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Surface wave dispersion and crustal structure in Asia—Indo-Pakistan sub-continent

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ABSTRACT. Long period vertical seismograph records of Shillong for six earthquakes having epicentres at southern Iran have been studied. The dispersion of surface waves of Rayleigh type were computed. Inference regarding the average structure of the crust across the Indo-Pakistan sub-continent was made by comparison with theoretical curves corresponding to Dorman case 8007. It was concluded that the average thickness of the crust in this region is about 45 km. Surface waves due to one earthquake having epicentre in Indo-Burma border have also been studied from the record of Long period vertical seismograph of Delhi.

1. Introduction

The dispersion of seismic surface waves of Love and Rayleigh type has for many years been known to depend on the structure of the earth's crust and of the mantle for the longer period waves. Many investigations beginning with Love (1911), have shown in the past that this dispersion is a natural consequence of the layering in the crust. This fact has now become a very effective tool for determining the crustal structure of a particular region.

The most complete, detailed and reliable data on the structure of the earth's crust can be obtained from recordings of waves generated by shots. Such determinations provide an idea of the crustal structure at isolated point of the surface. However, large and very expensive shooting operations are necessary. Less certain is the determination of the thickness of the individual layers from the recorded travel times of seismic waves emitted by natural earthquake foci. This finds its explanation, in the inaccuracies, however small may it be, in determining both the locations of the focus and the moment of originaion of the earthquake. The essence of the surface waves method of studying crustal structure of a region is the dispersion curve derived directly from the seismograms. The dispersion curve consists of a plot of points of observed group velocities. Comparison of the observed dispersion with theoretical curves computed for different crustal models and finding out the model, which approaches in its dispersion most closely to the observed. This method is proposed to be followed in the present paper.

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 analyse surface wave trains of earthquake recordings for numerous paths across various continents.

In a previous paper Nag (1966), from a study of surface wave dispersion has investigated the crustal structure of Asia from the Arctic in the north to Shillong in the south. The author's conclusion was that the average thickness of the crust in that region is of the order of 45 km. In the present work the purpose is to investigate the crustal structure of another Asian path at right angles to the former one, from southern Iran to Shillong across the Indo-Pakistan sub-continent. The method employed will be the same as was done in the previous investigations, *i.e.*, dispersion of surface waves of Rayleigh type.

2. Data and method used

The operation of the WWSS instruments at Shillong with adequate long period response and magnification has given us the opportunity to study the long period surface waves recorded by these instruments. For the purpose of the present study 6 earthquakes having their epicentres in southern Iran and one earthquake having its epicentre in Indo-Burma border have been selected. The details of these earthquakes are given in Table 1. Records of Shillong seismographs were analysed for the earthquake Nos. 1 to 6 and for the earthquake No. 7 Delhi record of the long period Press-Ewing seismographs was used. In 1961 three components of long period Press-Ewing instruments were operating in Delhi with T_0= 30 sec, T_g =100 sec and magnification about

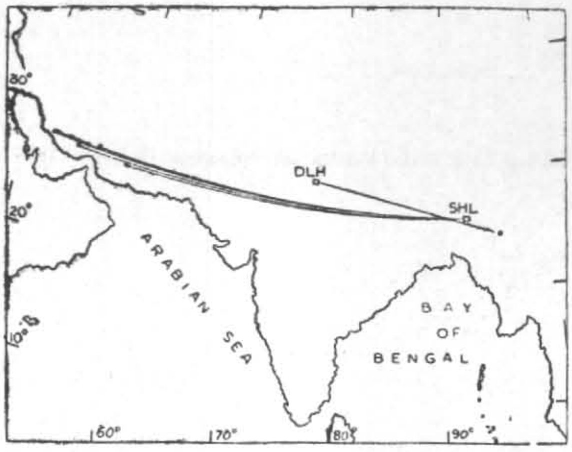

Fig. 1. Index map showing the epicentre of the earthquakes and the wave paths

TABLE 1

Date	Origin time (GMT)			Epicentre		Depth of focus (km)	Mag.	Epicentral distance (km)
	h	*m*	*s*	Lat. (°N)	Long. (°E)			
29 Jul 1963	06	10	22·6	27·8	55·6	37	5·2	3523
19 Aug 1964	09	33	10·0	28·2	52·6	50	5·6	3780
19 Aug 1964	15	20	13·9	28·2	52·7	52	5·6	3780
27 Aug 1964	12	56	46·1	27·5	55·9	33	5·3	3555
22 Dec 1964	04	36	34·7	28·2	57·0	42	5·5	3440
21 Jun 1965	00	21	14·5	28·1	56·0	28	6·0	3500
14 Jun 1961	00	41	13·0	24·5	94·8	62	—	1790

