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3. *Crustal Structure in Japan from the Phase Velocity of Rayleigh Waves.**

Part 3, Rayleigh Waves from the Mindanao Shock of Sept. 24, 1957.

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Introduction

The crustal structure in Japan has been studied by Aki[1] and Kaminuma and Aki[2] by the use of the phase velocity of Rayleigh waves from the Samoa and Aleutian shocks recorded by the network of many seismological stations operated by the Japan Meteorological Agency.

In order to confirm the conclusions obtained in the previous papers and to study the dependence of phase velocity on the difference in the direction of the wave approach, we analyzed the records of the Mindanao shock of Sept. 24, 1957 (08h 21m 05s G.M.T., $5^{\circ 1}/_{2}$N $127^{\circ 1}/_{2}$E, M $7^{3}/_{4}$) in this paper. The direction of the wave approach from this shock is nearly the reverse of that from the Aleutian shock and makes nearly a right angle to that of the Samoa shock. Rayleigh waves with periods of 20 to 40 sec from this earthquake are fairly clearly recorded by the Wiechert seismographs of the J.M.A. stations. The Wiechert seismographs operated at these stations are adjusted to maintain uniform characteristics (pendulum periods 5.0 sec, geometric magnification 70 to 80 and the damping ratio 6 to 8). The dynamic magnification of this instrument at the period 30 sec is about 1.5 and the trace amplitudes of Rayleigh waves from the shock were 5 to 10 mm on the records.

We found that the phase velocities obtained from these three shocks agree with each other for all regions in Japan, except for the Chubu region, where the value obtained from the Mindanao shocks agrees with that from the Aleutian shock, but is significantly greater than

* Communicated by T. HAGIWARA.

1) K. AKI, *Bull. Earthq. Res. Inst.*, **39** (1961), 249-277.

2) K. KAMINUMA and K. AKI, *Bull. Earthq. Res. Inst.*, **41** (1963), 217-241.

that from the Samoa shock. The deviation of the direction of wave propagation from the great circle direction to the epicenter is larger in the Mindanao and Aleutian shocks than in the Samoa shock.

Data

The records of the Wiechert seismographs were supplied from 40 J.M.A. stations (Table 1). Typical records of the Rayleigh waves are

Table 1. List of Station

Station	Abbreviation	Longitude		Latitude	
		deg.	min.	deg.	min.
Aomori	AO	140	42.1	40	49.0
Hachinohe	HA	141	31.5	40	31.5
Miyako	MY	141	58.0	39	38.6
Morioka	MO	141	10.0	39	41.7
Akita	AK	140	06.0	39	43.0
Sendai	SE	140	54.0	38	15.5
Fukushima	FU	140	28.5	37	45.3
Onahama	ON	140	54.3	36	56.7
Utsunomiya	UT	139	52.2	36	32.7
Kakioka	KK	140	11.6	36	13.9
Maebashi	MA	139	03.9	36	24.1
Tokyo	TK	139	45.8	35	41.3
Yokohama	YO	139	39.4	35	26.2
Tomisaki	TS	139	49.7	34	55.1
Niigata	NI	139	03.1	37	54.6
Aikawa	AI	138	14.5	38	01.2
Wajima	WA	136	53.8	37	23.4
Nagano	NA	138	11.8	36	39.6
Toyama	TY	137	12.3	36	42.4
Kofu	KF	138	33.5	35	39.9
Mishima	MS	138	55.7	35	06.7
Omaezaki	OM	138	12.7	34	36.1
Shizuoka	SZ	138	24.3	34	58.3
Nagoya	NY	136	58.1	35	09.9
Gifu	GI	136	55.9	35	23.8
Hikone	HK	136	14.8	35	16.4
Kameyama	KA	136	27.9	34	51.3
Owashi	OW	136	11.7	34	03.9
Shionomisaki	SH	135	45.8	33	26.9
Osaka	OK	135	32.2	34	39.0
Wakayama	WK	135	10.0	34	13.6
Sumoto	SU	134	54.5	34	20.0
Toyooka	TY	134	49.1	35	32.1
Takamatsu	TA	134	03.5	34	19.1
Kochi	KO	133	33.1	33	33.9
Shimizu	SI	132	57.7	32	46.5
Fukuoka	FK	130	22.8	33	34.7
Oita	OT	131	37.3	33	14.0
Kumamoto	KM	130	42.6	32	48.6
Miyazaki	MZ	131	25.6	31	55.0
Kagoshima	KG	130	33.1	31	34.3
Yakushima	YA	130	29.7	30	27.0

shown in Fig. 1.

It can be seen in this figure that the onsets of the Rayleigh waves are clearly identifiable on the records. There was no difficulty in tracing

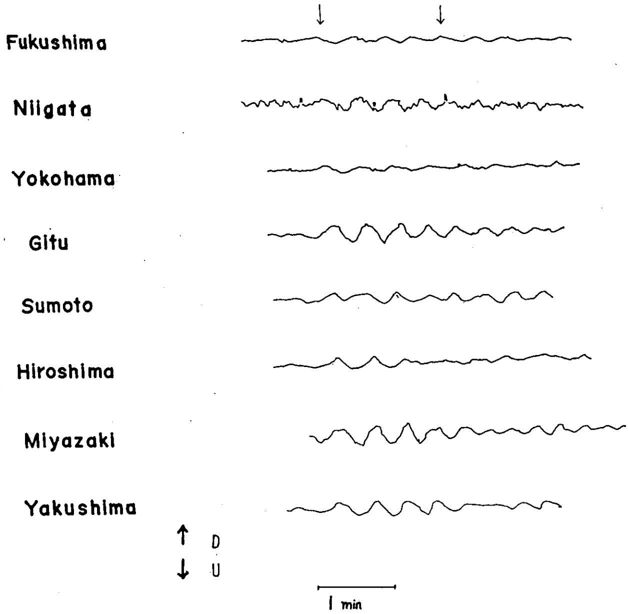

Fig. 1. Vertical component seismograms of Rayleigh waves from the Mindanao shock of Sept. 24, 1957. The arrows indicate the peaks 1.5 and 5.5.

the peaks and troughs from station to station. The arrival times and periods of each peak are determined by the same method as used in the previous papers. Arrival times and periods at each station are shown in Table 2.

Wave Front Chart

In Figs. 2 and 3, the arrival times of the 2nd and 3rd peaks are indicated on the maps of the stations. The position of the peak for successive increments in travel time of 30 sec is interpolated between stations, and is plotted on the map. Wave fronts are drawn to pass through these interpolated points. The dashed lines in these figures indicate the epicentral distances of 29° and 34°.

