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The 2002 Seismic Refraction/Reflection Surveys in the Kozu-Matsuda Fault Zone and Ashigara Valley

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Abstract

We conducted seismic surveys in western Kanagawa prefecture including the Kozu-Matsuda fault zone and Ashigara valley, in February and March 2002. The reflection surveys were carried out using vibrator sources along 2 receiver lines. Line A is 15-km long and extends east to west across the Kozu-Matsuda fault zone and Ashigara valley. Line B is 10-km long and extends north to south in the valley. 1151 receivers were deployed at intervals of 25 m for 210 vibration points. 3-D refraction surveys were also conducted with 4-dynamite shots at both sides of the lines A and B and repeated vibroseis sweeps were made at 3 points. In addition to the 1151 reflection receivers, 108 receivers were deployed along the 5 lines between the shot points, and 128 independent receivers were located over a wide area in the Ashigara valley. We overview the surveys and present datasets of seismograms and travel times.

Key words: Kozu-Matsuda fault zone, Ashigara valley, refraction survey, reflection survey, seismogram

1. Introduction

The Kozu-Matsuda fault is an active fault 12-km long with a westward declination. The fault is connected to the Matsuda-Kita fault at its northwestern end. The average slip rate of the fault is about 2–3 mm/y, and the average recurrence interval is estimated to be 800–1300 years (Earthquake Research Committee, 2006). The most recent event on the fault occurred 650–900 years ago (Kanagawa Pref., 2003). The Kozu-Matsuda fault is considered to be a splay fault from the Sagami trough and constructs part of subduction boundary of the Philippine Sea plate. Several historical events in and around the Sagami trough have been identified (Ishibashi, 1985; Tsuji, 1985), and the Kozu-Matsuda fault zone is also located in the source region of the 1923 Kanto earthquake (Matsuda, 1993). The events on the Kozu-Matsuda fault are called Oiso-type earthquakes. The Oiso-type earthquake is one of 3 regions of earthquakes in the Sagami trough zone, and has relatively short interval between earthquakes (Matsuda, 1985). These earthquakes cause uplifts in the Oiso hills and subsidence in the Ashigara valley. Earthquake Research Committee (2006) evaluates the magnitudes of the earthquakes to be about 7.5 from vertical displacement and length of the fault.

The Ashigara valley is a sedimentary basin 4-km wide east to west and 12-km long north to south in the western part of Kanagawa prefecture, which is located about 80 km from southwest Tokyo. Figure 1 shows this location and the topography around the Ashigara valley. The valley is bounded by the Hakone volcanos to the west and the Tanzawa mountains to the north. The valley is open to the Sagami

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bay to the south, so it appears to extend from northwest to southeast. The Kozu-Matsuda fault zone is located along the boundary between the Ashigara valley and the Oiso hills (Figure 2).

Several studies have been carried out to obtain an understanding of the ground motion characteristics and velocity structure in the Ashigara valley. Uetake and Kudo (1998, 2005) found large variations of seismic amplification, depending on the locations of stations in the Ashigara valley, using records from eastern Yamanashi and western Kanagawa prefecture earthquakes in 1996. They also showed variations of coda waveforms for the Japan Meteorological Agency (JMA) magnitude 4.5 earthquake in western Kanagawa prefecture, and confirmed them to be due to the complex 3-D velocity structure beneath the Ashigara valley. These studies suggest that we need accurate velocity structure models to precisely predict strong ground motions from an earthquake. In addition, the detailed velocity structure model around the Kozu-Matsuda fault zone can help us explore the geometry of this fault. Some reflection surveys (Hasegawa *et al.,* 1991; Sato *et al.,* 2005) and refraction surveys (Kasahara *et al.,* 2002; Sato *et al.,* 2005) have already been conducted in parts of the target region of this experiment including the Kozu-Matsuda fault zone, Ashigara valley, and Oiso hills. However, the 2002 seismic refraction/reflection surveys are the first attempt to construct a comprehensive velocity structure model in the Kozu-Matsuda fault zone and Ashigara valley.

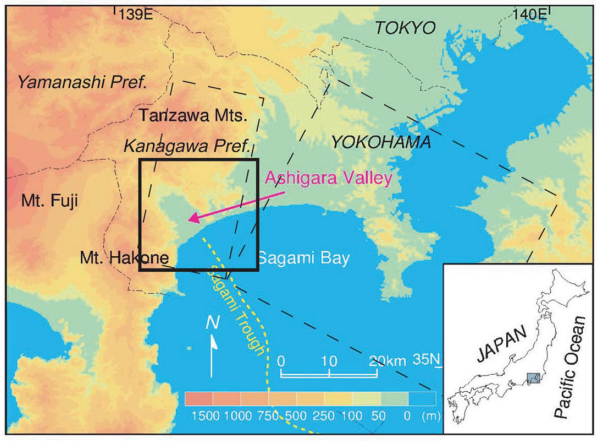

Fig. 1. Location map of the survey area in western Kanagawa prefecture. The Ashigara valley is located in the southwestern Kanto region of Japan. Broken squares are the source region of the 1923 Kanto earthquake (Matsuda, 1993).

2. Overview

The 2002 surveys were performed from February 20 to March 14, by a joint team of the Earthquake Research Institute, University of Tokyo and other institutions. We first conducted reflection surveys along 2 receiver lines with large vibrator sources. We then conducted refraction surveys with 4 explosions and 3 vibrator sources. The sources and receivers are shown in Figure 2. The reflection surveys aim to establish the structure of reflection boundaries and the fault along the receiver lines, while the refraction surveys aim to reveal the velocity structure of layers along the lines and the 3-D velocity structure beneath the Ashigara valley.

The reflection sources were set every 100 m along the receiver lines with a large vibrator. The sweep frequency was changed from 6 to 50 Hz, and the sweep length was 16 s. We used vertical-component geophones with natural frequencies of 10 Hz as receivers located every 25 m along the lines. The 15-km long receiver line A consists of 122 reflection sources and 751 receivers. The 10-km long line B has 98 sources and 400 receivers. The records of the reflection surveys were logged by a seismic recording system called GDAPS-4 with a sampling rate of 4 ms and a recording length of 6 s. The refraction sources were explosions of 200 kg of dynamite at TD 1 and TD2, 50 kg of dynamite at TD3, and 100 kg of dynamite at TD4 (Table 1). 751 and 400 receivers were deployed along lines A and B; 108 independent stations were installed around the sources along the lines connecting the C, D, E, F, and H source points; and, 128 independent stations were located over a wide area in the Ashigara valley. The independent stations cover the sparse zone of stations in the valley and increase the numbers of pairs between sources and stations. The receivers along lines C, D, E, F, and H consisted of vertical-component seismographs of L-22D, and loggers of Datamark LS8000SH/WD with a sampling frequency of 100 Hz and a recording length of 10 minutes. We also used 3 vibrator sources, which repeatedly swept 100 times at VP2, VP3, and VP4 on lines A and B. Stacking the recorded waveforms and cross-correlations with the sweep signals clarified the distribution of reflection

boundaries along the receiver lines. The refracted waves from the vibrator sources were recorded at the receivers along lines A and B.

