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SURFACE WAVE DISPERSION FOR SOME EURASIAN PATHS II. LOVE WAVES

by

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Abstract

Love waves from 19 earthquakes have been investigated. The dispersion data for paths from Japan, Formosa and Altai to Helsinki are consistent with one another. The paths which have crossed the great Asian tertiary massif show lower group group velocities for corresponding periods than the previous paths. With the aid of some simple assumptions, this effect is interpreted to indicate a crustal thickening of about 20 km in this region of young mountain ranges as compared with the average crust of this continent.

Introduction

It is an important geophysical problem whether the average crustal structure of various continents is similar or not. Many surface wave investigations have suggested that there exists a remarkable uniformity in the average properties of the crust of several continents. In order to solve this problem it is necessary to analyze surface wave trains of earthquake recordings for numerous paths across various continents. The object of the present study was to work out some new experimental dispersion curves of fundamental Lowe waves for Eurasian paths.

We shall study especially whether the effect of the great Asian tertiary massif is detectable by surface wave dispersion studies. This can be done by utilizing propagation paths crossing this massif.

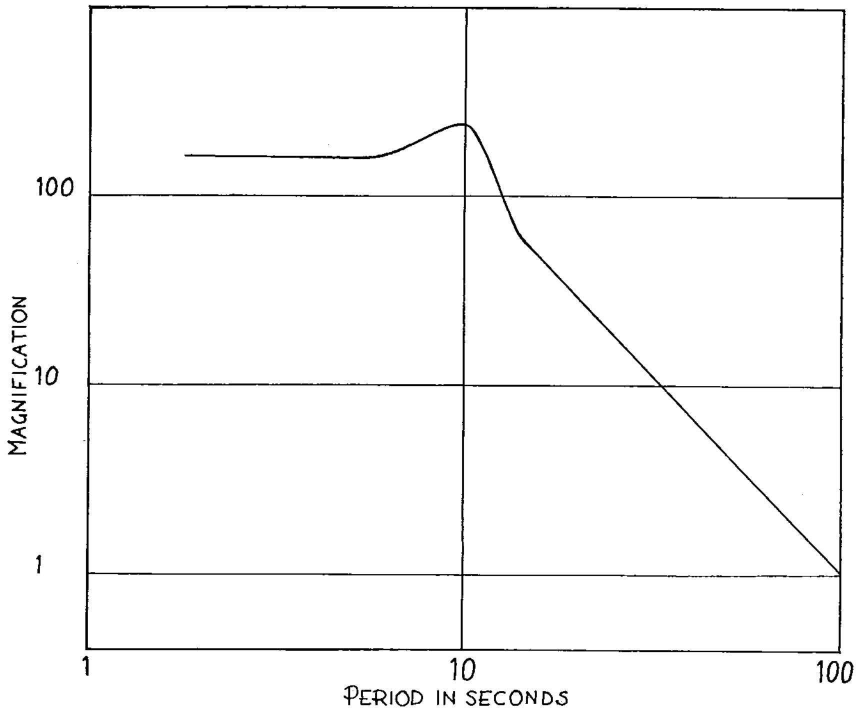

Fig. 1. Calibration curve for Mainka seismograph.

For a description of the methods used, reference is made to the part one of this work [5]. The present study is based on the records of the Helsinki seismograph station (60°10′32″N, 24°57′25″E) with Mainka horizontal instruments. They are furnished with a mechanical recording system. Figure 1 shows the calibration curve for the E-component seismograph according to a determination made in 1960 [4]. The two components are very similar and no great changes have occurred in the course of years.

No comparisons with theoretical crustal models are made in this paper.

Dispersion data

All the 19 earthquakes the Love wave trains of which were analyzed for this study are listed in Table 1. All these shocks were shallow. They have been divided into four groups according to the regions in which

Table 1. List of earthquakes.