In a part of western Japan (the west side of the Chugoku and Shikoku province), an accurate measurement of phase velocity was

Table 2. Arrival times and

Peak No.	1.5			2			2.5		
Station	period	arrival time		period	arrival time		period	arrival time	
	sec.	min.	sec.	sec.	min.	sec.	sec.	min.	sec.
Aomori	36.0	39	34.5	32.8	39	51.6	28.0	40	06.0
Hachinoe	37.5	39	30.6	33.5	39	48.8	28.5	40	04.3
Miyako	36.0	39	07.5	32.5	39	24.3	27.5	39	38.6
Morioka	36.5	39	06.0	32.5	39	23.2	28.3	39	38.5
Akita	34.0	39	00.0	30.2	39	16.2	28.3	39	30.3
Sendai	33.5	38	23.5	30.0	38	38.4	27.0	38	52.1
Fukushima	33.5	38	05.3	30.0	38	20.9	27.0	38	34.5
Onahama	32.5	37	47.0	29.0	38	01.5	28.5	38	15.0
Utsunomiya	32.5	37	28.5	29.3	37	43.5	27.2	37	57.0
Kakioka	32.0	37	21.0	29.0	37	35.5	28.4	37	49.5
Maebashi	32.0	37	19.0	28.5	37	32.8	26.8	37	46.0
Tokyo	31.5	37	02.2	28.0	37	16.9	26.3	37	30.4
Yokohama	32.5	36	55.0	28.0	37	09.1	26.0	37	21.5
Tomisaki	33.5	36	41.5	29.0	36	56.5	26.5	37	09.3
Niigata	35.5	37	58.0	29.5	38	13.1	27.5	38	26.8
Aikawa	35.5	37	59.0	30.5	38	15.3	27.5	38	29.3
Wajima	34.5	37	30.8	28.8	37	46.0	27.0	37	59.3
Nagano	33.0	37	18.5	28.5	37	33.5	27.0	37	47.0
Toyama	32.5	37	12.0	29.0	37	26.5	27.0	37	40.8
Kofu	32.0	36	50.5	28.0	37	05.5	27.0	37	18.6
Mishima	31.5	36	39.0	27.6	36	53.0	26.3	37	06.0
Omaezaka	31.5	36	19.8	28.3	36	33.5	27.3	36	47.5
Shizuoka	33.5	36	32.0	29.5	36	47.2	27.5	37	01.0
Nagoya	32.5	36	26.3	29.5	36	40.5	27.3	36	54.0
Gifu	31.6	36	28.4	29.3	36	43.3	27.2	36	57.0
Hikone	32.0	36	22.8	29.5	36	38.0	27.0	36	52.0
Kameyama	32.0	36	13.3	28.5	36	27.5	27.0	36	40.4
Owashi	32.5	35	50.5	28.0	36	05.3	26.0	36	18.5
Shionomisaki	30.0	35	29.0	28.0	35	44.0	25.5	35	57.2
Osaka	30.0	36	02.6	27.5	36	16.9	25.5	36	29.5
Wakayama	30.0	35	45.0	27.8	35	59.6	25.8	36	12.8
Sumoto	31.5	35	48.0	27.5	36	02.5	25.5	36	15.5
Toyooka	33.0	36	23.8	28.5	36	38.3	26.0	36	51.6
Takamatsu	30.0	35	42.5	27.5	35	56.8	25.5	36	10.0
Kochi	29.0	35	20.3	27.5	35	34.5	26.5	35	47.7
Shimizu	32.5	34	54.3	28.0	35	08.2	26.0	35	20.8
Fukuoka	34.0	35	13.0	31.0	35	28.6	28.5	35	43.8
Oita	34.5	35	07.5	31.0	35	23.0	28.0	35	37.2
Kumamoto	33.5	34	52.8	31.0	35	08.0	28.5	35	22.0
Miyazaki	35.0	34	29.4	29.0	34	44.3	28.0	34	57.7
Kagoshima	34.0	34	14.8	31.0	34	30.9	28.0	34	45.3
Yakushima	33.0	33	44.0	29.0	33	59.0	27.5	34	12.0

periods at each station.

3			3.5			4		
period	arrival time		period	arrival time		period	arrival time	
sec.	min.	sec.	sec.	min.	sec.	sec.	min.	sec.
27.5	40	19.6	26.5	40	33.3	24.5	40	46.5
27.0	40	17.6	25.0	40	30.0	24.3	40	42.4
24.5	39	51.5	25.0	40	02.0	20.0	40	12.0
25.5	39	52.0	25.0	40	04.5	24.8	40	17.0
26.5	39	42.9	25.0	39	55.4	24.2	40	09.0
26.2	39	06.3	24.5	39	18.0	23.0	39	30.0
26.5	38	48.0	25.0	39	01.3	23.5	39	13.2
26.0	38	28.5	24.5	38	41.0			
26.0	38	09.0	25.8	38	22.0	24.5	38	35.0
26.0	38	03.0	25.4	38	14.5	24.0	38	27.3
25.5	37	59.1	24.8	38	11.0	24.0	38	22.8
25.0	37	42.8	24.0	37	55.2	24.0	38	07.5
25.0	37	33.0	24.5	37	44.5	24.0	37	56.3
26.0	37	21.4	25.2	37	33.8	24.2	37	46.5
26.5	38	40.0	26.0	38	53.0	25.0	39	06.2
26.0	38	42.3	25.3	38	54.3	24.5	39	06.5
26.2	38	12.5	25.0	38	25.5	23.0	38	37.0
26.0	38	00.8	25.0	38	12.5	23.5	38	24.5
26.0	37	53.8	25.0	38	06.0	24.0	38	18.3
25.5	37	31.2	25.0	37	44.5	24.3	37	57.0
25.0	37	18.4	24.7	37	30.2	24.0	37	41.5
25.4	36	59.1	25.0	37	11.6	24.0	37	23.6
25.0	37	14.3	24.0	37	26.0	23.5	37	38.6
26.0	37	06.5	25.3	37	18.8	23.2	37	30.0
25.8	37	10.0	25.0	37	22.5	24.0	37	34.3
25.0	37	04.7	24.5	37	16.5	24.0	37	29.0
25.0	36	52.7	24.5	37	05.0	24.0	37	17.0
25.0	36	30.5	24.3	36	43.5	23.5	36	55.2
24.8	36	09.3	24.0	36	20.8	23.6	36	33.6
24.5	36	42.0	23.5	36	53.6	22.5	37	04.6
24.3	36	24.8	23.8	36	35.5	23.0	36	47.5
24.0	36	27.5	23.0	36	38.5	22.5	36	49.3
24.5	37	03.8	24.0	37	15.5	23.5	37	27.0
24.0	36	22.0	23.5	36	33.8	23.0	36	45.5
24.5	35	59.5	23.5	36	12.0	23.5	36	24.0
24.5	35	33.0	24.0	35	45.0	23.0	35	56.5
27.0	35	57.6	25.0	36	10.0	24.0	36	22.0
27.0	35	51.0	25.0	36	04.5	24.3	36	17.0
27.0	35	35.5	25.5	35	48.5	25.0	36	01.5
26.4	35	11.5	25.5	35	24.8	24.5	35	37.0
25.5	34	58.6	24.5	35	10.4	24.0	35	21.9
25.0	34	24.8	24.0	34	38.4	23.5	34	51.0