TABLE 2

Earthquakes													
No. 1		No. 2		No. 3		No. 4		No. 5		No. 6		No. 7	
T (sec)	U (km/s)	T (sec)	U (km/s)	T (sec)	U (km/s)	T (sec)	U (km/s)	T (sec)	U (km/s)	T (sec)	U (km/s)	T (sec)	U (km/s)
41	3·41	41	3·24	39	3·25	59	3·71	39	3·38	31	3·10	45	3·58
35	3·23	34	3·20	35	3·20	52	3·61	35	3·26	30	3·06	40	3·44
33	3·14	30	3·15	30	3·16	45	3·52	31	3·11	28	3·02	36	3·31
31	3·01	25	3·11	28	3·12	40	3·39	27	2·95	25	2·89	30	3·04
27	2·87	22	3·09	25	3·08	35	3·27	25	2·86	22	2·80	25	2·84
25	2·75	20	3·06	22	3·06	33	3·20	22	2·75	20	2·74	21	2·70
23	2·67	18	3·04	21	3·00	29	3·09	21	2·73	19	2·70	17	2·62

1500, paper speed was 15 mm/sec. The parameters relating to the epicentres, origin times and depths of foci have been taken from the *Seismological Bulletins* published by the U. S. Department of Commerce, Coast and Geodetic Survey, Washington. The epicental distances in all the cases except earthquake No. 7 were rather long and as such the results obtained were rather independant of small errors in the determination of epicentral distances and origin times. Fig. 1 is an index map showing the positions of the epicentres and the recording stations.

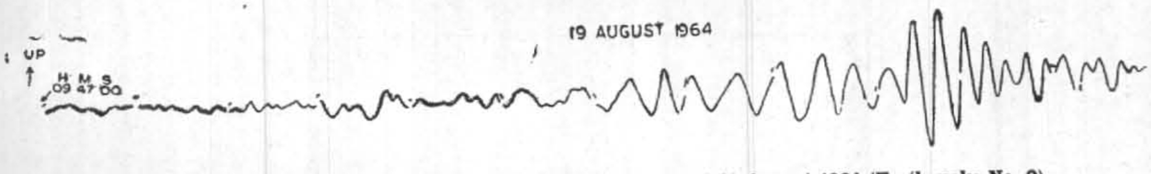

Fig. 2. Tracing of Shillong Long Period Vertical seismogram of 19 August 1964 (Earthquake No. 2)

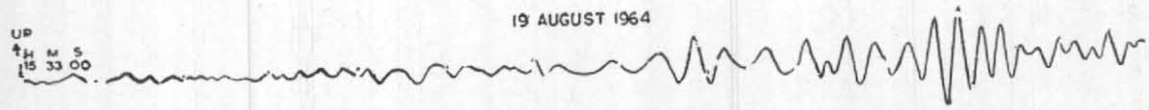

Fig. 3. Tracing of Shillong Long Period Vertical seismogram of 19 August 1964 (Earthquake No. 3)