No.	Date	Origin time[1]) GMT	Epicentre[1]) Lat.	Long.	Mag.[2])	Dist. km	Comp.
1	Mar. 9, 1931	03 48 57	40.5 N,	142.5 E	7.7	7450	N
2	Nov. 26, 1932	04 24 01	42.3 N,	142.4 E	6¾	7270	N
3	Jan. 7, 1933	04 06 44	40.3 N,	144.0 E	6½	7540	E
4	Oct. 18, 1935	00 12 04	40.2 N,	143.2 E	7.2	7515	E
5	Sep. 10, 1948	13 48 30	43.7 N,	147.6 E	7.1	7370	N
6	Sep. 12, 1926	15 43 36	22.0 N,	120.5 E		8180	N
7	Aug. 20, 1930	20 54 12	24.5 N,	122.2 E		8035	N
8	Dec. 8, 1937	08 32 08	22.9 N,	121.5 E	7.0	8170	N
9	Oct. 21, 1951	21 34 14	23.9 N,	121.7 E	7.3	8080	N
10	Oct. 22, 1951	03 29 26	23.9 N,	121.7 E	7.1	8080	N
11	Oct. 22, 1951	05 43 03	23.9 N,	121.7 E	7.1	8080	N
12	Feb. 23, 1957	20 26 09[3])	24 N,	121½ E[3])	7-7¼[4])	8050	N
13	July 2, 1930	21 03 44	25.8 N,	90.2 E	7.1	6170	N
14	Sep. 21, 1930	23 04 17	25.5 N,	98.5 E		6650	N
15	Jan. 3, 1935	01 50 14	30.8 N,	88.0 E	6½	5595	N
16	Apr. 26, 1936	23 59 11	28.7 N,	103.2 E	6¾	6625	N
17	Aug. 18, 1931	14 21 08	46.9 N,	90.0 E	7.2	4350	N, E
18	Oct. 19, 1938	04 13 24	49.0 N,	90.0 E	6¾	4195	N
19	Dec. 17, 1938	16 35 26	47.9 N,	92.2 E	6¼	4395	N

[1]) According to ISS.
[2]) According to GUTENBERG and RICHTER [3].
[3]) According to B. C. I. S.
[4]) According to Pasadena.

they occurred. The first group comprises the Japanese shocks, the second the Formosa shocks. The great-circle paths from the third group of earthquakes to Helsinki pass across the great tertiary mountain belts of Asia. The shocks of the fourth group occurred in the Altai region. Figure 2 shows the epicentral locations and the surface wave paths. The resulting dispersion data for various shocks are presented in Table 2 and they are also plotted in Figures 3 to 6.

Japanese shocks. Shocks Nos. 1 to 5 in Table 1 belong to this group. The epicentre of shock No. 2 lies in Hokkaido. The other four shocks occurred off the Pacific coasts of Hokkaido and northern Honshu.

The path travelled by surface waves first crosses Hokkaido and the

Table 2. Dispersion data.

