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ON THE SIGNIFICANT LATER PHASE OF SEISMOGRAMS AT KUMAGAYA, JAPAN

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SUMMARY

We have found a significant later phase in seismograms at Kumagaya JMA(Japan Meteorological Agency) station. It appears one minute after the principal phase of S-wave with rather long period, and it is caused by the restricted earthquakes which occurred toward the west from Kumagaya station. Considering the characteristics of this later phase and underground soil structure around Kumagaya district, this later phase can be known to arrive at Kumagaya by way of NW direction making adetour along valley, which is different from the way of the principal phase. The delay time of one minute corresponds well to the group velocity of 600-700m/s as Love wave in deep Neogene valley.

INTRODUCTION

We have found a significant later phase in the seismogram at Kumagaya JMA station during the Western Nagano Prefecture Earthquake of Sep.14, 1984. It appeared one minute after the principal phase of S-wave with rather long period. The existance of such later phase is important to estimate rather long period earthquake ground motions, because it makes their duration very long. And the response of huge structure, such as skyscraper, long spanned bridge and oil tank, which has low damping coefficient, will be increased by such ground motions. The object of this paper is to make clear why and how such later phase appeared only at Kumagaya district.

THE CHARACTERISTICS OF THE LATER PHASE

The seismograms during the Western Nagano Prefecture Earthquake of Sep.14, 1984 were recorded by strong motion seismograph with magnification of unity at each JMA station. The travel time diagram with those of NS component is shown in Fig.1. There are some differences on each seismogram by reflecting each geological site condition. Among them, we can recognize a significant later phase with rather long period, only in the seismogram at Kumagaya JMA station. As shown in Fig.2, there is not any later phase in the seismograms at Maebashi JMA station or Chichibu JMA station, which are neighbouring Kumagaya JMA station. Therefore, it will be sure that this later phase reflected the characteristics of underground structure around Kumagaya district as local effect. Then, we compared the seismograms at Kumagaya JMA with those of other JMA stations to make clear the characteristics of this significant later phase. We could know this later phase has following characteristics;

1) This significant later phase appears about one minute after the principal phase.
2) It has almost same amplitude with the principal phase in the period of 5 to 6 seconds.
3) We could not recognize it in vertical component, but only in horizontal component.

Next, we surveyed whole seismograms kept in Kumagaya JMA station since 1969, and selected ones in which similar later phase could be seen. As shown in Table 1 (Ref. 1), the earthquakes, which make the later phase at Kumagya, is found to have occurred only toward the west from Kumagaya, such as the Near Matsumoto Earthquake of 1969, the Western Nagano Prefecture Earthquake of 1984, the Central Gifu Prefecture Earthquake of 1969, and so on (see Fig.3). And the focal depth of these earthquakes is shallower than 10km. But we could not find similar later phase in the seismogram of the earthquake of Oct.3, 1984, which was one of the aftershocks of the Western Nagano Prefecture Earthquake of 1984. In the seismograms in which we could find the significant later phase, rather long period component was much contained in the principal phase. And among them, the period of 5 to 6 seconds component is predominant in the later phase. As shown in Fig.4, the shape of horizontal orbital motions of 5 to 6 seconds component is superior in NW-SE direction during the principal phase, but in NE-SW direction during the later phase.