3. Results

The reflection seismograms were processed using the Common Depth Point (CDP) method. The refraction records were corrected for errors due to the altitudes of the sources and receivers assuming *P*-wave velocity＝1.8 km/s for the top of the layer. We read travel times for each pair of source and receiver from these corrected seismograms. Table 2 shows a summary of the recordings along the receiver lines. The TD1 and TD3 shots are recorded in almost all of the survey lines, and the TD2 and TD4 shots are recorded in lines close to them.

We show the corrected seismograms in Figures 3, 4, 5, and 6, respectively, and obtained travel times along lines A, B, D, and E. The record sections of line A show clear arrivals from the shots of TD1, TD2, VP2, and VP4. Plotted travel times show a gradual increase of apparent *P*-wave velocity at some distance from each shot, and a sudden change of velocity around the Kozu-Matsuda fault zone. The record

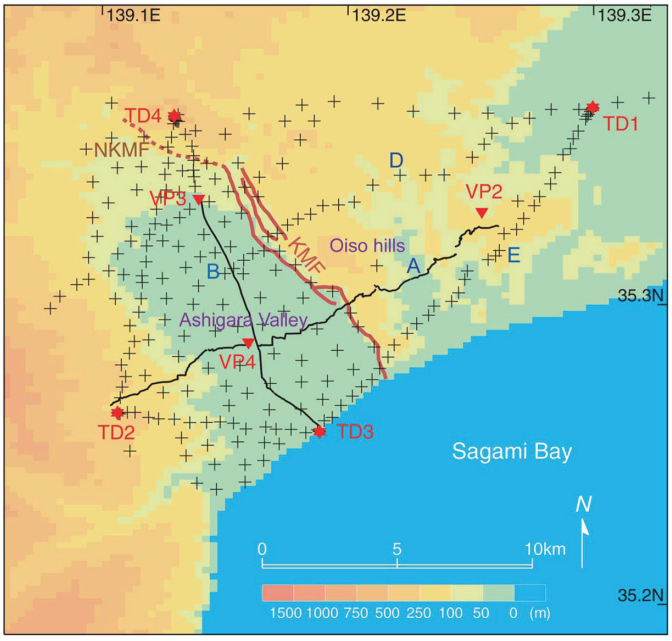

Fig. 2. Distribution of receivers and survey lines. Stars indicate the shot points of TD1, TD2, TD3, and TD4. Triangles denote the vibroseis points of VP2, VP3, and VP4. VP3 and VP4 coincide with the refraction receivers No.2399 and No.499, respectively. Crosses and lines indicate receivers. Lines A and B consist of reflection and refraction receivers. Lines D and E consist of refraction receivers. Solid line illustrates the Kozu-Matsuda fault (KMF) and broken line illustrates the Matsuda-Kita fault (NKMF).

Table 1. Locations, shot times, and charge amounts of dynamite shots (TD1 to TD4) and vibroseis shots (VP2 to VP4) for refraction surveys. The shots are in Japan Standard Time (JST).

Shot	Date	Time	Latitude	Longitude	Altitude(m)	Charge(kg)
TD1	Mar.3, 2002	1:02:10.051	35.365847	139.299675	-43	200
TD2	Mar.3, 2002	1:32:10.063	35.263972	139.106175	230	200
TD3	Mar.3, 2002	2:02:10.013	35.257650	139.188417	-30	50
TD4	Mar.3, 2002	2:32:10.002	35.363008	139.129197	435	100
VP2			35.331033	139.254478	90	-
VP3			35.335403	139.139208	45	-
VP4			35.287833	139.159475	17	-

Table 2. Quality of records for the pairs of shots and receiver lines. ○: Travel times were picked from almost all records. △: Travel times were picked from some records. ×: Travel times were picked from only a few records.

Shot	TD1	TD2	TD3	TD4
Line C	○	△	○	○
Line D	○	×	○	△
Line E	○	×	○	×
Line F	×	○	○	×
Line H	○	×	○	△
Independent Stations	△	△	△	△

