

INVESTIGATIONS OF FINE STRUCTURE OF THE CORE-MANTLE INTERFACE BY DIFFRACTED SH WAVES —A PRELIMINARY REPORT—

By

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Abstract

Seismic waves of six intermediate or deep earthquakes are Fourier-analysed selecting stations of the distance beyond 90 degrees.

From the observed relation between logarithmic amplitude spectra of SH waves and distance, we introduced an apparent attenuation function $\gamma(\omega)$. It is found that the absolute value of γ and the troughs at 0.03 to 0.04 Hz and 0.08 to 0.09 Hz are similar to each event.

1. Introduction

Although many researchers attempted to elucidate the fine structure—density, elastic and anelastic properties—of the Earth's Core-Mantle interface, definite answers have not yet been derived. Furthermore, the problem of lateral inhomogeneity concerning bumps or hot spots arises mostly from observations of gravity and geomagnetism.

It is most straightforward to analyse seismic body waves transmitted through the interface; grazing ray or diffracted waves by the Core (ALEXANDER AND PHINNEY (1966)). We use diffracted SH waves with the intention of degenerating the equations of motion and boundary conditions, and calculate the frequency-dependent attenuation function near the geometrical shadow point.

2. Analysis and discussions

We select suitable events referring to ISACKS AND MOLNAR (1971) and MIKUMO (1971), and derive seismic data of long-period seismograms ($T_1=15-30$ sec, $T_2=90-100$ sec) from WWSSN. The concerned parameters are listed on Table 1.

We assumed a linear filter system as below.

$$aP_o(\omega) \rightarrow P_{M_1}(\omega) \rightarrow P_{MCB}(\omega) \rightarrow P_{M_2}(\omega) \rightarrow P_I(\omega)$$

where a is the spatial term and $P_o(\omega)$ the frequency dependent term due to the source time function, $P_{M_1}(\omega)$ the frequency response of a ray path from a source down to the

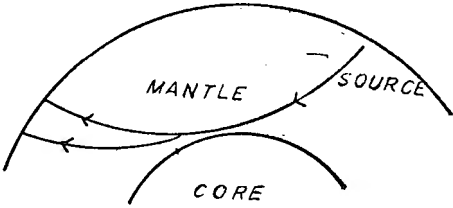


Fig. 1. Paths of observed rays

base of the Mantle, $P_{MCB}(\omega)$ the response of a diffracted wave or a ray grazing the Earth's Core, $P_{M_s}(\omega)$ the response of a ray path from the base of the Mantle up to an Earth's surface and $P_I(\omega)$ the instrumental response. (See Fig. 1)

When the corrected amplitude of the k -th station by terms of a , $P_o(\omega)$ and $P_I(\omega)$ is expressed as $A_{cor.}^{(k)}(\omega)$ and $P_{MCB}(\omega)$ of the k -th station as $P_{MCB}^{(k)}(\omega)$.

$$\frac{P_{MCB}^{(k)}(\omega)}{P_{MCB}^{(l)}(\omega)} = \frac{A_{cor.}^{(k)}(\omega)}{A_{cor.}^{(l)}(\omega)} \tag{1}$$



Fig. 2. Examples of waveform (event No. 7)

We give an illustration of waveforms with adjacent phases such as SKS, SKKS and pS from events No. 7, for instance, in Fig. 2.

The Fourier transform is performed in the frequency range between 0.01 and 0.15 Hz, with the time window, truncated length and digitized interval;

$$\left. \begin{aligned} W(t) &= 0.54 + 0.46 \cos(\pi t/T) \\ T &= 30 \text{ sec} - 60 \text{ sec} \\ \Delta t &= 0.5 \text{ sec} - 1.2 \text{ sec} \end{aligned} \right\} \quad (2)$$

respectively.

The example of Fourier spectra of amplitudes and phases is illustrated in Fig. 3 from event No. 4.

The frequencies for peaks and troughs of the amplitude spectra nearly correspond with those of the phase spectra. This could be explained by the effects of finite dimension of sources or partly, of contamination of preceded and later phases. It is noticeable that there are no systematic transitions of the peaks and troughs of the amplitudes and phase spectra with increasing epicentral distances in all events. The instanced amplitude spectra of event No. 4 appear to be divided into some classes, which might be related to the finite dimension of the source and complex source process.