Period sec.	Gr. vel. km/sec.
No. 1	
80.8	4.21
62.8	4.03
48.2	3.85
40.0	3.71
34.6	3.63
30.9	3.49
19.0	3.37
No. 2	
55.6	4.00
50.2	3.91
40.4	3.75
34.0	3.58
30.4	3.45
No. 3	
55.6	3.95
43.2	3.81
40.2	3.65
33.4	3.53
29.6	3.44
24.1	3.38
22.1	3.34
19.9	3.26
No. 4	
73.0	4.12
51.0	3.94
42.4	3.74
37.1	3.60
27.9	3.53
22.1	3.35
No. 5	
76.4	4.17
62.0	3.99
48.0	3.88
41.2	3.73
33.1	3.57
30.0	3.43
21.5	3.31
No. 6	
39.2	3.73
32.0	3.60
29.6	3.51
25.0	3.44
22.4	3.39
19.2	3.37
17.2	3.33
No. 7	
62.2	4.05
50.9	3.97
42.2	3.80
36.4	3.63
28.2	3.48
23.4	3.40
19.0	3.33
No. 8	
56.4	3.98
47.4	3.87
42.8	3.76
38.0	3.67
34.0	3.60
30.0	3.50
25.4	3.40
17.1	3.31
No. 9	
78.0	4.17
56.8	3.98
47.2	3.80
39.5	3.66
34.6	3.56
30.0	3.46
17.5	3.27
No. 10	
53.2	3.91
43.0	3.82
39.0	3.66
26.5	3.39
20.0	3.33
15.7	3.27
No. 11	
63.4	4.05
47.0	3.86
42.0	3.77
36.8	3.67
31.4	3.55
27.8	3.44
24.6	3.39
20.8	3.33
No. 12	
72.0	4.07
50.8	3.88
39.8	3.69
34.8	3.55
31.2	3.46
25.6	3.41
21.2	3.34
No. 13	
74.8	4.08
52.0	3.75
41.6	3.59
32.3	3.44
26.5	3.36
No. 14	
64.0	4.02
52.6	3.75
34.8	3.53
29.6	3.41
19.2	3.30
No. 15	
49.6	3.71
37.3	3.55
25.9	3.42
22.9	3.35
19.5	3.26
17.7	3.18
No. 16	
57.0	3.87
48.4	3.75
44.8	3.65
39.0	3.56
32.2	3.44
No. 17 (N)	
58.2	4.08
46.6	3.89
37.6	3.74
No. 17 (E)	
34.6	3.58
27.6	3.49
21.2	3.41
13.0	3.29
No. 18	
49.0	3.90
34.6	3.62
22.8	3.42
14.1	3.26
12.8	3.19
11.2	3.11
No. 19	
24.6	3.43
20.0	3.34
14.3	3.26

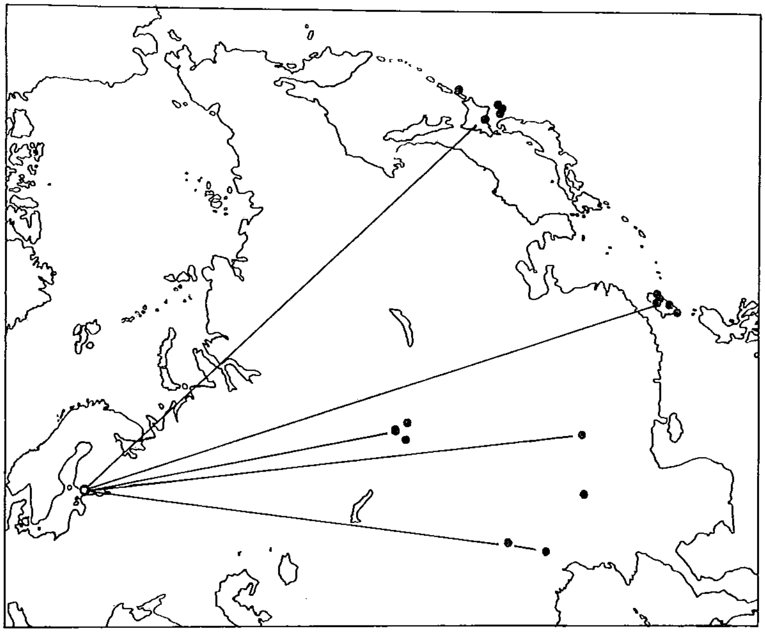

Fig. 2. Epicentres and surface wave paths.