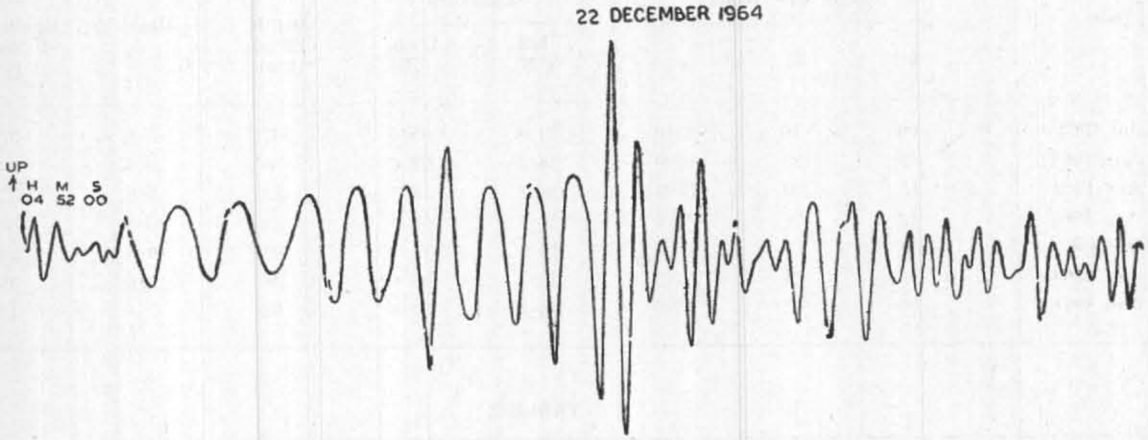

Fig. 4. Tracing of Shillong Long Period Vertical seismogram of 22 December 1964 (Earthquake No. 5)

The observed Rayleigh wave dispersion data as obtained from the seismograms were compared with the theoretical Rayleigh wave dispersion curves computed by Dorman for continental path.

The following symbols have been used—

β = Shear wave velocity,

ρ = Density, and

H = Layer thickness in km.

The dispersion data for the Rayleigh waves were determined by graphical method by ploting crests and troughs observed on the seismograms. Examples of the surface wave portions of the seismograms are shown in Figs. 2 to 4. The resulting Rayleigh wave disepersion data are presented in Table 2. These data have been plotted in Fig. 5 together with the two theoretical curves for two different crustal thickness corresponding to Dorman case 8007. These theoretical curves were computed for two-layered crust overlaying an infinite half space with the velocities, thickness and densities as indicated in the figure. These values for thickness, velocities and densities were chosen by Dorman as representative of the values obtained from seismic refraction measurements in the continental crust, and from the values obtained from gravity measurements.

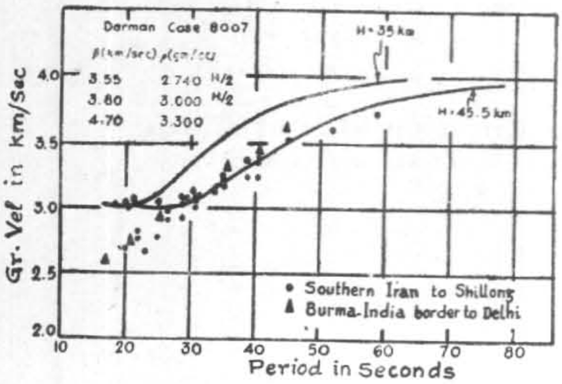

Fig. 5. Rayleigh wave dispersion

3. Discussion

A close look at the theoretical curves and the observed group velocities in Fig. 5 will indicate that the crust over this region is about 45-km thick. In the period range 25 to 45 sec the observed data from all the earthquakes agree very well with the theoretical curve for $H=45 \cdot 5$ km. Beyond 45 sec the longer period waves are strongly affected by the mantle, and the observed data fall below the theoretical curve for $H=45 \cdot 5$ km. The data suggests that for these long period Rayleigh waves the effect of a velocity gradient in the mantle is appreciable (Press and Ewing 1955).

In the region of about 17 to 25 sec some of th observed data are below the theoretical curve. This may be due to two reasons. One is that the shorter period waves had travelled a different path from the great circle path as a result of lateral refraction. The second, however, is that the propagation of these short period waves is strongly affected by variations and inhomogenities in the sedimentary column (Oliver and Ewing 1958). The second reason seems to be more plausible, as a look in the Fig. 1 will show that all the wave paths of the earthquakes taken into consideration are across the Gangetic basin. Chaudhury (1966) from a study of fundamental and higher modes of surface waves has shown that the Gangetic basin has a top 3-km layer of low velocity sediment.

4. Conclusion

From the above study it may be concluded that the average thickness of the crust across the Indo-Pakistan sub-continent is about 45 km. Tandon and Chaudhury (1964) have studied the surface wave dispersion across the path, Delhi to Shillong and have estimated the average thickness of the crust in that region to be between 40 and 45 km. Chaudhury (1966) has concluded that the average thickness of the crust in the region from Indo-Burma border to Delhi is 40 km. These are in close agreemet with that of the present study.

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