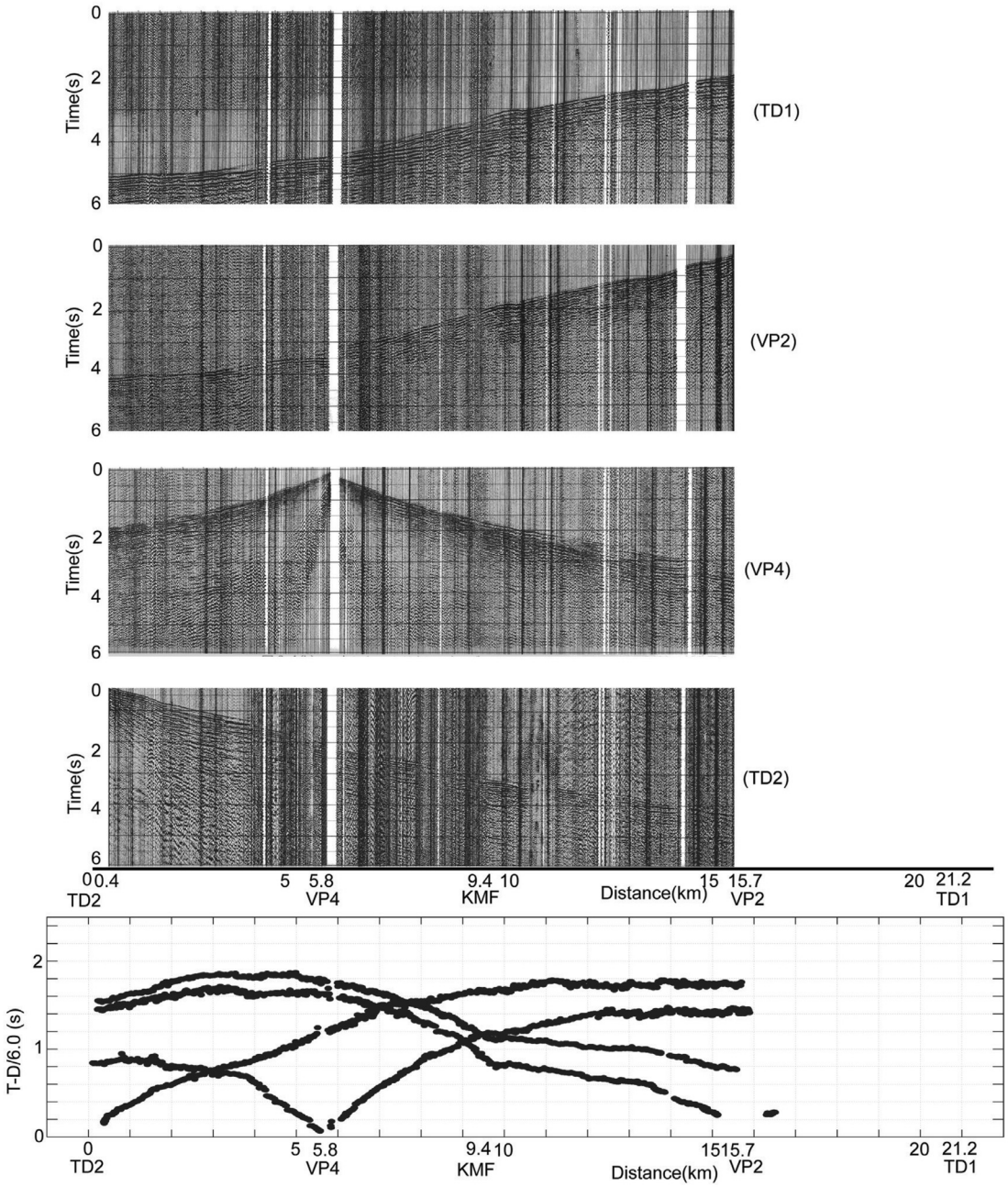

Fig. 3. Record sections (top: shot TD1, second: vibroseis VP2, third: vibroseis VP4, fourth: shot TD2) and the travel time curve (bottom) for line A. Amplitude is recovered by Automatic Gain Control (AGC) with 4000 ms gate length. Travel time curve is reduced with a reduction velocity of 6.0 km/s.

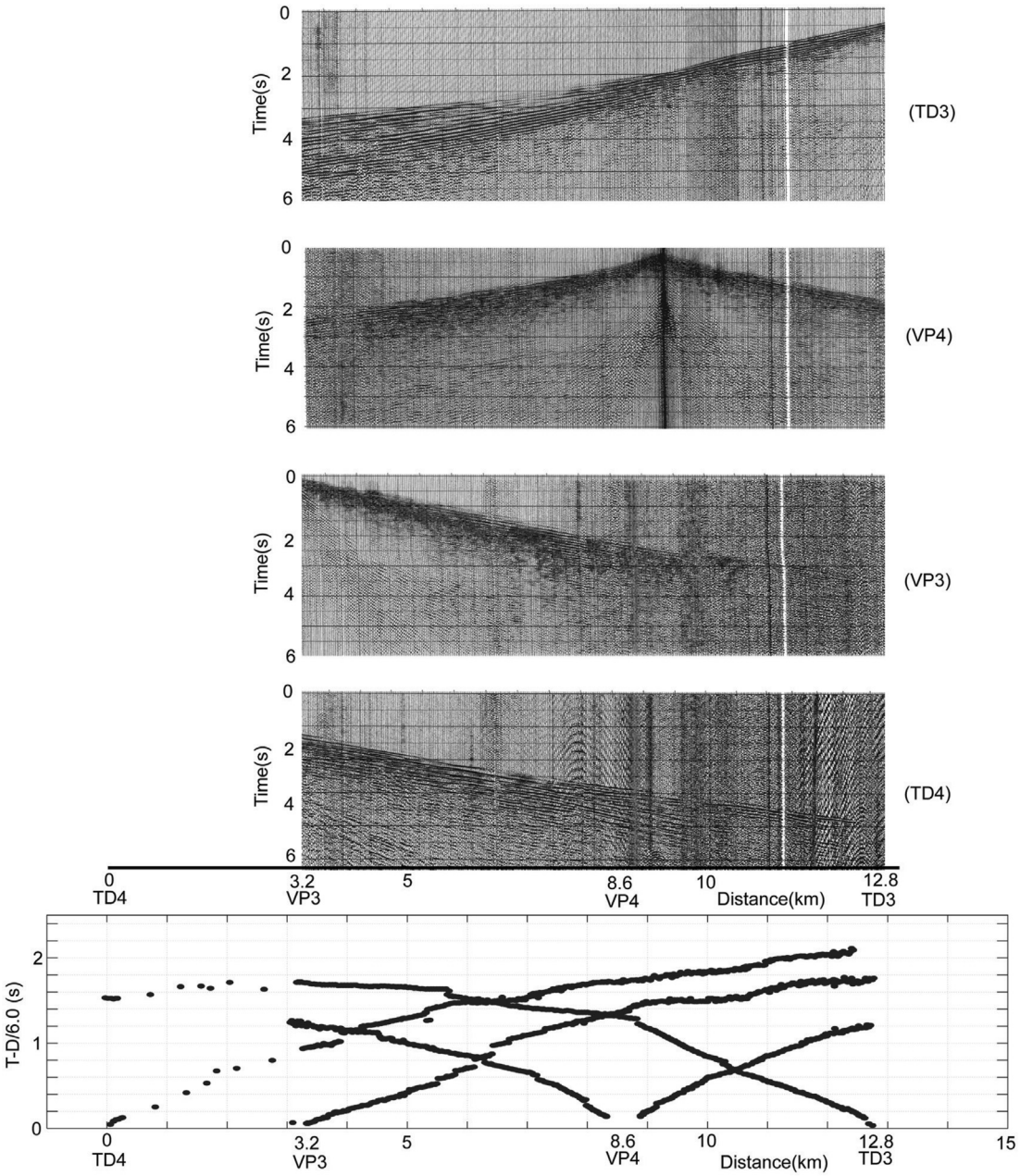

Fig. 4. Record sections (top: shot TD3, second: vibroseis VP4, third: vibroseis VP3, fourth: shot TD4) and travel time curve (bottom) for line B.

