earthquake (1)
(V = 1, T = 6sec (H), 5sec (V), v =8)

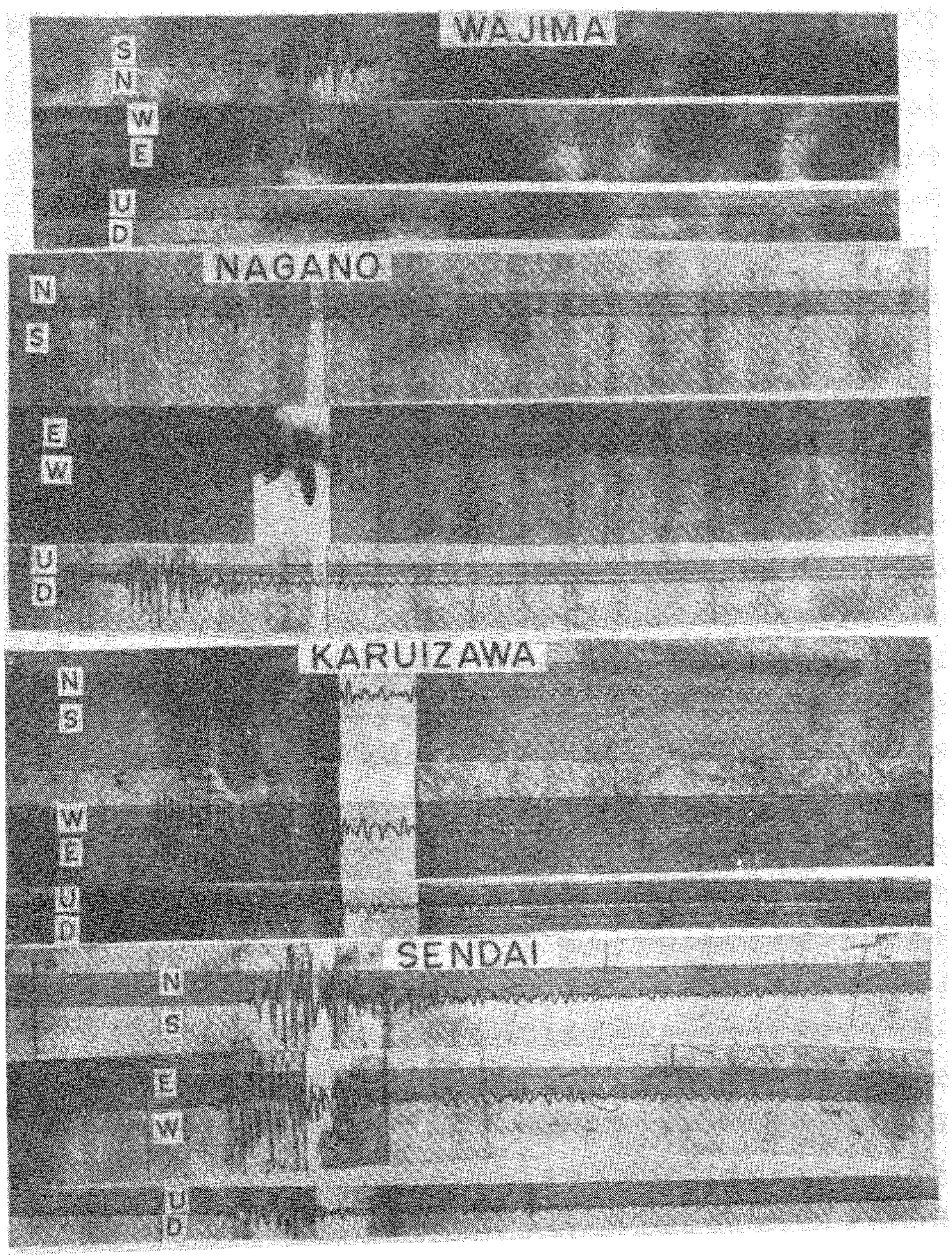

Fig. I.3.6(b) Strong-motion seismograms of the Niigata Earthquake (2)

