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PHASE VELOCITIES OF RAYLEIGH WAVES IN SOUTHERN FENNOSCANDIA

by

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Abstract

The phase velocities of Rayleigh waves in Southern Fennoscandia are determined from three nuclear exlosions in the Novaya Zemlya region. The analysis is performed by using the triangle Nurmijärvi—Copenhagen—Kongsberg. Because the sides of this triangle are rather long and the epicentres at a short distance the influence of a curvature of the wave fronts is determined by an approximation method developed for this special case.

1. *Introduction*

Because of the relationship between local phase velocities of Rayleigh waves and the thickness of the crust and elastic constants in and below the crust (Press, [3]) it is important to obtain phase velocities for separate regions. In this paper the phase velocities in Southern Fennoscandia have been determined from three nuclear explosions in the Novaya Zemlya region in the year 1962. The network of seismograph stations with identical long period instruments in Fennoscandia is not so dense that it would be possible to assume wave fronts as plane fronts from such near sources. On the other hand an identification of given crests and troughs with a period of about 22 to 50 seconds at each station was not difficult.

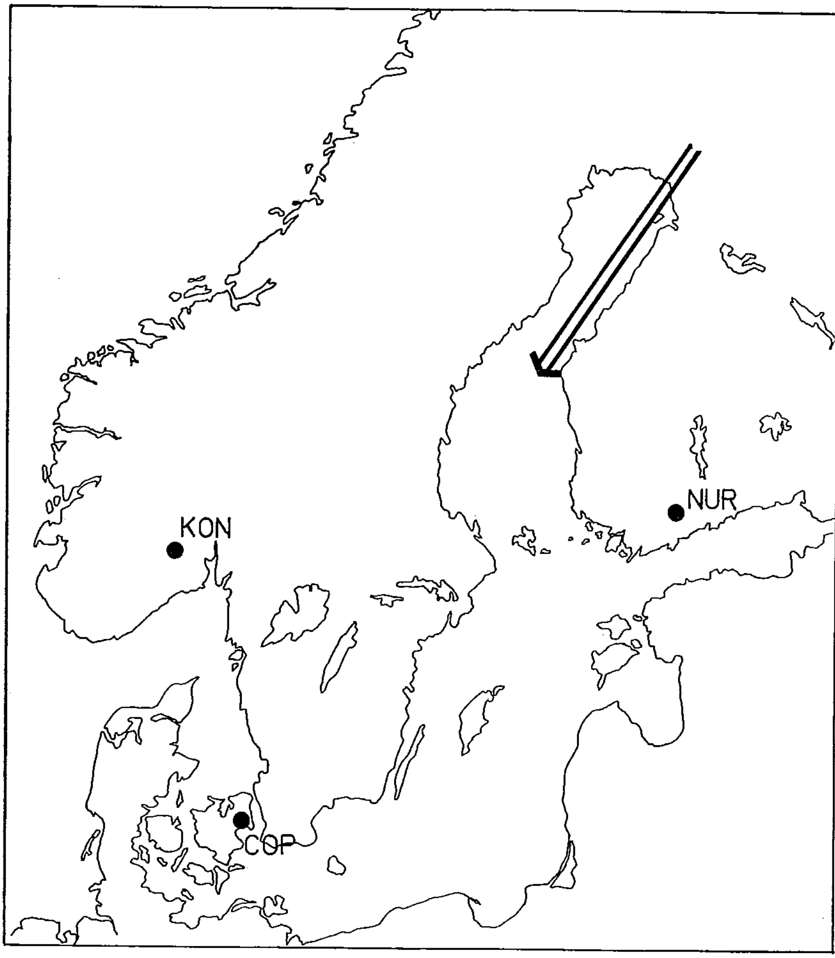

Fig. 1. Locations of the stations.

2. *Materials and Method used*

All the stations, Nurmijärvi in Finland, Kongsberg in Norway, and Copenhagen in Denmark, which are parts of the worldwide standardized seismograph station network of USCGS, have Press-Ewing type long period seismometers with identical constants. In Table 1 are given the co-ordinates of the stations, great circle distances between them, and some constants for long period vertical instruments. Figure 1 shows locations of the stations. Data about the explosions are given in Table 2.