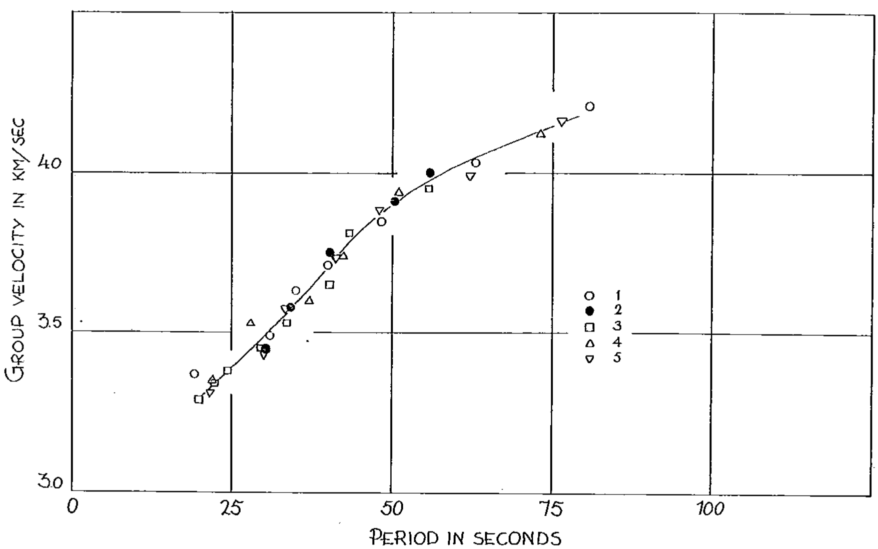

Fig. 3. Love wave dispersion, Japan to Helsinki. Numbers refer to Table 1.

Sea of Japan. It then passes across the mountain belts of eastern Siberia, Sikhote-Alin and Stanovoy ranges. They are followed by the highlands of the Siberian platform. The remainder of the path lies in the lowlands of northern Angara and the Russian shields. In the Sea of Japan the paths include segments of 100 to 300 km in which the water depth is more than 1 000 metres. However, no corrections have been made to the dispersion data because of the possible oceanic portions of the paths.

The periods investigated range from 20 to 80 seconds and, as is shown in Figure 3, the dispersion data are in good agreement with one another. The solid curve in Figure 3 represents the average curve best fitting the experimental points.

The dispersion data for Rayleigh waves along this same path were published earlier [5].

Formosa shocks. Shocks Nos. 6 to 12 occurred in Formosa or in its vicinity. The propagation path of these shocks crosses the shallow Formosa Strait and then passes across China, the highlands of inner Asia and the lowlands of Siberia and Russia.

The resulting Love wave dispersion data are presented in Table 2 and they are also plotted in Figure 4. The experimental points show good mutual agreement and the deviations from the average curve indicated by the solid line are quite small.

Shocks Nos. 13 to 16. These earthquakes occurred in Tibet, Assam and eastern China. In the following they will be referred to briefly as *Tibet shocks*. A common feature of all these shocks is that their great-circle paths to Helsinki traverse the Asian tertiary mountain belts.

The dispersion results which are shown in Figure 5 indicate that these paths are characterized by similar average dispersion properties. We shall see that the group velocities of Love waves for these paths are also lower than those obtained for the Japanese and Formosa shocks (Figure 7).

Altai shocks. Shocks Nos. 17 to 19 occurred in the Altai region. The surface waves from these shocks travelled mainly along the lowlands of Siberia and Russia.

The dispersion results are presented in Figure 6. These data are not so reliable as those from the Formosa and Japanese shocks because of the shorter propagation paths and of the frequent prominence of the shorter period waves corresponding to the higher modes of propagation. In many cases the higher mode waves on the records at Helsinki were so strong that reading of fundamental Love waves was not possible.