The logarithms of amplitudes of events No. 4 and No. 7 at 0.05 Hz are plotted against distances in Fig. 4, after normalizing the spectra at a distance of 90 degrees. It is observable that the amplitudes tend to decline linearly with increasing distances beyond 93 to 95 degrees, and that around 90 degrees are some fluctuations, which is possibly attributed to the interference of S and ScS. Hence we introduce an apparent attenuation function γ determined by the decline of the amplitude; $\exp(-\gamma \Delta)$, where Δ is the epicentral distance.

By least square method, the function $\gamma(\omega)$ is fitted in each of events.

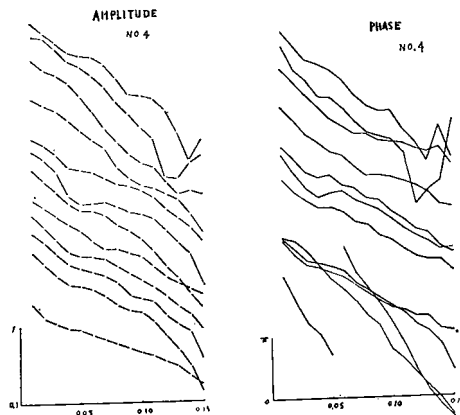


Fig. 3. Examples of amplitude spectra and phase spectra (event No. 4)

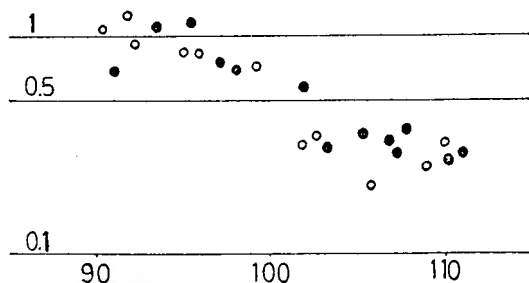


Fig. 4. Logarithmic amplitude spectra No. 4 (closed circle) and No. 7 (open circle) at 0.05 Hz to base ten.

The calculated γ 's are illustrated with estimated standard errors, in Fig. 5, where the dimension of γ is [1/deg].

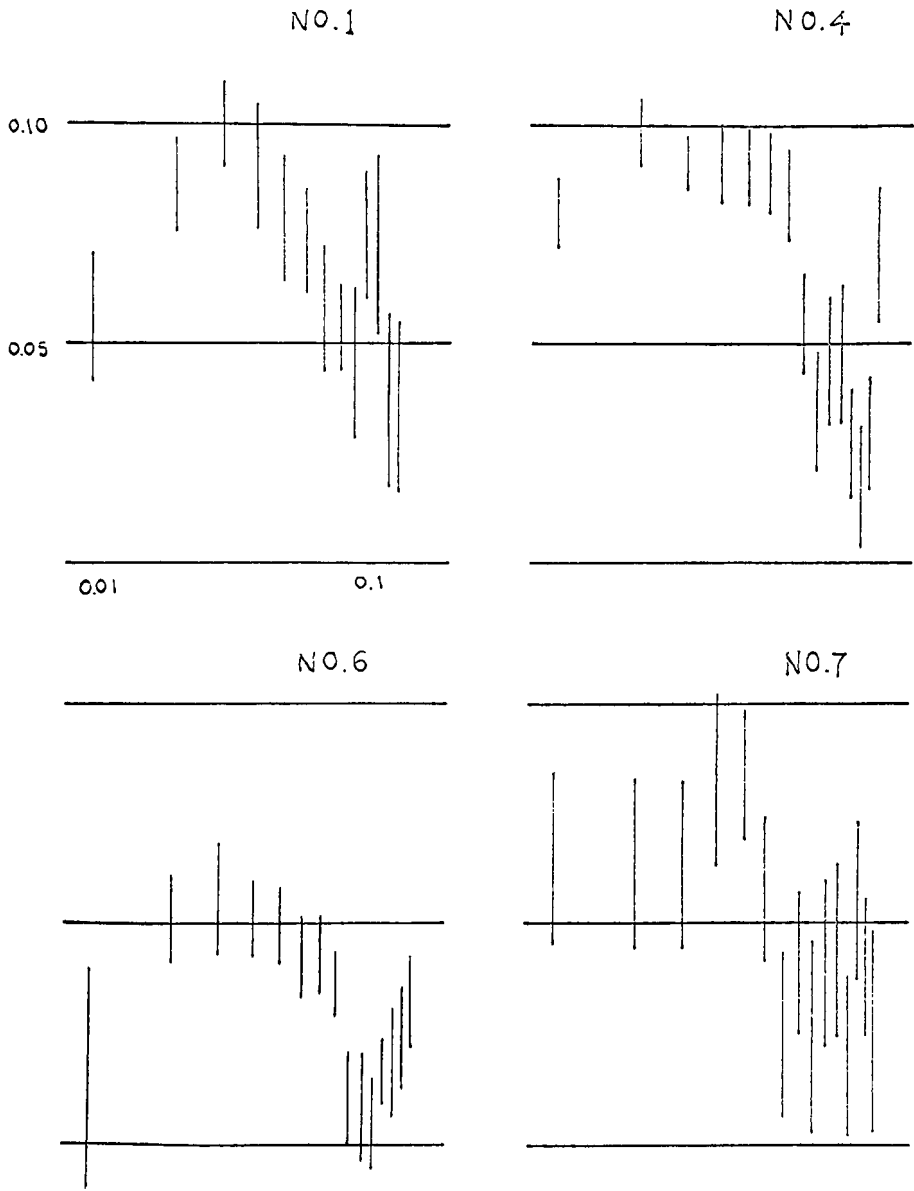
The trend of γ 's in events No. 1 and No. 7 has similarity with each other, including the absolute value of γ 's. Event No. 6 belongs to the above group, except the absolute value, and we can say that for higher frequencies γ in events No. 6 and No. 8 is similar. However we cannot get any meaningful value of γ for event No. 5, owing to large standard errors. The reason for this might be attributed to inappropriate combination of stations due to some allowance for the fault plane solutions and/or trapping of seismic energy within a seismic zone near the source region. It should be remarked that the distance ranges of the stations used are somewhat different; 95 to 110 degrees for events No. 1, No. 4 and No. 7, 95 to 117 degrees for events No. 6 and No. 8, 95 to 114 degrees for event No. 5.