EARTHQUAKE OBSERVATION TO CONFIRM THE LATER PHASE

We have been making a tripartite observatin of earthquake ground motion to make clear the characteristics of sesmic-wave propagation since Aug.28, 1986. As shown in Fig.5, the observation sites (SKR, NIB and CYJ) are located around Kumagaya JMA. We have never observed such earthquakes which occurred at western Nagano prefecture, but the Northern Nagano Prefecture Earthquake of Dec.30,1986 was the nearest one. The forcal depth was 1km, and the magnitude was 5.9. The seismograms which observed at NIB, SKR and CYJ are shown in Fig.6. The predominant period of this earthquake is rather short than that of the Western Nagano Prefecture Earthquake. Therefore, the wave forms does not fit with among stations. Although the later phase was not so clear, we could recognize it at the time of about 80 seconds in horizontal components of SKR. As the shape of horizontal orbital motions of this later phase is superior into N40°E, we changed the coodinate of horizontal component from NS and EW into N40°E and N50°W. And nonstationary spectrum was made at SKR and NIB, in which wave forms comparatively correspond well with each other, through multifilter analysis as shown in Fig.7. As the amplitude becomes maximum at about 80 seconds, it may be regarded as later phase. It seems that the later phase consists of surface wave because of its dispersive phenomena. Then, as show in Fig.8, we evaluated dispersion curve with group velocity by means of these two nonstationary spectra. Where, the group velocity of 5 to 6 seconds period component which predominates in the later phase is about 600m/s. As the direction, in which the later phase perdominates(N40°E), is nearly equal to the transverse component and the amplitude of vertical component is very small, we could regard such surface wave as Love wave.

MICROTREMOR MEASUREMENT TO CONFIRM LOCAL EFFECTS

We have already performed microtremor mesurements around Kumagaya district several times, including a tripartite observation to know the propagation velocity of rather long period microtremor. Although we are not sure it is microtremor or microseism, we call it as microtremor at this moment. As the rather long period microtremor propagates holizontaly, we got the propagation velocity from the time lag of common phases among three observation site. The period of 4 seconds component predominated at that time. The results which observed at NIB and Kumagaya Institute of Silk Raising(SS.) are shown in Fig.9. Circles shows the velocity which was obtained using horizontal component and triangles was obtained using vertical component. In the period range of 3 to 4 seconds at NIB, a slow velocity was obtained in horizontal component, and the velocity at the period of 4 seconds was faster than that at 3 seconds. On the other hand at SS. station, the propagation velocity becomes slower in the period rangr longer than 3 seconds.

THE MECHANISM OF THE LATER PHASE EXCITATION

A structural contour map for the bottom of Neogene in the Kanto plain is shown in Fig.10 (Ref. 2) with the profile of P-wave velocity along A-B line which was estimated by explosion survey (Ref. 3). But in the northwestern part of the Kanto plain, the survey of underground structure is not sufficient, and we do not have enough data about underground structure. According to Fig.8, the underground structure from Maebashi to Kumagaya is like a ravine between Kanto mountaineous district, covered with deep Neogene deposit. Then, we estimated underground structure around Kumagaya which was shown in Fig.11, and calculated group velocities for Love wave and Rayleigh wave. The result was shown in Fig.12. We interpret that the minimum velocity of 800m/s with the period of 6.9 seconds on Love wave, is corresponding to the minimum value in Fig.8 and the trend of dispersion curve for Love wave corresponds to propagation velocity obtained in Fig.9 as mentioned above. Assuming that the seismic wave, which consists of SH-wave including rather long period component, arrived at around Maebashi from the west and propagated through the Neogene deposit toward Kumagaya, the delay time of one minute can be elucidated as the significant later phase was propagated about 30km in distance from Maebashi to Kumagaya, with the velocity of 600-700m/s, and was observed clearly at Kumagaya JMA station.

CONCLUSION

This significant later phase was caused only by the earthquakes which occurred toward the west from Kumagaya. It arrived at Kumagaya from the north-west direction by way of Maebashi, and reflected the local effects of underground structure around Kumagaya. The delay time of one minute corresponds well to the group velocity of 600-700m/s in the Neogene deep deposit.

ACKNOWLEDGEMENTS

The authors would like to express their greatful thanks to whole JMA staitions, including Kumagaya JMA station, and local public officials where they have been making an observation of earthquake.