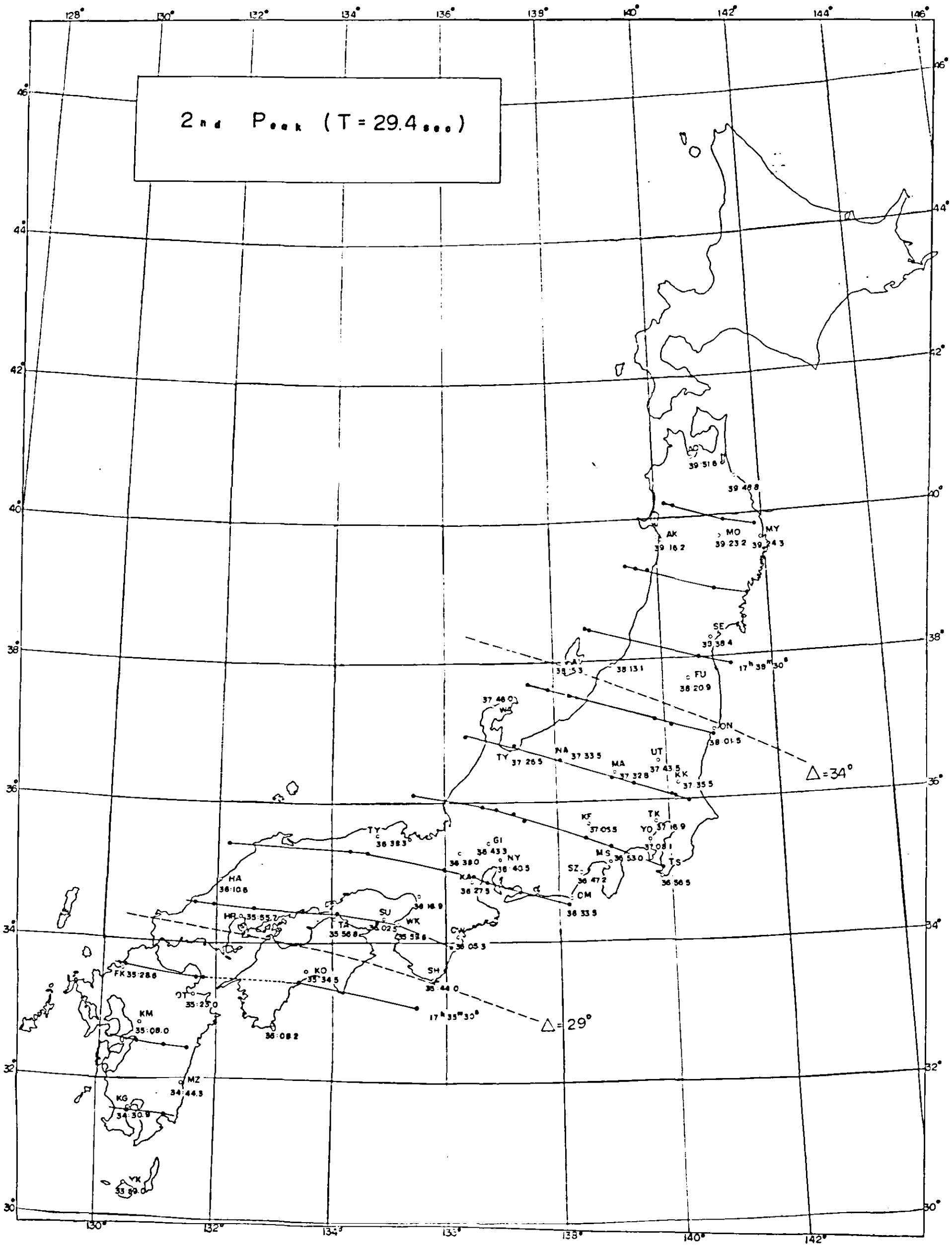

Fig. 2. Wave front of the 2nd peak at every 30 seconds across Japan. The broken lines indicate the epicentral distance of 29° and 34°.