In spite of some differences in the absolute value of γ , a trough around 0.08 to 0.09 Hz is most remarkable in common, and that a trough around 0.03 to 0.04 Hz is next remarkable, except event No. 1. It is very interesting that these features appear to suggest the existence of a "gallery" through which seismic waves transmit selectively.

Further we should add that the effect of the upper limit of the distance ranges could not be disregarded, contrasting events No. 6 and No. 8 with the others. A probable elucidation is that the deeper is the upper limit of the distances, the worse the SN ratio is, while closer examinations of Fig. 4 suggest that the amplitudes become saturated gradually.

References

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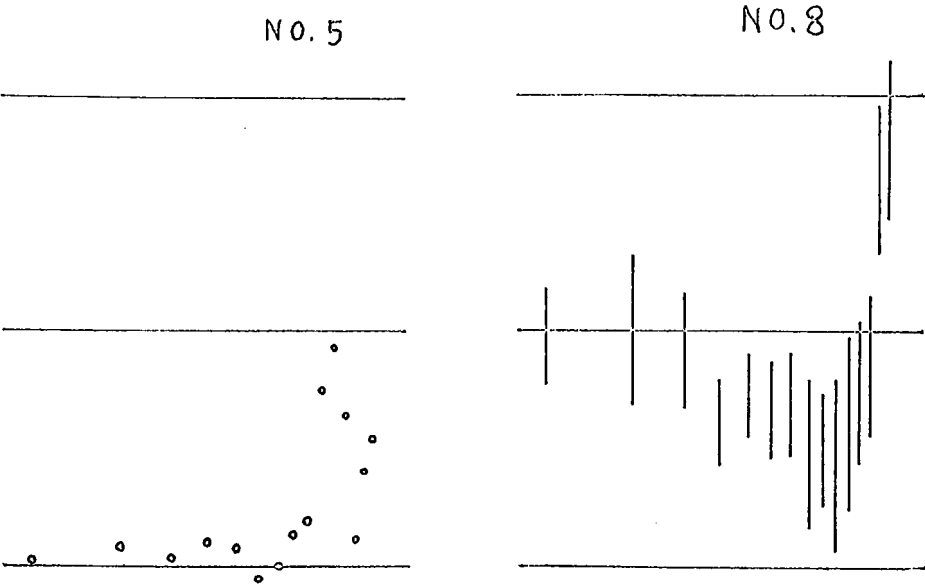


Fig. 5. Relations between γ and logarithmic frequency with estimated standard errors.