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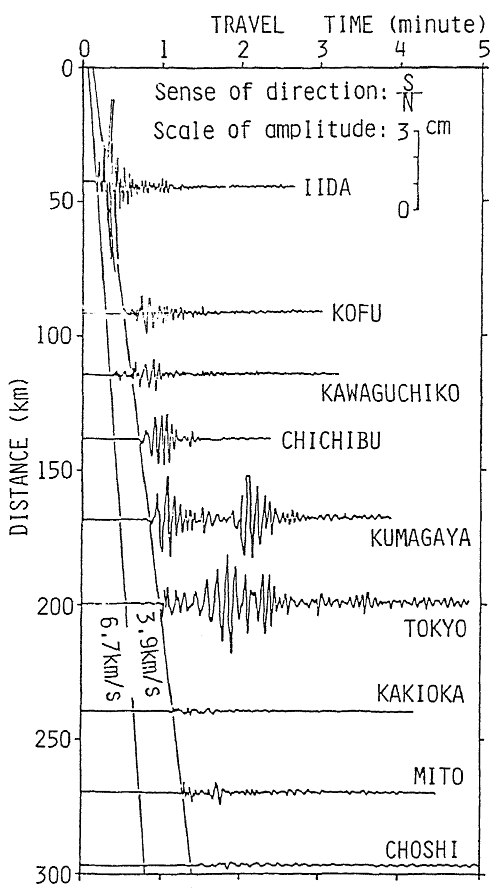