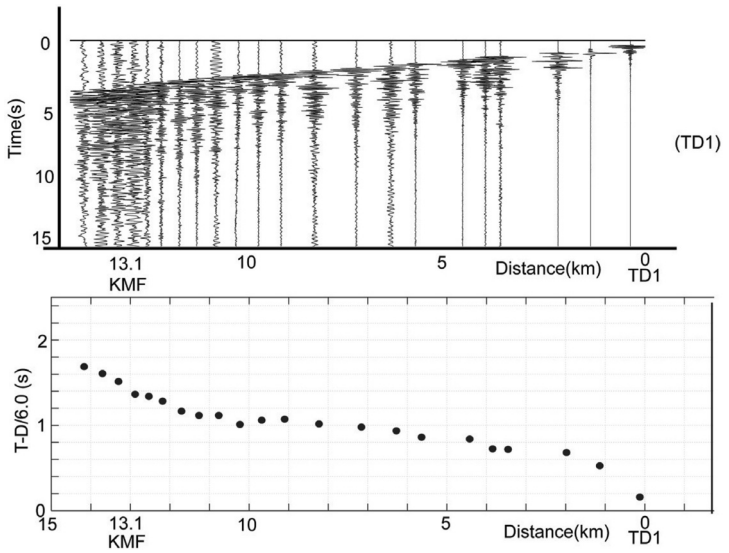

Fig. 5. Record section of shot TD1 (top) and travel time curve (bottom) for line D.

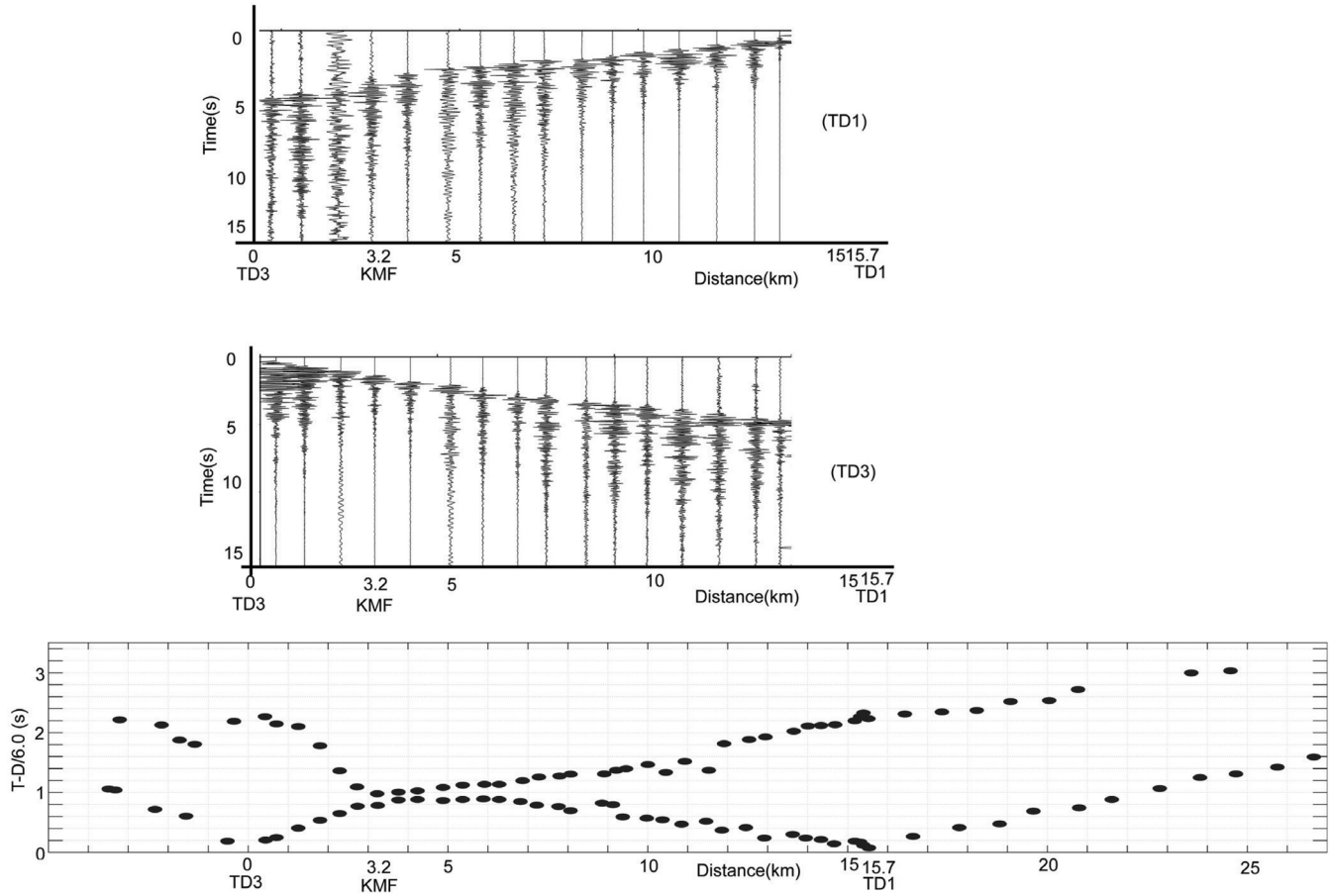

Fig. 6. Record sections (top: shot TD1, middle: shot TD3) and travel time curve (bottom) for line E.

Table 3. Locations of stations and travel times.

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Line C								
CL01	Odawarashi Kuno	35.2690	139.1073	200	5.04	0.20	2.51	2.83
CL02	Odawarashi Kuno	35.2726	139.1081	289	5.06	0.45	2.59	2.80
CL03	Odawarashi Kuno	35.2761	139.1095	220	4.94	0.55	2.53	2.69
CL04	Minamiashigarashi Mitake	35.2799	139.1077	216	4.91	0.71	2.62	2.59
CL05	Minamiashigarashi Mitake	35.2838	139.1110	159	4.84	0.81	2.57	2.52
CL06	Minamiashigarashi Mitake	35.2878	139.1130	138	4.81	0.97	2.59	2.41
CL07	Minamiashigarashi Tsukahara	35.2930	139.1112	130	4.77	1.13	2.68	2.22
CL08	Minamiashigarashi Tsukahara	35.2975	139.1148	73	4.68	1.21	2.67	2.29
CL09	Minamiashigarashi Ikoma	35.3020	139.1158	70	4.64	1.35	2.76	2.22
CL10	Minamiashigarashi Nakanuma	35.3074	139.1162	30	-	-	-	2.92
CL11	Minamiashigarashi Nakanuma	35.3096	139.1161	30	-	-	-	2.92
CL12	Minamiashigarashi Wadagahara	35.3143	139.1178	42	4.58	-	2.97	1.96
CL13	Minamiashigarashi Takematsu	35.3196	139.1180	40	4.60	-	2.98	1.83
CL14	Minamiashigarashi Takematsu	35.3235	139.1192	45	4.47	-	3.06	1.76
CL15	Kaiseimachi Nakanomyou	35.3270	139.1215	46	4.44	-	3.14	1.64
CL16	Kaiseimachi Entsuji	35.3319	139.1220	51	4.41	-	3.28	1.39
CL17	Kaiseimachi Nobusawa	35.3359	139.1238	54	4.35	-	3.37	1.16
CL18	Kaiseimachi Yoshidajima	35.3383	139.1260	55	4.16	-	3.38	0.95
CL19	Kaiseimachi Kanaishima	35.3435	139.1254	56	4.19	-	3.49	0.84
CL20	Matsudamachi Matsudasoshi	35.3473	139.1268	62	-	-	3.58	0.71
CL21	Matsudamachi Matsudasoshi	35.3526	139.1266	144	4.05	-	3.73	0.52
CL22	Matsudamachi Matsudasoshi	35.3559	139.1281	213	3.80	-	3.77	0.36
CL23	Matsudamachi Matsudasoshi	35.3604	139.1289	379	3.77	-	3.88	0.22