Table 1. Analysed earthquakes, referred stations of WWSSN in each event. (Referred papers: event No. 1, MIKUMO (1971); events Nos. 4, 5, 6, 7 and 8, ISACKS AND MOLNAR (1971))

Azimuth				Azimuth			
Station	Distance	(from focus) (at station)		Station	Distance	(from focus) (at station)	
No. 1				29 COP	109.31	71.10	327.42
85 GSC	90.07	307.39	48.45	55 KON	109.30	67.25	331.92
74 NAI	92.88	60.29	270.19	109 STU	113.40	70.92	321.07
43 GOL	94.07	317.67	39.18	40 GDH	116.56	357.63	0.86
119 TUC	95.85	310.77	47.61	38 ESK	117.45	56.67	331.32
7 ALQ	96.76	313.64	43.21	No. 7			
65 MAL	100.83	39.64	323.82	29 COP	90.29	91.33	325.51
2 AAM	101.97	331.04	24.44	55 KON	91.80	88.90	329.43
39 FLO	102.24	325.36	30.76	109 STU	92.22	88.99	318.58
123 WES	105.59	341.40	15.79	79 NOR	94.97	62.21	352.52
83 OXF	106.21	325.48	32.61	126 LOR	95.93	85.06	317.26
19 BLA	107.63	333.06	24.62	38 ESK	99.17	78.41	325.94
12 ATL	109.38	329.25	29.50	100 KTG	101.67	58.38	343.31
103 SHA	109.95	325.74	33.94	115 TOL	102.55	80.70	310.58
15 EEC	116.64	346.33	13.32	91 PTO	105.72	77.27	312.54
No. 4				27 CMC	108.71	321.01	13.80
85 GSC	91.45	307.42	47.87	40 GDH	109.83	26.66	350.79
96 RCD	93.41	313.69	34.36	No. 8			
43 GOL	95.42	314.93	38.58	7 ALQ	88.62	242.13	51.69
119 TUC	97.22	310.82	47.01	28 COL	89.04	209.11	12.84
7 ALQ	98.13	313.79	42.61	26 CHG	89.37	112.41	290.31
63 LUB	101.77	313.68	40.83	22 BOZ	90.24	239.67	40.46
2 AAM	103.22	331.65	23.72	43 GOL	91.52	243.79	47.83
35 JCT	105.23	317.57	41.68	35 JCT	91.82	246.69	58.10
123 WES	106.73	342.20	14.98	96 RCD	94.86	245.41	44.57
82 OGD	107.15	339.17	17.87	61 LPB	95.05	249.64	76.71
83 OXF	107.52	325.90	31.90	78 NNA	96.98	246.80	105.80
12 ATL	110.68	329.76	28.73	27 CMC	100.14	238.58	20.29
89 PRE	110.23	66.83	251.17	103 SHA	101.31	252.22	61.44
No. 5				83 OXF	101.45	252.34	57.41
18 BKS	85.86	242.23	47.74	60 LPB	102.77	243.32	113.41
85 GSC	88.66	245.66	51.97	67 MDS	103.75	254.03	48.65
58 LON	90.28	242.26	40.03	12 ATL	105.19	254.63	59.70
36 DUG	93.49	248.16	48.72	21 BOG	105.75	249.51	91.08
7 ALQ	96.42	251.44	55.40	54 KOD	105.99	109.06	274.99
43 GOL	98.71	252.67	51.11	87 POO	111.81	105.82	282.19
27 CMC	102.28	249.99	22.14	82 OGD	114.30	262.64	53.42
9 ANT	108.26	238.96	123.89	123 WES	116.89	265.33	116.89
78 NNA	108.28	245.30	110.04	No. 1 1968 May 14 D=168km Mb=5.9			
39 FLO	109.85	261.26	54.71	14h 5m 6.04s/29.93N 129.37E			
11 ARE	110.94	241.74	116.72	No. 4 1965 Sept. 21 D=195km Mb=6.0			
60 LUB	113.75	240.11	118.49	1h 36m 30.3s/28.96N 128.23E			
No. 6				No. 5 1963 May 1 D=142km Mb=6.8			
28 COL	92.43	261.81	25.10	10h 3m 20.0s/19.0S 168.9E			
47 HLW	99.14	91.36	299.22	No. 6 1965 Aug. 20 D=328km Mb=6.1			
52 KEV	99.37	81.08	339.78	5h 54m 50.6s/5.74S 128.63E			
79 NOR	102.63	35.50	355.08	No. 7 1967 May 21 D=173km Mb=6.3			
120 UME	103.20	75.90	334.38	18h 45m 11.7s/0.97S 101.47E			
27 CMC	105.02	292.57	20.63	No. 8 1966 Mar. 17 D=626km Mb=6.2			
13 ATH	105.26	85.33	305.66	15h 50m 32.2s/21.08S 179.18W			