Fig. 1 Travel Time Diagram

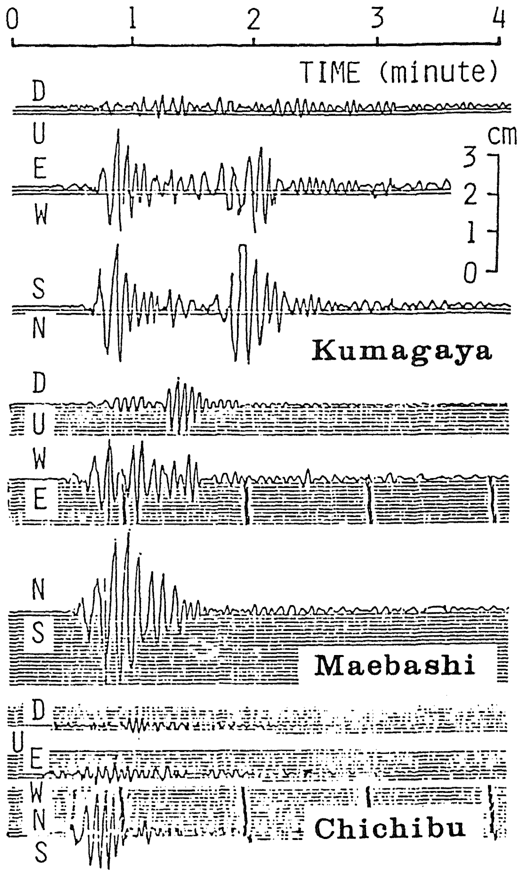

Fig. 2 Seismograms during The Western Nagano Pref. Earthquake of Sep. 14, 1984

Table 1 List of Earthquakes which make The Later Phase at Kumagaya

No.	ORIGIN TIME Y	M	D	h	m	s	LAT. D	M	LON. D	M	D km	M	LOCATION
1	1969	06	10	19	53	33.9	36	26	138	06	10	4.5	Near Matsushiro
2	1969	08	31	20	18	19.3	36	12	137	43	10	4.7	Near Matsumoto
3	1969	09	02	21	07	13.9	36	12	137	43	0	5.0	Near Matsumoto
4	1969	09	09	14	15	33.5	35	47	137	04	0	6.6	Central Gifu Pref.
5	1969	09	11	01	02	47.2	35	45	137	06	10	4.9	Central Gifu Pref.
6	1969	09	11	03	18	39.0	35	44	137	06	0	4.8	Central Gifu Pref.
7	1969	09	12	00	01	52.8	35	43	137	08	10	4.6	Central Gifu Pref.
8	1969	09	14	23	31	13.7	35	46	137	05	10	4.8	Central Gifu Pref.
9	1970	05	25	05	15	25.8	36	25	138	07	0	4.2	Near Matsushiro
10	1977	05	02	01	23	02.3	35	09	132	42	10	5.3	Central Shimane Pref.
11	1978	06	04	06	21	09.6	35	05	132	41	0	5.2	Central Shimane Pref.
12	1978	10	07	05	44	43.3	35	47	137	30	0	5.3	SE of Nagano Pref.
13	1980	09	16	05	48	57.2	35	51	137	18	0	4.6	Eastern Gifu Pref.
14	1983	03	06	06	32	18.5	35	41.2	136	01.6	8	5.0	Near Tsuruga
15	1984	09	14	08	48	49.4	35	49.3	137	33.6	2	6.8	Western Nagano Pref.
16	1984	09	14	09	20	58.7	35	48.8	137	28.7	8	4.5	Western Nagano Pref.
17	1984	09	14	12	49	44.6	35	48.3	137	29.9	8	5.0	Western Nagano Pref.
18	1984	09	15	07	14	32.6	35	47.1	137	28.2	6	6.2	Western Nagano Pref.
19	1984	09	15	07	39	10.2	35	47.0	137	29.3	9	5.6	Western Nagano Pref.
20	1984	09	15	09	05	45.5	35	47.7	137	30.4	10	5.1	Western Nagano Pref.
21	1984	09	16	15	56	45.6	35	47.4	137	30.2	9	4.4	Western Nagano Pref.
22	1984	09	17	12	22	09.4	35	49.3	137	34.5	7	4.3	Western Nagano Pref.
23	1985	02	26	19	53	52.8	35	50.3	137	34.8	8	5.0	Western Nagano Pref.
24	1985	10	03	20	57	32.7	35	10.7	135	51.7	8	5.1	NW of Shiga Pref.
25	1986	03	07	03	25		36	02	137	29	0	5.1	Northern Nagano Pref.

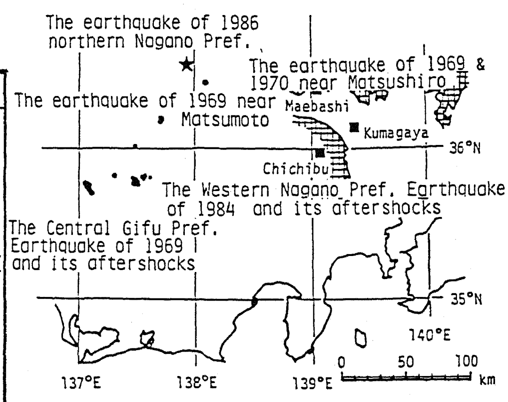

Fig. 3 Location of Epicenters which make The Later Phase in the Seismograms at Kumagaya

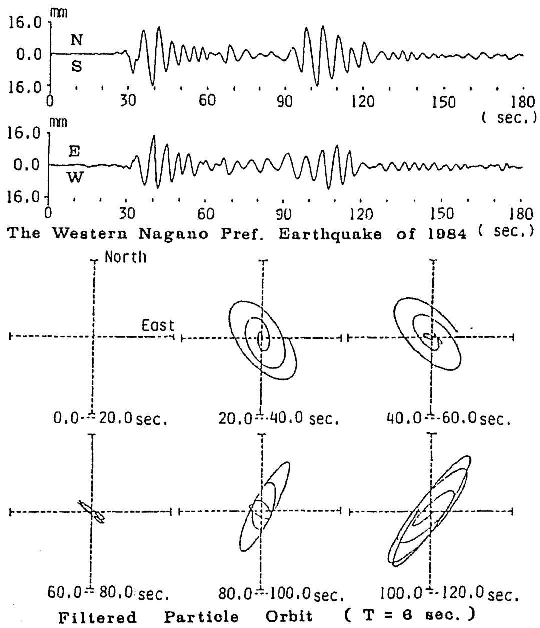

Fig. 4 Seismograms at Kumagaya during The Western Nagano Pref. Earthquake of Sep.14, 1984 & Filted Horizontal Orbital Motions