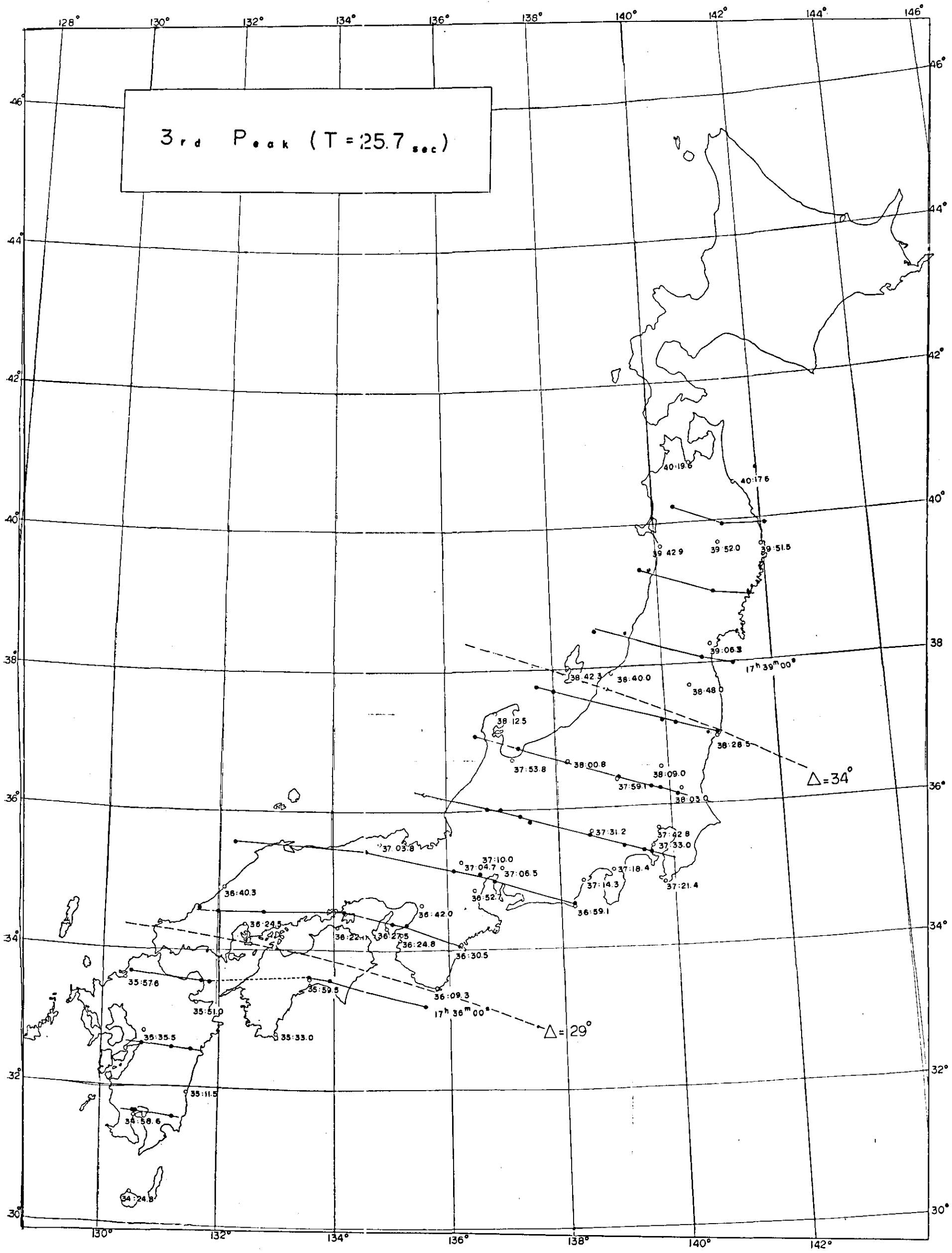

Fig. 3. Wave front of the 3rd peak at every 30 seconds across Japan. The broken lines indicate the epicentral distance of 29° and 34°.

impossible because Rayleigh waves are disturbed. Thin dashed lines are used to indicate this area.

In eastern Japan, the wave fronts are widely separated from the equi-epicentral distance line. This separation is caused by the difference in the travel time between the ocean and the Japanese Islands.

In order to obtain a phase velocity with a high degree of accuracy, we use the least squares method to the data from many stations within a certain area to compute the phase velocity for the area. Stations are divided into 9 regions as shown in Fig. 4. It was intended that the regions should coincide with those in the previous papers and that

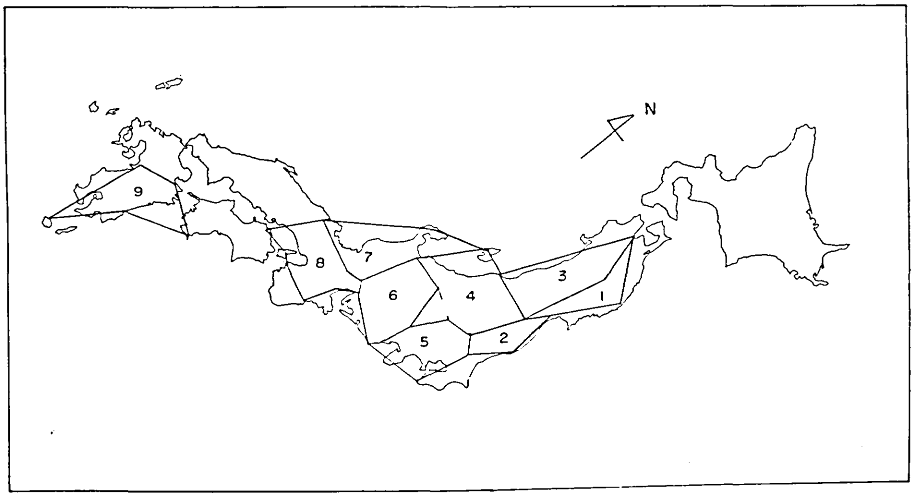

Fig. 4. Division of stations into 9 groups: 1, Eastern Tohoku; 2, Joban; 3, Western Tohoku; 4, Joetsu; 5, Kanto; 6, Chubu; 7, Hokuriku; 8, Kinki; 9, Southern Kyushu.

Table 3. List of the reference points with their epicentral distances and the great circle direction to the epicentre.

Station	Region	Epicentral distance		Great circle direction (from south to west)	
		deg.	min.	deg.	min.
Fukushima	1, 2	34	33	23	11
Niigata	3, 4	34	29	20	36
Yokohama	5	31	50	23	24
Gifu	6, 7, 8	30	57	18	19
Miyazaki	9	26	32	8	47

the boundaries of regions showed coincide with those separating major geological provinces in Japan. Care was taken also for the wave front to be nearly a straight line within each region. The reference point for each region is listed in Table 3 together with the epicentral distance and the great circle direction to the epicenter.

Phase Velocity

We use the same formula as given by Aki[3] to determine the phase velocity of Rayleigh waves. The reference points for each region are listed in Table 3 together with the epicentral distance and the great circle direction to the epicenter.

The phase velocity of Rayleigh waves and the direction of propagation of the peak measured from the south (west positive) are listed in Table 4 with the probable errors, for various regions.

The probable errors of the velocities of the 1st, 4th and 5th peak are large in most regions. In the determination of crustal thickness,

Table 4. The values of phase velocity V, direction of propagation θ and crustal thickness obtained under Aki's standard phase velocity curves and errors in various regions.

Wave No.	Period (sec)	V (km/sec)	θ (deg.)	Crustal thickness Aki's model (km)
Region 1				
1.5	35.5	3.794±0.040	14.7±1.0	28±4
2	31.9	3.685±0.047	15.2±1.1	35±4
2.5	27.7	3.623±0.072	15.7±1.1	34±5
3	26.2	3.648±0.075	14.7±1.0	31±5
			Average	32±2
Region 2				
1.5	32.8	3.784±0.068	18.9±1.9	27±7
2	29.5	3.754±0.055	16.5±1.6	27±4
2.5	27.6	3.762±0.037	16.6±1.1	25±3
3	26.1	3.683±0.031	19.5±0.9	28±2
			Average	27±1

(to be continued)

3) K. Aki, *loc. cit.*, 1).