Table 1. The co-ordinates of the stations, some constants of instruments and distances between the stations.

Station	North latitude	East longitude	T_0	T_g	Mutual distance (km)
Nurmijärvi (NUR)	60°30′32″	24°39′05″	30	100	840
Kongsberg (KON)	59°38′57″	9°37′55″	30	100	897
Copenhagen (COP)	55°41′	12°26′	30	100	472

Table 2. Data about the explosions.

Region	Date	Origin time and co-ordinates		
		USCGS	BCIS	Helsinki
Novaya Zemlya	Sept. 15, 1962	08-02-13.9 74.4 N 51.5 E	08-02-13 74½ N 52 E	08-02-11.5 74.5 N 53.0 E
Novaya Zemlya	Sept. 21, 1962		08-01-13 74½ N 55.6 E	08-01-13 72.6 N 55.6 E
Novaya Zemlya	Dec. 24, 1962	11-11-42.0 73.6 N 57.5 E	11-11-44 74 N 54 E	

One can see from the table that the locations of the explosions only slightly deviate from each other. Well-developed trains of dispersed Rayleigh waves are recorded at each station in every one of the cases.

Phase velocities are now determined by a method modified from the original method of Press [3]. Periods and arrival time differences between stations are determined for the crests and troughs. The stations NUR, KON and COP are marked with number 1, 2, 3 respectively and periods and time differences analogously with T_1, T_2, T_3 and t_{12}, t_{13}, t_{23}. Referring to Figure 2 which shows the geometry of a curved wave front traversing the station triangle, the length which waves have traversed during time t_{12} is $L_{12} \sin A/\cos\varepsilon$ and during time t_{13}, is $L_{13} \sin(A + \alpha)/\cos \varepsilon - \delta$, the phase velocity c is then expressed as follows:

$$c = \frac{L_{12} \sin A}{t_{12} \cos \varepsilon} = \frac{L_{13} \sin(A + \alpha) - \delta \cos \varepsilon}{t_{13} \cos \varepsilon}, \tag{1}$$

so that

$$\cot A = \frac{\sin \gamma}{\sin \alpha \sin \beta}\,\delta - \cot \alpha + \frac{\delta \cos \varepsilon}{L_{13} \sin \alpha \sin A}\,, \qquad (2)$$

where δ is t_{13}/t_{12}. To compute δ, the angle ECD has been assumed to be a right angle, and $\mathrm{tg}\varepsilon'$ has been determined by measuring CD from a great scale figure which has been drawn on the basis of epicentral distances computed from USCGS data for the explosion of Dec 24. The last term on the right hand side in (2) is now computed by taking for A a value of 38.5° from the figure. ε and ε' are nearly equal and since cosine and tangent for small angles change slowly it is assumed $\varepsilon = \varepsilon'$. Because the epicentres of the explosions are not so accurate (see table 2) and small changes in ε and δ have only a slight effect upon velocities

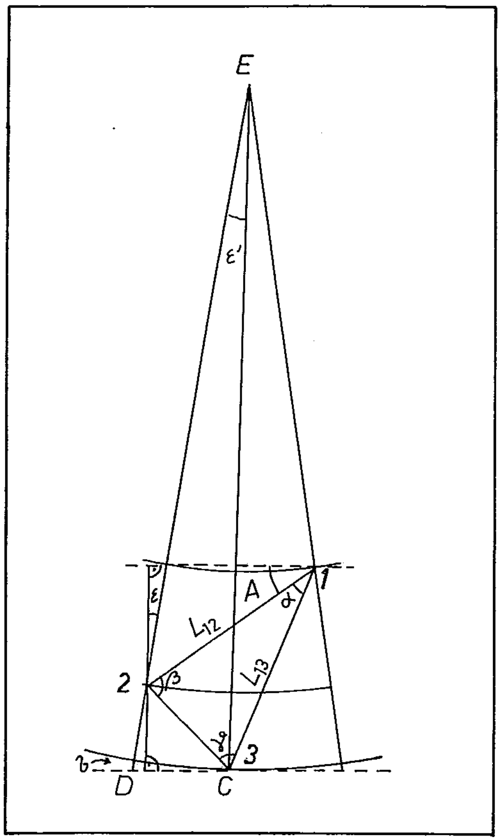

Fig. 2. The geometry of curved wave front traversing the station triangle.

the same values for ε and δ are adopted for the other two explosions also. After finding A for each crest and trough, c is computed by equation (1). Periods are taken as the mean between the nearest and the farthest stations from the epicentre, Nurmijärvi and Copenhagen.