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Line D								
DL01	Oimachi Nishioi	35.3121	139.1534	29	3.91	-	2.65	2.21
DL02	Oimachi Kamioi	35.3148	139.1575	30	3.75	-	2.61	2.10
DL03	Oimachi Nishioi	35.3171	139.1612	30	3.59	-	2.69	1.93
DL04	Oimachi Kamioi	35.3180	139.1658	34	3.37	-	2.65	2.02
DL05	Oimachi Yamada	35.3227	139.1674	90	3.32	-	2.88	1.90
DL06	Oimachi Yamada	35.3238	139.1712	79	3.20	-	2.81	1.80
DL07	Oimachi Yamada	35.3266	139.1754	126	3.03	-	2.85	1.75
DL08	Oimachi Akada	35.3286	139.1797	172	2.93	-	2.84	1.65
DL09	Oimachi Akada	35.3302	139.1847	194	2.86	-	2.91	1.78
DL10	Oimachi Akada	35.3330	139.1898	151	2.64	-	2.91	-
DL11	Nakaimachi Kamozawa	35.3333	139.1962	103	2.57	-	2.92	-
DL12	Nakaimachi Kamozawa	35.3342	139.2026	91	2.48	-	3.08	-
DL13	Nakaimachi Iwakura	35.3399	139.2101	70	2.27	-	3.11	-
DL14	Nakaimachi Sakai	35.3432	139.2212	115	2.08	-	3.29	-
DL15	Nakaimachi Inokuchi	35.3432	139.2316	136	1.90	-	3.34	-
DL16	Nakaimachi Inokuchi	35.3433	139.2392	80	1.69	-	3.52	-
DL17	Nakaimachi Inokuchi	35.3492	139.2506	109	1.48	-	3.82	-
DL18	Hadanoshi Shimoozuki	35.3536	139.2554	75	1.25	-	3.86	-
DL19	Hadanoshi Shimoozuki	35.3572	139.2586	59	1.17	-	4.03	-
DL20	Hadanoshi Minamiyana	35.3605	139.2668	75	-	-	-	-
DL21	Hadanoshi Minamiyana	35.3622	139.2739	64	0.89	-	4.15	-
DL22	Hiratsukashi Sanada	35.3652	139.2828	40	0.58	-	4.17	-
DL23	Hiratsukashi Sanada	35.3652	139.2940	16	0.29	-	4.34	-

Table 3. (continued)

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Line E								
EL01	Odawarashi Sakawa	35.2614	139.1903	5	4.81	-	0.28	-
EL02	Odawarashi Sakawa	35.2624	139.1935	5	4.64	-	0.37	-
EL03	Odawarashi Sakawa	35.2664	139.1971	10	4.51	-	0.62	-
EL04	Odawarashi Koyawata	35.2696	139.2018	9	4.10	-	0.84	-
EL05	Odawarashi Koyawata	35.2727	139.2055	5	3.59	-	1.03	-
EL06	Odawarashi Kozu	35.2751	139.2098	10	3.25	-	1.23	-
EL07	Odawarashi Kozu	35.2788	139.2129	65	3.09	-	1.36	-
EL08	Odawarashi Kozu	35.2826	139.2163	85	3.04	-	1.55	-
EL09	Odawarashi Maekawa	35.2866	139.2188	150	2.87	-	1.82	-
EL10	Odawarashi Kanomachi	35.2905	139.2241	63	2.70	-	1.93	-
EL11	Odawarashi Kanomachi	35.2937	139.2280	39	2.62	-	2.04	-
EL12	Odawarashi Nakamurahara	35.2965	139.2328	21	2.53	-	2.13	-
EL13	Odawarashi Yamanishi	35.2995	139.2350	32	2.46	-	2.20	-
EL14	Ninomiyamachi Yurigaoka	35.3011	139.2422	71	2.36	-	2.38	-
EL15	Ninomiyamachi Yurigaoka	35.3039	139.2450	50	2.22	-	2.50	-
EL16	Ninomiyamachi Yurigaoka	35.3084	139.2475	32	2.10	-	2.59	-
EL17	Ninomiyamachi Ishiki	35.3113	139.2486	50	1.99	-	2.68	-
EL18	Ninomiyamachi Midorigaoka	35.3150	139.2570	78	2.00	-	2.84	-
EL19	Ninomiyamachi Nakazato	35.3163	139.2601	135	1.96	-	2.98	-
EL20	Oisomachi Mushikubo	35.3181	139.2616	140	1.72	-	3.05	-
EL21	Oisomachi Kuroiwa	35.3237	139.2635	114	1.58	-	3.20	-
EL22	Oisomachi Kuroiwa	35.3251	139.2686	111	1.49	-	3.14	-
EL23	Oisomachi Kuroiwa	35.3287	139.2715	155	1.36	-	3.43	-
EL24	Hiratsukashi Kamikichisawa	35.3330	139.2758	130	1.29	-	3.37	-
EL25	Hiratsukashi Kamikichisawa	35.3361	139.2780	99	1.06	-	3.86	-
EL26	Hiratsukashi Kamikichisawa	35.3403	139.2825	60	0.98	-	4.01	-
EL27	Hiratsukashi Kamikichisawa	35.3440	139.2843	70	0.74	-	4.13	-
EL28	Hiratsukashi Minamikaname	35.3500	139.2876	39	0.66	-	4.32	-
EL29	Hiratsukashi Minamikaname	35.3521	139.2906	30	0.54	-	4.46	-
EL30	Hiratsukashi Minamikaname	35.3554	139.2917	25	0.45	-	4.52	-
EL31	Hiratsukashi Minamikaname	35.3579	139.2937	23	0.32	-	4.59	-
EL32	Hiratsukashi Kitakaname	35.3619	139.2968	18	0.28	-	4.74	-
EL33	Hiratsukashi Kitakaname	35.3629	139.2973	18	0.28	-	4.83	-
EL34	Hiratsukashi Minamikaname	35.3635	139.2979	18	0.24	-	4.90	-
EL35	Hiratsukashi Minamikaname	35.3645	139.2986	18	0.17	-	4.83	-
EL36	Hiratsukashi Sanada	35.3651	139.2990	18	0.11	-	4.85	-
EL37	Hiratsukashi Sanada	35.3654	139.2993	18	-	-	4.19	-