Table 4. (continued)

Wave No.	Period (sec)	V (km/sec)	θ (deg.)	Crustal thickness Aki's model (km)
Region 3				
1.5	35.1	3.665±0.058	19.0±1.6	40±5
2	31.0	3.589±0.053	20.1±1.4	40±3
2.5	27.8	3.546±0.061	21.0±1.6	39±3
3	26.5	3.539±0.044	21.7±1.2	37±3
3.5	25.5	3.536±0.014	21.6±0.4	36±1
			Average	37±1
Region 4				
1	40.2	3.750±0.054	17.4±1.0	37±6
1.5	32.1	3.657±0.042	18.2±0.8	38±4
2	28.4	3.640±0.043	19.7±0.8	34±3
2.5	26.9	3.627±0.056	20.3±1.0	30±3
3	25.5	3.566±0.062	19.6±1.2	30±4
3.5	24.9	3.566±0.072	19.3±1.4	34±3
4	24.1	3.544±0.090	20.9±1.7	34±5
			Average	33±1
Region 5				
1.5	33.5	3.819±0.080	18.5±1.0	25±14
2	29.3	3.722±0.090	17.7±1.2	32±7
2.5	27.1	3.695±0.092	17.3±1.2	29±6
3	26.1	3.666±0.084	17.0±1.1	29±5
3.5	25.3	3.628±0.068	17.6±0.9	30±4
4	24.1	3.611±0.061	17.6±0.8	30±3
			Average	30±1
Region 6				
1.5	32.4	3.661±0.054	19.8±0.8	37±3
2	28.9	3.614±0.054	19.8±0.9	36±3
2.5	27.2	3.624±0.066	19.0±1.1	33±4
3	25.7	3.547±0.075	18.5±1.1	36±6
3.5	24.9	3.568±0.051	18.8±0.9	35±3
			Average	36±1

(to be continued)

Table 4. (continued)

Wave No.	Period (sec)	V (km/sec)	θ (deg.)	Crustal thickness Aki's model (km)
Region 7				
1.5	33.2	3.485±0.038	11.2±0.8	51±3
2	29.3	3.461±0.055	11.8±1.1	47±3
2.5	27.0	3.476±0.061	12.7±1.2	42±3
3	25.6	3.470±0.051	13.3±1.0	40±3
3.5	24.8	3.457±0.029	13.5±0.6	40±2
			Average	43±2
Region 8				
1.5	31.5	3.780±0.096	15.3±1.1	25±8
2	28.4	3.744±0.082	15.1±0.9	27±6
2.5	26.3	3.679±0.070	14.8±0.8	29±4
3	24.8	3.635±0.070	15.1±0.8	30±4
3.5	24.1	3.601±0.079	15.7±0.9	31±4
			Average	29±1
Region 9				
1	40.8	3.847±0.049	5.9±0.9	24±9
1.5	33.8	3.795±0.056	3.4±1.1	27±6
2	29.7	3.744±0.067	1.5±1.3	28±5
2.5	27.7	3.676±0.072	−0.2±1.4	31±5
3	25.9	3.620±0.088	−1.5±1.8	32±5
			Average	29±2

Table 5. The average phase velocity and the crustal thickness in central Japan (averaged velocity in 4, 5, 6, 7 and 8).

Phase No.	Period (sec)	Phase velocity (km/sec)	Crustal thickness (km)
1	39.8	3.81	30
1.5	32.6	3.70	35
2	28.9	3.66	34
2.5	27.0	3.64	32
3	25.5	3.59	33
3.5	24.6	3.58	33
4	23.8	3.55	33
5	22.9	3.52	33
		Average	33

we use the peaks with probable errors less than about 2.5%. In general, the probable errors of peak 1.5, 2, 2.5 and 3 are small.

The average phase velocity of each peak in central Japan (region 4, 5, 6, 7 and 8) is shown in Table 5.

Crustal Thickness

In the previous papers, we compared the observed phase velocity with the theoretical curves based on Press' model 6EG[4] and Aki's model 6EJ[5] and showed that Aki's model better explains the observation in Japan than Press'. In this paper, the thickness of the crust is obtained by the application of Aki's phase velocity curves (Fig. 5).

Several values of the thickness of the crust are obtained for each region from different peaks. They are averaged over many peaks for each region with the weight inversely proportional to the variance as determined by the least squares method. The weighted averages are computed by the formulas given in Kaminuma and Aki[6].

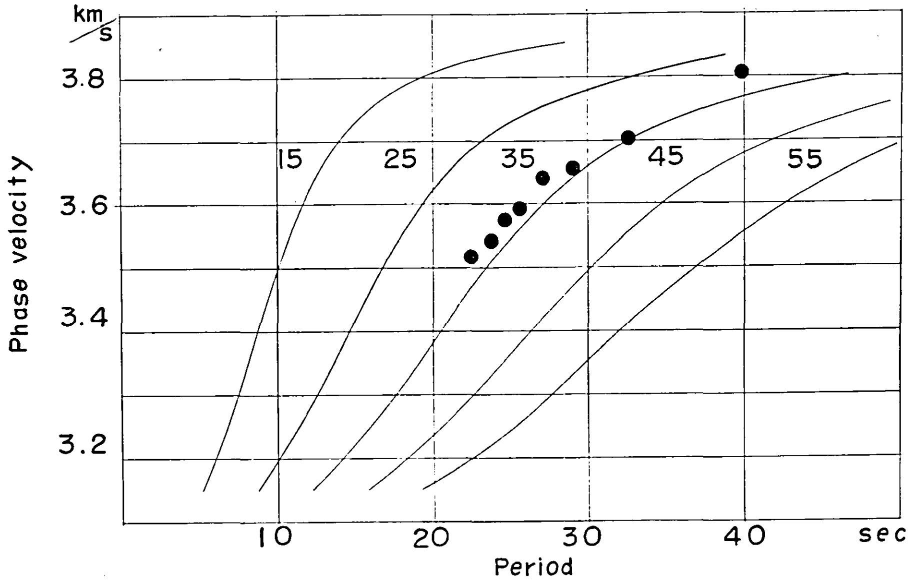

Fig. 5. Aki's standard phase velocity curves (Aki, 1961). The observed phase velocity in central Japan is also shown.