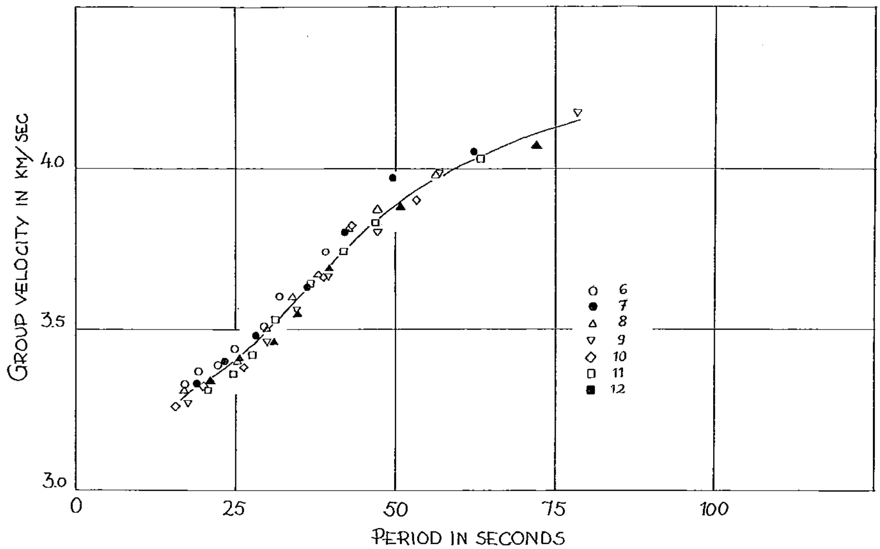

Fig. 4. Love wave dispersion, Formosa to Helsinki.

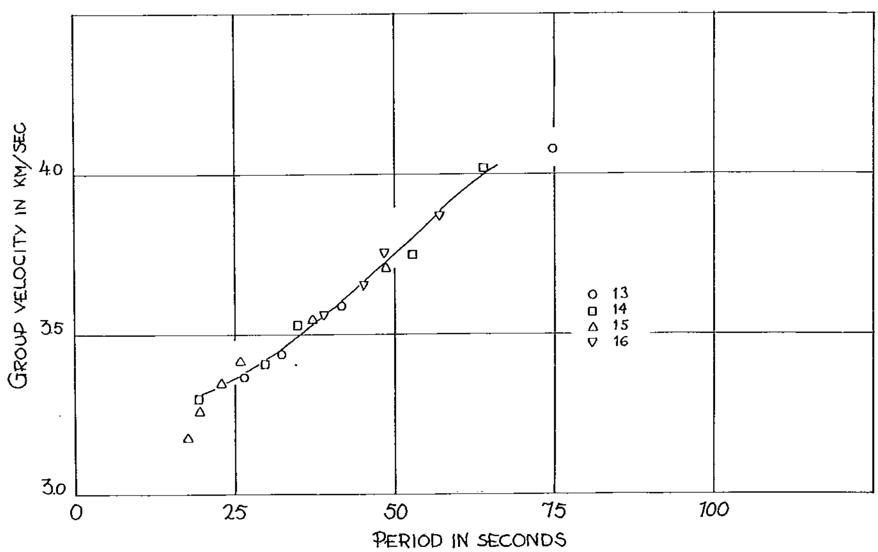

Fig. 5. Love wave dispersion, Tibet shocks.

However, the results obtained are consistent with those from the Formosa and Japanese earthquakes as shown in Figure 7.

Discussion

The average fundamental Love wave dispersion curves for our four earthquake groups obtained in the foregoing paragraphs are presented together in Figure 7. From this figure it appears that there is quite good agreement between the dispersion curves corresponding to the Japanese, Formosa and Altai shocks, suggesting similar crustal structures for the propagation paths associated with these shocks. By contrast, in the period range of 35 to 55 seconds the Tibet curve has group velocities 0.10 to 0.15 km/sec lower than the other curves for corresponding periods. This is an indication of greater crustal thickness.

We assume that two-thirds of the propagation path from the epicentres of the Tibet shocks to Helsinki have an average crustal structure similar to the path from Formosa to Helsinki and that along the remaining one-third of the path the crust is thicker, but structurally similar to that along the former main segment. So the crustal thickness is the only variable quantity. At a period of 45 sec the experimental group velocities for the paths from Tibet to Helsinki and from Formosa to Helsinki are 3.66 km/sec and 3.80 km/sec, respectively. Taking into consideration our assumptions, we arrive at a velocity of 3.40 km/sec for the mountain segment of the path. The Tibet paths pass across the mountain belt in separate places, but, as was shown, the dispersion data are consistent with one another. Therefore it is not probable that the lower group velocities were caused by lengthened paths due to lateral reflections.

With the aid of some curves drawn on the basis of DORMAN's [2] theoretical calculations, the observed deviation in the group velocities is interpreted as due to the crust being about 20 km thicker in the young mountain region than in the plain or old mountain areas of the continent.