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Line F								
FL01	Odawarashi Higashichou	35.2573	139.1828	8	-	-	-	-
FL02	Odawarashi Higashichou	35.2585	139.1768	6	-	-	-	-
FL03	Odawarashi Kotobukichou	35.2585	139.1707	7	-	1.84	0.79	-
FL04	Odawarashi Kotobukichou	35.2593	139.1665	10	-	1.88	0.97	-
FL05	Odawarashi Ogikubo	35.2586	139.1584	15	-	1.78	1.25	-
FL06	Odawarashi Ogikubo	35.2605	139.1534	18	-	-	-	-
FL07	Odawarashi Ogikubo	35.2609	139.1480	70	-	1.34	1.62	-
FL08	Odawarashi Kuno	35.2608	139.1424	100	-	1.18	1.79	-
FL09	Odawarashi Kuno	35.2607	139.1356	105	-	0.98	1.93	-
FL10	Odawarashi Kuno	35.2619	139.1293	90	-	0.64	1.89	-
FL11	Odawarashi Kuno	35.2620	139.1229	158	-	0.57	2.23	-
FL12	Odawarashi Kuno	35.2625	139.1189	212	-	0.46	2.33	-
FL13	Odawarashi Kuno	35.2641	139.1133	258	-	0.31	2.48	-
FL14	Odawarashi Kuno	35.2641	139.1102	260	-	0.23	2.56	-

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Line H								
HL01	Matsudamachi Matsudasouryou	35.3634	139.1308	527	3.58	-	3.89	0.11
HL02	Matsudamachi Matsudasouryou	35.3580	139.1379	493	3.55	-	3.79	0.37
HL03	Matsudamachi Matsudasouryou	35.3569	139.1500	451	3.32	-	3.74	0.71
HL04	Matsudamachi Matsudasouryou	35.3637	139.1597	140	2.99	-	3.65	0.80
HL05	Hadanoshi Chimura	35.3613	139.1743	165	2.83	-	3.62	1.18
HL06	Hadanoshi Shibusawa	35.3666	139.1813	190	2.64	-	3.75	1.26
HL07	Hadanoshi Shibusawa	35.3678	139.1944	150	2.50	-	3.85	-
HL08	Hadanoshi Hirasawa	35.3671	139.2122	120	2.10	-	-	-
HL09	Hadanoshi Ojiri	35.3646	139.2266	105	1.80	-	3.77	-
HL10	Hadanoshi Kamiozuki	35.3639	139.2434	80	1.40	-	3.94	-
HL11	Hadanoshi Shimoozuki	35.3639	139.2570	75	1.14	-	4.02	-

Table 3. (continued)

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Independent Stations								
CZ01	Odawarashi Nakazone	35.2928	139.1551	20	4.31	-	2.14	2.92
CZ02	Odawarashi Horinouchi	35.2913	139.1460	20	-	1.67	2.20	2.45
CZ03	Odawarashi Kayama	35.3000	139.1490	23	-	-	2.52	2.47
CZ04	Odawarashi Kayama	35.3104	139.1499	30	4.12	-	2.79	2.45
CZ05	Odawarashi Sobi	35.3063	139.1391	26	4.47	1.92	2.77	2.22
CZ06	Odawarashi Kayama	35.3001	139.1370	25	4.56	1.66	2.54	2.36
CZ07	Minamiashigarashi Numata	35.2896	139.1333	27	4.82	1.46	2.40	-
CZ08	Odawarashi Fukawa	35.2828	139.1310	33	4.82	-	2.28	2.89
CZ09	Minamiashigarashi Mitake	35.2764	139.1174	192	4.98	0.72	2.46	2.86
CZ10	Minamiashigarashi Mitake	35.2883	139.1188	101	4.90	1.15	2.66	2.71
CZ11	Minamiashigarashi Iwahara	35.2950	139.1255	59	4.75	1.49	2.78	2.53
CZ12	Minamiashigarashi Tsukahara	35.3020	139.1261	27	-	-	2.75	-
CZ13	Minamiashigarashi Wadagahara	35.3088	139.1244	32	4.54	-	2.80	2.11
CZ14	Minamiashigarashi Tsukahara	35.3124	139.1339	31	4.44	-	2.92	2.10
CZ15	Odawarashi Sobi	35.3160	139.1399	33	4.26	1.97	2.91	1.96
CZ16	Kaiseimachi Yoshidajima	35.3234	139.1413	41	4.20	-	3.02	1.69
CZ17	Kaiseimachi Miyanodai	35.3195	139.1309	35	4.47	-	3.06	1.85
CZ18	Kaiseimachi Miyanodai	35.3213	139.1245	40	-	-	3.15	1.84
CZ19	Minamiashigarashi Kano	35.3020	139.1053	118	4.82	1.47	2.88	2.30
CZ20	Minamiashigarashi Kano	35.3100	139.1087	30	-	-	3.14	-
CZ21	Minamiashigarashi Daiyuchou	35.2987	139.0788	339	5.23	1.48	3.27	2.62
CZ22	Minamiashigarashi Daiyuchou	35.3028	139.0827	271	5.06	1.49	3.17	2.46
CZ23	Minamiashigarashi Daiyuchou	35.3067	139.0896	203	4.91	1.48	3.11	2.34
CZ24	Minamiashigarashi Daiyuchou	35.3085	139.0944	140	4.90	1.57	3.12	2.24
CZ25	Minamiashigarashi Iizawa	35.3113	139.1026	60	4.80	1.60	3.03	2.09
CZ26	Minamiashigarashi Sekimoto	35.3170	139.1062	49	4.88	-	3.16	1.97
CZ27	Minamiashigarashi Nuda	35.3212	139.1116	75	4.73	-	3.25	1.95
CZ28	Kaiseimachi Miyanodai	35.3265	139.1262	45	4.58	-	3.26	1.65
CZ29	Kaiseimachi Yoshidajima	35.3290	139.1315	45	-	-	3.25	-
CZ30	Kaiseimachi Yoshidajima	35.3319	139.1355	44	4.33	-	3.40	-
CZ31	Kaiseimachi Yoshidajima	35.3376	139.1313	50	4.24	-	3.45	1.09
CZ32	Matsudamachi Matsudasoshi	35.3447	139.1325	56	-	-	3.62	0.84
CZ33	Minamiashigarashi Mamashita	35.3261	139.1119	48	4.62	-	2.88	1.73
CZ34	Minamiashigarashi Hiromachi	35.3157	139.0944	93	4.75	1.72	3.17	2.08
CZ35	Minamiashigarashi Fukusen	35.3228	139.0978	87	4.86	-	3.30	1.96
CZ36	Minamiashigarashi Nuda	35.3290	139.0960	102	4.56	-	3.53	1.91
CZ37	Minamiashigarashi Nuda	35.3340	139.1024	76	4.66	-	3.45	1.63
CZ38	Kaiseimachi Okano	35.3383	139.1140	60	4.46	-	3.45	1.19
CZ39	Kaiseimachi Kanaishima	35.3460	139.1159	70	4.48	-	3.65	0.85
CZ40	Minamiashigarashi Madarame	35.3457	139.1061	76	5.02	-	3.80	1.30
CZ41	Minamiashigarashi Nuda	35.3410	139.0961	107	4.84	-	3.70	1.58
CZ42	Yamakitamachi Kishi	35.3519	139.0934	110	-	-	-	-
CZ43	Yamakitamachi Mukouhara	35.3556	139.1037	105	4.70	-	3.90	0.91
CZ44	Yamakitamachi Mukouhara	35.3560	139.1169	220	4.19	-	3.86	0.56
CZ45	Yamakitamachi Hisari	35.3673	139.1037	149	4.61	-	4.18	0.78
CZ46	Odawarashi Sobi	35.3173	139.1459	34	4.12	-	2.86	1.01