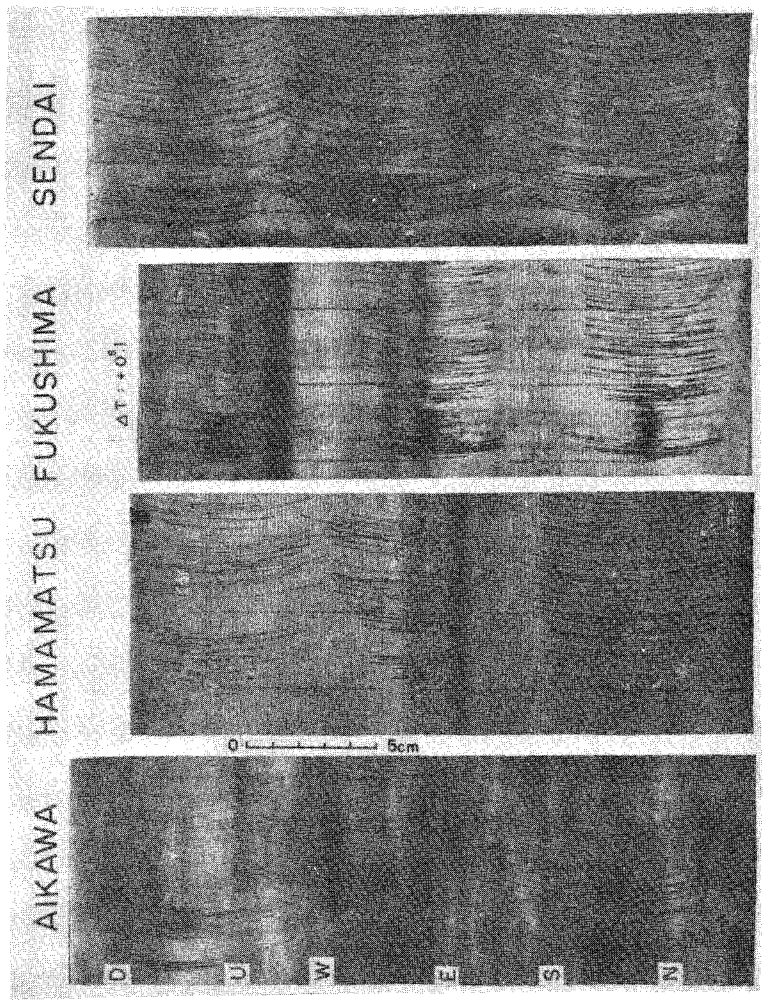

Fig. I.3.6(c) Electromagnetic seismograms of the Niigata Earthquake (1) (V = 100, T = 5sec, h = 0.55)

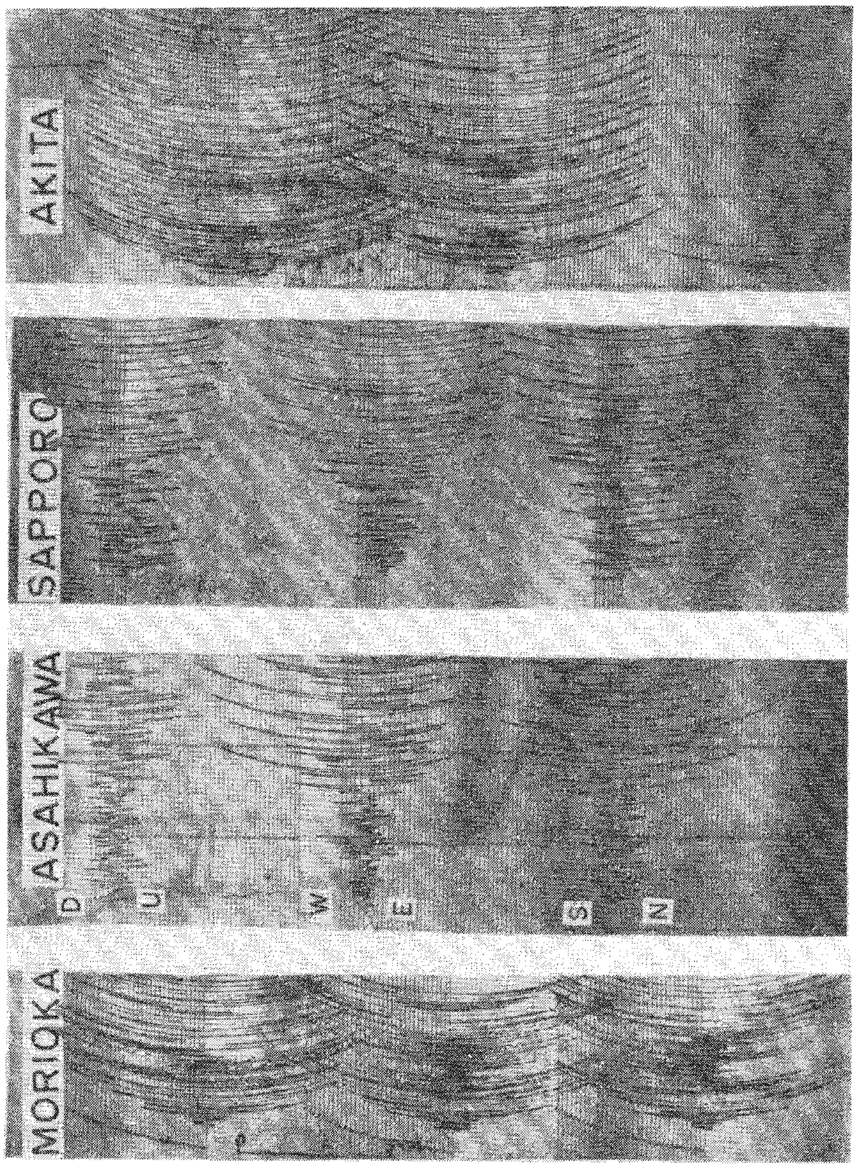

Fig. I.3.6(d) Electromagnetic seismograms of the Niigata Earthquake (2)

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