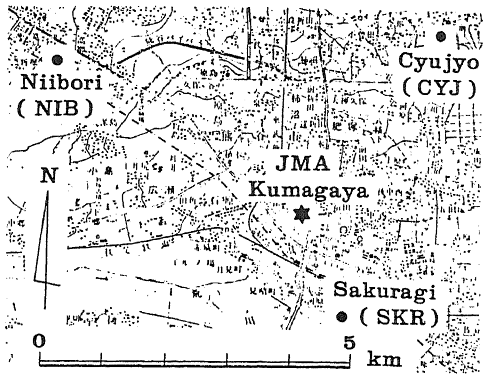

Fig. 5 Location of Observation Sites at Kumagaya District

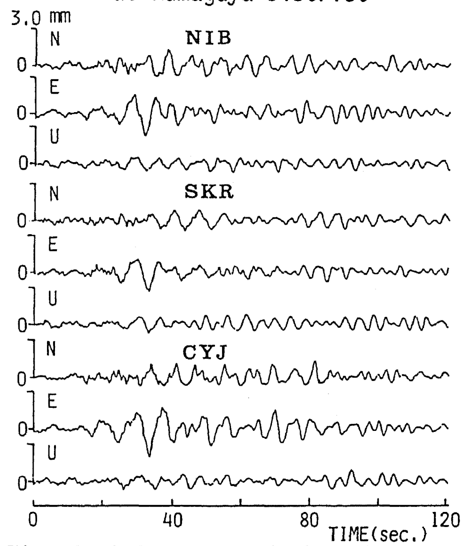

Fig. 6 Seismograms during The Earthquake of N of Nagano Pref. of Dec.30, 1986

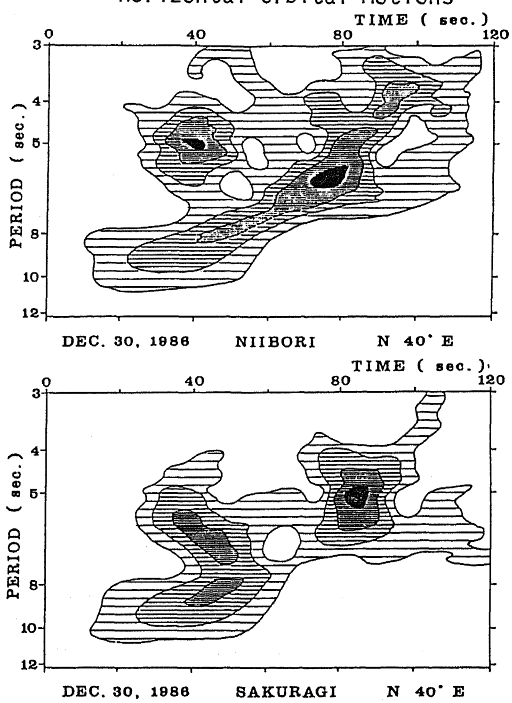

Fig. 7 Nonstationary Spectrum

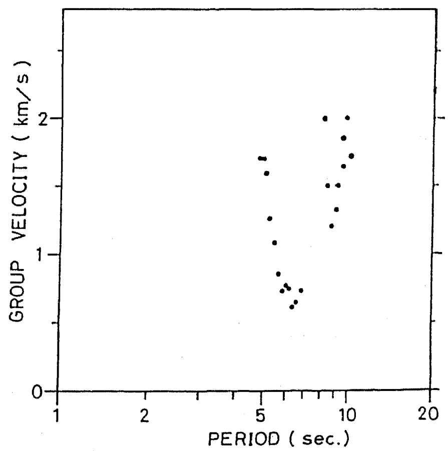

Fig. 8 Group Velocity which observed