Table 3. (continued)

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Independent Stations								
DZ01	Nakaimachi Tanaka	35.3130	139.2117	115	2.69	-	2.36	3.09
DZ02	Odawarashi Sogayatsu	35.3044	139.1937	60	3.14	3.10	2.17	3.16
DZ03	Odawarashi Kamisoga	35.3073	139.1849	69	-	-	-	-
DZ04	Odawarashi Sogakishi	35.3022	139.1817	28	3.10	-	2.13	2.90
DZ05	Odawarashi Nishiodomo	35.2978	139.1739	20	4.25	-	2.04	-
DZ06	Odawarashi Kuwahara	35.2934	139.1652	19	4.26	-	2.02	3.00
DZ07	Odawarashi Oniyanagi	35.3023	139.1643	22	-	-	2.28	-
DZ08	Oimachi Nishiooi	35.3103	139.1573	28	4.25	-	2.55	-
DZ09	Oimachi Nishiooi	35.3193	139.1522	33	3.94	2.35	2.90	2.19
DZ10	Odawarashi Sogaosawa	35.3115	139.1706	29	-	-	2.50	2.60
DZ11	Odawarashi Kamisoga	35.3133	139.1786	64	3.28	2.93	2.52	-
DZ12	Odawarashi Sogaosawa	35.3179	139.1721	46	3.29	2.72	2.64	2.18
DZ13	Oimachi Yamada	35.3360	139.1633	107	3.22	-	3.51	1.64
DZ14	Oimachi Kaneko	35.3305	139.1566	46	3.48	-	3.43	1.57
DZ15	Oimachi Kaneko	35.3277	139.1498	44	3.81	-	3.13	1.55
DZ16	Matsudamachi Matsudasouryou	35.3344	139.1435	49	3.89	-	3.23	1.21
DZ17	Oimachi Kaneko	35.3377	139.1512	61	3.66	-	3.33	-
DZ18	Oimachi Kaneko	35.3392	139.1579	136	3.35	-	3.24	1.57
DZ19	Matsudamachi Kouyama	35.3425	139.1639	260	3.25	-	3.39	1.53
DZ20	Oimachi Shinokubo	35.3471	139.1733	230	2.96	3.43	3.41	1.31
DZ21	Oimachi Shinokubo	35.3550	139.1806	240	2.79	-	3.56	1.25
DZ22	Hadanoshi Shibusawa	35.3613	139.1863	220	-	-	-	-
DZ23	Matsudamachi Matsudasouryou	35.3420	139.1458	70	3.71	-	3.46	1.07
DZ24	Matsudamachi Matsudasouryou	35.3473	139.1552	73	3.25	-	3.49	0.99
DZ25	Matsudamachi Matsudasouryou	35.3472	139.1425	98	-	-	3.67	0.92

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Independent Stations								
EZ01	Odawarashi Naruda	35.2837	139.1698	16	4.28	3.03	1.64	-
EZ02	Odawarashi Iizumi	35.2738	139.1684	14	4.58	-	1.15	-
EZ03	Odawarashi Kamonomiya	35.2743	139.1810	11	4.52	-	0.87	-
EZ04	Odawarashi Kamonomiya	35.2815	139.1811	15	3.97	2.55	1.20	3.63
EZ05	Odawarashi Takata	35.2848	139.1956	12	4.00	-	1.41	-
EZ06	Odawarashi Chiyo	35.2920	139.1874	25	3.05	-	1.66	3.30
EZ07	Odawarashi Sogabessho	35.2972	139.2010	57	3.09	2.01	1.89	3.38
EZ08	Odawarashi Tajima	35.2927	139.2041	76	3.19	3.21	1.75	-
EZ09	Odawarashi Kozu	35.2859	139.2106	35	3.10	-	1.65	-
EZ10	Odawarashi Kozu	35.2784	139.2022	10	4.32	1.46	1.15	-
EZ11	Odawarashi Sakawa	35.2746	139.1916	13	-	-	0.87	-
EZ12	Odawarashi Sakawa	35.2684	139.1897	10	4.79	3.04	0.55	-
EZ13	Odawarashi Nishisakawa	35.2653	139.1808	7	4.74	1.13	0.55	-
EZ14	Oisomachi Kuroiwa	35.3346	139.2691	110	1.38	4.86	3.36	-