4) F. PRESS, *J. Geophys. Res.*, **65** (1960), 1039-1051.
5) K. AKI, *loc. cit.*, 1).
6) K. KAMINUMA and K. AKI, *loc. cit.*, 2)

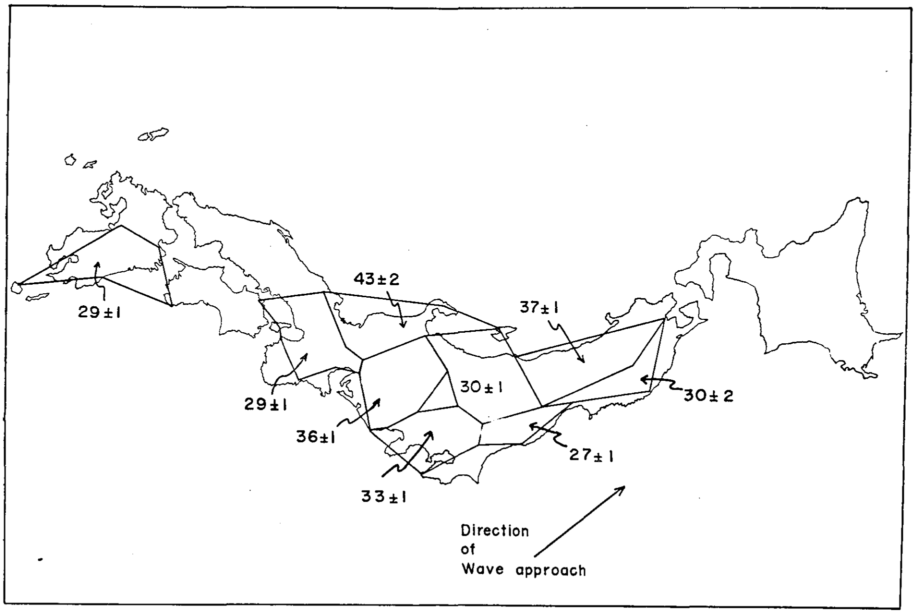

Fig. 6. Crustal thickness in kilometer for each region obtained by the use of Aki's standard phase velocity curves.

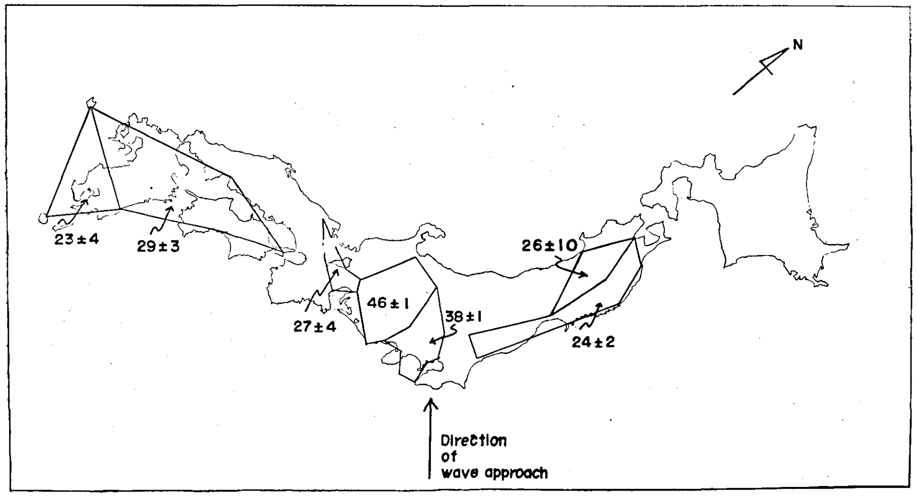

Fig. 7. Crustal thickness in kilometer for each region obtained by the use of Aki's standard phase velocity curves from the Rayleigh waves of the Samoa shock (Aki, 1961).

The average thickness in each region is shown in Fig. 6. The corresponding maps obtained in the previous papers are reproduced in Figs. 7 and 8. In western Japan, the thickness in this paper agrees

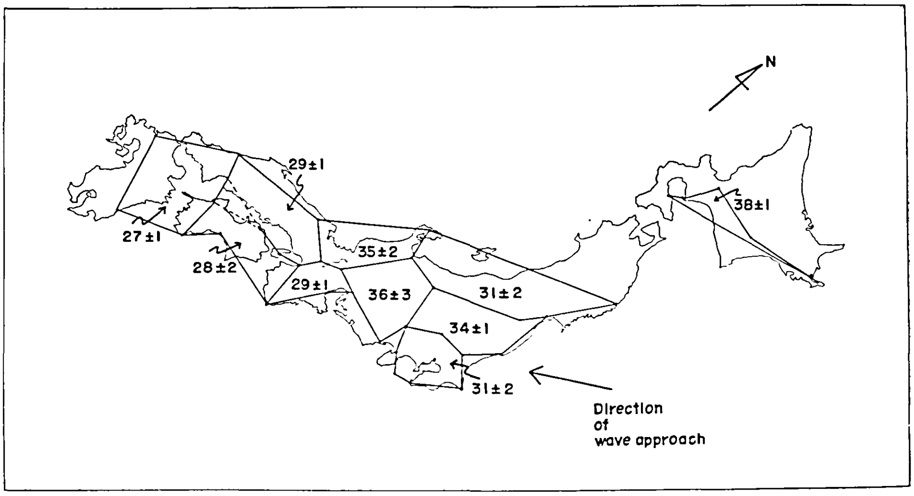

Fig. 8. Crustal thickness in kilometer for each region obtained by the use of Aki's standard phase velocity curves from the Rayleigh waves of the Aleutian shock (Kaminuma and Aki, 1963).

with the thickness in the previous papers within the limit of errors. The thickness in central Japan agrees with the thickness obtained from the records of the Aleutian shock. The stations in the Chubu region (region 6) are the same as used in the Samoa shock study and nearly the same as in the Aleutian shock. The thickness obtained from the Mindanao shock agrees with that from the Aleutian shock and does not agree with that from the Samoa shock. It is clear that the phase velocity depends on the direction of the wave propagation in this region. The phase velocity of Rayleigh waves propagated parallel to the trend of Japanese Islands is 4% greater than that for the perpendicular path.

The thicknesses in eastern Japan show a little difference between the Mindanao shock and the Samoa shock. The area of region 3 in the case of the Mindanao shock was spread out over central Japan and may have a thicker crust. If we use the stations as used in the Samoa shock study, we obtain a thickness of 30 km. Since the thickness obtained from the Samoa shock had probable errors of 10 km, it may be concluded that both results agree within the limit of errors.

A map of crustal thickness in Japan is drawn from the phase velocity of Rayleigh waves obtained from the Samoa, Aleutian and Mindanao shocks as shown in Fig. 9. The Hokkaido province is excluded because we have only one set of measurements for this area.