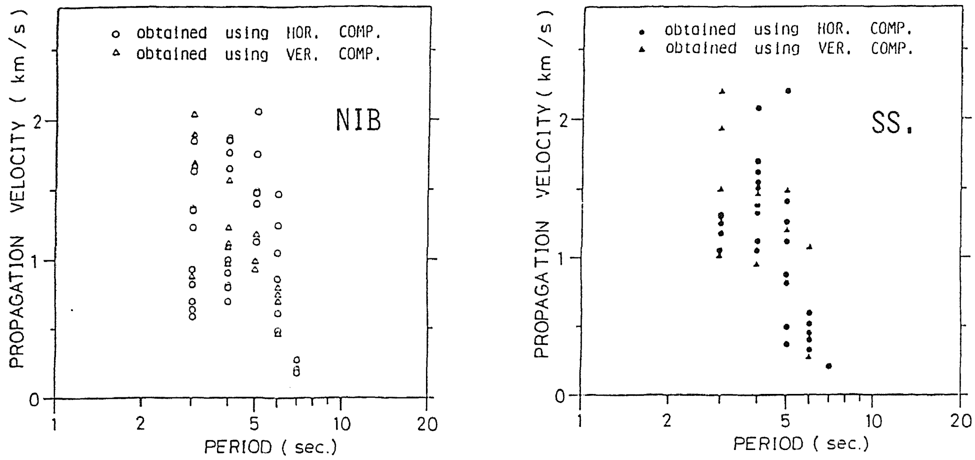

Fig. 9 Propagation Velocity observed using Microtremor

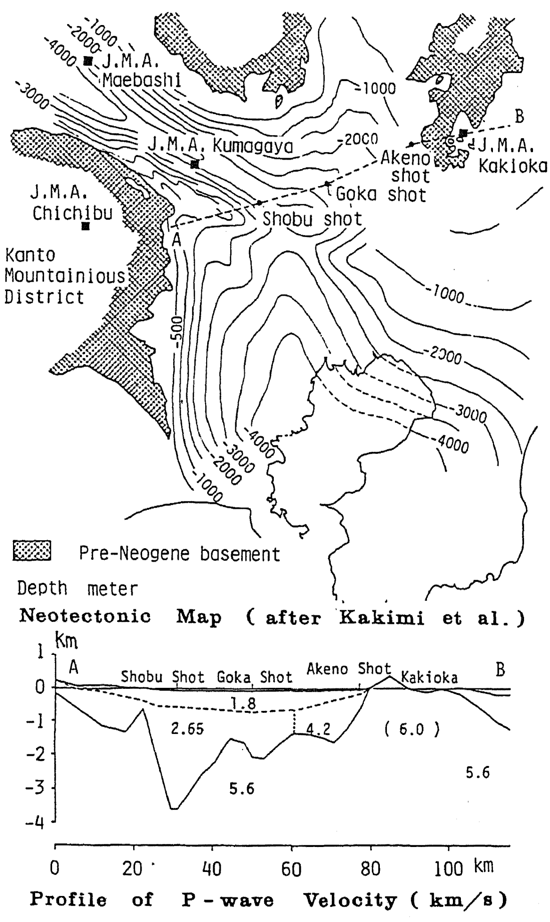

Fig. 10 Neotectonic Map (after Kakimi et al.) & Underground Structure(A-B)

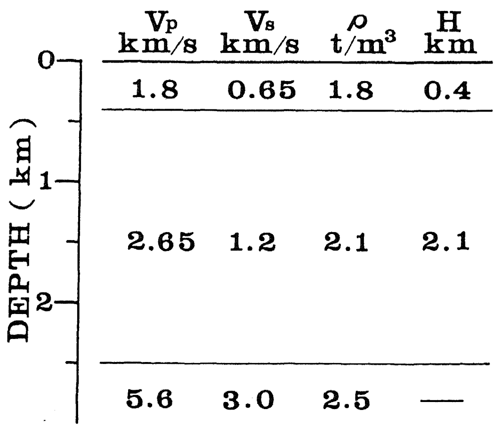

Fig. 11 Subsurface Ground Structure Model

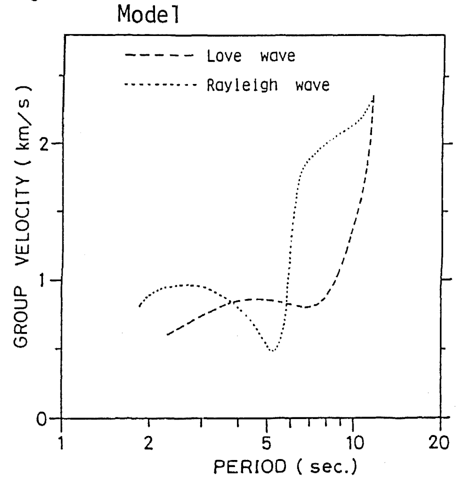

Fig. 12 Group Velocity which calculated