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SURFACE WAVE DISPERSION FOR SOME EURASIAN PATHS I. RAYLEIGH WAVES FROM KAMCHATKA AND JAPAN TO FINLAND

by

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Abstract

Rayleigh waves from six earthquakes that occurred in Kamchatka and Japan are investigated. The resulting dispersion curve in the period range of 18 to 60 seconds is compared with DORMAN's theoretical curves. The comparison suggests an average crustal thickness of about 37 to 38 km along the paths investigated. This crustal structure is also indicated for a path crossing the Arctic continental shelf.

Finland has a very suitable location for the study of the continental dispersion of earthquake surface waves. Many seismically active regions are so situated that they afford convenient seismogram material. In this study my aim is to determine empirical dispersion curves for several Eurasian paths, using records from seismological stations in Finland. The main purposes are to study the crustal structure of the Eurasian continent and to study the possibility of obtaining evidence of variations between different paths. Comparisons will be made with earlier results and with available theoretical curves. The present paper is the first in a planned series and it concerns the Rayleigh wave dispersion in the northern and northeastern parts of the Eurasian continent.

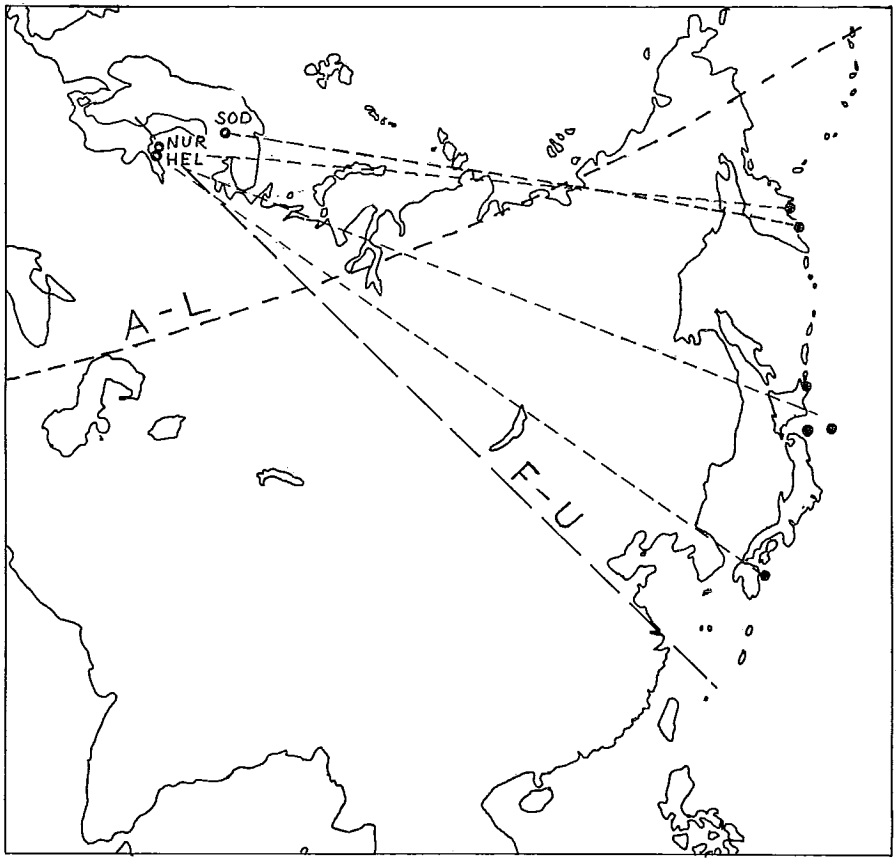

Fig. 1. Map of epicenters, seismograph stations, and surface wave paths. F—U = Formosa to Uppsala, A—L = Aleutians to Lwiro.

Information about the material used in this study is listed in Table 1. Two earthquakes occurred near Kamchatka. For the shock of May, 1959, the dispersion was determined from both the Sodankylä and the Nurmijärvi records. All other records were from Helsinki. Of the Japanese shocks one occurred in Hokkaido, two northeast of Honshu and one in the vicinity of Kyushu. In Figure 1 are indicated the locations of the epicenters and stations and the great-circle paths of the surface waves investigated. The locations of the seismograph stations and the instruments used are presented in Table 2.

Table 1. *Data on earthquakes studied.*

No	Date	Origin time GMT	Epicenter	Station and comp.	Dist. km
1	1931 Jul 18	11 23 50	54.0 N, 161.0 E (ISS)	Hel N	6725
2	1959 May 4	07 15 42	52½ N, 159½ E (USCGS)	Nur Z	6855
3	»	»	»	Sod Z	6150
4	1931 Mar 9	03 48 57	40.5 N, 142.5 E (ISS)	Hel Z	7450
5	1933 Mar 2	17 31 01	39.1 N, 144.7 E (ISS)	Hel Z	7670
6	1935 Sep 11	14 04 06	43.6 N, 146.0 E (ISS)	Hel Z	7295
7	1931 Nov 2	10 03 09	32.4 N, 132.1 E (ISS)	Hel Z	7770

Table 2. *Seismograph stations and seismographs used.*

Station	Coordinates	Seismographs	Type of recording
Helsinki (Hel)	60°10′32″N, 24°57′25″E	Mainka N and Z	Mechanical
Nurmijärvi (Nur)	60°30′32″N, 24°39′18″E	Nurmia Z, short period	Galvanometric
Sodankylä (Sod)	67°22′16″N, 26°37′45″E	Benioff Z, short period	Galvanometric