For paths crossing the Eurasian continent numerous Love wave investigations have been published. The observations of ROHRBACH [7] indicated that Love waves from northern Siberia to Göttingen have greater velocities than those from eastern Bengal to Göttingen for the corresponding periods. This results agrees with our data. SAVARENSKY and SIKHARULIDZE [8] have studied Love waves recorded at Tiflis. For paths over the Asian tertiary massif they found a velocity of about

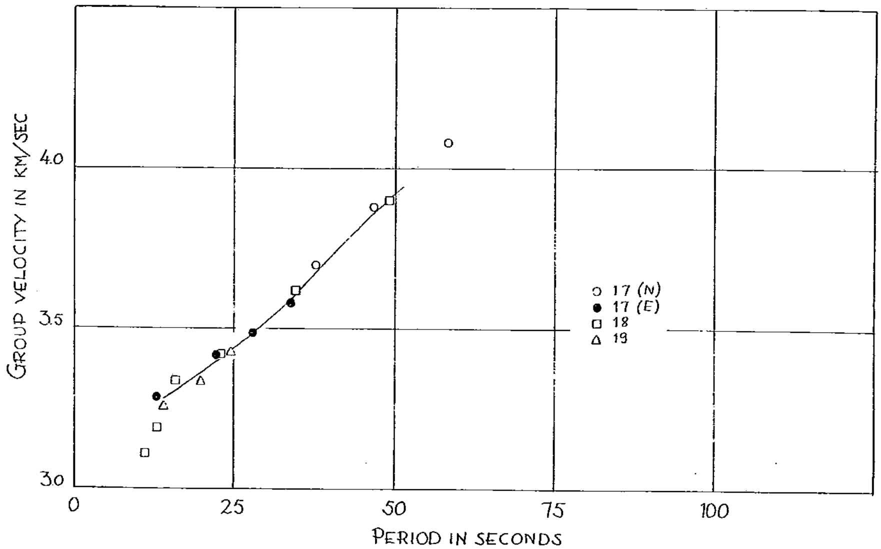

Fig. 6. Love wave dispersion, Altai to Helsinki.

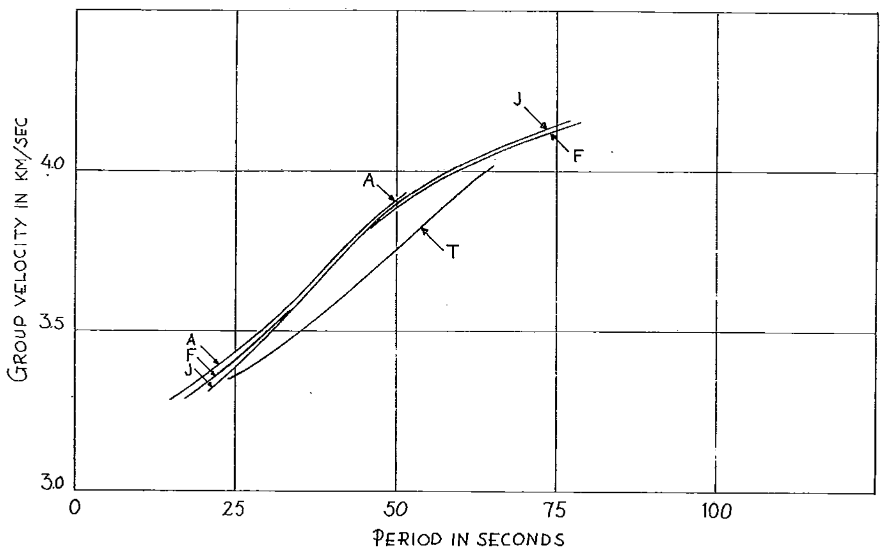

Fig. 7. Love wave dispersion. A = Altai to Helsinki, F = Formosa to Helsinki, J = Japan to Helsinki, T = »Tibet» to Helsinki.

3.45 km/sec at the period of 45 sec. This deviates only a little from our value calculated above for the young mountain segment of the path.

The dispersion results obtained by Båth [1] for a path from Formosa to Uppsala and by Press [6] for Asio-American and American paths do not differ very much from our Formosa data.

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