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Independent Stations								
FZ01	Odawarashi Renshouji	35.2798	139.1560	16	4.45	2.90	1.72	-
FZ02	Odawarashi Fukawa	35.2789	139.1431	31	4.68	1.28	1.93	2.88
FZ03	Odawarashi Kuno	35.2729	139.1504	65	5.01	-	1.87	-
FZ04	Odawarashi Kuno	35.2707	139.1247	100	4.94	0.67	2.26	2.98
FZ05	Odawarashi Kuno	35.2713	139.1347	69	4.87	1.33	2.16	-
FZ06	Odawarashi Kuno	35.2664	139.1516	17	4.78	1.86	1.65	3.35
FZ07	Odawarashi Ougichou	35.2705	139.1590	17	4.64	-	1.31	-
FZ08	Odawarashi Ougichou	35.2650	139.1679	13	-	1.58	0.99	-
FZ09	Odawarashi Nakachou	35.2536	139.1720	6	4.64	-	0.87	-
FZ10	Odawarashi Sakaechou	35.2540	139.1660	7	-	-	1.00	-
FZ11	Odawarashi Hamachou	35.2481	139.1657	5	5.10	-	1.11	-
FZ12	Odawarashi Minamichou	35.2409	139.1581	6	5.36	-	1.60	-
FZ13	Odawarashi Jounai	35.2466	139.1581	12	4.17	-	1.54	-
FZ14	Odawarashi Shiroyama	35.2543	139.1551	30	4.95	1.90	1.42	3.61
FZ15	Odawarashi Itabashi	35.2468	139.1457	27	5.14	1.28	1.77	-
FZ16	Odawarashi Hayakawa	35.2384	139.1464	21	5.32	1.73	1.97	-
FZ17	Odawarashi Itabashi	35.2405	139.1385	29	5.35	1.45	2.10	-
FZ18	Odawarashi Ogikubo	35.2531	139.1428	83	5.09	1.40	1.83	3.49
FZ19	Odawarashi Mizunoo	35.2496	139.1341	130	5.21	1.23	2.08	-
FZ20	Odawarashi Ogikubo	35.2556	139.1322	145	5.09	0.98	2.01	3.31
FZ21	Odawarashi Ogikubo	35.2512	139.1112	241	5.30	0.58	2.51	3.41

Table 3. (continued)

Station					Travel time(s)			
Name	Location	Longitude	Latitude	Altitude(m)	TD1	TD2	TD3	TD4
Independent Stations								
SKW	Hiratsukashi Sanada	35.3658	139.2997	18	-	-	-	-
A1	Hiratsukashi Okazaki	35.3675	139.3098	13	0.42	-	5.06	-
A2	Hiratsukashi Kitatoyoda	35.3690	139.3225	11	0.76	-	5.24	-
A3	Hiratsukashi Miyanomae	35.3714	139.3331	9	0.99	-	5.41	-
A4	Hiratsukashi Oshima	35.3752	139.3415	7	1.34	-	5.70	-
A5	Hiratsukashi Yokouchi	35.3769	139.3541	9	1.59	-	5.88	-
A6	Hiratsukashi Tamura	35.3781	139.3631	10	1.87	-	6.18	-
A7	Hiratasukashi Enzou	35.3808	139.3759	10	2.25	-	-	-
A8	Hiratsukashi Miyayama	35.3844	139.3861	10	2.60	-	-	-
A9	Hiratsukashi Miyayama	35.3857	139.3959	9	2.81	-	6.94	-
A10	Fujisawashi Miyabara	35.3883	139.4069	16	3.10	-	7.14	-
A11	Fujisawashi Enokido	35.3898	139.4168	16	3.42	-	8.30	-
B1	Iseharashi Tanaka	35.4014	139.3233	20	1.36	-	6.00	-
B2	Atsugishi Shimoaikou	35.4246	139.3378	27	1.99	-	6.22	-
B3	Atsugishi Asamayama	35.4417	139.3406	41	2.51	-	6.62	-
B4	Atsugishi Hayashi	35.4612	139.3542	27	3.12	-	7.08	-
B5	Atsugishi Sekiguchi	35.4793	139.3738	27	3.70	-	7.56	-
B6	Sagamiharashi Shimoisobe	35.5005	139.3845	33	4.26	-	8.82	-
C1	Iseharashi Kamiya	35.3910	139.3404	10	1.51	-	-	-
C2	Atsugishi Shimoochiai	35.4020	139.3562	14	1.94	-	-	-
C3	Atsugishi Onna	35.4116	139.3697	12	2.37	-	-	-

section and travel time curve for line B also show clear arrivals and an increase of apparent velocity. The record section of line D also shows clear arrivals from the TD1 shot. The TD3 shot was also observed well on line D, although TD3 is located away from line D. The record sections of line E show arrivals from TD1 and TD3. The travel time curve for TD1 also shows a sudden change of velocity around the Kozu-Matsuda fault zone as a local low apparent velocity zone around the Kozu-Matsuda fault zone and the shot point of TD3.

Table 3 lists the locations of stations and travel times obtained for the explosions. All of the stations tabled are also plotted in Figure 2. The error in reading travel times should be mostly within 10 ms, but the records for shots away from the receiver lines provide rather large errors in their travel times of up to 30 ms.

4. Conclusions

We conducted seismic refraction/reflection surveys in the Kozu-Matsuda fault zone and Ashigara valley in order to construct a 3-D velocity structure model of the Kozu-Matsuda fault. From the reflection surveys, 8 reflection profiles were obtained. From the refraction surveys, we picked 584 travel times from the corrected seismograms.

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国府津–松田断層帯及び足柄平野における 2002 年地下構造探査

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要　旨

2002 年 2 月から 3 月にかけて，国府津–松田断層帯と足柄平野を含む神奈川県西部を対象にして，屈折法・反射法による地下構造探査を実施した．探査手法のひとつはバイブレータによる反射法探査で，国府津–松田断層帯及び足柄平野を東西に横切る 15 km の測線 A と平野を縦断する 10 km の測線 B で行った．また，同時に A, B 各測線両端の 4 点におけるダイナマイト発震と 3 点のバイブレータ発振による面的な屈折法探査を実施した．受振点は A, B 測線の 1151 点に加え，発破点を結ぶ 5 測線 108 点及び平野に面的に配置された独立観測点 128 点である．これら測線沿いの記録は二次元的な地下構造の構築に，面的に配置された独立観測点の記録は三次元的な地下構造への展開に使用される．本報告では探査の概要，得られた主な波形記録，及び読み取った初動走時データを示す．

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