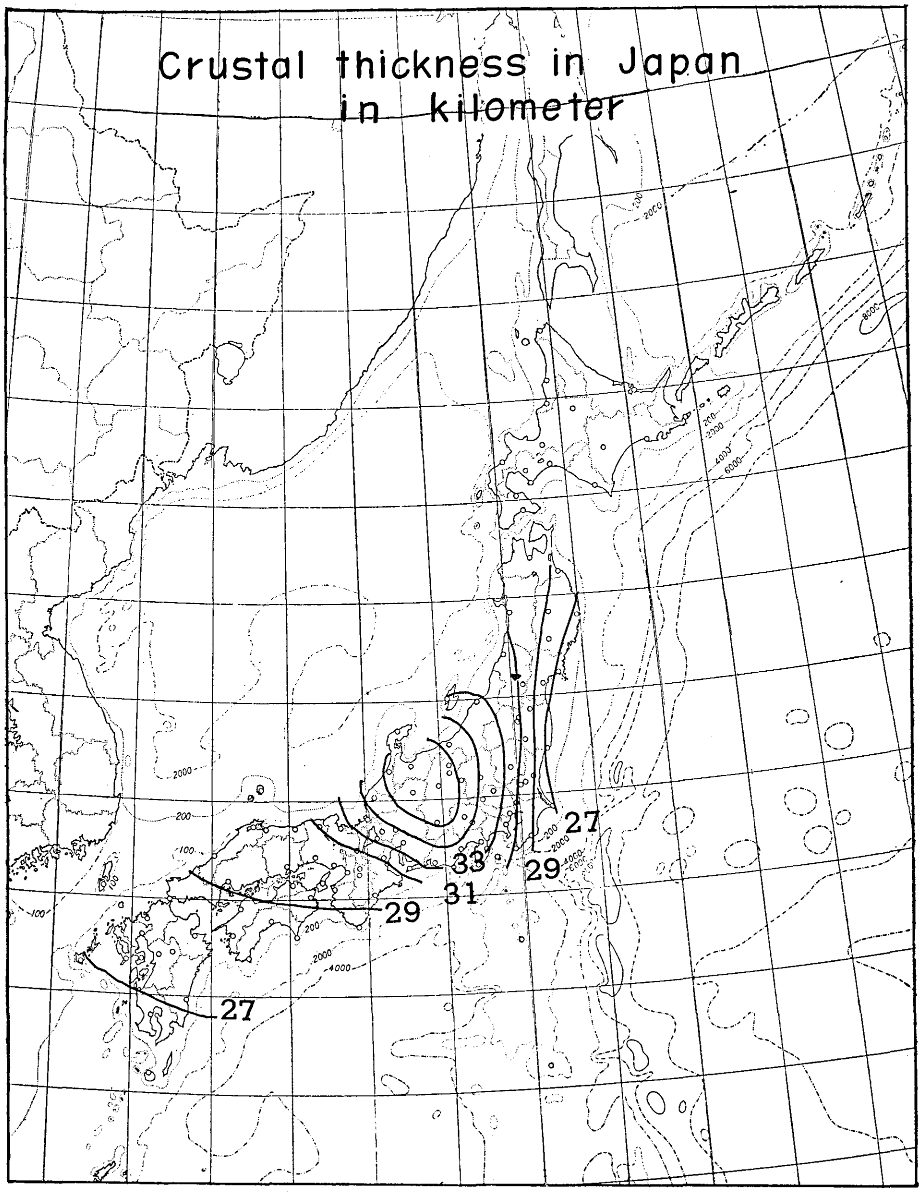

Fig. 9. A map of crustal thickness in Japan determined from the phase velocity of Rayleigh waves.

The Reduced Bouguer Gravity Anomaly and the Phase Velocity of Rayleigh Waves

Recently, Kanamori[7] computed the reduced Bouguer gravity for Japan. This gravity anomaly may be related to the crustal thickness in the following form, $D=D_0-\Delta G/2\pi k^2\Delta\rho$. The average reduced Bouguer anomaly and the average crustal thickness of each region are listed in Table 5 together with the phase velocity of Rayleigh waves with the period of 30 sec which was obtained from the average crustal thickness in each region by the use of Aki's standard phase velocity curve. The corresponding data for the regions studied in the previous papers is

Table 6. The reduced Bouguer gravity anomaly, the crustal thickness and the phase velocity of Rayleigh waves with a period of 30 sec in the Mindanao shock.

Region	Reduced Bouguer Anomaly (mgal)	Crustal thickness (km)	Phase velocity (T=30 sec) (km/sec)
1	70	32±1	3.70
2	86	27±1	3.75
3	37	37±1	3.62
4	6	30±1	3.73
5	1	33±1	3.69
6	−38	36±1	3.64
7	19	43±1	3.53
8	0	29±1	3.73
9	−20	29±2	3.73

Table 7. The reduced Bouguer gravity anomaly, the crustal thickness and the phase velocity of Rayleigh waves with a period of 30 sec in the Samoa shock.

Region	Reduced Bouguer Anomaly (mgal)	Crustal thickness (km)	Phase velocity (T=30 sec) (km/sec)
E. Tohoku	89	24±2	3.77
W. Tohoku	40	26±10	3.76
S. W. Kanto	−21	38±1	3.56
Chubu	−38	46±1	3.45
Kinki	0	27±4	3.75
S. W. Japan	−4	29±3	3.72

7) H. KANAMORI, *Bull. Earthq. Res. Inst.*, **41** (1963), 743-759.

Table 8. The reduced Bouguer gravity anomaly, the crustal thickness and the phase velocity of Rayleigh waves with a period of 30 sec in the Aleutian shock.

Region	Reduced Bouguer Anomaly (mgal)	Crustal thickness (km)	Phase velocity (T=30 sec) (km/sec)
S. Hokkaido	24	38±1	3.61
Shinetsu	25	31±2	3.72
N. Kanto	30	34±1	3.67
S. Kanto	10	31±2	3.72
Chubu	−37	36±3	3.64
Hokuriku	−16	35±2	3.66
Kii	37	29±1	3.73
Chugoku	9	29±1	3.73
Shikoku	14	28±2	3.74
Bungo	26	27±1	3.75