The dispersion observations were analysed by the usual graphical method (Ewing, Press, [2]). The arrival times of every crest and trough along the Rayleigh wave train were measured and plotted on a graph versus crest or trough number. The arrival time curve was approximated with straight-line segments. The slope and midpoint of each segment were read from these graphs. The period was computed

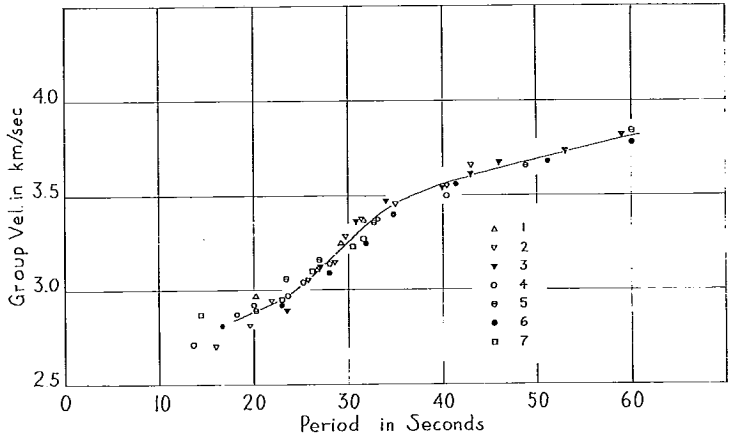

Fig. 2. Rayleigh wave dispersion, Kamchatka and Japan to Finland. The numbers of the earthquakes refer to Table 1.

from the slope and the corresponding arrival time was read from the midpoint. The travel time and the group velocity were then computed.

The resulting Rayleigh wave dispersion data are plotted in Figure 2. The periods observed range from 14 sec. to 60 sec. In Figure 2 an average curve corresponding to the points observed is also drawn. In the period range of 29 to 40 seconds dispersion data from the Japanese shocks have possibly 0.05—0.07 km/sec. lower group velocities than those for paths from Kamchatka to Finland, but deviations from the average curve are less than 0.05 km/sec. for corresponding periods. This good mutual agreement indicates that the average crustal structure is almost identical along the paths of the surface waves investigated.

Special interest attaches to case No. 3 in Table 1, which is a Kamchatka shock recorded at Sodankylä. Approximately half of the surface wave path of this shock lies on the Arctic continental shelf. The dispersion data observed in this case fit together with the results for other paths, indicating that the structure of the terrestial crust along this path is similar to that along the other paths studied. This result is in agreement with the Russian views on the crustal structure of the continental shelf in this region (HOPE, [3]), according to which the double layer crust under Franz Josef Land is shown as of continental thickness, 35 km.

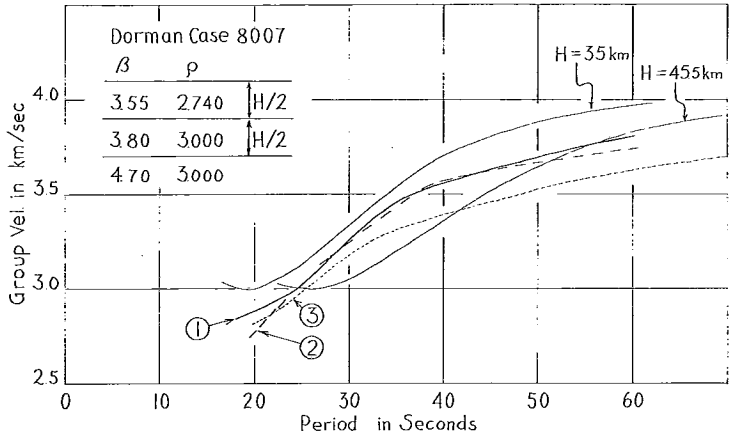

Fig. 3. Comparison of observed Rayleigh wave dispersion with theoretical curves and earlier results. The numbers are explained in text.

In Figure 3 are two theoretical Rayleigh wave dispersion curves computed by DORMAN for the two-layered crustal model shown in the figure (KOVACH, [4]). The following notations are used:

β = shear wave velocity in km/sec
ϱ = density in gm/cc
H = thickness of the crust in km.

The average dispersion curve from Figure 2 is reproduced in Figure 3 and marked 1. Comparison with DORMAN's theoretical curves gives a crustal thickness of 37 to 38 km for the paths studied. The average crust along the Kamchatka paths may be somewhat thinner than along the Japanese paths. At longer periods the average dispersion curve lies below the theoretical curves, showing the well-known effect of the gradient in mantle velocity. The shortest periods are affected by sedimentary layers.

In Figure 3 two observed dispersion curves drawn according to published data are plotted as broken lines. Curve 2 represents the Rayleigh wave data of KOVACH [4] for a path from the Aleutians to Lwiro in the Belgian Congo. This very long Asio-African path is also indicated in Figure 1. The average dispersion curve (1) agrees well with KOVACH's data, suggesting a similar average crustal structure for these paths.

BÅTH's [1] data for a path from Formosa to Uppsala are indicated by curve 3 in Figure 3. The great-circle path is included in Figure 1. For periods from 20 to 30 seconds BÅTH's group velocity data fall below cruve 1 only by about 0.05 km/sec. For longer periods the deviations in group velocity are about 0.2 km/sec. for corresponding periods.

SAVARENSKY and others [6] have studied Love wave dispersion for some paths from Japan to Moscow. These paths do not lie far from the Japanese paths investigated here. They concluded that the total crustal thickness is 30 to 40 km and that the thickness of the intermediate layer is approximately half that of the upper layer. This distribution of crustal layers agrees with the results obtained in Southern Finland based on seismic explosion measurements (PENTTILÄ and others, [5]), which indicate thicknesses of 21 and 8 km for upper and intermediate layers respectively.

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