3. *Results*

The phase velocities which were obtained, are represented by Figure 3. Each one of the explosions is expressed in the figure by different symbols. It is seen that the value agree well with each other. Agreement with the phase velocities found by Porkka [2] for the Finland region is also good. My values are perhaps a little greater, indicating a slightly thinner crustal thickness for this region than in Finland.

The curves in Figure 3 are calibrating phase velocity curves of Tryggvason [6], computed from the group velocity curve of Press, Ewing and Oliver [5] for the wave path Algeria to Natal. They differ somewhat from the curves of Press [3, 4] owing to different assumptions for the lacking data. If we assume that wave velocity and relative thickness of each layer are the same in Fennoscandia as in Africa we find from the figure a crustal thickness of about 35 km or slightly less, which agrees well enough with the results obtained by Penttilä and Tryggvason. From explosion seismic investigations Penttilä [1] gives a

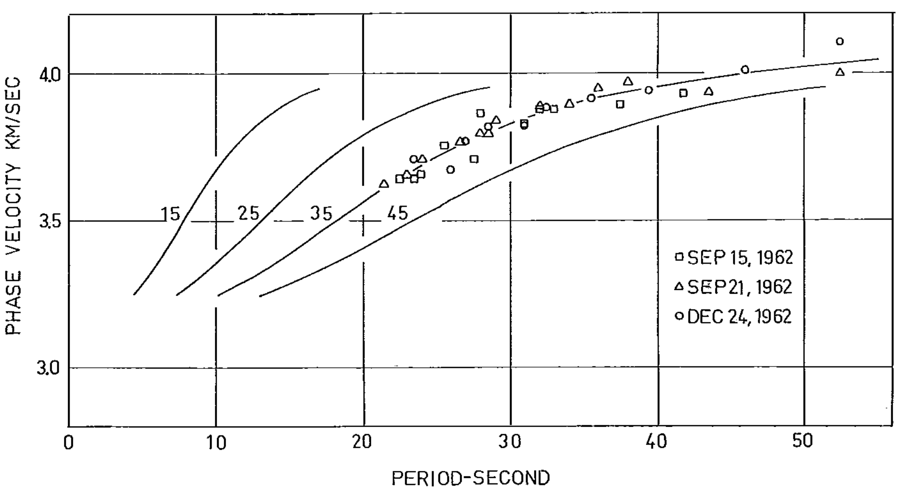

Fig. 3. Phase velocities of Rayleigh waves versus period.

mean 33 km for crustal thickness in Southern Finland. TRYGGVASON [6] found by using phase velocities of Rayleigh waves a mean 33—35 km for Southern Sweden.

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REFERENCES

1. PENTTILÄ, E., 1964: Personal communication.
2. PORKKA, M. T., 1965: Phase correlation method, in *Progress report on seismology and physics of the earth's interior in Finland 1964*, edited by Eijo Vesanen. Univ. of Helsinki, Institute of Seismology, **76** (in press).
3. PRESS, F., 1956: Determination of crustal structure from phase velocity of Rayleigh waves. Part I: Southern California. *Bull. Geol. Soc. Amer.*, 67, 1647—1658.
4. —»— 1960: Crustal structure in the California-Nevada region. *J. Geoph. Res.*, 65, 3, 1039—1052.
5. PRESS, F., M. EWING and J. OLIVER, 1956: Crustal structure and surface-wave dispersion in Africa. *Bull. Seism. Soc. Amer.*, 46, 97—103.
6. TRYGGVASON, E., 1961: Crustal thickness in Fennoscandia from phase velocities of Rayleigh waves. *Ann. di Geofisica*, 14, 267—293.