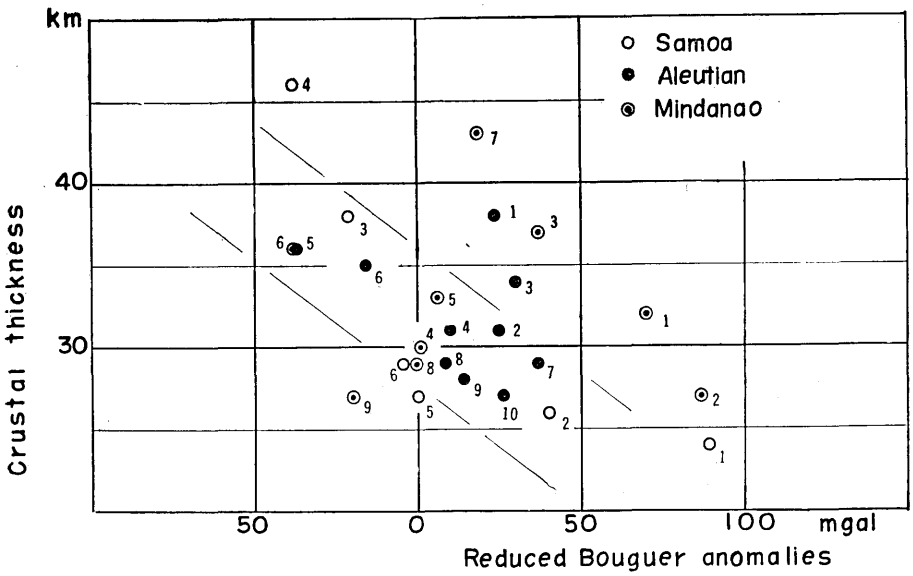

Fig. 10. Relation between the crustal thickness and the reduced Bouguer gravity anomaly for various regions in Japan.

listed in Tables 6 and 7.

Fig. 10 shows the relation between the crustal thickness and the reduced Bouguer anomaly for various regions in Japan. The theoretical relation is shown for the cases where the thicknesses of the standard continental crust are 28 and 36 km and the density contrast between the mantle and the crust is 0.4 gr/cm^3. Most of the points in this figure are included in the zone between the two theoretical lines in western and central Japan. Most of the deviated points from the zone are the regions of eastern Japan. It may be that the crustal structure of eastern Japan cannot be explained by the same model as for central and western Japan.

The Deviation Angle and the Direction of Wave Propagation

Fig. 11 shows the observed direction of wave propagation and the great circle direction to epicenter at some stations. The deviation angles between the observed direction and the great circle direction are at most 2 or 3 degrees at periods of 30 sec in the Samoa shock, but are much greater in the Mindanao and Aleutian shocks. The directions of wave propagation are deviated from the great circle direction to the side of the Pacific Ocean in the Mindanao and Aleutian shocks. It is caused by the fact that the velocity is higher in the Pacific Ocean in both cases.

There is one province where we could not determine the phase velocity of Rayleigh waves with a high degree of accuracy in each of the cases of Aleutian and Mindanao shocks. These provinces are shown by the shaded portion in Fig. 11. The shaded portion of eastern Japan

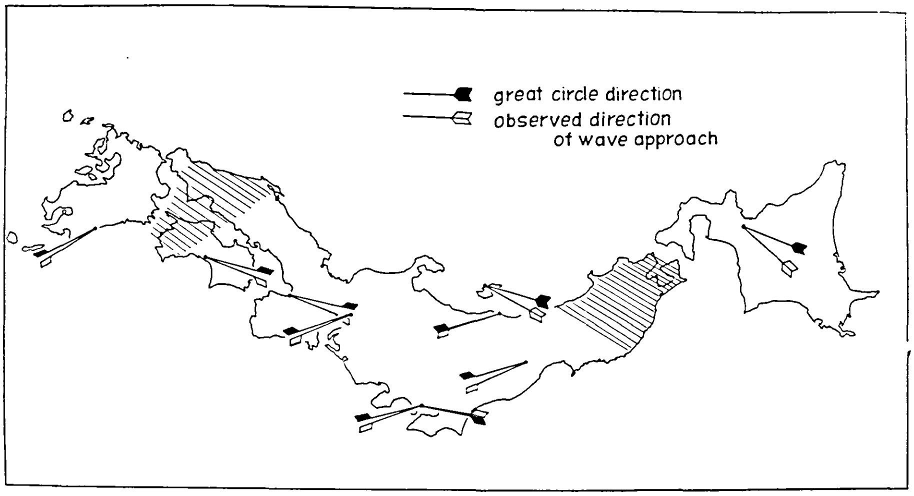

Fig. 11. The great circle direction and the observed direction of wave propagation of the 2nd peak in the Mindanao and Aleutian shocks at certain reference points. The shaded portions show regions where Rayleigh waves are disturbed.

is for the case of the Aleutian shock and that of western Japan for the case of the Mindanao shock. They may be caused by an interference phenomenon between two waves which passed both sides of a continental shelf. Further study is necessary to establish this.

Acknowledgment

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3. レーリー波位相速度法による日本の地下構造の研究（第3報）

東京大学理学部地球物理学教室　神　沼　克　伊

1957年9月24日のミンダナオ島附近に起つた地震によるレーリー波（周期20秒～40秒）は，気象庁ウィーヘルト観測網により，ほとんど日本全土にわたつて，かなり良く記録された（第1図）．気象庁の御好意により集められた記録のうち，42カ所の記象を解析し，日本各地でのレーリー波の位相速度およびその伝播方向が求められた．

前2回の報告は，波が日本列島に対し，北東および南東方向から伝播してきたが，今回は南々西の方向から伝播してきた．

これによつて，北海道を除き，大体日本列島全体にわたり，少なくとも2方向からくるレーリー波の位相速度が求められた．

今回の結果は，誤差の範囲内で，前2回の結果と一致している．

前回問題として残した，中部地方におけるサモア地震とアリューシャン地震の場合の位相速度の違いについては，今回の結果がアリューシャン地震の場合に一致した．つまり，中部地方では，波が日本列島に直角に入る方が，平行に入る場合に比して，位相速度が約4％遅くなる．

東北日本については，地殻の厚さがサモア地震から求めたものに比して，かなり厚くなつている．サモア地震の場合，選んだ地域の幅が，レーリー波の波長とほぼ同じか，やや短い位なので，その直下の地下構造が位相速度に充分あらわれていないことも考えられる．またその確率誤差が比較的大きいことなども考慮すると，両者は誤差の範囲内で一致しているといえる．

いわゆる reduced Bouguer anomaly と各地域の地殻の厚さとの間には，直線的関係がある（第9図）．ほとんどの地域がある一定の帯の中に含まれるが，東北地方だけは，大きくずれる．これは，東北日本の地殻が中央および西日本と同一の 6EJ というモデルで説明できないことを意味するのかもしれない．

サモア地震の場合は，震源への大円方向と計算によつて求めた波の伝播方向との間に，大きな違いはなかつたが，アリューシャンおよびミンダナオ地震の場合には，各地域とも5～10°のずれがある．これらはいずれも，太平洋側の速度が大陸側にくらべて速いことに原因がある．

また，アリューシャン地震の場合には，東北地方北部域で，ミンダナオ地震の場合には，中国，四国地方の西部域で，純粋なレーリー波が得られなかつた．これは，丁度，この地域で二つの道すじの波が合して干渉しあうためであろう．